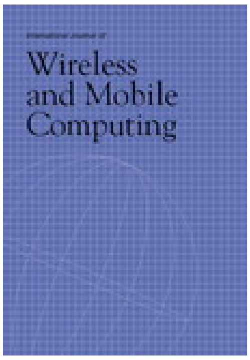

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Network life-time maximisation with low-power consumption by the usage of ANFIS-based technique in wireless sensor networks

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Network life-time maximisation with low-power consumption by the usage of ANFIS-based technique in wireless sensor networks

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Abstract: Clustering strategies for reducing the energy consumption and extending the network life have been employed widely in Wireless Sensor Network (WSN). The clustering mechanism can extend the network's service life and network failure in WSN. In the study, we proposed the technique for improving network performance with a new energy efficient Adaptive Neuro-Fuzzy Inference System (ANFIS)-based routing approach for WSN. A new distributed cluster creation methodology that enables the self-organisation of local nodes, a novel method for the adjustment of clusters and the turning of the Cluster Head (CH) centre location to distribute energy burden equally through all sensing nodes incorporates the suggested ANFIS-based routing. The simulation result shows that the proposed scheme outperforms conventional methods with an improvement of 80% in network lifetime.

Keywords: energy-efficient routing protocol; base station; cluster head; network lifetime; wireless sensor network.

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1 Introduction

Without any addition infrastructure, physical environment is controlled by the sensor node in WSN, which is a low-cost environment. In the field to be sensed are randomly planted hundreds to thousands of sensor nodes. In tracking and monitoring projects such as environmental monitoring, weather predictions, precision farming, prevention of natural disasters, management of disasters, border surveillance, intelligent cities, etc. (Kandris et al., 2020) WSN plays important roles. Different physical characteristics, such temperature, pressures, humidity levels, gas, sound, vibrations, etc., can be observed in the real scenario (Chandel et al., 2021). In WSN, the sensor node consists of sensors, microcontrollers, communication units and electricity. The sensor unit monitors the environment, collects and analyses data and communicates data via a communication unit to other sensor nodes (Abid and Darabkh, 2020).

But energy, bandwidth, memory and computation are restricted to the nodes. In addition, certain usual problems include security, tolerance of faults, connectivity, coverage, sync, scheduling and localisation. Sensor nodes are generally installed in severe settings in which the recharge or replacement of batteries is extremely difficult or not possible (Kumar et al., 2019). The cost of communication exceeds the cost of sensing and calculating (Amiri et al., 2019) a thousand times. The node's available energy should be utilised efficiently due to limited and non- rechargeable batteries. Taking into account the peculiarities of WSN, the main problem influencing overall network performance is energy efficiency. The design of the protocols of the WSN should therefore be simple and energy efficient.

In the literature several clustering and routing protocols have been created to establish an energy-efficient WSN (Hamzah et al., 2019). Clustering technology divides the network into clusters and groups neighbouring nodes. The CH leader is chosen and the other nodes are named cluster members (Heinzelman et al., 2000). A cluster with the same number of nodes is called a clustering process, whereas the irregular number of nodes is referred to as an unequal clustering process (Afsar and Tayarani, 2014). A CH is chosen from each cluster according to certain criteria. The CH is responsible for three operations: the reception, aggregation and transmission of data from cluster members to Base Station (BS). CH serves as a relay node for the transmission of data to BS by other CHs. Equal clustering works well only with uniform node distribution and delivers superior results.

The uniform distributions are exceedingly unlikely due to the random deployment of nodes. This means that the nodes, particularly the CHs closer to BS, do not consume energy equally. CHs closer to BS operate as relays for far-away CHs when multi-hop transmission is used. Hence CHs nearer to BS consume their energy and perish sooner than farther CHs. It interrupts network connections and substantially reduces network life. This problem can be described as a hot spot problem and removed by the unequal clustering procedure. Clusters located near BS are less in size with unequal clustering, and the size of the cluster increases as the distance from CH to BS increases. Fewer clusters means less traffic within the cluster. It so spends less energy on communication within the cluster and conserves more energy for inter-clusterrouting. It builds balanced clusters and spends the same amount of energy across the network on all the CHs. This results in a uniform use of energy and extends the life of the network.

