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A Clustered Fuzzy and Dynamically Well-Organized Load Balancing Algorithm (CFDLB) for Network Life Time Enhancement in Wireless Sensor Networks

K. Selvakumar , G. Pattabirani

Abstract: ***In recent past, wireless sensor networks have been exploited and tapped for their immense potential as they are ideal choices for real time wireless communication applications. Nodes which form the back bone of the wireless sensor networks (WSN) together with an efficient routing scheme define the overall efficiency of the WSN. In recent times, research on load balancing algorithms have been investigated as the nature of incoming traffic composed of packets of information is mostly stochastic and unpredictable in nature. Since the nodes are limited by their power provision in the form of batteries which cannot be frequently replaced, are prone to over utilization in transmitting all information through a single or selected nodes closest to the base station resulting in quick drain of power supply. Hence an intelligent and efficient method of load balancing mechanism is necessary to ensure that the work load is distributed in a more or less uniform manner resulting in ideal power saving. A clustered fuzzy engine model is proposed in this research article which is capable of sensing the input traffic conditions and consequently invokes the fuzzy engine to decide upon an optimal cluster head among the set of available nodes to handle the incoming traffic. The proposed algorithm utilizes a rotational method of utilization of cluster head (CH) to ensure that all member nodes are utilized in a uniform manner based on the incoming traffic. The proposed algorithm has been implemented, experimented and compared in performance with LEACH, DLBA and GLBA algorithms and the proposed hybrid approach outperforms the existing techniques in terms of average energy consumption and load distribution.***

Index Terms: ***Wireless sensor networks, Load balancing algorithms, soft computing, fuzzy inference engine, cluster head selection.***

I. INTRODUCTION

Communication technologies have been experiencing a great revolution in the past decade especially with the advent of state of the art communication protocols and gadgets [1]. Hand held and portable gadgets are being effectively used for a wide range of applications in recent past. Portable and hand held equipments derive their evolution from wireless sensor networks which for an open or closed loop network with the nodes deciding to be part of the network or leave the network at their own free will [4]. These nodes are provided with certain processing capabilities depending upon the application to which they being put use to. They are autonomous in nature especially in case of MANETs and VANETs where they can make certain decisions on their own. Nodes which form the backbone of wireless sensor networks (WSNs) are provided with a limited supply of battery power to initiate and perform the aforementioned processing functions. In recent times, WSNs are being more prominently deployed for remote monitoring and surveillance in locations where human presence is not desirable. They find effective utility in monitoring of volcanic activity, disaster prone areas to aid in search and rescue, evacuation operations etc. They are also being actively used in surveillance of hostile territory along border lines or even mounted on unmanned aerial vehicles to go deep into enemy territory unnoticed. WSNs have become more critical in such applications as surveillance normally involves sensing and transmission of multimedia content such as video, audio and high definition images related to movement of enemy vehicles, troops etc. In all the above mentioned cases, power utility is a major concern for these nodes as they require more power especially in case of transmission of multimedia content [19]. The nature of deployment of these nodes in remote locations also does not facilitate frequency replacement of batteries and hence necessitates intelligent and optimized use of available battery power to discharge its functions in an uninterrupted and effective manner. A typical wireless sensor network is depicted in figure 1.

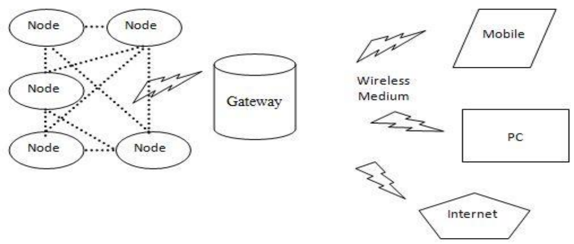

Figure 1 Illustration of a typical wireless sensor network

Figure 1 illustrates a typical deployment of a wireless sensor network along with the terminal user and gateway for data access. Depending upon the type of application, the node deployment in the scene of activity may vary from a few nodes to several hundreds of nodes sensing data either in a homogenous or heterogeneous environment.

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*Correspondence Author(s)
Dr.K.Selvakumar, Associate Professor, Department of Information Technology, Annamalai University, Chidambaram, Tamilnadu.
G.Pattabirani, Research Scholar, Department of Computer Science and Engineering, Annamalai University, Chidambaram, Tamilnadu.

In each of the case, sensing of data from the environment at the terminal side and transmitting them to the next forwarding node is the primary duty of the nodes in the framework.

