The CSI Journal on
Computer Science and Engineering
Vol. 12, No. 2 & 4 (b), 2014
Pages 47-58
Regular Paper

Empirical Approach for Optimising Cumulative Network Lifetime in WSN with Hierarchical Clustering Technique Based on Fuzzy Logic

Prabhavathi Sanbal[1] Subramanyam Arige[2] Ananda Rao Akepogu[3]

[1]Department of Computer Science and Engineering, Rao Bhadur Y Mahabaleshwarappa Engineering College, Bellary, India
[2]AITS, Rajampet, India
[3]Planning, JNTUA, Anantapur, India

Abstract

The area of wireless sensor network is shrouded with significant ranges of problems where majority of the prior research attempts were carried out to address energy conservation issues. The present manuscript introduces a novel technique called as ENLPL or Enhancing Network Lifetime Using Probabilistic Logic where the prime focus is laid on conserving the energy for large scale wireless sensor network. ENLPL presents design of inter and intra clustering approach using probability theory. It also laid emphasis on ensuring maximum participation of the sensor nodes in selection process of cluster-leader with an aid of maximum number of parameters. The outcome of the study was compared with conventional and standard hierarchical clustering algorithm (LEACH) to find ENLPL ensures better energy efficiency for large number of the sensor. With the adoption of the probabilistic reasoning technique, the simulation results shows that the proposed system maximizes the cumulative lifetime of the network, along with an efficient selection process of the cluster leader in every iteration.

Keywords: Wireless Sensor Network, Energy Consumption, Probabilistic Logic, Clustering Technique, Network Lifetime.

1. Introduction

Wireless Sensor Networks (WSN) constitute one of the most important upcoming areas of reconfigurable network, Internet-of-Things, etc. [1]. Generally, a WSN will consist of a huge quantity of electronic sensing motes with high radio frequency and a base station, which characteristically act as a relative link to many other processing networks facilitating the potential processing of data, location of storage, and an access point to the sensor motes in its network. Sensor motes sense their environment, gather the data sensed, and transmit the data to the base station. Unfortunately, the area of the wireless sensor is also accompanied by various issues, such as restriction of power, computational capability, and memory. A WSN can be deployed in various applications, such as military, biomedical, and environmental utilization [2]. Although extensive research has been carried out in the area of energy [3] [4], this area remains a major obstacle towards the development of an effective routing algorithm in WSN. One of the most discussed routing protocols in connection with the conservation of energy is the low-energy adaptive clustering hierarchy (LEACH) routing protocol. A fundamental properties of WSN is its static nature, where the sensor nodes remain fixed in their respective positions. Majority of the prior research have concentrated on power utilization in wireless sensor nodes. The algorithm is known as PEAS (probing environment and adaptive sensing) [5], which retains power by unraveling all the active sensor nodes by a smallest amount of distance and making sure of the condition of neighboring sensor nodes, whether they are operating or not. Each sensor node transmits a probe message after being inactive (or at sleep) for an arbitrary period. A node then enters the active mode only if it receives no replies from the working neighbors; otherwise it will continue in the off-duty mode or sleep mode. A second algorithm is the coverage configuration protocol (CCP) [6], which enlarges the number of sleeping or inactive sensor nodes while maintaining the quality of service as K-coverage and K-connectivity. To maintain K-coverage, a sensor node only confirms whether the intersection points inside its sensing area are K-covered. Finally, the most discussed algorithm is the LEACH cluster-based algorithm, which uses randomized rotation of the cluster heads, so that every sensor node gets the prospect to act as a cluster leader at least once in its lifetime. Deploying smart and intellectual techniques enhances the effectiveness of WSN. In applications that require real-time decision making, fuzzy logic can be considered as a commanding tool that can make decisions even if data are insufficient [7], whereas sufficient data (which is rare in real applications) are needed to make a decision in classic control. Fuzzy logic has also been utilized as a means to select cluster heads [8]. Because of the proven efficiency of the clustering techniques in power consumption, this system proposed to deploy a clustering routing algorithm. This paper, evaluate the acceptability of a sensor node to be elected as cluster leader using fuzzy logic.

The proposed system has two modules: the first module uses the confined level for decision making, and the second module uses the universal level of decision making for choosing the cluster leader. At the confined level, the eligible sensor nodes are chosen depending on their connection with other sensor nodes within transmission range and retained power level. At the universal level, the best node cooperation is analyzed and identified in relation to mean power saving factor. The following sections will discuss the issues with existing research work by identifying the research gap, and then will propose a mathematical model called Enhancing Network Lifetime Using Probabilistic Logic (ENLPL) to solve the issues. In section 2, we discuss the previous research work in this area. Problem description related to energy consumption, and clustering techniques and their respective parameters are discussed in section 3. The proposed system is discussed in section 6, followed by the ENLPL protocol design in section 5. Section 6 discusses the performance analysis of the proposed model. This is followed by a comparative analysis in section 7 and a summary of the research paper and the conclusions in section 8. Future Direction of work is stated in Section 9.

2. Related Work

Among the various approaches that have been proposed in the literature to minimize energy usage in WSN, energy-aware routing attempts to extend the life of a WSN at the network layer. Energy-efficient routes can be computed using either the minimum energy path, the maximum residual energy path, or the path with minimum number of hops to sink, among others [9]. Chang et al. [10] have argued that always selecting the route with minimum energy will quickly deplete the energy of the sensor nodes on the minimum energy path, thereby decreasing the life of the WSN. Rahall et al. [11] have presented an energy-aware routing protocol that keeps a set of minimal energy paths and randomly selects one of these sub-optimal paths, thereby significantly increasing the network lifetime. Where as in [12] convex nonlinear optimization techniques are used. In [13], an energy-aware routing algorithm for cluster-based WSN is proposed, in which a cost function is defined between two sensor nodes in terms of energy conservation, delay optimization, and other performance metrics.

Zhao et al. [14] have proposed a medium-contention-based energy-efficient distributed clustering (MEDIC) scheme, through which sensors self-organize themselves into energy-efficient clusters by bidding for cluster headship. Although the proposed MEDIC uses only local information, it achieves better energy efficiency than native LEACH in terms of data/energy ratio and an effective lifetime. Sudhir [15] has focused on the use of classification techniques using neural networks to reduce the data traffic from the node and thereby reduce energy consumption. Yumei et al. [16] have proposed a multi-path routing protocol for mobile ad hoc networks. The key idea of the protocol is to find the minimal nodal residual energy of each route in the process of selecting path and sort multi-route by descending nodal residual energy. Once a new route with greater nodal residual energy emerges, it is reselected to forward the rest of the data packets. It can balance the individual node's battery power utilization and hence prolonging the entire network's lifetime. Rouzbeh et al. [17] have proposed fuzzy logic control of automatic repeat request as a way of reconciling these factors, with a 40% saving in power in the worst channel conditions due to economizing on transmissions when channel errors occur.

