Fuzzy-based Clustering for Wireless Sensor Networks: Survey, Applications and Solution

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Abstract

Wireless sensor networks (WSNs) are the essential unit of the Internet of Things (IoT). In recent years, WSNs have attracted interest in various applications due to their low cost and prospective use. Given that sensor nodes are equipped with limited battery, careful monitoring of the energy consumption is important. Minimizing node energy consumption is therefore clearly essential to extend the life of the network. A Fuzzy-based clustering scheme is introduced in this paper. The fuzzy-based protocols not only prolong the lifetime of the network but also balance the load between nodes. The findings obtained show that other state-of-the-art protocols are outperforming the fuzzy dependent protocols.

Keywords: Energy efficiency, fuzzy logic, network lifetime, wireless sensor networks

1. Introduction

The recent advancements made in wireless sensor networks technology have produced great developments in the applications that require it, such as traffic monitoring, mechanical monitoring, cropping, etc. [1]. In this area, innovative and constructive thoughts need to be created so that their use can be more helpful [2]. In recent years various studied methods have been implemented in information routing, compression as well as network aggregation [3].

It is not possible for a node to communicate with the other nodes through any direct links. The range is out of reach and the information thus to be transferred is passed with the help of various nodes that lie within the path in the network. This process is known as multi-hoping communication [4]. For processing requests across the network, various nodes co-ordinate with each other and transfer the data to each other. There is a shared communication provided within the network and so they are not concentrated. One can add as well as remove the nodes within the network in the wireless sensor networks. This can also provide various changes to be made within the network topology. A hub within the network that gathers all the important information is known as sink. Within the time constraints the information can be utilized for certain purposes by exchanging the particular information with the outside world with the help of internet [5].

The battery present within WSN nodes has smaller dimensions. The nodes are often situated at very far distances where human involvement is less. Therefore, the key problem within the WSNs is battery use within them. For communicating the information across the network, the energy consumed is more as

compared to the other executions. Thus, it is very important to address the energy conservation issue in the WSNs [6].

Instead of the single sensor hubs placed within the network, the distributing sensing allows the sensing nodes to be positioned neared to each other. For locating the nodes in a prominent manner, proper sensing methodologies are to be utilized in cases where locations are not easy to be defined. Numerous sensor nodes are utilized here for the identification of various environmental problems arising within the surroundings of the network. There is no framework provided for the energy or communication within the surroundings that are to be monitored.

There is limited amount of energy to be consumed and data to be transferred within the wireless channel. Some basic criteria are to be followed here for providing such facilities within the network [7]. Another important task for the WSNs is the ability of preparing distributed networks. The communication occurring within the network acquires energy and so this is of major concern within the network. Other operations however do not acquire much energy as compared to the communication. There is more energy depletion within the network once the sensor nodes communication over larger distances. Various operations are to be performed by these communications. The issue can be handled on the personal basis but the main goal here is no reduce the total number of bits that are being transmitted across this communication. This is to be handled through smarter operations [8].

The monitoring of sensor is done for examining the environmental conditions surrounding the nodes of the network. The information gathered is helpful for applications of various fields such as industries, commercials, public as well as consumer applications. There are various factors to be ensured such as the expansion of security, convenience etc. This helps in arranging the sensors for the utilization of clients. The degrees of profits within the WSNS can be determined by the organizations through various factors such as [9]:

- Reduction of energy utilization
- Security enhancement
- Providing convenience
- Minimizing the cost expenses of labor

2. Sensor Network Architecture

There are large numbers of sensor nodes present within the architectural design of the sensor networks. The communication of sensor nodes is done through the sensor field across which the information related to their surroundings is transferred to each other. This is depicted in figure 1. The data transmission can be easily done with the help of these nodes.

There are limited computational constraints to be provided for reducing the overall cost of the networks. Within the devices, the sensing abilities are to be provided. The applications in which the human cannot reach physically include the sensor nodes. This provides the sensor hub to be involved for providing such facilities. The battery power is utilized for deploying these nodes in locations where humans are not able to present. However, the battery life is limited for all such batteries. The usage of power should be in a proper manner such that there is no depletion of resources energy and the lifetime of the node increases. The nodes are closed once they are not of any use within the network.

The capacities of nodes are superior in cases where more applications are to be involved. The applications involve sensor nodes which have advanced properties that are not present in other methods. The sizes of the sensor nodes vary from millimeter-sized devices that are created in custom silicon to the PDA sized devices that have huge capacities. Figure 1 shows straightforward sensor network engineering. Within a sensor field, the constrained capacities are provided by the sensor nodes [12]. The communication is done towards the powerful base station present within the sensor nodes. Internet is used for linking the base station with the internet.

