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Enhancing lifetime of network using clustering algorithms: A literature survey

Suganthi S
Assistant Professor, Department of Computer Science, G Venkataswamy Naidu College, Kovilpatti
Corresponding author email: krish.sugi1@gmail.com

Usha D
Assistant Professor, Department of Computer Science, Mother Terasa Women`s University, Kodaikanal
Email: ushadanabal@gmail.com

Mahizharuvi P
Assistant Professor, Department of Computer Science, Sri Meenakshi Govt Arts College for Women, Madurai
Email: mahizharuvi2008@gmail.com

Illakiam D
Assistant Professor, Department of Biotechnology, Mother Terasa Women`s University, Kodaikanal
Email: illakiam@gmail.com

***Abstract*---**Wireless Sensor Networks (WSNs) are considered as the main challenging features by the researchers for pursuing their research. The vital challenges in WSNs are to preserve energy and to do this the networks are made as clusters. The concept of clustering is, the nodes are segregated into several clusters and few nodes act as Cluster Heads. The nodes collect and send the data to CH. In turn CH, collect all datas and after grouping it, transmits the data to Base Station. The advantage of nodes being clustered includes: energy-efficiency, scalability, etc. Depending on the network architecture and application, the Clustering algorithms may differ for the Wireless Networks. Load balancing of network is also to be looked into. The amount of energy consumed by CH must be checked for enhancing the lifetime of the network. In this paper the authors has done a survey on three papers and have summarized the findings.

***Keywords*---**wireless sensor network, cluster heads, base station, threshold, K-coverage, genetic algorithm.

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Introduction

Sensors are tiny devices that are used to identify any event that is happening in the environment and after identifying, sends the collected information to some other devices, mostly an electronic device as in [1]. A sensor can detect anything say, heat; pressure; light; temperature; etc,. Sensors have small memory and the processing power is low. The output what we receive from the sensors are usually signals which are human readable, which are considered for additional processing. Each sensor acts as a node in a network and is capable of forming a network by combining with other nodes. A wireless sensor network (WSNs) uses various types of sensors based on the application. The uniqueness of WSN is energy conservation among the nodes and to increase the lifetime of network. For increasing the lifetime, a new technique called clustering was introduced in [2]. In common, the Wireless Sensor Networks are grouped into two: i) tracking, and ii) monitoring, as in [3, 4]. Generally WSNs are mainly used in locations like combat zone, jungles, engineering and medical fields, where human beings have restricted access. Hence it is necessary for the WSNs to function in an autonomous mode by self configuring them. WSNs function in the form of network and they are more conserved towards saving energy as in [5]. Usage of energy will be high when the data are transmitted to Base Station (BS), and every assessment is done at the node level itself. One significant problem faced by WSNs is to extend the lifetime of the network, and at the same time with controlled energy reserve as mentioned in [6]. In the network, if the nodes continuously transmit the data and receive the data, then there is a change for the data to collide with each other resulting in congestion. Once this happens then the nodes will be running short of energy.

Scalability of the network is also an important factor to be considered. For implementation purposes the network size must be taken into account, since the nodes number may get growing. For increasing the scalability of the network in an efficient manner, the best approach to follow is the Hierarchical architecture as in [7]. In Wireless Sensor Network, the nodes that are positioned in the similar layer are made as group to form clusters. The nodes must be properly managed and for this some of the nodes are elected as Cluster Heads (CHs). The energy of the WSN must be properly and efficiently consumed. Hence the clustering of nodes makes use of correlation amongst the data and thereby reducing the load to a greater extent on the network. All the nodes in the cluster are represented by CH. The nodes in the network will be sending the data, and these data must be gathered and aggregated by the CH, which in turn transmits these data to the BS. The success of Wireless Sensor Network operation is determined by the sensor nodes battery life as in [8]. We have to design the WSN in such a way that the energy consumed must be efficient so that the network lifetime can be extended. To boost the network lifetime, several clustering algorithms are formulated, which help WSN for a better efficient energy approach as in [9, 10]. Load balancing is also an important factor to be considered for the long duration of network lifetime. Depending on the cluster size, the lifetime of a network may be reduced. In a cluster, some clusters size may be small and few might be large in size, thus making the load unbalanced in a network causing the lifetime of the network to decline. The rest of the paper is organized as follows: Section 2, discussion of related work, and Section 3, present the conclusion.