Ran et al. [18] have presented a work that claims to improve the LEACH protocol using fuzzy logic, which takes battery level, distance, and node density into consideration. Nikravan et al. [19] have deployed a fuzzy logic system as a decision mechanism for next-hop node selection. Both transmission rate and energy are the chosen parameters for choosing the next-hop node in real-time packet transmission. Simulation results show that the proposed scheme provides improvement for real-time transmission and energy efficiency performance, when operating in varying real-time environments.

The outcome of the investigation towards existing literatures is that there are various studies focusing on energy efficiency in Wireless Sensor Network and some of them e.g. [14] and [18] have claimed better performance as compared to standard LEACH. However, none of the study have ever emphasized on the large scale of network on variable density of nodes, where it is quite difficult to understand the applicability of its outcomes in terms of energy efficiency. It can be seen that there are huge blocks of research work being done in the field of routing issues related to power consumption in WSN using fuzzy logic. However, every approach has yielded only a 50% enhancement in performance using fuzzy logic, whereas we have achieved around 80% in performance efficiency using a dual-level fuzzy inference system. Therefore, it can be seen that the majority of the prior research work has focused on the distance between the cluster leader and the sensor motes, ignoring the majority of the other parameters that influence power draining and maximize the network's lifetime. Taking into account the research gap from the review of the prior research, the current research considers three factors: magnitude of remoteness between the cluster leader and the sensor motes, the Euclidean distance between the cluster leader, and the power factor of the cluster leader.

3. Problem Description

Organizing sensor networks into clustered architectures has been extensively explored over the previous couple of years, leading to the surfacing of an excellent variety of tasks-specific clustering protocols in WSN. Clustering is a cost-effective approach for information aggregation within the WSN. Every sensor node within the network sends information to the aggregator node, meaning the cluster leader, then the cluster leader performs the aggregation method on the received information and sends it to the bottom station. However, performing the aggregation operation over the cluster leader causes the vital energy drains.

In case of a homogeneous type of WSN, the cluster head can soon die out, and once more re-clustering should be done, which once more causes energy consumption. In this study, the focus is placed on designing a protocol that can extract information for data dissemination within the range of clusters. The termination of the old clustering technique and the design of a new clustering technique will be highly avoided to maintain algorithm efficiency.

The behavior of power utilization in WSN is one of the most challenging areas in this field, as it is never possible to attain the ideal solution in terms of power preservation. However, a couple of research works [21] were carried out in the field of control systems, as was a study on the electrical impulse to the core computing system. It was also seen that the types of WSN will totally depend on the resource-constrained sensor motes accumulate information from the physical environment. Power preservation is known to be one of the most critical concerns in the majority of the research work. To analyze the reason for the unwanted draining of power from the sensor motes, it is important to understand its root cause. The existence of the cluster leader is one of the most significant phenomena of effective communication.

All the other nodes communicate to the cluster leader, which will transmit data to the defined base station. Therefore, an efficient selection procedure is required to maintain power efficiency. The cluster should be formed in the best way possible to ensure that power is utilized in a reasonable manner for a power-proficient process. Generically, every process of the cluster formation on the WSN is classified into various rounds, where every round is developed by the election of the cluster leader, the formation of the cluster, and the transmission of the data. The cumulative lifetime of the network is the quantity of the rounds in which all the sensor motes will have certain power retained. Certain prominent groups of researchers have concentrated on the selection process of the cluster leader [19]. However, the focus of the current study is more on analyzing the LEACH protocol [14], where every sensor mote decides which cluster it belongs to by selecting the cluster leader that requires the minimum power for radio transmission.

4. Proposed Model

The proposed system intends to optimize the energy consumption in WSN based on a robust election methodology adopted for the cluster leader. For this purpose, the proposed technique introduces an ENLPL algorithm, which defines the efficiency of the optimization technique for power management in WSN. A model based on probabilistic logic is designed for a WSN that is facilitated to every individual sensor node, which transmits its respective information to the cluster leader and the accumulated information is directed towards the base station. The considerations of the design of the proposed model are as follows: a) only homogenous static sensor nodes are assumed [19]; b) the magnitude of remoteness of the wireless sensor nodes is with respect to each cluster; c) entire sensor nodes are initialized with an initial energy; and d) the location of the base station is very far away from the coordinates of all the clusters, assumed for better results in the worst-case scenario. The network model is designed considering the energy factor, where the quantity of the energy utilized in *L* bit is based on the magnitude of the remoteness distance d. Let us consider P_{elec} as the quantity of power utilized per bit to operate various hardware sensor motes as both transmitter and receiver design. The value of d_o of Eq. (2) is derived, where P_{fs} and P_{mp} are the quantity of power that is unwantedly consumed by the transmission schema [20]. Therefore, Eq. (1) highlights utilization of energy in wireless sensor network as

If $d<d_o$,

$$P_{tx}= L.\ (P_{elec}+P_{fs} * d^2),$$

Or else,

$$P_{tx} = L.\ (P_{elec} + P_{mp} * d^4). \tag{1}$$

$$d_o = \sqrt{\frac{P_{fs}}{P_{mp}}} \tag{2}$$

Consequently, the measurement of the energy factor that is unwanted utilized in accepting *L*-bit size of the incoming package can be represented as in Eq. (3):

$$P_{rx} = L * P_{elec}\ . \tag{3}$$

If a simulation square area of M meters is considered where the wireless sensor nodes are distributed, then the consideration of the mathematical model for ENLPL will be that the base station is located far away from the cumulative location of the majority of the clusters. Therefore, the distance of any sensor mote to the base station along with cluster leader is more than d_o. However, the power indulgence in the cluster leader node during the round will be represented as below:

$$P_{CL} = (\frac{n}{k}-1).L.P_{elec} + \frac{n}{k}.L.P_{DA} + L.E_{elec} + L.\varepsilon_{fs}.d_{BS}^2\ .$$

In the above equation, *k* is the cluster quantity, P_{DA} is the cost of dispensation of a bit report to the base station, and d_{BS} is the mean distance between the base station (BS) and the cluster leader (CL). Moreover, it is also feasible to show the amount of power utilized in certain wireless sensor motes, which will not be considered as the cluster leader, as follows:

$$P_{NCL} = L.P_{elec} + L.\varepsilon_{fs}.d_{CL}^2$$

In the above equation, d_{CL} is the mean distance between the cluster leader and all other candidate cluster constituents. If we consider that the nodes are distributed in the simulation area, it can be proved mathematically that

$$d_{CL}^2 = \int_0^{X_{max}} \int_0^{Y_{max}} ((x^2 + y^2).\rho(x, y))dxdy = \frac{M^2}{2\pi k},$$

where the node distribution is represented as *ρ(x, y)*. However, when the entire network is considered, the cumulative power indulgence can be empirically represented as

$$P_t = L.(2.n.P_{elec} + n.P_{DA} + (k.d_{BS}^2 + n.d_{CL}^2)) \cdot$$

Similar to the work done in [7], in the proposed system model, after differentiating part with respect to *k* and making it equal to 0, the best quantity of the newly designed cluster leader of the base station can be represented as in Eq. (4).