Another issue related to battery and power utility by nodes is reflected in the lifetime of the entire network as the subsequent failure of nodes due to improper utilization of power or overloading may result in consequent network lifetime reduction. Another issue which may lead to power drain from the nodes is due to improper load balancing system in the network. In general nodes with good connectivity links to base station take up more loads become overloaded causing quick drain of power from the nodes while the rest of the nodes which are alternately termed as underutilized nodes take up less power resulting in partial loss of nodes near the base station resulting in overall reduction in network lifetime. Typical sensor architecture is depicted in figure 2 shown below.

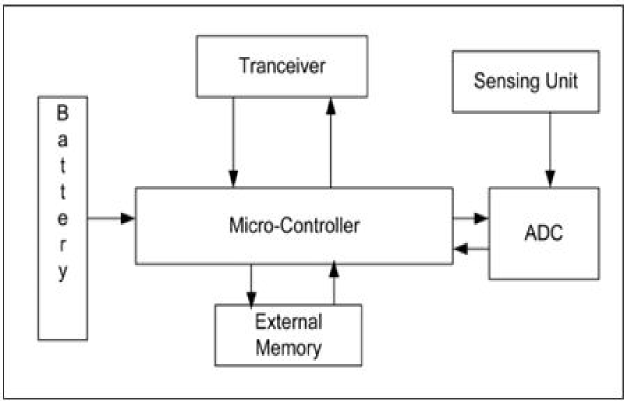

Figure 2 Internal architecture of a wireless sensor node

Figure 2 illustrates the internal architecture of a general wireless sensor node which consists of a power source along with the processing unit and associated circuitry. Conventional batteries used in these nodes are available as Nickel Cadmium, Carbon Zinc capable of providing 300mAh and 320 mAh power. Hence, proper and intelligent methods of power management on par with the load requirements and demand from the base station should be taken into account to provide a load balanced and energy efficient node deployment system. Routing plays a major role in mobilizing the load balanced and energy efficient node deployment scheme as it is the routing algorithm which determines the optimal path involving active nodes based on the load requirement from source to sink. A routing algorithm is generally multi objective in nature and dependant on several attributes such as throughput, bandwidth, hop count, energy consumption, packet size etc. This research article proposes a soft computing approach to provide a dynamic and well organized load balancing algorithm for an energy efficient routing in the given WSN. A fuzzy clustered approach is proposed in this paper for the single objective of load balancing. The rest of the paper is organized into an extensive survey of literature related to the objective of this research paper, implementation of the proposed algorithm, the experimental results and inferences drawn based on the observations.

II. RELATED WORK

The efficiency of a WSN implementation is largely influenced by an efficient routing scheme which have investigated and researched in literature in a vast manner. Certain findings of the literature related to the proposed objective have been elaborated in this section. Most of the wireless sensor networks are implemented in a cluster based approach [3] [13] and graph cut based methods [6] [9] which greatly help in reducing the complexity of the entire network. Cluster based methods reduce the entire network by partitioning them into several sub clusters based on similarity features. Each cluster is coordinated and controlled by a cluster head which is selected based on several optimization attributes. Several algorithms and routing schemes which take into account the load into consideration have also been observed in the literature. A weighted method of routing for load balancing is proposed in the literature [2]. The weights are assigned based on distance factors between the cluster head (CH) and the members of its cluster taking part in the communication and the residual energy of the nodes. A threshold based method has been used to detect node overloading at a future point of time from the current processing. A three layered secured and load balancing protocol has been discussed in the literature [3] where the first layer corresponds to the sensor nodes, the intermediate correspond to the CHs and the third layer corresponds to the pseudo sink nodes. It operates on threshold based method where the aggregated data is sent to the pseudo layer thus reducing the overhead on the CH. This method is found to be quite effective as it improves the packet delivery time as these packets need not wait for the aggregation factor to rise above the threshold.

A directed diffusion method of clustering and load balanced routing algorithm is observed in the literature [4] where reduction of load on the nodes is done by establishing multiple paths between the communicating terminals (source and destination). In spite of improving the load balancing condition, it results in some deficiency in energy optimization as the algorithm does not consider node energy or battery levels while establishing the multi path between source and sink. Moreover, complexity is increased by a certain extent compared to conventional algorithms. Load balancing algorithms have also been tested one existing LEACH algorithms [10] in the form of R-LEACH algorithms [5] where energy conservation is achieved by rotating the CH on a frequent basis thus providing a uniform circulation of nodes to be CHs which eliminates the condition of power drain of a single node being the CH. However, this method is not quite optimal with respect to energy and congestion time, it produces an efficient load balancing method and prevents any node from being overloaded. Another variant of the rotation mechanism is found in HEED algorithm [9] found in the literature in which the CH is replaced based on proximity of node to the next forwarding node and residual energy.