Using the first moving sink in Kaswan et al. (2017), energy consumption can be reduced and a solution to the hot spot problem can be found because nearby nodes to the sink are often modified. With mobile sinks, in another terms, the uniform consumption of energy within the network is achieved (Gu et al., 2016; Kanthimathi et al., 2019; Akkaya and Younis, 2005). Despite the advantages of mobile sinks, WSNs face additional obstacles. The publicity of the mobile sink position to SN is one of the major issues. In order to convey its data to the sink, each sensor node must be informed of its sinking position. This problem can be solved by use of the flooding algorithm. Methods of flooding propose that the mobile sink needs to continually extend its location throughout the network in order to tell the sink's sensor nodes. However, regular updates to the position from the sink can both contribute to excessive energy usage and increasing network collisions. The hierarchical routing structures can be utilised to decrease position updates from the sink. In these arrangements, the nodes close to the high hierarchical level have unfortunately a greater energy use than those farther away, which can lead to the hot spot occurring. A mobile sink-based routing method is efficient if it reduces power consumption and network delay.

The majority of the works are focused to lessen the energy consumption and increase the throughput. The main objectives of this work are stated as follows:

1 To lessen the energy consumption in sensor nodes and increase throughput to transfer data packets in the WSN.

2 To increase the efficiency of routing process to the maximum extent for high-speed multimedia WSN.

The rest of the paper is prearranged as follows: Section 2 provides the study of existing techniques for refining the network lifetime. The explanation of the proposed technique is given in Section 3. The validation of proposed method with existing techniques is discussed in Section 4. Lastly, the conclusion of the research study is provided in Section 5.

2 Literature review

The most critical optimisation issues in the WSN are clustering and routing. Many of the clustering strategies for routing were researched and many protocols produced. CH selection, Synchronisation, Security, Routing, Data aggregation, include computer intelligence techniques such as neural networks, enhanced learning, swarm intelligence, evolutionary algorithm and fluid logic in WSN. Since the nodes are interdependent with interconnected metrics, the building of the clusters using pre-determined rules is not extremely appropriate. In cases when the extent of uncertainty is high, fuzzy logic is extremely useful. Owing its efficacy in solving different optimisation issues in diverse fields, in recent years a great number of researchers have been engaged in swarm intellectual optimisation technology. This section discusses in depth clustering-based routing protocols, such as conventional techniques.

Heinzelman et al. (2000) introduced Low-Energy Adaptive Clustering Hierarchy (LEACH), which is the most common and often mentioned clustering methodology, as their initial clusterm method. The CHs are randomly selected in every round of distributed protocol. The CHs receive data in a single packet from their cluster members, and transfer it to BS in one single hop. The random choice of CHs causes a sensor node to be selected as CH even though its residual energy is extremely low. This is LEACH's main disadvantage. Moreover, in large-scale WSNs, single-hop data transmission is unworkable. It causes sensors to die earlier and reduces the network life dramatically. LEACH-C (Centralised Leach) was presented as a modified form of LEACH by Heinzelman et al. (2002). At the start, BS receives residual power and position information from the sensor node. As LEACH-C is a centralised protocol, the Clustering process is carried out by BS. BS picks a few nodes as candidate node based on residual energy. By simulating the ringing process, the final CHs are picked. This leads in a better selection of CHs and less energy than LEACH. The direct transfer of data, however, remains an inconvenience.

The first Threshold sensitive Energy Efficient sensor Network protocol (TEEN) reactive protocol was presented by Manjeshwar and Agrawal (2001). It is useful when the nodes communicate data if the sensed value crosses a predetermined threshold value in a critical time. It eliminates regular transmission which, in turn, minimises the number of data transmissions and save energy. The nodes will not communicate data and the user cannot follow the existing sensing field scenario when the threshold is not achieved. For multi-level heterogeneous networks consisting of advanced nodes and normal nodes, an additional protocol named Distributed Energy-Efficient Clustering (DEEC) is proposed.