$$d_{BS}^2 = \int_A (x^2 + y^2).\frac{1}{A} dA = 0.765.\frac{M}{2} \quad (4)$$

The proposed mathematical model of ENLPL will consider the work done in [22] to assume that if the magnitude of remoteness of a prominent proportion of the sensor motes is maximum in comparison to d_o then Eq. (5) can be obtained.

$$k_{best} = \sqrt{\frac{n}{2\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}.\frac{M}{d_{BS}^2} \quad (5)$$

Now, based on the above equation, the best probability of the regular node to be elected as a cluster leader can be empirically estimated as below:

$$p_{best} = \frac{k_{best}}{n}. \quad (6)$$

The best probability of the regular candidate nodes to be elected as cluster leader is one of the major concerns of the proposed research work. It was shown in [7] that the cumulative energy consumption of the gross sensor network per round maximizes exponentially if the concentration is not directed to the design of efficient clustering formation in the simulation network. It also gives rise to all types of unwanted power consumption whenever a transmitter tends to communicate with other intermediate nodes, if adhoc routing policies are adopted. In the proposed system, the wireless sensor motes are arbitrarily deployed in a transmission area of radius *R*. The system also considers the fact that every individual sensor mote will direct its respective location information as well as its residual power information to the base station that is located at a defined distance from all the clusters. The base station that is dependent on the proportion of the projected clustering leader (p) can allocate the simulation network with defined division. Therefore, the cumulative network can be classified into *NxP* division where N is the quantity of the sensor motes and direction between dual divisions (θ) as represented by Eq. (7).

$$\theta = 2\pi / N.P \quad (7)$$

It can be understood that each of these divisions according to figure 2 creates a cluster with a direction of θ and in any cluster selects a cluster leader using fuzzy logic.

The election of the cluster leader in the current research is done completely by the probabilistic logic that considers the associated parameters based on residual energy, the Euclidean distance between the base station and sensor motes, and the mean distance between all the candidate cluster nodes. As these considerations are processed in the program, the expected output is a candidate cluster node with the best probability of getting elected as cluster leader. During the experiment, it becomes quite obvious that the current elected cluster leader will also drain power, so the network updates its residual information through the distribution of cumulative and individual residual energy to the probabilistic sets that are now governed by probabilistic logic for the next election process for the next cluster leader. The process needs to iterate until complete energy is drained out, in order to understand the best simulation results. In this phenomenon, the candidate nodes that were previously elected as cluster leader will be discarded in the next round, where the priority will shift to the next candidate cluster node with the highest probability of getting elected as cluster leader in all the consecutive rounds.

5. Design Schema of ENLPL

The prime target of the proposed ENLPL scheme is to address the energy-efficiency problems in the low-powered sensor nodes, while performing data aggregation. However, it is quite a challenging task to ensure that all or the maximum nodes are assisting in the process of selection of cluster-leader in large scale networks. The proposed study considers that if an effective cluster-leader is design, it can significantly conserve battery life within the sensor nodes. It is due to the reason that cluster-leader consumes maximum amount of energy during data aggregation process. The design of the ENLPL scheme is done to ensure effective participation of various sensor nodes in selection of cluster-leader. For scalability in the computational process in desiging ENLPL, a probability theory is used as shown in adopted schema of ENLPL in figure 1.

At the initial stage of the network formation, the base station will gather all the required data from the candidate sensor motes, and the cluster leader will be elected based on the hierarchical clustering techniques with respect to the residual power consideration. Which will mean that sensor nodes with larger residual energy will have higher probability to become cluster-leader. To make the election process of cluster-leader a little challenging, the system model will consider only 5% of the cluster leader quantity of every sensor mote in every round. This fact will mean that in every simulation round, only 5% of the total nodes involved will have the probability to become cluster-leader based on its higher residual energy. The most challenging aspect of the design is to create a probabilistic reasoning protocol that can efficiently elect a best cluster leader and rule out the chances of other candidate cluster leaders in every individual round of evaluation. The candidate nodes are those nodes that have greater residual energy and fairer chances of getting elected as cluster leader in the current round, while non-candidate nodes have the least residual energy and have less chances of getting elected as cluster leader. However, they might be considered in the next round. The main criterion is retention of residual power to a greater extent.

The complete consideration of the associated probabilistic parameters in the clustering approach in ENLPL is based on two provision: a) Intra-phase clustering, which is the phase in which the cluster leader will be considered to be rooted in a position of required locus considering the power issues; and b) Inter-phase clustering, which is the phase that will tend to maximize the power retention scheme for both individual node and the cumulative WSN.

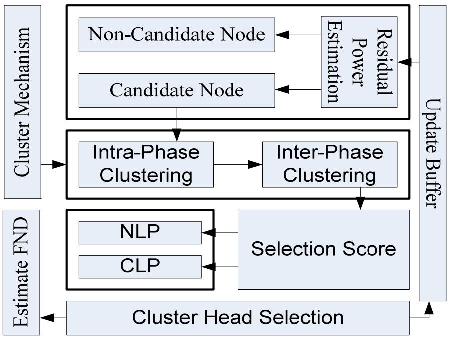

Figure 1. Schema of proposed ENLPL

1) Intra-Phase Clustering: This is one of the most important stages in clustering. This stage considers all associated probabilistic parameters, where the probabilistic set to analyze the various information of the sensor motes with respect to distance among the candidate nodes and their residual energy. Communication or the transmissions of updated information regarding the respective individual sensor mote's residual energy, their current coordinates, and their transmission relation with other clusters are the prime considerations at this stage. As the cluster leader will communicate on behalf of every other member node, there is a possibility of congestion in the network due to the high number of network overheads. Moreover, another prominent functional requirement of the cluster leader will be to collect all the precise data (energy, location, and neighborhood) and send them instantly to the base station without any delay. Therefore, this stage of probabilistic operators will consider mitigating all the network overhead, power issues, and smooth communication from the cluster members to the cluster leader and from the cluster leader to the base station.

2) Inter-Phase Clustering: The main objective of this phase is to maximize the probability of energy preservation within all the cluster nodes. All the cluster member nodes are sufficiently separated at spatial distances in the simulation area. Another prominent condition of this phase is to ensure the involvement of all the member sensor nodes in the election process. This is done in order to maximize the cumulative network lifetime. This phase of the design of probabilistic associated parameters considers an optimal locus (position) of the sensor motes, such locus now are considered as the position of cluster leader from the previous stage. Hence, identification of cluster-leader is done. The secondary priority focuses on the proper distribution of network load at the instant of heavy traffic in communication. The eminent parameters, such as residual energy, Near Locus Point (NLP), Core Locus Point (CLP) with respect to entire cluster, and distance to data sink will be evaluated in this phase.

