

# Life-time Improvement of Wireless Sensor Networks using Relay Nodes and Fuzzy Logic

[1] Dr.S. Selva Nidhyananthan, [2] S. Surya, [3] H. Basheer Ahamed Batcha

[1] Associate Professor, Electronics and Communication Engineering, Mepco Schlenk Engineering College, Sivakasi,

[2] Electronics and Communication Engineering, Mepco Schlenk Engineering College, Sivakasi,

[3] Electronics and Communication Engineering, Mepco Schlenk Engineering College, Sivakasi ,

[1] Email: nidhyan@mepcoeng.ac.in,

[2] Email: suryaknagar@gmail.com,

[3] Email: basheerahamedbatcha@gmail.com

**Abstract**— *Wireless Sensor Networks play a major role in military purposes like surveillance, target detection and defense mechanisms. The sensor nodes here are deployed in a region and they monitor the region continuously. Lifetime of these nodes is a major factor as these cannot be recharged regularly. To enhance the lifetime various algorithms and protocols have been proposed. Most algorithms use fuzzy logic in their algorithms. Algorithms are mostly for the selection of the suitable Cluster Head(CH). In this paper we analyze the various algorithms and present their merits and demerits. As an extension we present some future predictions.*

**Index Terms**— *wireless sensor networks, clustering, fuzzy logic.*

## I. INTRODUCTION

Wireless Sensor Network is a collection of sensor nodes which are employed for various applications. The nodes are deployed randomly and they have a pre-charged battery. The energy level cannot be replaced regularly as these are randomly deployed. Hence, we come to know that the lifetime of a network is a major factor in Sensor Networks. Data transmission from the nodes to the Base Station (BS) occurs randomly. When a particular node is active for a certain reason the other nodes may be inactive during which an overhead might be continuously been sent to the BS this results in delay of the message from the node. Also, data collision occurs when all these nodes simultaneously contact the BS. To reduce these shortcomings clustering approach is employed in the networks. Wireless sensor networks also employ large number of nodes this facilitates easy sensing of the region. The basic architecture of a sensor node is shown in Fig.1. The major constituents of a sensor node are ADC, processor, power unit and storage. In the proceeding sections, we see about clustering in wireless sensor networks, fuzzy based clustering algorithms, merits and demerits followed by our conclusion.

## II. ROUTING PROTOCOLS USED IN WIRELESS SENSOR NETWORKS

Routing is the process used to find the path between source and destination. However, routing is a tedious process in Wireless Sensor Networks. Protocol is a rule base used to determine the correct path for communication of the nodes. There are various factors to overcome for establishing a suitable routing protocol. Let us see the various factors,

### II.A Challenges in routing for wireless sensor networks

#### II.A.1 Node deployment:

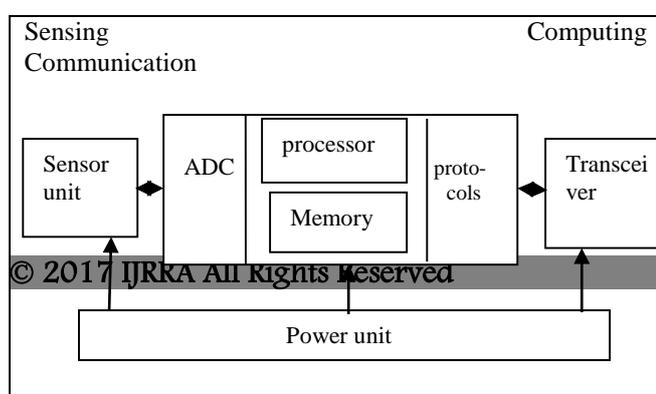
The deployment of nodes is either randomly or manually done. In random deployment the nodes are dropped at locations without any knowledge of location of the nodes after their deployment. In case of manual deployment, the nodes are dropped at some predetermined locations. Manual deployment is done in case of costly nodes.

#### II.A.2 Energy consumption:

As we know earlier that energy is an important aspect in case of sensors. Sensors use energy for sensing, processing, transmitting and receiving purposes. The energy present in the nodes should be carefully managed. For topology changes the network should be changed resulting in loss of energy. To reduce this, we introduce routing protocols which gives us a great trade-off between energy and accuracy.

#### II.A.3 Node nature:

Nodes are of two types mainly they are, homogenous and heterogeneous. In homogenous nodes they have same capabilities such as battery life, transmission range and



storage whereas heterogeneous nodes have different capabilities.