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A load balancing clustering algorithm is discussed in the literature [6] where a specific group of nodes known as gateway nodes are primarily vested with the functions of sensing the traffic on the channel and load requirements and establishing communication paths between the source and sink. Geographic aware routing algorithms which basically work on the principle of location awareness of nodes have been adapted to handle dynamically varying loads and traffic on the channel [7] using geographic load balancing routing algorithms by using greedy search algorithms which take the node overhead as well as the hop distance as the parameters in the search process. With the help of this search process and subsequent optimization, the GLBR algorithm routes the incoming traffic to another node if the current load is overloaded. Scalable cluster based load balancing algorithms have been researched in the literature where the given network is partitioned into several overlapping sub clusters with multi hop capability [9]. Other works also indicate a multi hop load balancing algorithm modified on existing PEGASIS [21] [23] algorithms where a small percentage of nodes from the overall node availability is selected to be cluster heads for the time being. Their primary objective is to coordinated and complete the intra cluster communication thus reducing the overhead on other nodes in the cluster. Another method of load compensation is achieved by continuously monitoring the access points. In case of overloading, points from another cluster are migrated to the overloaded clusters to share the work load [10] [11].

Dynamic load balancing in case of distributed WSNs have been achieved using a tree splitting approach [12] [16] of the nodes into domains and balancing of load based on residual energy of the nodes in the domain is achieved through the routing algorithm. Experimental results indicate an improved network lifetime in this approach. The proposed technique is also scalable and flexible with nodes given the freedom to change domains as and when required. A similar kind of tree splitting approach has been observed in the literature [13] where sensing the traffic burden on the node under study and forwarding the probability of next node allocation to the parent node based on its residual energy. A dynamic load balancing algorithm based on a stochastic and mathematic formulation has been observed in the literature [15] where three steps of rotation are carried out based on broadcast method done by the sink. The sink broadcasts the packet information to all nodes and the node with the least time and cost is selected as the CH and the rotation done thrice to reduce the overall energy consumption and load overhead.

Other algorithms found in the literature [14] are multi objective optimization based algorithms of which traffic congestion and load balancing form one of the parameters in the optimization target set. A number of soft computing algorithms have been proposed in the literature [17] [20] [21] [22][24] which are multi objective in approach and considering load balancing as one of the research issues in the NP-hard completeness problem. Genetic algorithms [18] and neural network models have been effectively used to obtain an energy efficient routing algorithm with load balancing been given as one of the inputs to the neural network input layer models. Other models include fuzzy decision based models being used in wireless multimedia networks in hybrid combinations with evolutionary algorithms on a multi objective optimization approach. In spite of the fact that multi objective optimization provides improvement in overall Quality of Service (QoS), improvements on load balancing have also been observed to a certain extent. However, algorithms with load balancing as a single objective of optimization are few in number as observed in the literature. Many algorithms exist in multi objective optimization but load balancing is achieved at the cost increasing hop count, increasing congestion etc which is not suitable for a standalone system with load balancing as the sole objective. Hence, based on the survey of literature carried out, the problem of load balancing to improve network lifetime is considered as NP- complete hardness problem and supervised fuzzy based cluster routing algorithm is proposed and formulated in this paper.

III. PROPOSED WORK

Any given wireless sensor network could be viewed off as an un-partitioned and uni-directed graph $G = (N \cup E, C)$ where N defines the number of nodes present in the given network and C indicating the transmission links between the nodes. E reflects the terminal environment which is sensing by nature. Two different nodes N1 and N2 in the environment C is said to be connected if N1 << N2. Under normal conditions, the state of nodes is in one of four possible states as shown in figure 3.

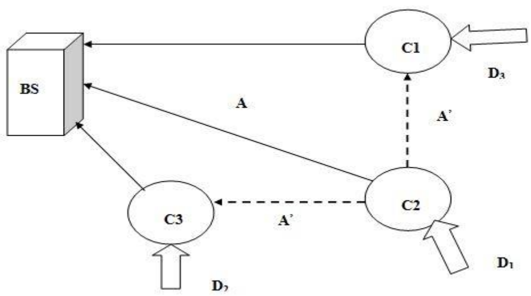

Figure 3 Illustration of incoming traffic scenario for a 2D topology

Given a wireless sensor network as shown in figure 3, with N nodes, the objective of this research is to determine a load balancing routing strategy to transfer information packets from source to destination. This could be achieved by considering a first order radio propagation model where the total energy consumed in transmitting an information bit could be arrived as

$$E_{TX}(t) = E_c(t) + E_{int}(t) \quad (1)$$

In (1), $E_c(t)$ denotes the power consumed by the associated circuitry in transmitting the one bit of information while $E_{int}(t)$ denotes the power consumed by sensor circuitry in improving the intensity of the sensed data or transmitted data. In the above equation, the energy associated with terminal nodes related to sensing of state of environment is considered to be uniform and the energy changes due to variation of incoming load or traffic alone is considered. Considering a NxM distribution of nodes in a wireless sensor network, the load balancing problem can be formulated by considering the following scenario depicted in figure 3.