To estimate CLP, the base station chooses every sensor node and estimates the sum of the squared distances of other nodes from those chosen nodes. The energy required for transmission is directly proportional to d^2; hence, the lower the value of CLP, the lower the amount of power required by other sensor nodes for transmitting the data through that node as cluster leader. This phase also monitors the network to maximize the cumulative network lifetime. To accomplish this, a relative distance estimation of the cluster leader to the base station is conducted. The proposed mathematical model of ENLPL can represent the design of a typical probabilistic logic that permits exemplifying a discrete function with the values between 0 and 1. Empirically, it can be represented as

$$A= \{(x,\mu_A(x)) \mid x \in U\} \quad (8)$$

According to the proposed solution, the discrete function of a typical set A that is a subset of U is the characteristic function definite to closed interval [0, 1] for set A. Hence, empirically, the proposed probabilistic associated parameters can be broadened as follows:

$$B= \{(x, \mu_B(x)) \mid x \in U\} \quad (9)$$

Here, B represents the proposed probabilistic associated parameters in the universal set U, and $\mu_B(x)$ is the degree of probabilistic reasoning parameters of x in B. The term $\mu_B(x)$ in the above formula will also consist of all possible real numbers in the definite interval of [0, 1] and not just 0 and 1. Hence, the characteristic function can be represented empirically as follows.

Only if $x \in A$,

$$\mu_A(x) = 1,$$

or else,

$$\mu_A(x) = 0. \quad (10)$$

Therefore, $\mu_A(x)$ is a characteristic function for set A, and A is a typical set of the universe. The probabilistic associated parameters described above will be an extension of the typical set; the constituents in probabilistic associated parameters will broaden the perception of a binary characteristic function in a typical set in order to multiply values on the continuous interval [0, 1] considering the entire WSN.

$$B= \{(x, \mu_B (x)) \mid x \in U\} \quad (11)$$

Here, B represents the probabilistic associated parameters in the universe U, and $\mu_B(x)$ denotes the probabilistic reasoning parameters of x in B. The adopted design of the probabilistic logic is designed for evaluating various scales of parameters, e.g., transmission distance, candidate nodes, non-candidate nodes, cluster leader, and residual energy. Figures 2 to 6 show the flow of the work.

When these factors are considered, it can be said that the proposed ENLPL technique will receive extensive recognition and can be most frequently deployed for the future enhancement of the experimental model. The proposed ENLPL scheme has two significant characteristics that are considered in cluster leader selection, which are a) overall energy level of the node that is extracted from every sensor node and represented by probabilistic associated parameters that are scaled while depicting the probabilistic reasoning parameters.

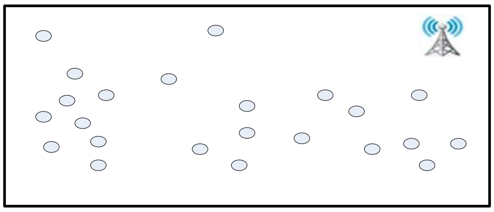

Figure 2. Simulation area with sensor nodes and base station

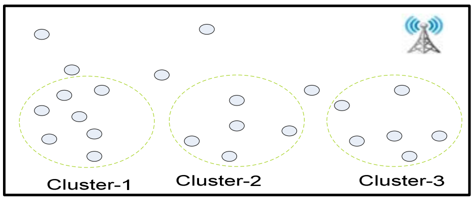

Figure 3. Grouping of sensor nodes as clusters

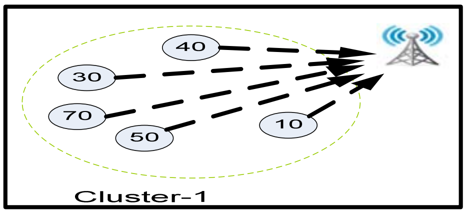

Figure 4. Sensor nodes forwarding their energy information to the base station

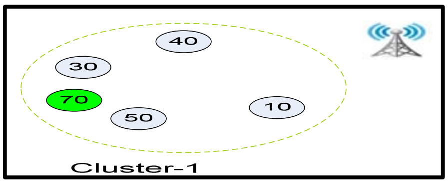

Figure 5. Choosing the node with highest energy for cluster leader

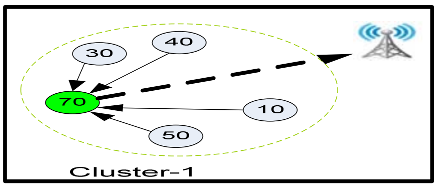

Figure 6. All sensor nodes sending data to the cluster leader, which then forwards the date to the base station

The above deployment of probabilistic logic actually ensures the precise power preservation schema along with the proper election of the cluster leader. For this purpose, the system model considers a comparative analysis with the minimum score coefficient of α (which is considered as 0.5). According to this consideration, when the probabilistic associated parameter is done with the analysis of the selection criterion of the cluster leader in the intra-phase clustering, the sensor motes whose acceptability criteria are greater than α will be iteratively analyzed in the inter-phase clustering depending on the position of the nodes, the distance of the cluster leader to the base station, and the distance between every cluster leader observed in every round. At this stage, however, the assessment for the best candidate cluster node is conducted in order to select a set with the highest acceptability as the absolute cluster leader in every current round. Another prominent parameter consideration is the Euclidean distance from the cluster leader to the other cluster members. This phenomenon is also assisted by associating every Euclidean distance (cumulative) to the base station.

The efficiency of the model lies in its ability to facilitate the base station to evaluate the distance from itself to the selected cluster leader. In the inter-phase clustering, all the above essentials are again considered as inputs to the probabilistic reasoning protocols, with an expected output of sensor mote acceptability of being elected as cluster leader. In the concluding phase, it is also important to estimate the life of the sensor motes. One of the major considerations of the current research is that it is not 100% possible to extend the lifetime of one individual sensor mote, but it is feasible to attempt an optimization technique for maximum preservation of power retention by building an efficient technique for acceptability criteria of candidate cluster nodes to be elected as cluster leader in each round. The ENLPL algorithm is as below:

Algorithm for ENLPL Schema
Input: Node ID, transmission range, length, breadth of simulation area
Output: Selection of cluster leader with greater power efficiency
Steps:
START
1 Define a simulation area [LxB].
2 Define node parameters [Node ID, Tx_D, BS].
3 Define BS coordinates:
BS_x=Area+B_{dist}
BS_y=Area+B_{dist}
4 Define percentage (P) of CL selection (5%).
5 Define limits for maximum neighbor nodes (L_{max}=N-1).
6 Evaluate CLP:

$$CLP = L_{\max}\sqrt{x_m^2 + y_m^2}\ .$$

7 Evaluate NLP:

$$NLP = (P-N).\sqrt{BS_x^2 + BS_y^2}\ .$$

8 Estimate maximum distance from CL:

$$(P.N-1).\sqrt{x_m^2 + y_m^2}$$

9 Compute acceptability of intra-phase clustering.
10 If Power<=0, node has died.
11 Estimate FND (first node death).
12 $Node_{ALIVE}=N_{node}-\sum Node_{DIED}$.
13 Estimate inconsistencies in power.
14 Estimate residual energy=∑P.
15 Update buffers.
16 Remove intra-phase clustering acceptability of dead node.
17 Formulate Min Acceptability COEFF.
18 Take the eligible data in 1st round and apply inter-phase
19 Clustering for re-evaluation.
20 Select $PrevCL_{MAX-ELG}$.
21 Consider positions of nodes, CL-BS distance, and distance between every cluster leader.
22 Count each round.