#### II.A.4. Area of coverage:

A sensor has only a certain range until which it can sense. After this range the sensor loses its sensing capability. Hence, the coverage area for a particular node should be defined using routing protocol.

#### II.A.5: Scalability:

The number of nodes may vary drastically from hundreds to thousands or more. Hence the network should be capable of scaling the nodes. Geographical knowledge of the nodes is to be known.

#### II.A.6. Quality of Service (QoS):

The routing protocol however is seen to be effective it should satisfy some measures such that a certain level of QoS parameters is satisfied. The various QoS parameters are bandwidth, jitter, throughput and delay. For target tracking applications delay should be less and in case of file transfer throughput should be high.

#### II.B. Classification of routing protocols:

There are various routing protocols and these are broadly classified based on protocol operation, network structure, path establishment and various other factors. In our paper we mainly see about the network structure-based routing protocols and they are classified as below,

- Flat
- Hierarchical (Cluster based)
- Location based

From the above classification we are going to see about hierarchical routing extensively.

### III. CLUSTERING IN WIRELESS SENSOR NETWORKS

The sensor nodes are grouped into groups of definite or random number. This approach is known as clustering. [14] The groups of nodes are known as clusters. For each cluster a node is selected as a Cluster Head (CH). This CH is selected randomly from the member nodes of a cluster. For the selection of CH various strategies are used. The CH should be eligible for maintaining the cluster. In a cluster there is one CH and the remaining nodes are Member Nodes (MN). The work of the CH is to aggregate the data from the Member Nodes and send it to the BS. While the other nodes continuously sense the area and send the information to the CH. The lifetime of CH is shorter compared to the member nodes hence, the node selected as CH should have high energy level. Nodes with less energy fail very quickly. In clustering both inter and intra cluster communication takes place. The members of the cluster can communicate with the CH and the CH can communicate with the other CH's. Also clustering approach involves definition of cluster size. The node density near BS should be less compared to the nodes far away. The BS should be capable of sensing the far away clusters or else data is lost. Clustering approach is shown in the Fig.2. in the next section routing protocols are seen.

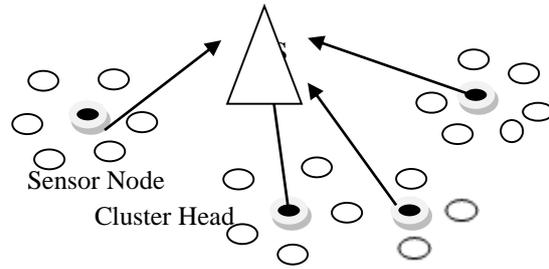


Fig.2. Clustering approach

### IV. CLUSTER BASED ROUTING PROTOCOLS

Cluster based routing protocols involve the usage of CH. Any node from the cluster can be selected as a CH. During the advent of clustering the nodes were randomly selected as Cluster Heads. After certain issues in this way of selecting CH new methods were continuously adopted and implemented. The important clustering protocols used presently are LEACH, PEGASIS, HEED, etc. Let us see about LEACH protocol as this is a prominent member in the architecture of clustering algorithms. [12][13] LEACH (Low Energy Adaptive Clustering Hierarchy) is a TDMA based MAC protocol. In this protocol stochastic approach is used for selecting the CH. As the name suggests this protocol uses less energy to maintain the clusters. The nodes transmit data to the cluster heads and they forward them to the BS. In this protocol 'P' is the required percentage of cluster-heads. When a node has been a cluster-head it cannot become CH until P rounds. After this, other nodes have 1/P probability to become cluster-head. A threshold T(n) is to be satisfied to become a cluster head. Let us assume there are G number of nodes that have not been cluster heads in the previous rounds and 'r' is the current round.

$$T(n) = p / (1 - P(r * \text{mod}(\frac{1}{P}))) \quad \text{if } n \in G$$

$$T(n) = 0 \quad \text{Otherwise}$$

For a particular node the above threshold is calculated. The nodes in a cluster are assigned a random number between 0 and 1. The node with less number than the threshold becomes the cluster head for the particular round. There are two important phases in the LEACH protocol they are, setup and steady phase. During the former case the cluster head advertises to the other nodes and in response the nodes request the CH to become member nodes. In the latter case data transmission occurs from the member nodes to the cluster heads and subsequently to the BS.

