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Adaptive Neuro Fuzzy Inference Systems Based Clustering Approach For Wireless Sensor Networks

Vishalatchi Selvara

Assistant professor in computer science,
P.K.R ARTS COLLEGE FOR WOMEN,GOBI

Abstract:
Wireless Sensor Networks (WSN) can be defined as a self configured network formed using a large numbers of sensor nodes distributed over a geographical area with either predefined location or randomly deployed. Individual sensor nodes posses limited processing, communicating and energy recourses. These sensor nodes can sense, measure, and gather information from the vicinity, based on the local pre defined decision process, can transmit the sensed information (data) to the user or information sink. Communication of sensed data from the sensor nodes to information sink happens to be the main cause of energy depletion in sensor nodes. In order to extend the active life of WSN, it is required to process data locally and send the processed information to sink node. One of possible solution for optimal use of available energy is by using cluster based routing protocols

1 .Introduction

A Wireless Sensor Network (WSN) consists of a large number of sensors, each of which are physically small devices, and are equipped with the capability of sensing the physical environment, data processing, and communicating wirelessly with other sensors. Generally, assume that each sensor in a wireless sensor network has certain constraints with respect to its energy source, power, memory, and computational capabilities.

The communication paradigm of wireless sensor networks has its root in wireless ad hoc networks, where network nodes self-organize in an ad hoc fashion,′usually on a temporary basis. In a wireless ad hoc network, a group of wireless nodes spontaneously form a network without any fixed and centralized infrastructure. When two nodes wish to communicate, intermediate nodes are called upon to forward packets and to form a multi-hop wireless route. Due to possibilities of node mobility, the topology is dynamic and routing protocols are proposed to search for end-to-end paths. The network nodes rely on peers for all or most of the services needed and for basic needs of communications. Due to the lack of centralized control and management, nodes rely on fully distributed and self-organizing protocols to coordinate their activities. In both scenarios, distributed protocols need to accommodate dynamic changes at any given time: (1) a node may join or leave the network arbitrarily; (2) links may be broken; and (3) nodes may be powered down as a result of node failures or intentional user actions. Figure 1.1 illustrates a wireless ad hoc network formed by the mobile nodes. As shown in the figure, each network node has a finite transmission range represented by the dotted loop around the node. The arrows represent the network topology resulted from the transmission ranges.

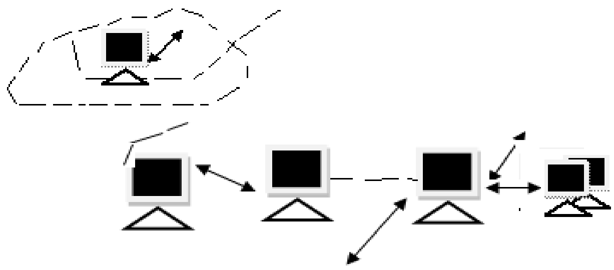


Figure 1.1: The communication paradigm

Ad Hoc Wireless Sensor Networks have the capacity to revolutionize the contemporary technical arena. Offering a more convenient means of communication, this idea of infrastructure less networks can transform many applications, including military strategy, home security, information transfer, environment monitoring, and surveillance.

2. Clustering In Wireless Sensor Networks

Wireless sensor networks (WSNs) used in many applications, including environmental monitoring and military field surveillance. In these applications, tiny sensors are deployed and left unattended to continuously report parameters such as temperature, pressure, humidity, light, and chemical activity.

Several WSN applications require only an aggregate value to be reported to the observer. In this case, sensors in different regions of the field can collaborate to aggregate their data and provide more accurate reports about their local regions.

For example, in a habitat monitoring application, the average reported humidity values may be sufficient for the observer. In military fields where chemical activity or radiation is measured, the maximum value may be required to alert the troops. In addition to improving the fidelity of the reported measurements, data aggregation reduces the communication overhead in the network, leading to significant energy savings.

In order to support data aggregation through efficient network organization, nodes can be partitioned into a number of small groups called clusters. Each cluster has a coordinator, referred to as a cluster head, and a number of member nodes.