23 Iterate Step-6 to 16 till
24 If $Node_{ALIVE}$ <=0, Break.
25 Evaluate intra-phase clustering with different energy.
26 Evaluate intra-phase clustering with different neighbor nodes.
27 Evaluate inter-phase clustering with different CLP.
28 Evaluate inter-phase clustering with NLP from BS.
29 Evaluate inter-phase clustering with NLP from BS.
END

6. Performance Analysis

The current research was carried out on Windows 32-bit OS with 1.84 GHz dual core processor considering Matlab as the programming language. At present there are various types of simulators that are used in study of wireless networks e.g. QualNet, OmNet, OpNet etc. These simulation have the significant advantage of possession of networking protocols and however, it has limitations of result analysis. Such simulation doesn't allow to study the outcomes in run-time and moreover they are not enriched in mathematical tools. Hence, programming depends on the extensive skills. However, adoption of Matlab ensures to overcome such issues as it has some of the enriched set of mathematical and signal processing toolbox, that makes the study analysis easier, flexible, and highly extensible too. The experiment had a simulation area of 100 x 100 m^2. We considered various scenarios with 60 nodes with arbitrary distribution. The preliminary power of the sensor motes was initialized at 0.1 Joules with 100 rounds. The proposed system is compared with the frequently used LEACH [15] protocol. table 1 shows the network simulation parameters considered.

Table 1. Simulation Parameters

Total Number of Nodes	60
Size of network	100 x 100 m^2
Position of BS	(60,150) m
Preliminary Energy Initialization	0.1J
Probability of CL election	0.5
Size of packet	6500 bits

One of the prominent parts of the comparative analysis consisted of checking the efficiency of the ENLPL protocol schema designed for the proposed system. The deployment of the protocols should maximize the proficiency in the election process of the cluster leader and minimize the unwanted power consumption issues, which is the significant concern of this research work. The parts of the protocol are designed in such a way that inter-phase clustering is a highly enhanced version of the intra-phase clustering using probabilistic logic.

Figure 7 highlights the acceptability score information for the deployment of the intra-phase clustering acceptability factor along with power (0.1 J). The experiment is performed by varying neighbor nodes of size 30, 40, and 50. It can be seen that the greater the number of neighbor nodes, the greater the chances of the cluster member becoming a cluster leader in the intra-phase clustering of probabilistic logic. It can also be seen from figure 10 that when the number of nodes is increased from 30 to 40 and then to 50, the intra-phase clustering core is also maximized with the increment in the number of nodes. Hence, it can be said that as the intra-phase clustering score increases, the greater the chances of assuring node participation in the election process of the cluster leader.

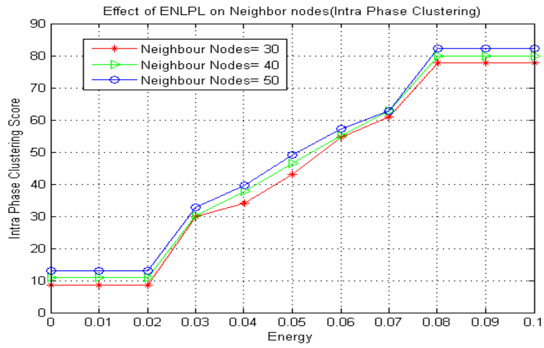

Figure 7. Effect of ENLPL on neighbor nodes (intra-phase clustering)

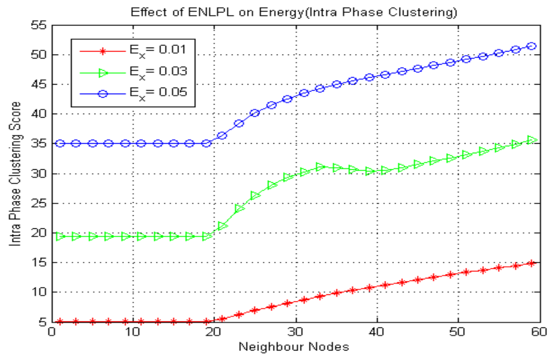

Figure 8. Effect of ENLPL on energy (intra-phase clustering)

Figure 8 highlights the intra-phase clustering acceptability score information with respect to energy. It can be seen from the figure that with the increment in the number of nodes (0, 10, 20, 30, 40, 50, 60) as well as their energy values (0.01J, 0.03J, 0.05J), the probability of the cluster member getting elected as cluster leader increases. Another significant observation is that intra-phase clustering itself selects the best probability of the candidate cluster leader, considering energy and total number of node participation. Hence an optimal deployment of ENLPL is assured in the network.

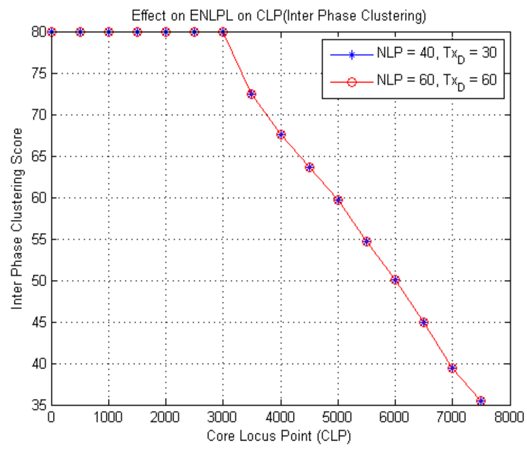

Figure 9. Effect of ENLPL on CLP (inter-phase clustering)

Figure 9 highlights inter-phase clustering acceptability score information. It can be seen that the increase in the value of CLP with respect to distance, position, and total participation of cluster members increases the probability of selection as cluster leader.