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It could be seen that three traffic patterns in the form of data packets D1, D2 and D3 are incident on the three nodes C1, C2 and C3 which are closest to the base station BS. It is evident that the nodes closest to the BS bear the entire burden of incoming traffic from all other nodes and are considered to be overloaded in the general sense. The matrix of the traffic pattern on the nodes closest to the BS could be formulated as

$$\bar{D} = \begin{matrix} d_{11} & d_{12} & d_{1k} \\ d_{21} & d_{22} & d_{2k} \\ d_{k1} & d_{k2} & d_{kk} \end{matrix} \qquad (2)$$

And the associated cost matrix with respect to (2) is listed as

$$\bar{C} = \begin{matrix} c_{11} & c_{12} & c_{1k} \\ c_{21} & c_{22} & c_{2k} \\ c_{k1} & c_{k2} & c_{kk} \end{matrix} \qquad (3)$$

From figure 3, it could be seen that node C2 issues a broadcast related to the volume of traffic incident on it as A while those related to C1 and C3 are labeled A'. It could be seen from figure 3 that broadcast from C2 to C1 is more costly relatively issuing a direct broadcast to the BS which could be formulated as

$$E_{RX}(t[C1, C2]) = D_3\, \beta E_d + A' D_1 \beta\, E_d (1 + D_1) \qquad (4)$$

And the transmitted power is given as

$$E_{TX}(t[C1, C2]) = E_{RX}(t[C1, C2]) + \beta E_d \qquad (5)$$

On a similar note, the energy required for transmitting from node C_2 to BS could be derived as

$$E_{RX}(t[C2, C2]) = D_1\, \beta E_d + A(1 + D_1) \qquad (6)$$

In the equations (4), (5) and (6), β denotes the propagation constant along the channel and E_d denotes the power consumed by node for a distance 'd' units. Hence the objective of the load balancing algorithm would be to minimize the energy consumed by nodes C1, C2 and C3 which could be formulated as

$$O(\emptyset) = \min \{\max\big(E_{RX}(t[C1, C2]), E_{RX}(t[C2, C2])\big)\} \qquad (7)$$

(7) could also be alternately stated as an optimization problem as

$$O(\emptyset) = \min\, [E(t)] \qquad (8)$$

Where $E(t) = \max\big(E_{RX}(t[C1, C2]), E_{RX}(t[C2, C2])\big)$ (9)

A soft computing based supervised model is proposed in this work based on a clustered topology to reduce the complexity where the cluster heads alone take part in the communication process thus reducing the overall energy consumption thus improving the life time of the nodes. A clustered approach used in the proposed work is depicted in figure 4.

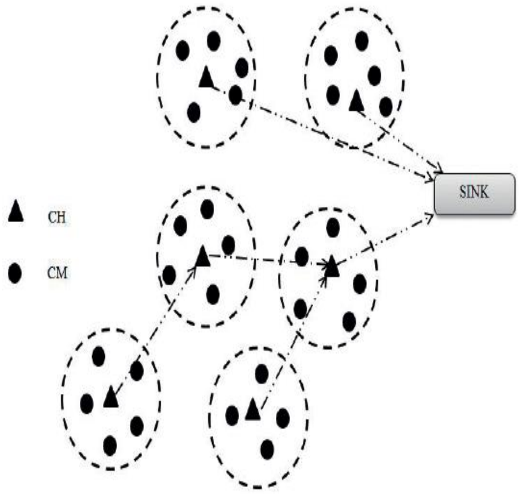

Figure 4 Structure of Clustering with Cluster Head

It could be seen from the above figure that the total set of available nodes are grouped in M clusters with CH denoting the cluster head and CM denoting the cluster member or the normal nodes which are part of their own cluster. The sink relates to the base station depicted in figure 3. The set of nodes are depicted as

$$\mathrm{N} = \{\mathrm{n}_1, \mathrm{n}_2 \mathrm{n}_3 \dots . \mathrm{n}_\mathrm{p}\} \in \mathrm{R} \qquad (10)$$

From (10), the cluster head selection is reflected as a probability factor that a node n_p will become a cluster head and formulated as

$$P[d, CH] \in cluster(CH) = e^{-\delta_{CH} \pi r^2} \qquad (11)$$

Where δ_{CH} denotes the density of cluster heads in the given network. A hard threshold is used in the proposed work based on distance metric *d* resulting in two clusters. The nodes form part of i[th] cluster if the intra node distance is <*d* while the rest belong to (i+1)[th] cluster if the distance is greater than *d*. The process repeats itself until no more nodes are left. The redundant and left over nodes are appended into the last cluster.