Related Work

Few papers are surveyed here for enhancing the lifetime of Network in WSNs using clustering methodology. The papers are limited to some extent, unfinished, or even outdated (few methods in clustering may not have been covered

Cluster Based Energy Efficient Routing (CBER) algorithm

Mammu et al. [6] proposed a Cluster Based Energy Efficient Routing (CBER) algorithm. According to this algorithm, the CH are elected depending on the nodes which are very nearer to the best possible CH distance and also the nodes residual energy. To increase the lifetime of the network the author considers the residual energy while electing the CH. The primary advantage of clustering is that they reduce the expenses that are occurring owing to communication. The interferences and the consumption of energy are also reduced due to clustering techniques. With clustering the data efficiency is improved by reducing the node numbers that are needed to forward the data. By means of data aggregation, the overall packet lose is decreased due to intra cluster communication by CHs. The CHs are elected on an efficient rotation basis. The main aim of CBER algorithm is to increase the lifetime of network and extending the efficiency of energy. According to this scheme, the election of CH is determined by the best possible CH distance and the left over energy of the node. The author has used a radio model which was proposed in [11] for measuring the consumption of energy for CBER algorithm. In the radio model, the transmitter circuitry and the power amplifier are utilized for the energy used by the transmitter. The receiver circuit will be used for the energy utilized in the receiver for getting data. The distance between the transmitted and the received packet is (d) as mentioned in [12], and the receiver side, the signal power received is calculated as given in (1),

$$p_{rec}(d) = p_t G_{tra} G_{rec}\, \lambda^2 \ / \ (4\ \pi)^2\ d^{\beta} loss \qquad (1)$$

where G_{tra} = transmitter gain, G_{rec} = receiver gain, loss = extra loss during packet transmission, λ= carrier wavelength, β = propagation loss factor [differ amid 2 and 4], (p_{thres}) is minimum threshold power. At the transmitter side, the amount of energy absorbed is given by (2),

$$\begin{aligned} Ener_{tran} &= (e_{cons} + p_{thres}\ (4\pi)^{\ 2}\, R^{\beta} / \ \lambda^2 d_r\ ) \text{ x } Packet \\ &= \ (e_{cons} + e_{absor}\, R^{\beta}\ ) \text{ x Packet} \end{aligned} \qquad (2)$$

where e_{cons} = consumed *energy / bit* in transmitter, $e_{absor} = p_{thres}\ (4\pi)^{\ 2} \ / \ \lambda^2\ d_r$, = absorbed *energy*/*bit* in transmitter, d_r = data rate (*bit*/*second*) [both transmit and receive], Packet = number of bits in the packet

CBER makes use of self-organization technique intended for clustering and routing. In addition, the author considers the network with homogeneous sensor nodes. Here in CBER, every node needs to execute the job of sensing the ground parameters, data packets formation, and they must be in touch with the CH. The concept of clustering is that the nodes are partitioned into various clusters in the network. The author here has considered a Hexagonal structure for his network model. Sensor nodes are capable of functioning in two states: i) active, and ii) sleeping. The information regarding the present energy state of every node is shared only to the nodes neighbors. In CBER, the nodes are in four different modes: i) Cluster Head, ii) Cluster Member, iii) Dead Node, and iv) Isolated Node. A) Cluster Head (CH) – The Cluster Head is fully responsible for gathering the information from its members, and also for aggregating the information before transmitting the information to the Base Station (BS). CH employs two ways of communication: i) Intra Cluster, and ii) Inter Cluster. The former is between CH and its members, and in the latter, the communication is between CH and its nearby CHs. B) Cluster Member – belongs to a specific cluster. The collected information is regularly transmitted to the CH by this member. C) Dead Node – Since the energy of this sensor node is completely exhausted, it cannot operate further. Even when the residual energy (E_{res}) of this node comes down to 0.005J then it will attain this state. D) Isolated Node – it is detached from the network.