Clustering results in a two-tier hierarchy in which cluster heads (CHs) form the higher tier while member nodes form the lower tier. Figure 1.2 illustrates data flow in a clustered network. The member nodes report their data to the respective CHs. The CHs aggregate the data and send them to the central base through other CHs. Because CHs often transmit data over longer distances, they lose more energy compared to member nodes. The network may be re clustered periodically in order to select energy-abundant nodes to serve as CHs, thus distributing the load uniformly on all the nodes. Besides achieving energy efficiency, clustering reduces channel contention and packet collisions, resulting in better network throughput under high load.

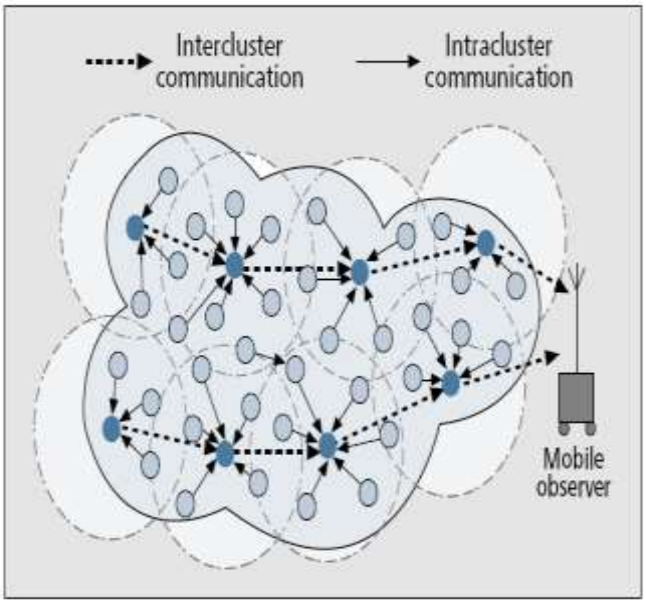


Figure 1: Illustration of Data Flow in a Clustered Network

Clustering has been shown to improve network lifetime, a primary metric for evaluating the performance of a sensor network. Although there is no unified definition of "network lifetime," as this concept depends on the objective of an application, common definitions include the time until the first/last node in the network depletes its energy and the time until a node is disconnected from the base station. In studies where clustering techniques were primarily proposed for energy efficiency purpose, the network lifetime was significantly prolonged.

Clustering has been extensively studied in the data processing and wired network literatures. The clustering approaches developed in these areas cannot be applied directly to WSNs due to the unique deployment and operational characteristics ad hoc manner and have a large number of nodes. The nodes are typically unaware of their locations. Hence, distributed clustering protocols that rely only on neighborhood information are preferred for WSNs (however, most studies in this area still assume that the network topology is known to a centralized controller). Furthermore, nodes in WSNs operate on battery power with limited energy. Hence, the employed clustering approach must have low message overhead. Finally, harsh environmental conditions result in unexpected failures of nodes.

Hence, periodic re clustering is necessary in order to heal disconnected regions and distribute energy consumption across all nodes. Periodic reclustering is also necessary, as the parameters used for clustering (e.g., the remaining energy, node degree, etc.) are dynamic.

2.1 Classification of Clustering Techniques in Wireless Sensor Networks

Clustering in WSNs involves grouping nodes into clusters and electing a CH such that :

- The members of a cluster can communicate with their CH directly.
- A CH can forward the aggregated data to the central base station through other CHs.

Thus, the collection of CHs in the network forms a *connected dominating set*. Research on clustering in WSNs has focused on developing centralized and distributed algorithms to compute connected dominating sets. The focus on distributed approaches in this article since they are more practical for large-scale deployment scenarios. Since obtaining an optimal dominating set is an NP-complete problem, the proposed algorithms are heuristic in nature.

Classify the clustering techniques based on two criteria:

- The parameter(s) used for electing CHs
- The execution nature of a clustering algorithm (probabilistic or iterative)

2.2 Election of Cluster Heads

One class of clustering techniques uses the node identifier to elect CHs. The success of this approach depends on two assumptions:

- Every node has a unique identifier.
- These identifiers are uniformly assigned throughout the field.