The minimization of computed fuzzy score is reflected as

$$\min(Fscore) = rule1; if E_{residual} = = weak|\gamma_n == medium|d_{n\to BS} = = medium|size(D) == large$$

$$\min(Fscore) = rule2; if E_{residual} = = medium|\gamma_n == strong|d_{n\to BS} = = weak|size(D) == medium$$

$$\min(Fscore) = rule3; if E_{residual} == strong|\gamma_n == weak|d_{n\to BS} = strong|size(D) == small \qquad (12)$$

(12) depicts the rules for a sample 3 case. Since four attributes are used 16 rules are framed for the proposed work.

The pseudo code of the proposed intra node distance based clustering is given below.

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$\boldsymbol{Input}$: $set\ of\ nodes\ \mathrm{N} = \{\mathrm{n}_1, \mathrm{n}_2\mathrm{n}_3 \ldots .\mathrm{n}_\mathrm{p}\} \in \mathrm{R}$
$\boldsymbol{Output}$: $set\ of\ cluster\ heads\ CH_L$
$= \{CH_1, CH_2CH_3 \ldots .CH_L\}$
$init_{thresh} = d(avg)$
$for\ k = 1\ to\ n$
$D_k = dist(n_i, n_j)$
$end\ for$
$while\ D_k < init_{thresh}$
$assign\ CH_L <= (\mathrm{n}_1, \mathrm{n}_2) \in D_k$
$else$
$assign\ CH_{L+1} <= (\mathrm{n}_1, \mathrm{n}_2) \in D_k$
$end\ while$
$i = i + 1$
$while\ i! = null$
$repeat$

Following the clustering algorithm implemented as per the pseudo code shown above, the minimization of received energy at the nodes nearest to the base station could be optimized by using a Fuzzy inference system whose pseudo code for minimization and decision making is given below. The proposed fuzzy inference system used in the proposed work is shown in figure 5.

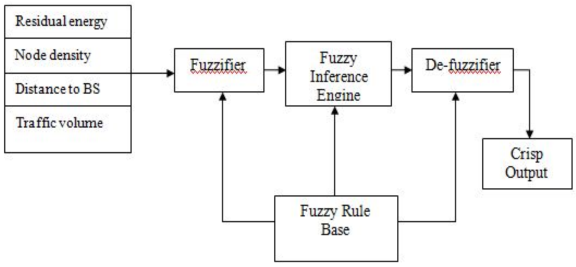

Figure 5 Fuzzy based dynamic load balancing algorithm flow process

In the proposed work, four inputs have been given as input to the fuzzy engine namely residual energy of nodes, the node density, and distance of current node to the base station and the volume of packets incoming to the terminal nodes. The pseudo code of the proposed FCDLB algorithm is given below.

$\boldsymbol{Input}$: $set\ of\ cluster\ heads\ CH_L$
$= \{CH_1, CH_2CH_3 \ldots .CH_L\}$
$\boldsymbol{Output}$: $O(CH_L) = \min\ (E(t))$
$Init\_randn(C_i); i = 1,2,3 \ldots \ldots .k$
$for\ i = \ 1\ down\ to\ k$
$if\ E(t) < init_{threshold}$
$compute\ Fscore\ [E(t)]\ \ as\ (12)$
$assign\ \ CH_L <= \min\ [Fscore[E(t)]]$
$else$
$assign\ CH_{L+1} <= \max\ [Fscore[E(t)]]$
$End\ if$
$update\ task\ list\langle D(Task)\rangle$
$while\ (D_{incoming} \gg D_{current})$
$call\ cluster$
$end\ while$
$End\ for$
End

IV. RESULTS AND DISCUSSION

Network Simulator 2 has been used to implement and simulate the proposed load balancing fuzzy clustering algorithm. The objective of the proposed algorithm is to dynamically adjust and adapt the network settings and configuration parameters to changing patterns of input traffic of packets. Minimization of energy consumption while maintaining the load balancing at optimal levels to prevent underutilization or overloading of any node is the sole objective of this research work. The proposed algorithm progresses in two phases in a sequential manner with a nested structure of implementation. During the first phase, a normal traffic condition is assumed t initiate the dynamic well organized load balancing algorithm and a clustering algorithm partitions the input network into cluster subsets based on feature vectors like residual energy, bandwidth, distance to the base station etc. The proposed algorithm has been tested with three corner nodes near the base station which are normally overloaded as almost all of the information from the terminal sensor nodes are routed through them to the base station. Whenever the current traffic condition $\mathrm{D}_{\mathrm{current}}$ is overcome by the incoming traffic by a threshold, the fuzzy module is invoked with residual energy, distance of node under consideration to base station, node density in the environment and traffic volume for the input to the fuzzy inference engine. Unlike the other algorithms, the CHs act as the main nodes with rotation of nodes done whenever the incoming packet traffic or load exceeds the current traffic volume. This ensures that all CHs are given an uniformly distributed loading condition thereby preventing a quick drain of any one of the CH due to over utilization. Moreover, drastic energy reduction is observed in this method as the CMs do not take part in active communication. On the other hand, the idle nodes in the cluster group take turns to become the next CH dictated by the fuzzy inference engine. The simulation settings taken for the experimentation is specified in table 1.