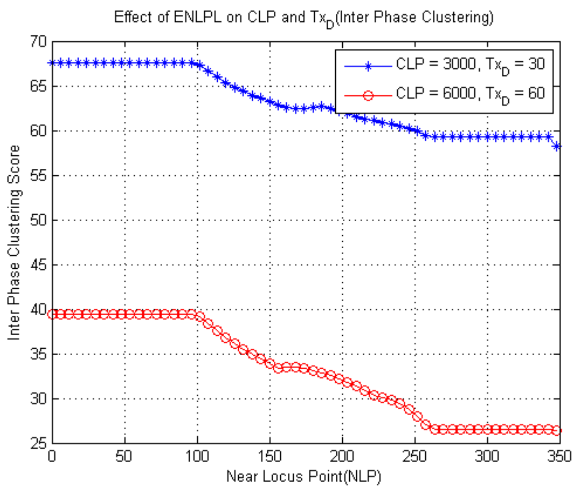

Figure 10 Effect of ENLPL on CLP and TxD (inter-phase clustering)

Figure 10 shows the inter-phase clustering acceptability score information with respect to distance between the cluster leader and the base station. It can be seen from figure 13 that with the increase of values of NLP, the inter-phase clustering acceptability score is still highest for the curve with CLP=3000 and Tx_D=30m in comparison with the other curve with CLP=6000 and Tx_D=60m. This phenomenon indicates a better optimization technique applied by ENLPL.

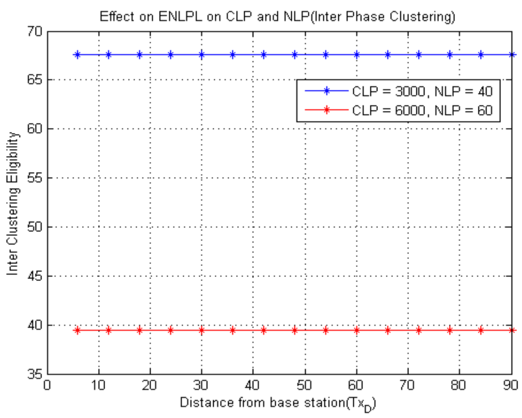

Figure 11. Effect of ENLPL on CLP and NLP (inter-phase clustering)

Figure 11 highlights the inter-phase clustering acceptability score information with respect to distance from base station. It can be seen that the proposed system has highly optimized the inter-phase clustering of probabilistic logic implementation in order to maintain maximum retention of power as well as better and efficient selection of a robust cluster leader with extremely less network overhead. Therefore, the proposed system is highly computationally efficient to deploy even in a real-time scenario.

7. Comparative Analysis

In accordance with the above-considered simulation parameters, the proposed ENLPL protocol is executed and compared with the most famous LEACH protocol. Although the LEACH protocol is frequently used, it can be seen that LEACH carries out inter-phase clustering in order to choose or elect the cluster leader sensor nodes. It can also furnish an assessment policy for evaluating enhancements. To compare the ENLPL protocol with the LEACH protocol, the experiment is conducted on a standard network with 60 nodes that are randomly generated over a specific area with a cluster leader election probability of 0.05. Hence, the possibility of about a single sensor node per iteration becoming cluster leader renders it appropriate for us to make the comparison. The application probabilistic logic operators are scaled accordingly, with the other simulation parameters remaining the same as the reference network. Residual energy is one of the prime factors for evaluating the preservation of the power-saving scheme of the proposed technique using fuzzy logic based on each round. Figure 12 highlights the quantity of alive nodes using the proposed protocol and the LEACH protocol, where it is very obvious that the proposed technique outperforms the LEACH protocol.

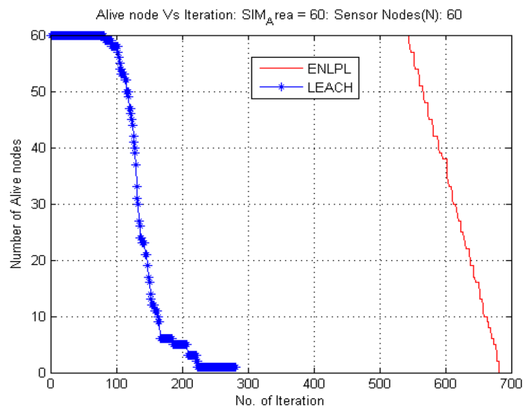

Figure 12. Alive nodes vs. iterations (simulation area=60, sensor node (N):60)

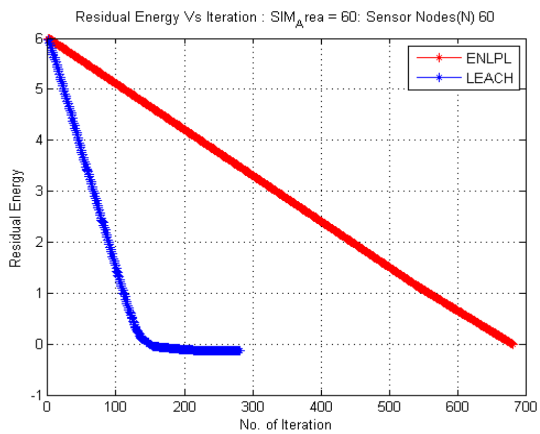

Figure 13. Residual energy of the nodes

It can be seen that in the LEACH protocol, the number of alive nodes starts a gradual descent and stops only at around 300 iterations, whereas the proposed ENLPL protocol too has a gradual and smooth descent at around 700 iterations. The results show that ENLPL can ensure maximization of the cumulative lifetime of the WSN. Figure 13 shows one of the prime distinctions between the LEACH and the ENLPL implementation techniques. There is a steep declination of the curve representing residual energy for LEACH in and around less than 300 iterations, whereas the proposed ENLPL has a gradual, linear, and smooth declination that stops in and around 700 iteration stages. Hence, better energy conservation can be ensured using ENLPL. It is quite obvious from table 2 that in the LEACH protocol sensor motes run out of power at a very early stage, whereas it is optimized to maximum with the proposed protocol. Therefore, understanding the power variance should be another prominent factor of comparative analysis.

It can be observed that the mean FND value for the proposed protocol is around 656 out of 700 observation rounds, whereas it is only 378 out of 700 observation rounds for the LEACH protocol. Figure 14 shows the power variance versus a total of 700 observation rounds.

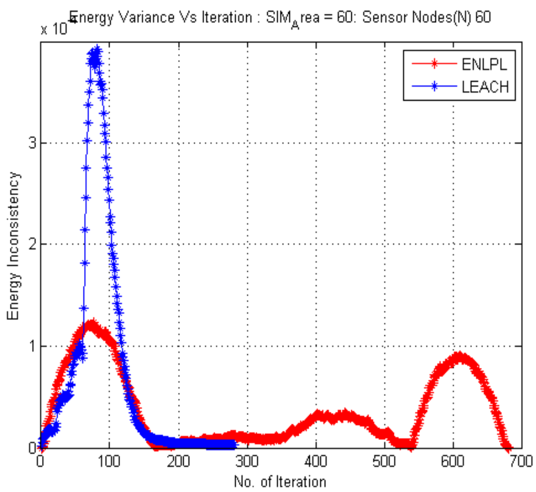

Figure 14. Power variance vs. number of iterations

To analyze the power efficiency of the proposed system compared with the LEACH protocol, it is critical to consider the parameter of FND in order to visualize and compare the efficiency of our algorithm for maximizing the cumulative network lifetime.