For example, the scheme in favors nodes with lower identifiers to become CHs. This approach may not be suitable for energy-constrained sensor networks because it penalizes specific nodes in the network irrespective of their battery lifetimes.

Another class favors nodes with larger degrees in order to create dense clusters and elect the minimal dominating set of CHs (the degree of a node is the number of its neighbors within a prespecified transmission called the cluster range). This, however, may result in quickly draining the battery of larger-degree nodes. From an application perspective, balancing cluster sizes reduces the load on CHs.

However, this comes at the expense of having more clusters in the network and thus a larger routing overlay.

A third class of techniques favors nodes with higher weights to become CHs. The weight of the node is used to define its significance. For example, it can be the residual battery energy (as in the HEED protocol), its degree (as in the ACE protocol), or a combination of parameters (e.g., remaining energy, degree, mobility, and average distance to neighbors).

Some protocols, such as GAF and SPAN, were proposed for controlling the network topology by exploiting node redundancy. These protocols select certain nodes to be active (i.e., participate in sensing and data forwarding), while others are put to sleep to save their energy. In GAF, for example, a node belongs to a region that is determined by its location. A region in this context is defined as an area A in which any node u can communicate via a single hop with any node v Î B, where B is a neighboring region to A. Thus, only one representative node in any region needs to participate in the routing infrastructure at any given time to ensure network connectivity. In SPAN [4], a node decides whether to remain active or go to sleep according to its two-hop neighborhood connectivity. Although these protocols are not clustering techniques, their effect on the network topology is similar to that of clustering.

2.3 Main Objectives and Design Challenges of Clustering in WSNs

Hierarchical clustering in WSNs can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster, performing data aggregation and fusion in order decrease the number of transmitted messages to the BS. On the contrary, a single-tier network can cause the gateway to overload with the increase in sensors density. Such overload might cause latency in communication and inadequate tracking of events. In addition, the single-tier architecture is not scalable for a larger set of sensors covering a wider area of interest because the sensors are typically not capable of long-haul communication. Hierarchical clustering is particularly useful for applications that require scalability to hundreds or thousands of nodes. Scalability in this context implies the need for load balancing and efficient resource utilization. Applications requiring efficient data aggregation (e.g., computing the maximum detected radiation around a large area) are also natural candidates for clustering. Routing protocols can also employ clustering..Clustering was also proposed as a useful tool for efficient pinpointing object locations.

In addition to supporting network scalability and decreasing energy consumption through data aggregation, clustering has numerous other secondary advantages and corresponding objectives. It can localize the route setup within the cluster and thus reduce the size of the routing table stored at the individual node. It can also conserve communication bandwidth because it limits the scope of intercluster interactions to CHs and avoids redundant exchange of messages among sensor nodes. Moreover, clustering can stabilize the network topology at the level of sensors and thus cuts on topology maintenance overhead. Sensors would care only for connecting with their CHs and would not be affected by changes at the level of inter-CH tier. The CH can also implement optimized management strategies to further enhance the network operation and prolong the battery life of the individual sensors and the network lifetime. A CH can schedule activities in the cluster so that nodes can switch to the low-power sleep mode and reduce the rate of energy consumption. Furthermore, sensors can be engaged in a round-robin order and the time for their transmission and reception can be determined so that the sensors reties are avoided, redundancy in coverage can be limited, and medium access collision is prevented.

2.4 Major Sources of Energy Waste in WSNS

Energy is a very scarce resource for such sensor systems and has to be managed wisely in order to extend the life of the sensor nodes for the duration of a particular mission. Energy consumption in a sensor node could be due to either “useful” or “wasteful” sources. Useful energy consumption can be due to transmitting or receiving data, processing query requests, and forwarding queries and data to neighboring nodes.