Table I shows the ration of Network Lifetime using various algorithms. From Table I, one can infer that CBER (when α = 0) gives better Network Lifetime compared with the other two algorithms, LEACH and HEED. The main purpose of this CBER algorithm is to extend the lifetime of the network.

Table I
Ratio of Network Lifetime using various Algorithms

S No	Algorithms	Ratio
1	HEED	0.78
2	LEACH	0.56
3	CBER(α =1)	0.55
4	CBER (α =0.5):	0.94
5	CBER(α =0)	1

α = is the weight function

The author compares his work with LEACH ad HEED algorithms. The simulation measurements are shown in the below Table – II.

Table II
Simulation Measurements

	Network Lifetime (s)	No of Packets
α =0	1900	140
α =0.5	1800	143
α =1	1045	95
LEACH	1081	86
HEED	1500	116

α = is the weight function
Source [6]

Future work proposed by this author is that to reduce the overhead of control packets and the efficient operation of nodes which are near the BS. In addition, make this algorithm to execute in the scenario where there is dynamic traffic with adaptable hexagonal arrangement depending on the size of the cluster.

Balanced Cluster size Clustering Approach

Vipin et al. [13] has proposed a clustering approach called the balanced cluster size, for extending the network lifetime. For the clustering algorithms to perform well, the important feature to be considered is the cluster size. Mostly all the clustering algorithms imagine that in each cluster have equal amount of nodes. Keeping this imagination these algorithms start their processing as mentioned in [14, 15]. In majority of the present clustering algorithms, the transmission of data is separated as frames. Further these frames are separated into time slots as stated in [16, 17]. In the cluster, every node will be having one time slot per frame. Finally, the CH will be sending the aggregated information to BS at the end of every frame. During the initial formation of cluster, a threshold (Th_{clus}) has been set, depending on the number of nodes present in clusters. Another threshold called distance threshold (Th_{dist}), is set for the nodes which are not clustered, to come and join the cluster. Thus these two above thresholds keep the network lifetime longer, and also they results in a better cluster formation with a balanced one. To achieve better load balancing, the proposed clustering algorithm will rotate the role of CH amongst the nodes. The death rate of the node is also less in contrast to the usual clustering algorithm. Depending on the node number in a cluster, length of frame is determined by the quantity of nodes present in a cluster.

To calculate the frame length (time), consider n nodes are present in a cluster. Then for transmitting a data packet, the time required is T_{tr}. After aggregating the data, the CH needs to send the data to the BS, and for doing this the required time is T_{CH}. The equation for calculating the frame length (time) is given in (3) and Time slots available per node is calculated as given in (4)

$$\text{Frame Length (time)} = (n \times T_{tr}) + T_{CH} \tag{3}$$

$$\text{Time slots (available per node)} = Trd \, / \, \text{Frame Length (time)} \tag{4}$$

where T_{rd} = data transmission time per round. The threshold Th_{clus} is calculated as in (5)

$$Th_{clus} = N_{actnod} \, / \, X \tag{5}$$

where N_{actnod} = active nodes, X = Number of CHs

Thus this has set two thresholds and has better balanced clusters and good cluster quality. Also the lifetime of network is surpassing the present clustering algorithms. The death rate of the node is also less.

K – Coverage based on Genetic Algorithm (GA)

Mohamed et al. [18] proposed an algorithm for WSN applications like target monitoring. Sensors are structured into groups and are known as sensor covers for monitoring targets. People use only one sensor for covering the classical target as cited in [19, 20]. And suppose if that sensor is dead, then the algorithms will not be able to do the necessary processing. For that reason, a target must be covered by a couple of sensors. This type of scenario is called as K-coverage problem. This procedure takes lot of time and energy. Here every time there must be association with the sensors as referred in [21]. To overcome this problem, the author proposes a genetic algorithm which is K-coverage model based for extending the network lifetime of WSN. The author had performed experiments with a range of K-coverage cases. Thus the proposed model had enhanced the lifetime of the network and energy consumption was also better. The time needed to switch among different covers was also better. In addition to energy, few optimization parameters are also considered, like consumption of time, permanent coverage, modes of sensor (ON/OFF), and cover structures are also incorporated. This K-coverage comes under NP- hard optimization problem which can be explained using an algorithm called metaheuristic optimization algorithms as in [22].