#### IV.A. Merits of leach:

- Lifetime improvement is observed.
- Aggregation of data by cluster heads result in reduced traffic to the BS.
- Single hop communication results in reduced energy usage.

#### IV.B. DEMERITS OF LEACH:

- Cluster size is random and not known.
- We don't know about the number of cluster heads present in the current round.
- If a cluster head dies the cluster cannot transmit data to the BS.

Also, in LEACH the location of a node is not known exactly. The node may be present at the edge of the network at this point the energy required to transmit to the BS is high than other nodes. If a node of lesser energy is elected as a CH then the node may die out soon. We see that various physical parameters are not considered in election of the CH in LEACH protocol. Hence fuzzy logic and other strategies are implemented in CH election. The next section is about various fuzzy based clustering algorithms.

### V.FUZZY BASED CLUSTERING ALGORITHMS

From the above discussion about LEACH we come know about the defects of the stochastic approach. We cannot rely only on the probability model. As an improvement fuzzy logic is introduced for selecting the CH. Fuzzy logic is used in making uncertain decisions when the data required is incomplete. When the data is presented incomplete to the fuzzy system human like decision making is done. The data presented to the fuzzy system is considered as the fuzzy parameters. The various parameters are selected from the nodes and fed into the fuzzy block from this we get an output, this is the required value which is checked with a threshold. If the condition is satisfied the node becomes a CH. The fuzzy system consists of a fuzzifier, fuzzy interference engine, defuzzifier and a rule base. The data presented to the fuzzifier is known as crisp input. This input gets fuzzified and is passed to the interference engine where human like decision making is done. Then the defuzzifier block gives a crisp output analogous to the fuzzifier. The fuzzy system is shown below in the Fig.3. This gives a clear explanation of the fuzzy system used in the upcoming clustering algorithms. Using the parameters if then else rules are applied and the output is obtained.

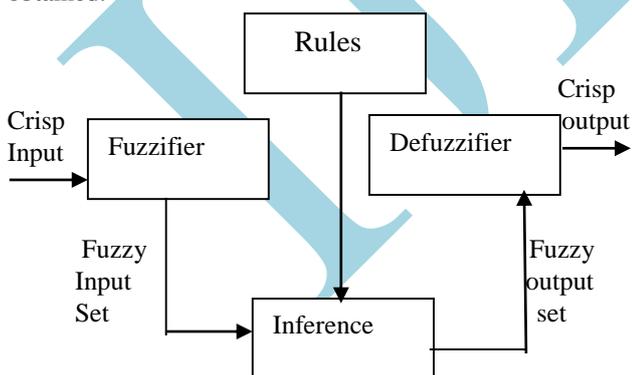


Fig.3. Components of Fuzzy block system.

Based on the inputs given to the fuzzy system various algorithms have been proposed. These inputs known as fuzzy parameters are physical parameters. In [6] the paper presents the novel approach for the CH election. Here they use the fuzzy parameters,

- Node energy- The energy present in the node.
- Node centrality- The location of node within the cluster is given by this factor.

- Node Concentration- The number of node present within the cluster.

These parameters are used by the fuzzy system and the suitable CH is elected. The CH selected is good but however there are various demerits. The deployment of nodes is not known. Also, only manual deployment can be done using the above method. In case of military purposes random deployment is the method used.

Further improvements are made in fuzzy logic for electing CH. [2] here the nodes selected as CH remain as CH for a particular amount of time. In LEACH and other protocols, the CH is elected for each round. Using this new CH is elected after each round this result in high traffic due to messages from and to the member nodes. In MCFL approach the CH is selected and it is kept as CH for few rounds.

Even though this approach seems better there are some demerits. When the elected CH has battery level less after certain rounds it may die. This death is premature and the entire cluster loses its communication with the BS. This approach has both the pros and cons.

Fuzzy logic is efficiently used in most of the algorithms but the major factor to be considered is overheads. These occur when the nodes repeatedly communicate with other nodes or BS during cluster head selection. [3] Here the CH election is done by reducing the overhead by using fuzzy logic efficiently. The two fuzzy parameters used are,

- Local distance- sum of distances from other nodes.
- Energy – remaining energy in the node.