The information gathered by the nodes is handled by the control manager. The direct communication of sensor nodes to the BS is not possible by all the sensor nodes. The connection of nodes with each other is helpful in providing new forms of communication. Due to restricted communication, the nodes are not within the range of the BS. Various applications provide different facilities for nodes present at different ranges from the BS or the gateway. Within the sensor node, the BS more efficient [13].

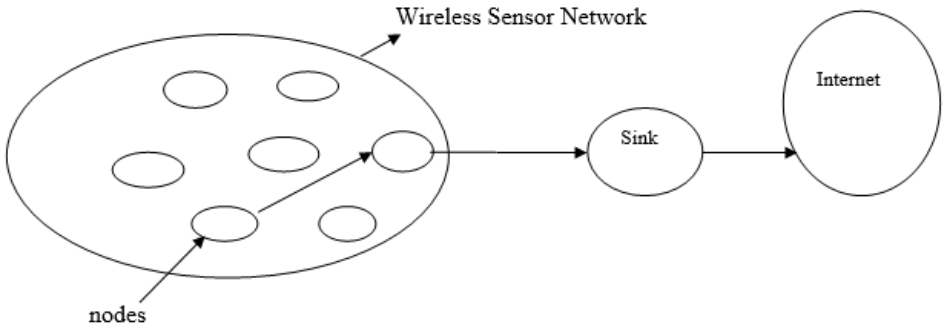

Figure 1. A Wireless Sensor Network

3. Structure of WSN

Internal architecture of a sensor node as shown in figure 2. It consists of,

- Power management
- Sensing unit
- Processing unit
- Storage and timing sync
- Transceiver
- Medium access

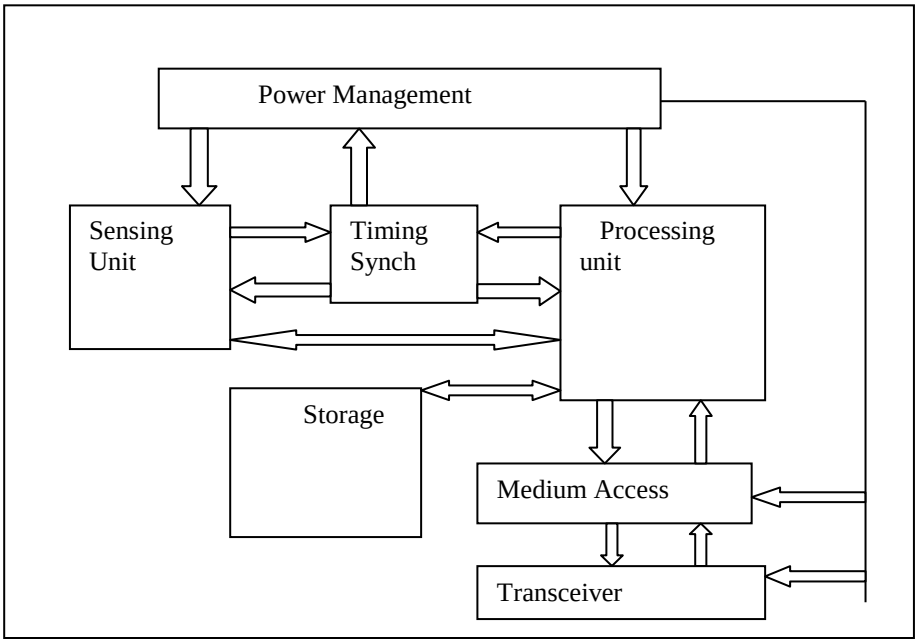

Figure 2. Architecture of a sensor node

Power management unit: The power consumption within the sensor nodes is to be managed through this unit. To the maximum limit it can be reduced, it should be done.

Transceiver: Another name for this block is the communication unit as it provides communication channel in which the various ways are utilized for communication. It uses radio, laser, optical or infrared rays for communication.

Processing unit: Along with the storage unit the processing unit works. The sensed data is computed with the help of sensing unit. There is an internal RAM present within the processing unit. The message between the nodes and the working of nodes all together is managed by the processing unit. There are other components such as RAM and microcontroller present within it. There are various components such as operating system and timer that are responsible for storing, processing and executing the events.

Sensing unit: The environmental conditions such as temperature, pressure and many other are sensed with the help of sensing unit. There are collections of signals that produce electrical signals which help in forming a block. They are further utilized for sensing the surrounding environments. The transformation of various signals is done through the Analog to Digital converter (ADC). It completely depends on the application regarding which type of sensor is to be involved here. There are numerous sensors to be used in the sensing unit [14].