Table 1 Simulation specification

Parameter	Value
Network size	1000×1000 m
Number of sensor nodes	100-200
Radio propagation range	250 m
Channel capacity	2 M bits/sec
Initial Node energy	2J
Physical layer	IEEE 802.11b DCF
Data packet size	1000 bytes
Buffer size	65 data packets
Simulation time	360 Seconds

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Following the setting of configuration parameters as listed in table 2, the node distribution pattern in a random manner in proposed work is depicted in figure 6. The proposed algorithm has been successfully implemented and tested against conventional LEACH algorithms (cluster based approach without load balancing), dynamic load balancing algorithm [14] and Greedy Load balanced routing algorithm [19] which is essentially a graph cut based algorithm. The algorithm proceeds with initialization of 200 nodes deployed in a random manner. The intra node distance is used as the metric for clustering process and it is repetitive until the residual node count equals to zero. The output of the proposed routing scheme has been quantified in terms of delay analysis, packet drop ratio, network lifetime and average energy consumption of nodes. Two load balancing algorithms have been used for comparison by way of DLBA and GLBA while a non load balancing algorithm in the form of LEACH has been taken for comparative analysis of the response of proposed algorithm. The membership function used in the proposed work is illustrated in figure 6.

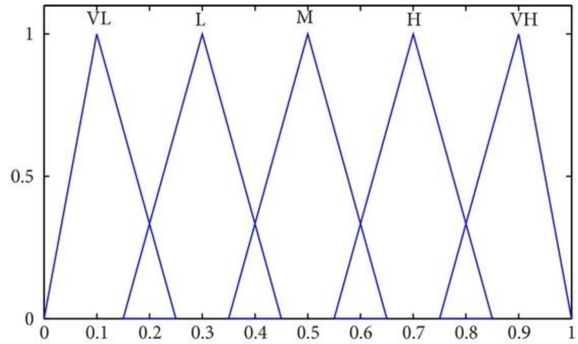

Figure 6 Membership function of proposed clustered fuzzy algorithm

The overlap ranges/threshold ranges are specified in table 2.

Table 2 Threshold ranges of membership values used in proposed work

Index	Value/Range
Very Low – VL	[0.00-0.12-0.28]
Low – L	[0.15-0.32-0.45]
Medium – M	[0.35-0.47-0.65]
High – H	[0.55-0.68-0.85]
Very High - VH	[0.75-0.91-1.00]

When the input traffic exceeds the current load condition on the servicing node, the fuzzy logic is invoked and the rules are designed based on the threshold distribution as listed in table 2. Based on the ranges, the incoming traffic are categorized accordingly and passed through the inference engine to obtain the desired crisp output regarding selection of CH among the set of candidate CMs. The efficiency of the proposed work over other techniques have been quantified in terms of four factors namely the end to end delay, average energy consumption, throughput and network lifetime.

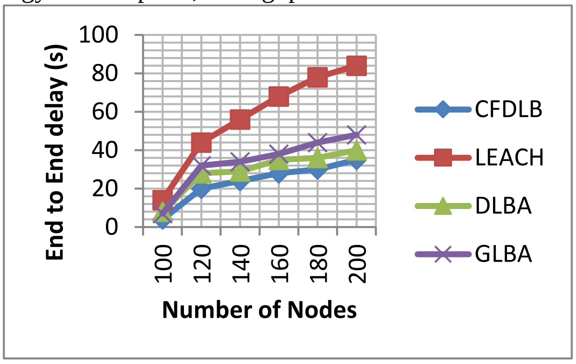

Figure 7 Delay analyses for the proposed work

Figure 7 illustrates the performance of the proposed energy efficient algorithm as compared against Low energy adaptive clustering hierarchy algorithm (LEACH), Dynamic load balancing algorithm (DLBA) and Greedy load balancing algorithm (GLBA). It could be seen that the end to end delay in the proposed work is drastically reduced by over 50% for a maximum node count of 200 nodes and of up to 42% when the number of nodes is at 100. The response time of the proposed algorithm for the given network is obtained by varying the node count to observe the complexity of the proposed algorithm. The observation is tabulated in table 3 where it could be seen that proposed clustered fuzzy is able to drastically reduce the response time when compared to the other cluster and load balancing algorithm thus justifying the relatively simplified logic behind fuzzy inference engine. However, increasing the number of rules and inputs at the fuzzy engine may result in proportional increase in complexity.