To extend the network lifetime and to get the best sensor covers, the author has proposed a Genetic Algorithm (GA) based model. From the above, the GA model can decide the active sensor cover for transmitting the data. Two works are involved. i) GA based model is formed with all potential sensor covers involving K-coverage environments, and ii) a method known as covers management was used for switching among various covers for extending the lifetime of network. The energy spent (E_n) for a cover is given in (6) as,

$$E_n = \sum_{i=1}^{Ns-1} E^{Tra}{}_{i,\,BS} \tag{6}$$

where N_s = members, $E^{Tra}{}_{i,BS}$ = Quantity of energy consumed when data is transmitted by a sensor (i) to BS. A sensor node`s energy consumption (E^{Tra}) for transmitting a message, say l bits is given in (7),

$$E^{Tra} = E_{idle} + l\, d^n \tag{7}$$

where E_{idle} = idle energy spent, d = distance amid transmitter and receiver, n = power term [takes some values]. Thus with the help of the energy consumed, the nodes energy can be calculated below as in (8)

$$\widetilde{Es} = E(0) - \sum_{ti=1}^{T} E\,{}^{Tra}_{S}\ (ti) \tag{8}$$

where E (0) = node`s initial energy, ti = lifetime of network

According to GA model, a group of nodes must always be active in order to look for a suitable cover. Three features are taken into account for preferring these active nodes: i) the distance amid Base Station (BS) and cover head, ii) the probable amount of energy consumed, and iii) the quantity of left over battery power. The future work of this paper says, apart from the performance, this model has to be tested in real situation.

Clustering Enhanced Approach

Kanakaraju et al. [23] proposed a clustering enhanced approach. The sensor nodes are grouped together as Clusters. The process of effectively using the energy the nodes is known as clustering. Low Energy Adaptive Hierarchical

Routing Protocol (LEACH) is considered as the main clustering algorithm in which the Cluster Heads (CHs) are decided by probabilistic approach. Numerous new protocols are introduced for selecting the CHs and making them to reliable energy. Mobility plays a vital role with the nodes in the network. To move ahead with effective energy in a clustering approach, the nodes are made to move freely, i.e. mobility of the nodes are taken care of. Here in this paper, for improving the life time of network, LEACH-ERE protocol was introduced alongside Handover method. The algorithm is proposed as follows: First, sensors are deployed in the network. Then the neighboring nodes distance are calculated. Transmission of data is performed, once Clusters are formed and CHs are selected. The energy for all the nodes present in the network is determined. Data is communicated among the nodes and CHs and as well between CHs and Base Station (BS). If the mobile nodes cross the boundaries of cluster, then Handoff mechanism is performed and once again re-clusters is done. The nodes are moved freely with handover scenario. Here the cluster of nodes is formed depending on the boundaries. The following figure 1 shows the proposed model by [23].

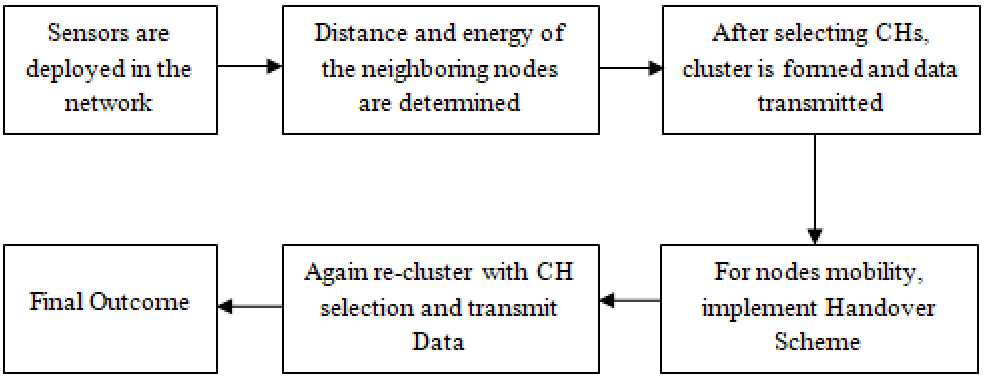

Fig: 1 The proposed system by [23]