Because of their initial energy and residual energy, the CHs are selected and nodes with higher energy level become CHs. Another reactive HEER protocol is proposed by the Javaid et al. (2013), working in a similar manner with DEEC Hybrid Energy Efficient Reactive (HEER). Furthermore, data transfer based on thresholds is used. CH communicates two threshold values, and when the sensed data exceeds the threshold values, the nodes will broadcast data. Using the data transmission based on thresholds decreases power consumption and improves stability and network service life. But the same inconvenience for TEEN is also suffering. A hybrid protocol dubbed APTEEN was put up to remove the disadvantages of TEEN (Manjeshwar and Agrawal, 2002). In APTEEN, the nodes periodically send data in an energising fashion and adapt to the changes in the physical environment promptly. The user can also ask for data on past, current and future values. This is important for applications with crucial time and real-time alerts. The overall consumption of energy and durability of the network is minimised (Qing et al., 2006)..

Salarian et al. (2014) established a mobile sink-based routing protocol with the purpose of solving the hot spot problem and reducing the use of WSN energy. Rendezvous points, picked from sensor nodes, store data from other nodes at the right time for transfer to the sink.

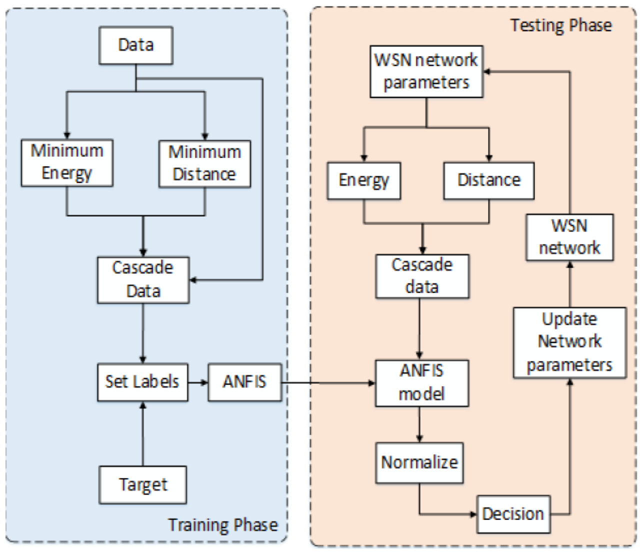
Zhu et al. (2015) provided an algorithm on the mobile sink and rendezvous spots for data collecting in the WSNs. Several trees are constructed in this technique. Rendezvous points are the roots of the trees. A sum of other nodes are chosen based on traffic and the sum of ‘sub rendezvous’ sites called hops to the root. The sink must pass through both nodes and halt to gather data from them at certain points. The roots of the trees have to wait for the sink to appear in their radio series and then transfer their information to the sink, hence increasing the network delay.

3 Proposed methodology

In this part, the algorithm proposed to solve and route the CHs is outlined. This approach is actually a WSN routing method based on the ANFIS paradigm and its implementation. The route reconfiguration or re-clustering can be performed based on the energy which is available on the sensor and cluster head. Initially the CH is estimated based on the fuzzy c-means clustering techniques.

The block diagram given below in the Figure 1 shows the proposed design with the training and the testing phase. In the training phase the data is split into two extra fields of minimum energy and minimum distance then it is cascaded to the old data and the labels for these data is assigned by the target value.