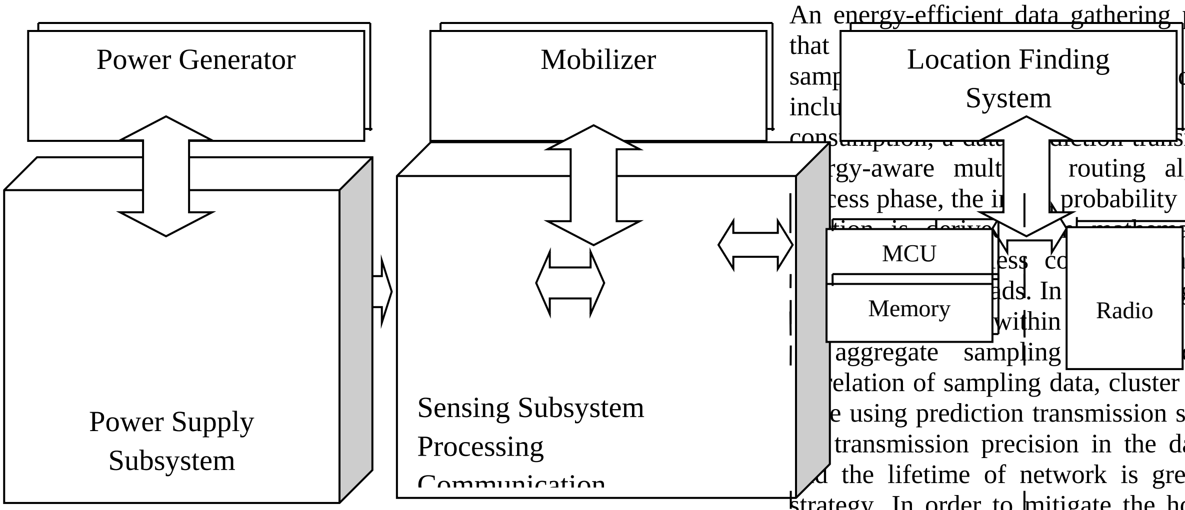
Wasteful energy consumption can be due to one or more of the following facts. One of the major sources of energy waste is idle listening, that is, (listening to an idle channel in order to receive possible traffic) and secondly reason for energy waste is collision (When a node receives more than one packet at the same time, these packets are termed collided), even when they coincide only partially. All packets that cause the collision have to be discarded and retransmissions of these packets are required which increase the energy consumption. The next reason for energy waste is overhearing (a node receives packets that are destined to other nodes). The fourth one occurs as a result of control-packet overhead (a minimal number of control packets should be used to make a data transmission).

Finally, for energy waste is over-emitting, which is caused by the transmission of a message when the destination node is not ready. Considering the above-mentioned facts, a correctly designed protocol must be considered to prevent these energy wastes.

2.5 General Approaches to Energy Conservation in WSN

Based on the below architecture and power breakdown, several approaches have to be exploited, even simultaneously, to reduce power consumption in wireless sensor networks. At a very general level, identify three main enabling techniques, namely, duty cycling, data-driven approaches, and mobility.

Duty cycling is mainly focused on the networking subsystem. The most effective energy-conserving operation is putting the radio transceiver in the (low-power) sleep mode whenever communication is not required. Ideally, the radio should be switched off as soon as there is no more data to send/receive, and should be resumed as soon as a new data packet becomes ready. In this way nodes alternate between active and sleep periods depending on network activity. This behavior is usually referred to as duty cycling, and duty cycle is defined as the fraction of time nodes are active during their lifetime. As sensor nodes perform a cooperative task, they need to coordinate their sleep/wakeup times. A sleep/wakeup scheduling algorithm thus accompanies any duty cycling scheme. It is typically a distributed algorithm based on which sensor nodes decide when to transition from active to sleep, and back. It allows neighboring nodes to be active at the same time, thus making packet exchange feasible even when nodes operate with a low duty cycle (i.e., they sleep for most of the time).



Fig

Figure 1.3: Architecture of a Typical

Wireless Sensor Node

Duty-cycling schemes are typically oblivious to data that are sampled by sensor nodes. Hence, data-driven approaches can be used to improve the energy efficiency even more. In fact, data sensing impacts on sensor nodes' energy consumption in two ways:

• Unneeded samples. Sampled data generally has strong spatial and/or temporal correlation, so there is no need to communicate the redundant information to the sink.