After choosing the CHs, data is communication between the cluster nodes and CHs. Now CHs will communicate to BS and once again the nodes are re-clustered. The mobile nodes once entering the nearby clusters, the connection must not be terminated. The nodes must be in connection with the new nodes in the cluster and the connection to the nodes in the previous cluster must be cut off. This is done using the Handover mechanism. After each round, the sensor nodes forward the clustering information to the BS, so that the CHS are selected centrally. Yet again the Cluster Head is selected from the nodes which have the high residual energy. This process is keep on repeated. This LEACH-ERE protocol is mainly mobility based for the mobile nodes of various sizes (say 45 or 55). Different metrics are considered: consumption of energy, Average Throughput, and Average Packet Delivery Ratio. The results keep on varying with respect to the nodes placement in the network for a range of parameters. Table III shows the various simulation parameters used in the experiments. In Future, the work is to be implemented using Fuzzy logic concept.

Table III Simulation Parameters

S No	Parameters	Value
1	No of Nodes	45 or 55
2	Number of clusters expected	5
3	Deployment of nodes	Random
4	Energy	2J
5	Bandwidth	1 Mb/s

Impact of Fuzzy Interference System

Rajaram et al. [24] proposed a new technique for improving the network lifetime using Fuzzy Interference System. The two parameters used for effective power utilization are: i) selecting Cluster Head (CH), and ii) Aggregation and routing. For improving the effectiveness of the above mentioned parameters lot of techniques have been employed. Artificial Intelligence (AI) is used for assisting the problems to be sorted out. For sorting out the issues, few optimization techniques are used such as: Particle Swarm Algorithm (PSO), Genetic Algorithm (GA), Fuzzy Logic (FL), etc,. Here, few protocols utilized on WSNs by means of type 1 and type 2 fuzzy logic. For identifying the uncertainty of certain variables like low, high, very high, very low, etc, Fuzzy Logic is used for getting a good conclusion. For getting the desired conclusion, Fuzzy Logic used membership functions. Figure 2 shows the block diagram for type 1 fuzzy logic.

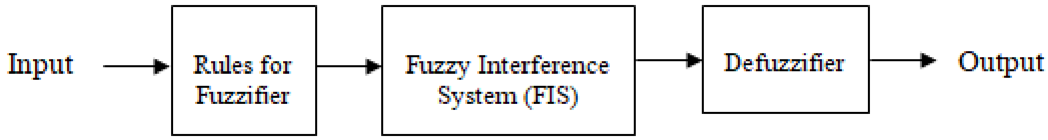

Fig 2 Type 1 Fuzzy Logic

The member functions involved will be Gaussian, Trapezoidal, etc,. Depending on the input to the fuzzifier, the necessary mapping of crisp input is processed to fuzzified input. FIS composed of rules and it has an interference engine for processing the inputs and for computing fuzzified output. Fuzzy logic is implemented to any application facing uncertainty. Figure 3 shows the block diagram for type 2 fuzzy logic. It consists of fuzzifier, interference engine, fuzzy output, type reducer, and defuzzifier. The function of type reducer is that it will be passing the fuzzified output from type 1 fuzzy logic to the defuzzifier. This defuzzifier will in turn give the final crisp output.