Table 3 Performance of response time for various techniques

No. of Nodes	Algorithm	Response time (s)
50	CFDLB	14.2
	LEACH	19.8
	DLBA	21.4
	GLBA	18.9
100	CFDLB	18.9
	LEACH	26.77
	DLBA	32.44
	GLBA	39.44
150	CFDLB	22.1
	LEACH	27.4
	DLBA	29.66
	GLBA	34.44
200	CFDLB	24.41
	LEACH	34.55
	DLBA	38.44
	GLBA	44.1

The next metric in justifying the performance of the proposed CFDLB is the packet drop ratio which is observed in the plot depicted in figure 8.

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It could be clearly observed that the proposed energy efficient algorithm outperforms the conventional cluster based techniques like LEACH, DLBA and GLBA ensuring a maximum transfer of information from source to destination which is reflective from the reduced packet drop ratio analysis. A packet drop ratio of up to 74% improvement is observed in the proposed algorithm as compared to LEACH algorithm, 56% improvement when compared to DLBA and 42% improvement when compared to Greedy based load balancing algorithm.

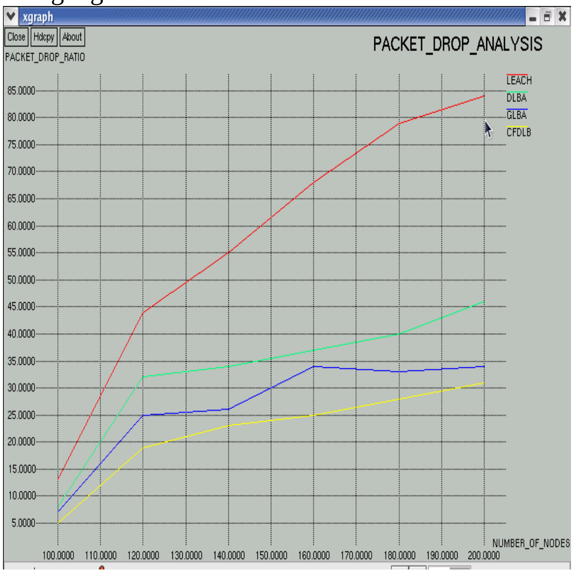

Figure 8 Performance of packet drop ratio

Figure 9 depicts the routing overhead incurred during route discovery. The performance has been computed by varying the number of paths and observing the incurred overhead. Proposed CFDLB exhibits a reduced overhead indicating reduced burden on the nodes nearest to the base station.

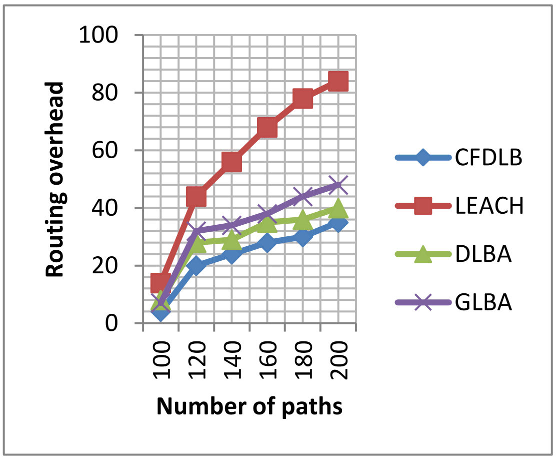

Figure 9 Routing overhead comparison of proposed CFDLB

Figure 10 depicts the energy consumption analysis measured in Joules with increasing number of node counts.

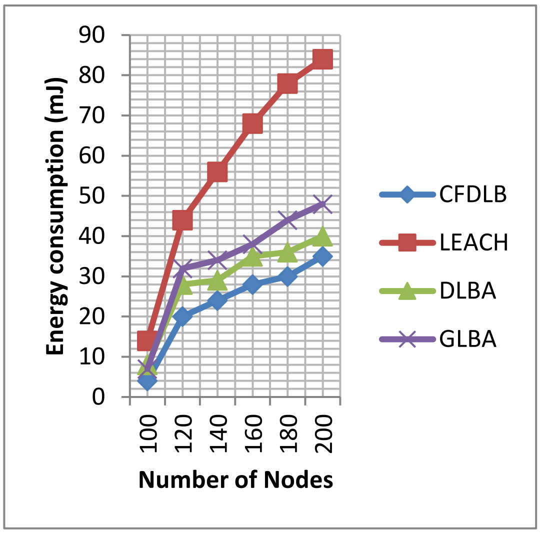

Figure 10 Energy consumption analysis of proposed work

Figure 11 depicts the residual energy measured over a period of time period and it could be seen that the residual energy is maximum for the proposed fuzzy based approach indicating a good load balancing at the sink node.