In this paper they consider the local distance to eliminate the problem of node being present in the edge of the network. Energy efficiency is also major factor in the wireless sensor networks. Improvement of energy automatically improves lifetime of the network. In most of the algorithms the basic LEACH architecture is used to construct the protocol. LEACH-C is a centralized algorithm in which the BS collects information about the sensor nodes directly and the BS elects the CH. By this way the BS now knows about the network partially. Here the fuzzy parameters are distance from BS and energy present in the node.

In the above discussion there are some shortcomings. First of all, the network is not globally known. If the network is known, multi-hop routing can be done such that energy consumption by CH is reduced. [4] Here the energy prediction is done to select the suitable CH. The nodes here should not be mobile. Stationary nodes are present such that their energy remains is to be determined. The fuzzy parameter used here is predicted residual energy of nodes. For calculating this we need to know about the expected energy consumption of nodes. This favours good CH selection but the distance issue is not considered as it is also a factor affecting the CH. [1] this paper suitably covers the demerits of the previous papers. The node distribution here is non-uniform. Energy Efficient Distributed Clustering Algorithm based on Fuzzy approach (EEDCF) is used in this paper. The fuzzy parameters used here

are,

- Nodes energy
- Nodes degree from other nodes
- Neighbour nodes residual energy

Hence, these parameters are used such that the load balancing problem is solved and an effective CH is obtained.

Another major factor in clustering approach is the load to nodes. Generally, the nodes nearer to the BS suffer from radiation and die prematurely. This problem is known as hotspot problem. The clustering process involves grouping the nodes in many ways. The preferred method is non-uniform distribution where deployment of nodes is random. [8] Here the above approach can be seen. The algorithm is based on the distance and distribution of nodes. Each node has a radius of cluster; this is checked by the node whether it can form a cluster. The cluster size threshold should be met to obtain a cluster. If this is not satisfied another node is checked with. In the [7] the paper suggests that the clusters nearer to the BS should be small than clusters that are far away. This enables less traffic near the BS therefore minimizing packets dropped. Another major problem is energy hole problem which is due to different energy consumption pattern for different nodes at different locations. [9] Explains a different approach where both the hotspot and energy hole problem are reduced. Coverage also is an important parameter for a node. Based on various factors the coverage may get affected. In case of non-uniform distribution of nodes, the nodes may get densely populated at a particular region and sparsely in another region. This may affect the coverage of nodes. Hence after deployment of nodes the fuzzy logic is used to redeploy the nodes based on the coverage. [10] Explains this strategy. Most of the algorithms discussed above have merits but also some demerits. Considering the merits, we can see that fuzzy logic implementation has reduced overheads and introduced new election procedures for CH.

## VI. CLUSTERING ALGORITHM TO IMPROVE LIFETIME:

From the inferences above we determine a new approach for lifetime improvement. Here, around the area of interest a temporary group of clusters are placed which act as a relay between the inner clusters and BS. This reduces the radiation effect on the inner clusters. Also, the traffic due to packets can be reduced by this relaying process. The cluster head is selected using the fuzzy logic. Additionally, these cluster heads don't communicate with the BS directly but send the aggregated data to the nodes above this layer. This relay like approach eliminates the radiation effect to the nodes closer to the BS thereby increasing the duration of the first node to die. As a result, the nodes acting as a relay die early and these nodes can be replaced. Therefore, there is an overall improvement in the lifetime of the network. The nodes employed at the edge of the network are manually deployed such that the coverage of the network is not biased. The entire

area should be monitored by the inner nodes and the outer nodes should have coverage for at least half the area. This approach can be adopted such that the lifetime increases due to reduced radiation, decrease in the number of packets to BS. The approach for this model is shown in the Fig.4.

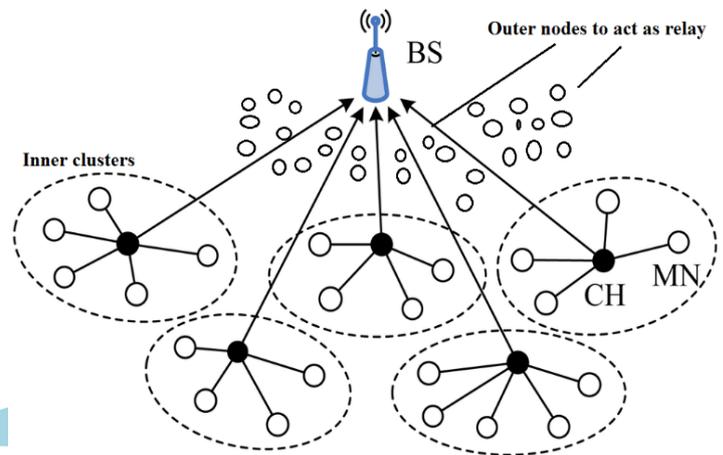


Fig.4. Approach for improving lifetime of network.