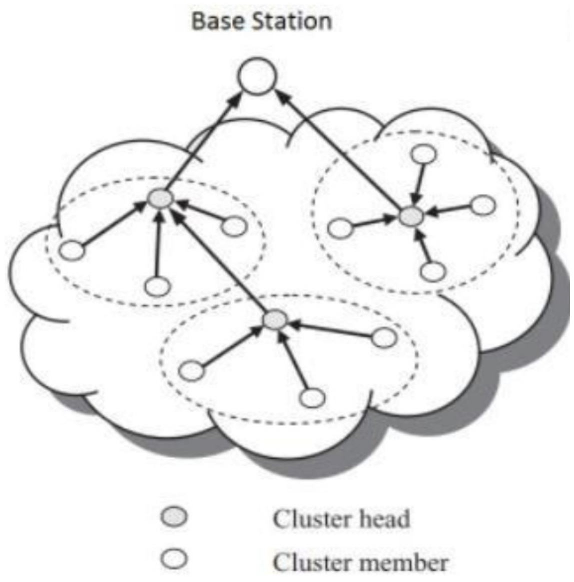
Figure 1 Proposed method block diagram



This final data is sent for ANFIS training and a trained ANFIS model is generated. In the testing phase the trained model is used to take the decision for the routing in the WSN. Based on this decision the network parameters are updated. In the testing phase the network parameters are updated on a regular interval.

Clusters have heads, and the aggregate data is transmitted to the BS or sink by these cluster heads. The principal benefit of clustering is the performance scalability throughout the expanding sensor networks. Furthermore, clustering has various secondary advantages. It guarantees reliability with its targeted solutions and prevents one-point failures (Zhang and Dong, 2015). A sleep or wakeup schedule can propose a clustering method in order to decrease electricity efficiently. Figure 2 shows the network structure of the proposed method. It consists of 3 cluster heads, 10 cluster members and one base station; all the cluster heads are connected with cluster members.

Figure 2 Network structure of the proposed method



3.1 Distance calculation between nodes

Get the maximum range of the producing knot and receiving node to compute the transmission distance of each node. The distance from the Euclides is the straight line in Euclides. Euclidean space becomes a metric space with this distance. The norm referred to above is the Euclidean norm. The L2 or distance of L2 is a generalised term for the Euclidean standard.

$$d(i,j) = \sqrt{\sum_{i=1}^{k} (in - jm)^2} \tag{1}$$

An Euclidean vector is positioned in a Euclidean n-space. Thus, *i* and *j* can be portrayed as Euclidean vectors beginning from the source of the original space, where their tips stop at two places.

3.2 Energy available in nodes

The energy of the node is defined agreeing to the specifications of node distance and power consumption. The energy is computed according to the fading relationship of the signal.

$$E_{es}(m,n) = \begin{cases} m \times \left(E_{elec} + \varepsilon_{js} n^2\right), \; n < d_0 \\ m \times \left(E_{elec} + \varepsilon_{js} n^2\right), \; n \geq d_0 \end{cases} \tag{2}$$

$E_{es}(m,n)$ indicates the energy consumed by the wireless transmitter to transmit a set of *e* bits of information. E_{elec} is the energy consumption required to communicate each bit of data, where m is the amount of bits used for transmitting information, n is the total amount of bits used for receiving the information, is distinct as the distance to the current node.

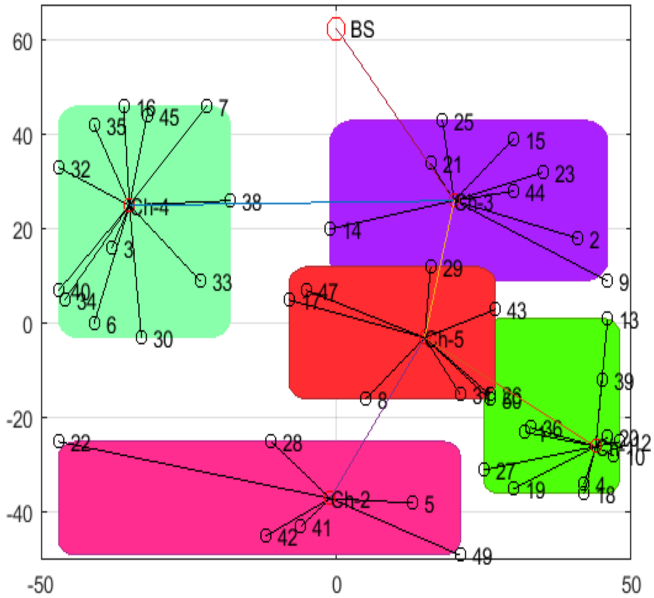
$$E_{es}(m,n) = \begin{cases} m \times E_{elec}, \; n < d_0 \\ m \times E_{elec}, \; n \geq d_0 \end{cases} \tag{3}$$

where the energy consumption of transmission is largely the energy consumed during data transfer and power increase.