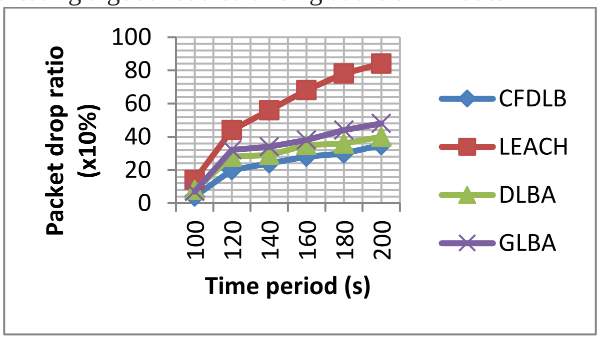

Figure 11 Analysis of residual energy for proposed work

A final analysis is in terms of standard deviation of power consumption for increasing number of nodes which depicts and reflects a fair distribution of load balancing among the nodes. Figure 12 depicts the plot of standard deviation.

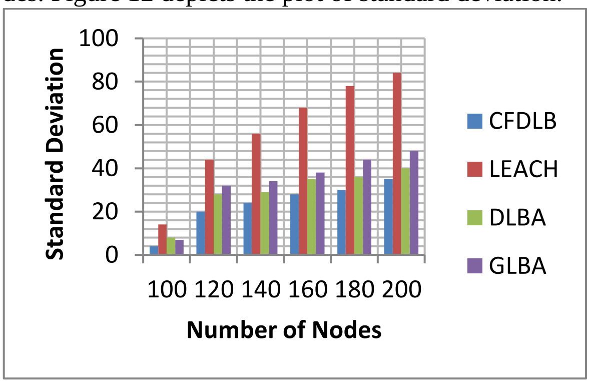

Figure 12 Comparative analysis of standard deviation

From the above plot it could be observed and concluded that the proposed clustered fuzzy algorithm records a low standard deviation relative to the other three techniques which indicates a uniform distribution of load reflected as minimal power consumption of nodes in the plot.

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V. CONCLUSION

A wireless sensor network has been taken up for investigation in this research article and dynamically well organized load balancing algorithm based on a clustered fuzzy engine operating on four attributes at its input layer to produce a supervised and known target output of choice of optimal CH. The algorithm exhibits reduced computational complexity due to the clustering approach based on a fuzzy based decision and the algorithm is recursive in nature. Based on the incoming traffic volume and load, the fuzzy engine and clustering algorithm is called in a recursive manner from the current time instant to decide upon a new cluster head among the candidate nodes. The proposed method follows a rotational utilization method of cluster head to distribute the load among the set of nodes in the cluster thereby avoiding overloading a single CH for the incoming traffic. The proposed algorithm is compared for its performance against three other techniques namely LEACH, DLBA and GLBA and is quantified in terms of packet drop ratio reflecting its throughput, end to end delay analysis reflecting the minimization of congestion in the transmission path, routing overhead reflecting the complexity in number of optimal paths selected based on the incoming traffic, average energy consumption of nodes and finally the standard deviation which reflects the degree of load sharing among the CHs. It could be clearly observed that the proposed clustered fuzzy engine model outperforms the LEACH without load balancing and two other algorithms which are dynamic and greedy search based respectively in all aspects of the aforementioned performance metrics. As a future scope of work, minimization of load balancing together with improvement of complexity and residual energy could be explored using nature inspired multi objective optimization algorithms.

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AUTHORS PROFILE

Dr. K. Selvakumar, obtained his Bachelor's Degree in Electronics and Communication Engineering in Kongu Engineering College, and the Master's Degree in Communication Systems from NIT Trichy, and Ph.D in Computer Science and Engineering from Annamalai University. He works as Associate Professor in Annamalai University. He has 29years of experience in teaching. His area of interest includes Cryptography and Wireless Network, Network Security, Mobile Computing.

G. Pattabirani ,Obtained her Bachelor's Degree in Information Technology in periyar maniammai college of Engineering and Technology, and the Master's Degree in Computer Science and Engineering from Annamalai University,and doing Ph.D in Computer Science and Engineering from Annamalai University .She works as Assistant Professor in Annamalai University.She has 12 years of experience in teaching.Her area of interest includes networking and Image processing

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