Energy usage is an important issue in the design of WSNs which typically depends on portable energy sources like batteries for power .WSNs is large scale networks of small embedded devices, each with sensing, computation and communication capabilities. They have been widely discussed in recent years.. Micro-Electro-Mechanical System (MEMS) sensor technology has facilitated the development of smart sensors, these smart sensors nodes are small devices with limited power, processing and computation resources. Smart sensors are power constrained devices that have one or more sensors, memory unit, processor, power supply and actuator. In WSNs, sensor nodes have constrained in term of

processing power, communication bandwidth, and storage space which required very efficient resource utilization. In WSNs the sensor nodes are often grouped into individual disjoint sets called a cluster, clustering is used in WSNs, as it provides network scalability, resource sharing and efficient use of constrained resources that gives network topology stability and energy saving attributes. Clustering schemes offer reduced communication overheads, and efficient resource allocations thus decreasing the overall energy consumption and reducing the interferences among sensor nodes. A large number of clusters will contest the area with small size clusters and a very small number of clusters will exhaust the cluster head with large amount of messages transmitted from cluster members. LEACH protocol is hierarchical routing based on clustering and find the optimal number of clusters in WSNs in order to save energy and enhance network lifetime.

3. Energy Efficiency In Wsn

An energy-efficient data gathering protocol called E2DGP that [illegible] temporal correlation of samp[illegible]d in the survey. E2DGP inclu[illegible] of balancing energy consumption, a data [illegible] transmission strategy and an [illegible]rgy-aware mult[illegible] routing algorithm. In clustering [illegible]cess phase, the i[illegible] probability of node for cluster head [illegible] is derive[illegible] mathematical relation between [illegible]ess co[illegible]ction and numbers of [illegible]ds. In [illegible]gation phase, the spatial [illegible] within [illegible] utilized by cluster head [illegible] aggregate sampling [illegible]ccording to temporal [illegible]elation of sampling data, cluster heads send data to sink [illegible]e using prediction transmission strategy while satisfying [illegible] transmission precision in the data transmission phase, [illegible] the lifetime of network is greatly prolonged by this strategy. In order to mitigate the hot spot problem among cluster heads, a greedy geographic and energy-aware multihop routing algorithm is presented for inter-cluster communication

3.1. Cluster Design In Energy Conservation

Cluster-based design is one of the approaches to conserve the energy of the sensor devices since only some nodes, called cluster heads (CHs), are allowed to communicate with the base station. The CHs collect the data sent by each node in that cluster, compress it, and then transmit the aggregated data to the base station. The representative design is low-energy adaptive clustering hierarchy (LEACH) protocol, which uses a pure probabilistic model to select CHs and rotates the CHs periodically in order to balance energy consumption. However, in some cases, inefficient CHs can be selected. Because LEACH depends on only a probabilistic model, some cluster heads may be very close each other and can be located in the edge of WSNs. These inefficient cluster heads could not maximize the energy efficiency. Appropriate cluster-head selection can significantly reduce energy consumption and prolong the lifetime of WSNs. Based on LEACH, most existing fuzzy clustering approaches considered the residual energy of sensor nodes during the CH selection. However, the remaining energy after being selected as a CH and running around has never been discussed. A round refers to the interval between two consecutive cluster formation processes

3.2 Leach:Low-Energy Adaptive Clustering Hierarchy

LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. In LEACH, the nodes organize themselves into local clusters, with one node acting as the local base station or *cluster-head*. If the cluster heads were chosen a priori and fixed throughout the system lifetime, as in conventional clustering algorithms, it is easy to see that the unlucky sensors chosen to be cluster-heads would die quickly, ending the useful lifetime of all nodes belonging to those clusters. Thus LEACH includes randomized rotation of the high-energy cluster-head position such that it rotates among the various sensors in order to not drain the battery of a single sensor. In addition, LEACH performs local data fusion to "compress" the amount of data being sent from the clusters to the base station, further reducing energy dissipation and enhancing system lifetime.