3.3 Data gathering and re-clustering

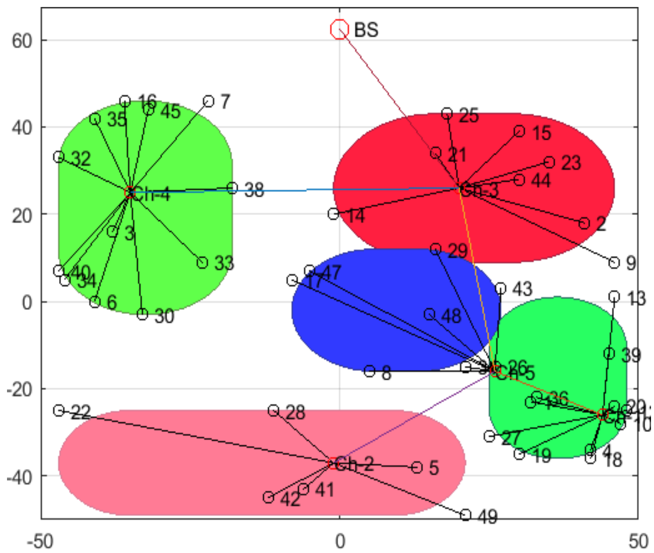
Now the nodes can start sending their data to the base station. Figure 3 demonstrations the initial clustering and the Figure 4 demonstrations the re-clustered network.

Figure 3 Initial clustering (see online version for colours)



After gathering of the data such as distance and energy remain in the nodes network will be re-clustered. In this phase data will remain as long as the network is alive.

Figure 4 Re-clustered network (see online version for colours)



3.4 Fuzzy c-means clustering

Fuzzy *c*-means clustering algorithm is used to find the initial clustering. Let $X = \{x_1, x_2, x_3, \ldots x_n\}$ be the set of data points and $V = \{v_1, v_2, v_3, \ldots v_c\}$ be the set of centres. Calculate the fuzzy *c*-means clustering membership μ_{ij} using:

$$\mu_{ij} = 1 \Big/ \sum_{n=1}^{m} \left(d_{ij} / d_{ik} \right)^2 k^{-1} \tag{4}$$

where *n* is represented as the number of data points, *k* is the fuzzy *c*-means clustering index μ_{ij} signifies the membership of *i*-th data to *j*-th cluster centre, d_{ij} signifies the Euclidean distance among *i*-th data and *j*-th cluster centre.

$$v_j = \left(\sum_{i=1}^{n} \left(\mu_{ij} \right)^m x_i \right) \Big/ \sum_{i=1}^{n} \left(\mu_{ij} \right)^m \tag{5}$$

$$J(u, v) = \sum_{i=1} \sum_{j=1} \left(\mu_{ij} \right) m \left\| x_i - v_j \right\|^2 \tag{6}$$

where $\left\| x_i - v_j \right\|$ is the Euclidean distance among *i*-th data and *j*-th cluster centre

3.5 Routing

The cluster communication routing tree based on ANFIS is used for communication between the gateways and the BS. After each SN has been allotted to a gateway, the base stations will then inform the members of each gateway. The approach presented in this section generates the routing tree while the information is transmitted in the network to disperse the routing load across a greater number of nodes to balance the network's energy usage.