## CONCLUSIONS

Wireless sensor networks have been a boon to both military and civil applications. In target detection, environment monitoring etc., sensor networks are used. In these applications a large number of nodes are used to monitor the events. Hence, here nodes should remain alive for a large duration. Clustering approach favors this need but an efficient CH is to be selected. Fuzzy logic is used effectively to select the CH. In this paper we have discussed about various algorithms used to determine clustering. Most of the algorithms are similar except the parameters used. From the discussions we see improvement of lifetime of network, coverage and many other factors.

## REFERENCES

- [1] Ying Zhang, Jun Wang, Dezhi Han, Huafeng Wu and Rundong Zhou, "Fuzzy-Logic Based Distributed Energy-Efficient Clustering Algorithm for Wireless Sensor Networks", published in journal "Smart Communication Protocols and Algorithms for Sensor Networks", July 2017.
- [2] Mostafa Mirzaie and Sayyed Majid Mazinan, "MCFL: An Energy Efficient Multi Clustering Algorithm Using Fuzzy logic in WSN" Mirzaie, M. & Mazinani, S.M. WirelessNetw (2017). <https://doi.org/10.1007/s11276-017-1466-5>
- [3] Z.W. Siew, A. Kiring and H.T. Yew, "Energy Efficient clustering algorithm in Wireless Sensor Network using Fuzzy Logic Control", Published in "Humanities, Science and Engineering (CHUSER), 2011 IEEE Colloquium on" March 2012.
- [4] Jin-Shyan Lee, "Fuzzy logic-based Clustering Approach for WSN using Energy Prediction", IEEE

SENSORS JOURNAL, VOL. 12, NO. 9, SEPTEMBER 2012.

- [5] Jong-Myoung Kim, Seon-Ho Park and Young-Ju Han, "CHEF: Cluster Head Election mechanism using Fuzzy logic in Wireless Sensor Networks" **Published in** "on" April 2008.
- [6] Indranil Gupta, D. Riordan and Srinivas Sampalli, "Cluster-head election using fuzzy logic for wireless sensor networks" **Published in** "Communication Networks and Services Research Conference, 2005. Proceedings of the 3rd Annual" May 2005.
- [7] Ying Liao, Huan Qi, and Weiqun Li, "Load-Balanced Clustering Algorithm with Distributed Self-Organization for Wireless Sensor Networks", IEEE SENSORS JOURNAL, VOL. 13, NO. 5, MAY 2013.
- [8] Hakan Bagci and Adnan Yazici, "An energy aware fuzzy approach to unequal clustering in wireless sensor networks", Applied soft computing, Vol13, Issue4, April 2013, Pages 1741-1749.
- [9] Seyyit Alper Sert, Hakan bagci and Adnan Yazici, "MOFCA: Multi-objective fuzzy clustering algorithm for wireless sensor networks", Applied, Volume 30, May 2015, Pages 151-165.
- [10] A. Osmani, M. Dehghan and H. Pourakbar, "Fuzzy-Based Movement-Assisted Sensor Deployment Method in Wireless Sensor Networks" **Published in** "Computational Intelligence, Communication Systems and Networks, 2009. CICSYN '09. First International Conference on" July 2009.
- [11] Ningbo Wang and Hao Zhu, "An Energy Efficient Algorithm Based on LEACH Protocol", **Published in** "on", March 2012.
- [12] Yuling Li, Luwei Ding and Feng Liu, "The improvement of LEACH protocol in WSN", **Published in** "Computer Science and Network Technology (ICCSNT), 2011 International Conference on", Dec. 2011.
- [13] Abdullah Erdal Tumer and Mesut Gunduz, "An improved leach protocol for indoor wireless sensor networks", **Published in** "Signal Processing and Integrated Networks (SPIN), 2014 International Conference on", Feb. 2014.
- [14] Chunjuan Wei, Junjie Yang and Yanjie Gao, "Cluster-based routing protocols in wireless sensor networks: A survey", **Published in** "Computer Science and Network Technology (ICCSNT), 2011 International Conference on", Dec. 2011.