Sensors elect themselves to be local cluster-heads at any given time with a certain probability. These cluster head nodes broadcast their status to the other sensors in the network. Each sensor node determines to which cluster it wants to belong by choosing the cluster-head that requires the minimum communication energy. Once all the nodes are organized into clusters, each cluster-head creates a schedule for the nodes in its cluster. This allows the radio components of each non-cluster-head node to be turned off at all times except during its transmit time, thus minimizing the energy dissipated in the individual sensors [51]. Once the cluster-head has all the data from the nodes in its cluster, the cluster-head node aggregates the data and then transmits the compressed data to the base station. Since the base station is far away in the scenario, this is a high energy transmission. However, since there are only a few cluster-heads, this only affects a small number of nodes.

The cluster-head drains the battery of that node. In order to spread this energy usage over multiple nodes, the cluster-head nodes are not fixed; rather, this position is self-elected at different time intervals. Thus a set C of nodes might elect themselves cluster-heads at time t_1, but at time $\mathrm{t}_1 + \mathrm{d}$ a new set C' of nodes elect themselves as cluster-heads. The decision to become a cluster-head depends on the amount of energy left at the node. In this way, nodes with more energy remaining will perform the energy-intensive functions of the network. Each node makes its decision about whether to be a cluster-head independently of the other nodes in the network and thus no extra negotiation is required to determine the cluster-heads.

The system can determine, a priori, the optimal number of clusters to have in the system. This will depend on several parameters, such as the network topology and the relative costs of computation versus communication. The simulated the LEACH protocol for the random network shown in Figure 3 using the radio parameters in Table 1 and a computation cost of 5 nJ/bit/message to fuse 2000-bit messages while varying the percentage of total nodes that are clusterheads. Figure 8 shows how the energy dissipation in the system varies as the percent of nodes that are cluster-heads is changed. Note that 0 cluster-heads and 100% clusterheads is the same as direct communication. From this plot, find that there exists an optimal percent of nodes $\widehat{\mathrm{N}}$ that should be cluster-heads. If there are fewer than $\widehat{\mathrm{N}}$ clusterheads, some nodes in the network have to transmit their data very far to reach the cluster-head, causing the global energy in the system to be large. If there are more than $\widehat{\mathrm{N}}$ clusterheads, the distance nodes have to transmit to reach the nearest cluster-head does not reduce substantially, yet there are more cluster-heads that have to transmit data the long-haul distances to the base station, and there is less compression being performed locally. For our system parameters and topology, $\widehat{\mathrm{N}} = 5\%$.

3.3 Disadvantages of LEACH

Despite the obvious advantages in using LEACH protocol for cluster organization, few features are still not supported. LEACH assumes a homogeneous distribution of sensor nodes in the given area. This scenario is not very realistic. Let us consider a scenario in which most of the sensor nodes are grouped together around one or two cluster-heads. Cluster-head a have more nodes close to its than the other cluster-heads. LEACH's cluster formation algorithm will end up by assigning more cluster member nodes A. This could make cluster head nodes a quickly running out of energy.

In addition, cluster heads are randomly selected, it is possible the scenario illustrated and in which two or even more cluster heads are very close to each other [41].

H1 and H2 are two cluster heads, nodes ▲ and are their cluster members, respectively. H1 and H2 are very closely located. According to data communication model, the energy that a cluster head consumes is the sum of that consumed in receiving data and that in sending data.

$$E_{ch} = L\,E_{bit}\,N_{mem} + L\,E\,(N_{mem} + 1) + L\,E_{bit} + L\,m\,d_{to\ Bs}$$

where L is the length of data, m the power consumption of transferring l bit of data, E_{bit} the power consumption of processing 1 bit of data, N_{mem} the number of members in a cluster, d *to Bs* the distance between the cluster head and node Sink, $LE_{elec}N_{mem}$ the power that N_{mem} cluster members consume when each of them send out length of l data to the cluster head, and LEN_{mem} the power that the cluster head consumes when it receives data of length *l* from its cluster members. It follows from (1) that the amount of energy that cluster heads H1 and H2 consume during data transfer is:

$$E_{h1} = LE_{bit}N_{mem1} + LE(N_{mem1} + 1) + LE_{bit} + Lmd_{h1\ to\ BS}$$

$$E_{h2} = LE_{bit}N_{mem2} + LE(N_{mem2} + 1) + L\,E_{bit} + L\,m\,d_{h2\ to\ BS}$$