This means that each node will utilise its energy equally. Instead of constructing a single fixed path, the routing algorithm provides numerous ways for each CH to the BS. Each time a gateway sends data to the BS, a route for the message to travel is selected. A balance of the energy use of the nodes can however result in an overall higher network energy use. This is because the quickest path is no longer the only path to take and also longer pathways to convey data. Thus, the distance of data transmission channels is considered in the proposed routing method such that a node does not use a lengthy route repeatedly only if the remaining node energy is sufficiently low on the other ways.

3.5.1 ANFIS

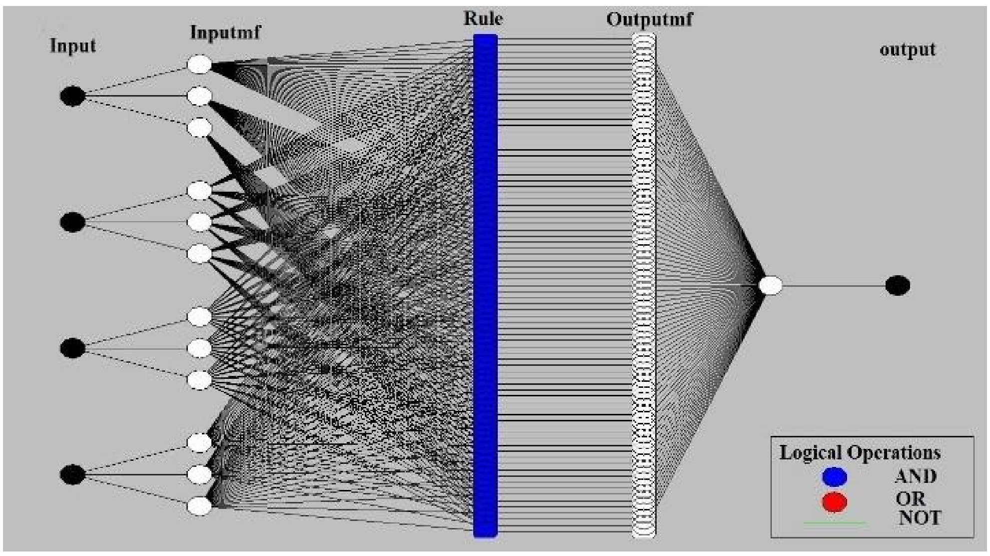
The Takagi-Sugeno fuzzy inference system is a sort of ANN. In the early 1990s the technology was developed. It can capture the benefits of both in a single framework, because it blends both neural networks and floured logical principles. Its deduction system is a set of fuzzy IF–THEN rules that have the aptitude to learn about nonlinear features. ANFIS is therefore regarded as a universal estimator. The best parameters acquired by the genetic algorithm will be used in a more efficient and optimal method.

3.5.2 ANFIS architecture

Two sections, namely roots and impacts, can be identified in the network structure. The architecture is made up of five layers in more depth. The first layer accepts the values of the input and determines their membership functions. The fuzzification layer is usually referred as. Each function's membership degrees are calculated using the premise set parameter $\{a, b, c\}$. The second layer produces the firing forces for the rules. The second layer is called a 'rule layer' because of its function. The third layer is responsible for normalising the calculated firing strengths by dividing every value into the total firing force. The fourth layer enters the standardised values and the parameter set for the consequence $\{p, q, r\}$. These values are the defused values returned by this layer, which are transferred to the last level for the final output.

Figure 5 expressions the ANFIS model structure here four inputs are given and it gives one output. Different membership functions are added to this network layers, here input membership function and output membership function are added. The rule set is added and represented as the blue line in the figure. Finally, a single output value is produced at the end of the network.

Figure 5 ANFIS model structure (see online version for colours)



4 Results and discussion

This section covers the concept of simulation, performance measurement and performance comparison of WSN deterministic cluster deployment models by simulating various performance metrics. MATLAB 2020a with 4 Gb RAM is used to simulate the process. Detection of faults occurs utilising the proposed ANFIS model for all WSN deterministic models for the use of the cluster. Two parameters are mainly involved in this analysis, distance and energy these will affect the network throughput directly. The existing scheme selects an optimal node based on traditional technique. Table 1 shown below will compares the proposed ANFIS to the existing technique.