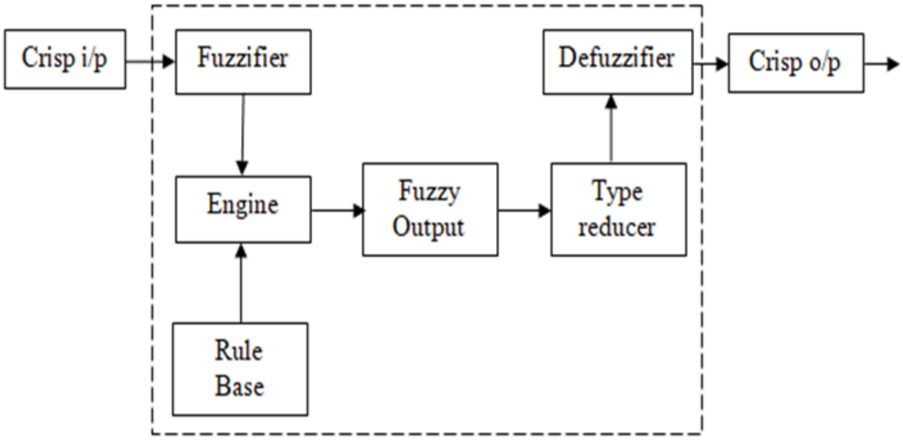

Fig 3 Type 2 Fuzzy Logic

Following are the steps to be carried out in fuzzy operation. The parameters for both input and output are to be identified. Then the variables are analyzed. Mapping of membership functions are done for both (input and output) the parameters. Now fuzzy rules are applied. Properly one needs to select the fuzzifier method. Also select the defuzzifier method too. For more operations to be done, the crisp outputs are transformed to defuzzified outputs.

Genetic Algorithm based on Virtual Grid based Dynamic Routes Adjustment

Mandeep et al. [25] proposed a new algorithm which is an energy efficient Genetic Algorithm (GA). It is based on the concept of Virtual Grid based Dynamic Routes Adjustment (VGDRA), thus enhancing the overall performance of WSNs. The energy efficiency is better in the proposed approach. The critical issue in WSN is energy consumption. If energy is consumed more, then the network lifetime will be reduced since the sensor nodes will be consuming more amount of energy. This leads to the nodes being dead before their stipulated time period. To overcome this issue, the author proposed a Genetic Algorithm (GA) based on Virtual Grid. GA complies with the following four principles: i) selection, ii) mutation, iii) crossover, and iv) evaluation.

The working of the proposed GA algorithm is as follows: The nodes are deployed first. The areas where the nodes are to be deployed are segregated into blocks of equal size using virtual grid. The nodes are also divided into same numbers for all blocks. GA declares the initial parameter required such as size of population, and number of iterations. Fitness function is evaluated for various iterations. The optimal path which is considered as best is calculated. The cluster head (CH) is selected from the nodes which have optimal solution. Data is communicated as per the CH selection. The routes are selected with the help of CH in the next block. Load balancing approach is formulated. The corresponding parameter values are calculated. The following table IV shows the parameters used for enhancing the lifetime of network.

Table IV parameters used

S No	Parameter	Value
1	Sensing area [case one]	$100*100m^2$
2	Sensing area [case two]	$300*300m^2$
3	Total number of nodes	180
4	Area	9 blocks
5	Block 1	Origin
6	Block 9	Destination
7	Population Size	10
8	Energy consumption [Tr & Rr]	50nJ/bit
9	Energy consumption free space	10 $pJ/bit/m^2$
10	Energy consumption multipath	0.0013 $pJ/bit/m^4$
11	Packet size	5000 bytes
12	No of rounds	3500

Conclusion

As the sensor nodes are dispersed in places where humans don't have access, they have to operate on their own with their self organization capability. For doing this they need lot of energy and hence it is a great challenge for us to preserve the energy and to enhance the lifetime of network. Many algorithms have been proposed by Researchers for solving the problems of conserving nodes energy. One such solution is clustering, which acts in two layered mannered. The first layer constitutes the regular nodes, and the second layer comprise of the Cluster Heads. In this paper, the presented a few survey on various clustering approaches and their algorithms. According to the analysis done on the survey, the design of a particular clustering protocol will heavily depend on the application and the requirement of the user. The main aim of the present algorithms surveyed says how to enhance the network lifetime.

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