Where N_{mem1} and$N_{mem2}$the number of members in clusters $H1\ and\ H2$, $d_{h1toBs}\ and\ d_{h2to\ Bs}$ the distance between the two cluster heads and node Sink, Therefore, the total energy consumed by the two clusters is:

$$E_{h1} + E_{h2} = LE_{bit}(N_{mem1} + N_{mem2}) + LE\,(N_{mem1} + N_{mem2} + 2) + 2LE_{bit} + Lm(d_{h1\ to\ BS} + d_{h2\ to\ BS})$$

When H1 and H2 are very close,

$$d_{h1\ to\ BS} + d_{h2\ to\ BS}$$

Then (4) becomes

$$E_{h1} + E_{h2} = LE_{bit}(N_{mem1} + N_{mem2}) + LE\,(N_{mem1} + N_{mem2} + 2) + 2LE_{bit} + 2Lm\,d_{h1\ to\ BS}$$

In this case the total energy consumption of two clusters is only $LE_{bit} + Lmd_{h1tobs}$ Rgreater than the case that there is only one cluster head. In addition, because $LE_{bit} + Lmd_{h1tobs}$ Ris much greater than therefore, the total energy consumption when there are two cluster heads is approximately twice of that when there is only one cluster head.

It is clear now that when multiple cluster heads are randomly selected within a small area, a big extra energy loss occurs. The amount of lost energy is approximately proportional to the number of cluster heads in the area. Of course, there is a precondition on this conclusion, that is, cluster heads are very closely located and the distance between them becomes negligible.

Proposed LEACH-ANFIS Clustering Algorithm

Similar to the LEACH, this proposed clustering method configures clusters in every round using the ANFIS approach. The pseudo code of the clustering method is described as Algorithm 1. In every

Clustering round (lines 4-30), each sensor node generates a random number between 0 and 1 [18]. If the random number for a particular node is bigger than a predefined threshold T, which is the percentage of the desired tentative CHs, the node becomes a CH candidate. Then, the node calculates the chance using the ANFIS which is mentioned above and broadcasts a Candidate-Message with the chance. This message means that the sensor node is a candidate for CH with the value of chance. Once a node advertises a Candidate-Message, the node waits Candidate-Messages from other nodes. If the chance of itself is bigger than every chance values from other nodes, the sensor node broadcasts a CH-Message which means that the sensor node itself is elected as the CH. If a node which is not a CH receives the CH-Message, the node selects the closest cluster head as its CH and sends a JOIN-REQ request to the head.

Algorithm 1 Proposed Clustering Algorithm

Input $N: a\ network$

$a: a\ node\ of\ N$

$V: \{v | v\ is\ a'svicinity\ node\ which\ is\ a\ CH\ cana$

$T: a\ threshold\ value\ to\ become\ a\ CH\ candida$

$chance(a): a\ suitability\ value\ of\ the\ node\ a\ \imath$

$k: the\ numbers\ of\ clusters$

$r: the\ number\ of\ times\ to\ be\ a\ CH$

Output $CH(a): the\ cluster\ head\ of\ the\ node\ a$

$isClusterHead(a): true\ if\ CH(a) = a$

Function $broadcast(data, distance);$

$send(data, destination);$

$neurofuzzylogic(E_{residual,} E_{expResidual});$

initialization

1. $Chance(a) \leftarrow neurofuzzylogic(E_{residual,} E_{expResidual});$
2. $isClusterHead(a) = false;$
3. $r \leftarrow 0;$