Table 1 Performance evaluation

Methods	*Initial route*	*After ANFIS routing*	*Energy remaining*
Total existing nodes	50	50	100.00
Total ANFIS nodes	45	48	82.12
Alive nodes existing	30	30	74.15
Alive nodes ANFIS	48	49	89.71
Dead nodes existing	22	21	18.23
Dead nodes ANFIS	12	6	0.00

4.1 Performance metrics

By simulations of the following performance of the proposed WSN cluster deterministic models is compared with each other.

a) *Dead nodes (DN)*: DN metrics are network lifespan estimators. The simulation round at which the node dies without energy is provided by the DN. The network lifetime of a small-scale WSN is measured.

b) *Alive nodes (AN)*: AN metrics are network lifespan estimators as well. The AN provides the simulation round where the node remains with least energy. It measures a sparsely deployed WSN's network life.

c) *Network lifetime (in minutes)*: It's time that the network is fully divided due to the network CHs failure.

d) *Energy cost (in Joules)*: It is the energy consumed for various network cluster deployments.

e) *Loss probability*: It is shown by the proportion of the amount of packets received by the BS (b) and the number of data packets received by the end of a simulation (a) and the amount of data packets discarded. That is, Loss Probability = $a / (a + b)$.

4.2 Performance evaluation

Table 1 shows the performance evaluation of the network with the existing methods here alive nodes at the existing initial route is 30 and after ANFIS routing is 30 no energy is loosed here. Similarly, dead nodes are reducing to 6 after the ANFIS routing.

Figure 6 shows the energy available in the nodes based on rounds of data transfer, where Figure 7 presents the amount of dead nodes based on rounds of data transfer and amount of alive nodes based on number of rounds is described in Figure 8.

Figure 6 Number of energy available in nodes (see online version for colours)

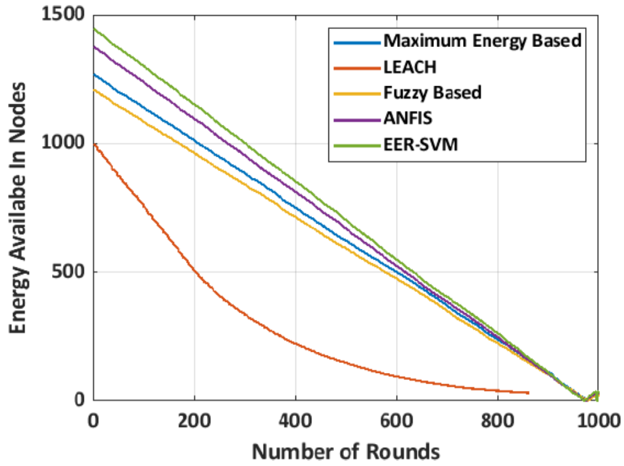


Figure 7 Number of total dead nodes (see online version for colours)

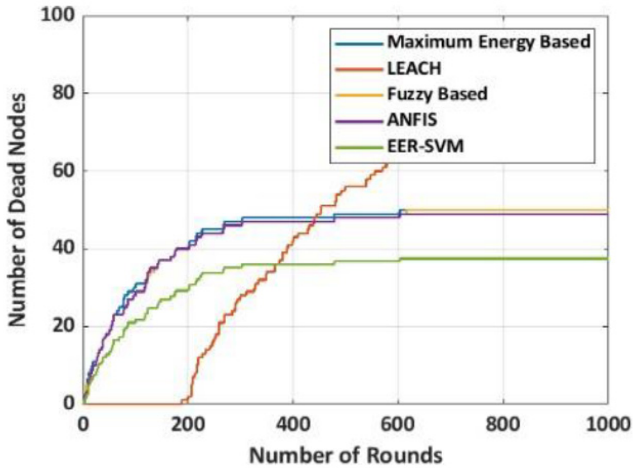
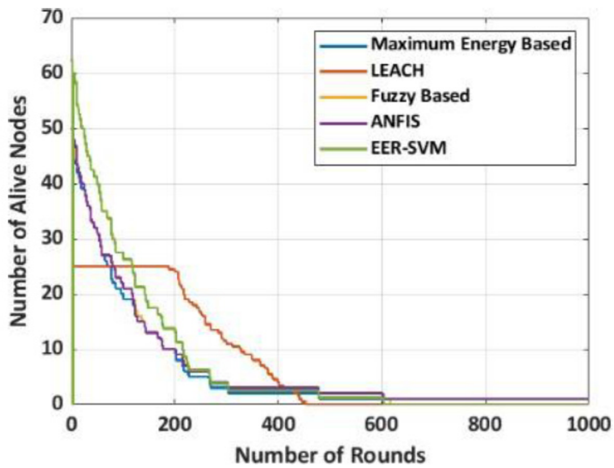