Table 2. Comparison of FND parameter for ENLPL and LEACH protocol

Run	ENLPL-FND	LEACH-FND
1	610	340
2	625	342
3	635	359
4	645	365
5	667	370
6	668	377
7	670	389
8	675	395
9	679	421
10	689	425
Mean	656	378

Figure 15 show that the proposed technique actually assists the sensor motes to utilize the power in a more consistent pattern. It can also be said that power assigned to the sensor motes in the traditional LEACH protocol is often deflected, with certain motes having very high power allocation while some are drained of power to zero joules. It can be seen, however, that the proposed system has overcome the above mentioned issues in the LEACH protocol.

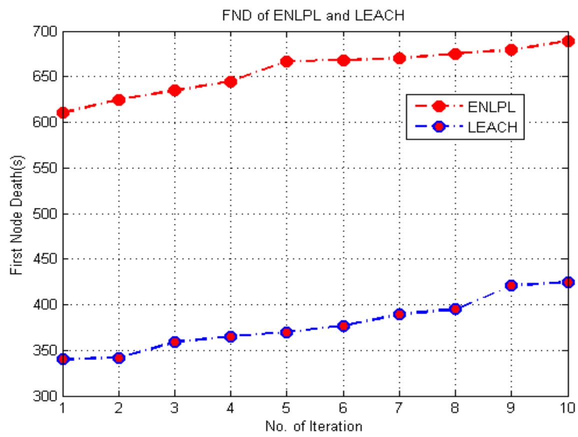

Figure 15. First node death values for the proposed and the LEACH protocols

In the LEACH protocol, the motes ran out of power at around ~370 rounds, while in proposed system, the power drained out near to ~690 rounds in approximation.Energy is one of the most critical factors in designing routing schema for WSN, and LEACH is one frequent and famous mechanism used in clustering as it chooses a cluster leader depending on a probability framework. Conversely, LEACH is based purely on a probability framework where certain clusters may be very close to each other and can be located at the edge of the WSN. However, energy efficiency cannot be maximized using these inefficient cluster leaders.

The proposed technique introduces the ENLPL protocol, which is designed to overcome the issues in LEACH using probabilistic logic and selecting energy level, transmission distance, and density of nodes as the prime factors for the election mechanism of the cluster leader. The proposed technique highlights the sensor motes for more estimations and communication in order to receive the data of the node density and the transmission distance. The cluster formation in the LEACH protocol is based completely on universal information, which requires certain specific routing strategies in order to be accessed.

Table 3. Summary of Comparative performance Analysis

Factor	ENLPL	LEACH
Energy	Much Higher	Lower
Supportability of Large Network	Yes	No
Scalability	Yes	No
Power Variance	Quite uniform in long run	Highly fluctuating and sustains only in short run.

In that sense, the LEACH protocol can be considered a semi-distributed protocol for WSN. Another prominent issue in the LEACH protocol is the arbitrary cluster leader selection method that cannot assure that the required quantity of cluster leaders is chosen or that the selected cluster leaders are evenly positioned. Therefore the study outcomes are as follows.

8. Conclusions

The proposed system highlights a novel protocol of ENLPL, which deploys probabilistic logic for the purpose of efficient election of the cluster leader along with maximization of the cumulative network lifetime of the sensor motes. The proposed system has been compared with the LEACH protocol and has outperformed the traditional LEACH protocol in every aspect. The prominent claim of the research experiment is its design in two stages, i.e., intra-phase clustering and inter-phase clustering, for better selection of the cluster leader. A hierarchical clustering technique is used for the purpose.

The comparative analysis also highlights that the considered parameters are also higher in quantity in comparison with the traditional LEACH protocol. The core of the LEACH protocol always considers the relative magnitude of remoteness from sensor motes to the currently elected cluster leader, which is not the optimal parameter when it comes to maximizing the complete network lifetime. The simulation result analysis is benchmarked for optimal throughput considering the power retention process in WSN. The simulation shows a highly satisfactory result for the implemented algorithm, which outperformed the LEACH protocol with respect to residual power, number of neighbor motes, acceptability criteria, and distance among the motes as well as to base station.

9. Future Work

Although the proposed system has highlighted a technique that could optimize the energy conservation in wireless sensor network, but there are still a larger feasibility of extending this optimization in terms of novelty. Most recently, there are much hype of using swarm intelligence in optimization principle. The conventional swarm intelligence algorithms e.g. ant colony optimization, bird flocking techniques, and particle swarm optimization were already used in optimization. For future work, we can develop a swarm intelligence based on cognitive and social behavious of animals. We have identified one of the distinct behavior of killer whale as follows:

- A group of killer whale gathers together to hunt single prey.
- All the whales are in constant communication with each other while approaching the prey.
- The location information of the prey is constantly being communicated using echolation process.
- Personalization of velocity of swim is one of the interesting charecteristics which lets all the killer whale to approach and attack the prey at same time irrespective of their start distance of travel.

All these principle can be used for optimization where the concept of prey can be considered as residual battery life, killer whales as sensor nodes. A better round of communication updates by manipulating the concept of echolation in routing can be used that can significant conserve the energy required for performing data aggregation. The concept of group based communication in killer whales can also be designed for higher supportability of multi-hop communication system.

References

[1] S. C. Mukhopadhyay, *Internet of Things: Challenges and Opportunities*, Springer Science and Business, 2014.

[2] Y. Li, M. T. Thai, and W. Wu, "Wireless Sensor Networks and Applications," Springer Science, 2008.

[3] Y. Zou, and K. Chakrabarty, "Energy-aware Target Localization in Wireless Sensor Networks," *Proc. IEEE Intl Conf. on Pervasive Computing and Communications*, pp. 68-74, 2003.

[4] A. Sharma, K. Shinghal, N. Srivastava, and R. Singh, "Energy Management for Wireless Sensor Network Nodes," *Journal of Advances in Engineering and Technology*, vol. 1, no.3, pp. 431-442, 2011.

[5] F. Ye, G. Zhong, J. Cheng, S. Lu, and L. Zhang, "PEAS: A Robust Energy Conserving Protocol for Long-Lived Sensor Networks," *Proc. IEEE Intl Conf. on Distributed Computing Systems*, pp. 28-37, 2003.

[6] X. Wang, G. Xing, Y. Zhang, C. Lu, R. Pless, and C. Gill, "Integrated Coverage and Connectivity Configuration in Wireless Sensor Networks," *Proc. IEEE Intl Conf. on Embedded Networked Sensor Systems*, pp. 28-39, 2003.