Main

4. /* for every clustering round*/
5. $if(r == \left\lceil \frac{size(N)}{k} \right\rceil)$
6. $isClusterHead(a) \leftarrow false;$
7. $T \leftarrow 1;$
8. $else\ T \leftarrow \left\lceil \frac{k}{size(N)} \right\rceil;$
9. $endif$
10. $if(rand(0,1) > T)$
11. $CH(a) \leftarrow a;$
12. $chance(a) \leftarrow neurofuzzylogic(E_{residual,} E_{expResidual});$
13. $broadcast(chance(a), V); /Candidate - Message$
14. $On\ receiving\ Candidate - Messages\ from\ CH\ candidates;$
15. $for\ each\ v\ \in V$
16. $if(Chance(a) < chance(v))$
17. $CH(a) \leftarrow v;$
18. $isClusterHead(a) \leftarrow false;$
19. $broadcast(Quit - Election - Message, V)$
20. $else\ isClusterHead(a) \leftarrow true;$
21. $r \leftarrow r + 1;$
22. $endif;$
23. $if(isClusterHead(a) == true)$
24. $broadcast(CH - Message, V)$
25. $On\ receiving\ JOIN - REQ\ messages;$
26. $else$
27. $On\ receiving\ CH - Message;$
28. $Send\ JOIN - REQ\ messages\ to\ the\ closest\ CH;$
29. $endif$

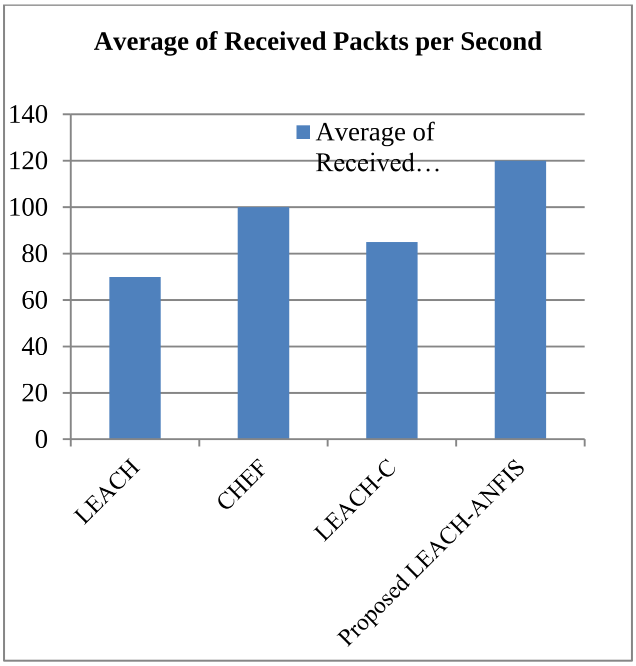
4. Simulation Results

Handy et al. (2002) proposed the metric Half of the Nodes Alive (HNA) which denotes an estimated value for the round in which half of the senor nodes die. This metric is useful in densely deployed sensor networks. As shown in Fig. 4.2, the proposed LEACH-ERE approach outperforms LEACH and CHEF. LEACH-ANFIS is more efficient than LEACH about 42.61% and CHEF about 2.87%

Table 4.1 shows the average and standard deviation of the number of clusters up to round 600. It is apparent that the number of clusters in LEACH-ERE is steadier than that in other distributed clustering algorithms (LEACH and CHEF).

Table 4.1: Average and Standard Deviation of the Number of Clusters Up To Round 600

	LEACH	LEACH-C	CHEF	LEACH-ANFIS
Average	4.2	4.7	4.7	4.7
Std.dev	2.11	1.03	1.6	1.52



5. **Conclusion**

Energy is a major factor in designing WSNs. To achieve the energy efficiency, many clustering algorithms are proposed and LEACH is the representative one. LEACH uses the probability model to distribute the concentrated energy consumption of the CHs. However, it depends on only a probability model and the energy efficiency is not maximized. In this research work, ANFIS based clustering approach based on LEACH architecture with an extension to the energy predication has been proposed for WSNs, namely LEACH-ANFIS. The main objective of our algorithm is to prolong the lifetime of the WSN by evenly distributing the workload. To achieve this goal, they have mostly focused on selecting proper CHs from existent sensor nodes. LEACH- ANFIS selects the CHs considering expected residual energy of the sensor nodes. The simulation results show that the proposed LEACH- ANFIS is more efficient than other distributed algorithms, such as LEACH and CHEF.

In this research work, the proposed LEACH-ANFIS algorithm is designed for the WSNs that have stationary sensor nodes. As a future work, it can be extended for handling mobile sensor nodes. Also, a further direction of this work will be to find the optimal fuzzy set and to compare the enhanced approach with other clustering algorithms.

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