Figure 8 Number of total alive nodes (see online version for colours)



We study algorithms energy usage in relation to average energy ingesting per node and total network power consumption. Suppose the duration of the network life to the first node equals the duration. The average consumption of energy per node is the average used energy per node. For 1500 sensing nodes, we used the algorithms to detect their average energy consumption per node and overall energy consumption in the network. The existing techniques namely LEACH, fuzzy-based, maximum energy based and EER-SVM are compared with proposed ANFIS technique. Total numbers of rounds are 1000 in the simulation setup. From the figure it is clearly proves that ANFIS consume less energy than existing techniques. The reason is that numerous ANFIS-layers tell the sensors with a lesser energy consumption of the newest sink location. On the other hand, since the amount of normal nodes is bigger than the router nodes, it costs more to inform the SN from the sink position than to upgrade the sink position.

The lifetime of WSN is represented in many different ways. The time of life in this work is defined as the amount of completed rounds till the nodes die. The death of the first node does not affect the complete function of the network but the data excellence begins to deteriorate as the nodes in the neighbouring areas result in equal data. The data quality becomes poor if Half of the Node Dies (HND) in a network. The network ceases running when the last node dies in the network. It is evident from Figures 7 and 8 that in comparison to LEACH, fluid-based and energy-based maximum approaches, the suggested technique delays the death of the first-round nodes in scenario 1. Owing (i) a correct CH and cluster size, depending on five variables, the suggested method considerably increased the network life of 80%. (ii) proactive and reactive data transmission reduces transmission numbers, and the energy conservation. (iii) cluster maintenance phase improves network life by allowing all CHs to spend the same amount of energy. The projected approach generally attains energy efficiency and extends the lifetime of the network.

5 Conclusion

A WSN is a randomly deployed group of SN in a region. SN sense and relay information about events and physical phenomena in the region (sink). The communication range and battery of each SN are restricted. Sensor nodes transmit data directly to a BS, consuming large quantities of energy and rapidly depleting the energy supply of the node. Hierarchical routing protocols have been proposed to solve the problem of energy dissipation during the transmission and receiving of data. The energy depletion caused by sending data from a CH to the BS affects the entire WSN operation. As the energy required to transfer data from a CH to the BS is significant, the node chosen as CH is energy-efficient. If a node is often chosen as a CH, it dies faster than other nodes. This decreases the life span of the WSN. The study provided in this paper seeks to address communication issues using optimisation as a major solution at several phases. The ANFIS-based technology prefers to use the most effective node at the centre of the cluster to better position the cluster head. In terms of the effectiveness of the base station placement, the number of intermediate hops required from the base station has decreasing dramatically to the remainder of the network. Data transit from the sensor to the BS provided the performance of wireless sensor network communication by metrics, e.g., network throughput, number of live nodes and number of dead nodes. The results have shown an important package shipping ratio compared to previous methodologies. The simulation result shows that the proposed scheme outperforms conventional methods with an improvement of 80% in network lifetime. Further, we will introduce some optimisation technique to improve the network parameter to get better performance as life time and power consumption in WSN situation.

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