[7] I. Gupta, D. Riordan, and S. Sampalli, "Cluster-Head Election using Fuzzy Logic for Wireless Sensor Networks," *Proc. IEEE Intl Conf. on Communication Networks and Services Research*, pp. 255-260, 2005.

[8] S. Dasgupta, and P. Dutta, "An Improved Leach Approach for Head Selection Strategy in Fuzzy C-Means Induced Clustering of Wireless Sensor Network," *Proc. of the IEMCON Organised by IEM in Collaboration with IEEE*, pp. 54-60, 2011.

[9] F. Akyildiz, "A Survey on Sensor Networks," *Computer Journal of IEEE Communications Magazine*, vol. 40, no. 8, pp. 102-114, 2002.

[10] H. Chang, S. Leandros, and L. Tassiulas, "Maximum Lifetime Routing in Wireless Sensor Networks," *Computer Journal of IEEE/ACM Transactions on Networking*, vol. 12, no. 4, pp. 609-619, 2004.

[11] R. Shah, and J. Rabaey, "Energy Aware Routing for Low Energy Ad Hoc Sensor Networks," *Proc. IEEE Intl Conf. Wireless Communications and Networking*, pp. 350-355, 2002.

[12] B. Krishnamachari, and F. Ordo, "Analysis of Energy Efficient Fair Routing in Wireless Sensor Networks Through Non-Linear Optimization," *Proc. IEEE Intl Workshop on Wireless Ad Hoc Sensor and Wearable Networks*, pp. 2844-2848, 2003.

[13] M. Younis, M. Youssef, and K. Arisha, "Energy Aware Management for Cluster Based Sensor Networks," *Computer Journal of Networks*, vol. 43, no. 5, pp. 649-668, 2003.

[14] L. Zhao, and Q. Liang, "Medium-Contention Based Energy-Efficient Distributed Clustering for Wireless Sensor Networks," *International Journal of Distributed Sensor Networks*, vol. 3, no. 2, pp. 347-369, 2007.

[15] S. G. Akojwar, and R. M. Patrikar, "Improving Life-Time of Wireless Sensor Networks Using Neural Network Based Classification Techniques With Cooperative Routing," *International Journal of Communications*, vol. 2, no. 1, pp. 332-346, 2008.

[16] Y. Liu, L. Guo, H. Ma, and T. Jiang, "Energy Efficient On–Demand Multipath Routing Protocol for Multi-hop Ad Hoc Networks," *Proc. IEEE Intl Symp. of Spread Spectrum Techniques and Applications*, pp. 592-597, 2008.

[17] R. Razavi, M. Fleury, and M. Ghanbari, "Power-Constrained Fuzzy Logic Control of Video Streaming over a Wireless Interconnect," *EURASIP Journal on Advances in Signal Processing*, pp. 38-52, 2008.

[18] G. Ran, H. Zhang, and S. Gong, "Improving on LEACH Protocol of Wireless Sensor Networks using Fuzzy Logic," *Journal of Information and Computational Science*, vol. 7, no. 3, pp.767-775, 2010.

[19] M. Nikravan, S. M. Jameii, and M. H. Kashani, "An Intelligent Energy Efficient QoS-Routing Scheme for WSN," *International Journal of Advanced Engineering Sciences and Technologies*, vol. 8, no. 2, pp.121-124, 2013.

[20] A. Lakshmi, and S. V. Manisekaran, "Fuzzified Dynamic Power Control Algorithm for Wireless Sensor Networks," *International Journal of Engineering Science and Technology*, vol. 3, no. 4, pp. 21-35, 2011.

[21] W. Dargie, and C. Poellabauer, *Fundamentals of Wireless Sensor Networks: Theory and Practice*, Wiley, 2010.

[22] N. Israr, and A. Wan, "Coverage Based Inter Cluster Communication for Load Balancing in Heterogeneous Wireless Sensor Networks," *Telecommunication Journal*, vol. 32, no. 3, pp. 121-132, 2008

Prabhavathi Sanbal received her B.E degree in Electronics & Communication Engineering from Gulbarga University, Karanataka, India, her M.S degree in Electronics & Control from BITS Pillani, Rajasthan, and her M. Tech degree in Computer Network Engineering from VTU Belgaum University, Karnataka. She is now pursuing her PhD degree at JNTU Ananthapur University, Andhra Pradesh. Her research interests include wireless sensor networks, especially the clustering techniques in wireless sensor networks. She is currently working as Professor in the Department of Computer Science Engineering of Rao Bhadur Y Mahabaleshwarappa Engineering College, Bellary, Karnataka.

E-mail: prabkir@gmail.com

Subramanyam Arige received his Ph.D. degree in Computer Science and Engineering from JNTU College of Engineering, Anantapur. He obtained his B.E. (ECE) from the University of Madras and his M. Tech.(CSE) from Visweswaraiah Technological University. He has 20 years of experience in teaching. He is currently working as Professor & HOD in the Department of Computer Science and Engineering of Annamacharya Institute of Technology & Sciences, Rajampet, Y.S.R. Dist. A.P. He has presented and published 40 papers in international and national conferences and journals. He is guiding a few PhDs. His research areas of interest are parallel processing, computer networks, network security, and data mining.

E-mail: smarige@gmail.com

Ananda Rao Akepogu received his B. Tech degree in Computer Science & Engineering from the University of Hyderabad, Andhra Pradesh, India, and his M. Tech degree in A.I & Robotics from the University of Hyderabad, Andhra Pradesh, India. He received his PhD degree from the Indian Institute of Technology Madras, Chennai, India. He is Professor of Computer Science & Engineering Department and is currently working as Director Acadamic and Planning in Jawaharlal Nehru Technological University, Andhra Pradesh, Anantapur, India. Dr. Rao has published more than 100 papers in various national and international journals/conferences. He received the Best Research Paper award for the paper titled "An Approach to Test Case Design for Cost Effective Software Testing" in an International Conference on Software Engineering held at Hong Kong, 18-20 March 2009. He also received the Best Educationist Award for outstanding achievements in the field of education from the International Institute of Education & Management, New Delhi, on 21st Jan. 2012. He was conferred the Bharat Vidya Shiromani Award by the Indian Solidarity Council and the Rashtriya Vidya Gaurav Gold Medal Award by the International Institute of Education & Management, New Delhi on 19th March, 2012. His main research interests include software engineering and data mining.

E-mail: akepogu@gmail.com

Paper Handling Data:

Submitted: 09.12.2014
Received in revised form: 06.05.2015
Accepted: 16.06.2015
Corresponding author: Prabhavathi Sanbal,
Department of Computer Science and Engineering, Rao Bhadur Y Mahabaleshwarappa Engineering College, Bellary, India.