Storage and time synchronization: There are various components such as storage and time synchronization components. A flash memory is present within the sensor devices for storage purposes. For accessing the shared interfaces, a medium access control unit works with the transceiver. There are also many potential external sensing units present along with the battery which helps is providing power to the sensor device. Other components such as antenna help in localizing the sensor within the network [15].

4. Features of Sensor Networks

Followings are the features of sensor network:

Lifetime: In sensor network, sensor nodes have constrained battery power, so the life time of sensor nodes is less. Lifetime is more vital in some more basic applications. Despite the fact that it is frequently accepted that the power transmitted connected with transmission of packet represents the sensing, signal handling and equipment operation in standby mode chomp through a consistent measure of power also. In a few applications, additional power is required for large scale actuation [16]. At the physical layer routing and channel access protocols could be advantage to trade the information. Lower radio obligation cycles and dynamic scaling can be helpful at physical layer for consumption of energy. The loss of the nodes because of depletion of battery ought to stay away from by utilizing energy-proficient routing.

Flexibility: Sensor networks are vibrant in nature they can become accustomed the applications; most sensor nodes may stay tranquil as long as nothing fascinating happens. In any case, they should have the capacity to respond to exceptional occasions that the network expects to think about with some level of granularity [5]. In a self-recuperating minefield, various sensing mines may rest as long as none of their companion's blasts, however need to rapidly get to be operational on account of a foe attack. In control application, respond time is exceptionally basic (sensor/actuator networks) where the network gives a delay-ensured service [17]. In sensor network, nodes are self-configured and nodes can without much of a stretch adopt the distinctive conditions.

In sensor network, if there is a breakdown of individual node, the sensor network is vigorous to change in its topology. Connectivity and exposure in r nodes are dependably to be ensured. Connectivity is accomplished if every hub is connected to BS direct or indirect. To check the network coverage, to gauge the nature of services is given by network specifically zone. Complete coverage is especially critical for observation applications.

Maintenance: The maintenance in a sensor network is essential. The sensor network is upgraded finished or halfway over the wireless channel. All nodes ought to be upgraded, and the constraints on the size of the code ought to be the same as on account of wired encoding. Packet misfortune must be represented and ought not obstruct right reprogramming [5]. The code which is continually running in the nodes, ought to upheld to reprogramming like a little impression, and upgrading systems ought to only aim a brief interruption of the ordinary operation of the node [5]. The failures can happen because of numerous reasons like battery depletion to flighty outside occasions, may either be autonomous or spatially related.

Adaptation to internal failure is especially pivotal as ongoing maintenance is once in a while an option in network applications [18]. Self-configuring sensor nodes ought to permit to process of deployment run easily without interaction of human, the nodes are put in given particular land territory. The nodes ought to have the capacity to survey the nature of the network deployment and show any issues that may emerge, and in addition adjust to varying environmental conditions via automatic reconfiguration [5]. Time synchronous is must to participating among nodes, for example, information fusion, channel access, sleep mode coordination, or security-related interaction.

Data Collection: The network connectivity as well as coverage is present within the data collection. The pervasive mobile agents which move around in a random manner provide a better solution for it. The data crossing is accumulated across various sensor nodes and access points. The data is present within the base station is known as the centralized type of data. However, the accumulation of data in such manner can affect the network lifetime [15]. The non-uniform power consumption designs are provided by the relaying data towards the data sink. This might result in providing burden within the sensing nodes. The sensor nodes which provide end links to the BS suffer more than the other sensor nodes. The traffic that comes from each node can relay which might further result in providing limited throughput within the network.

For the purpose of transferring information within the sensor networks, the classification technique can be utilized. The cluster head is the main point to which all the data is sent from each of the nodes present. The data received here is then sent to the sink. Within a cluster, there is one node which is denoted as the CH and the rest of the sensor nodes form the clusters. There are less packets transmitted and the consumption of energy is in a uniform manner such that the periodic re-clustering can be given. The correlated measurements are changed with the help of aggregation process which further also helps in reducing the redundancy of data [19].

Towards the sensing nodes various applications are provided. With a specific area, the main goal for instance can be to provide data to particular location within the network which also has various other nodes. The gander at a sensor network as a database is given by the database within the sensor network. The data is protected by the nodes from the external nodes. However, there are various situations in which the security of the network can be compromised due to the lower-end sensor node hardware [20].

5. Energy Consumption Issues in WSN

As studied, due to the small size of the nodes present within the wireless sensor networks, the energy consumption within these networks is a critical issue. The various parameters such as the size of battery, the processors as well as the storage of gathered data are small as per their size. So, the up gradation of the energy consumption within the WSNs is the important step to be taken here [21]. The few amounts of information that is gathered after fixed time durations is to be sent so that there is no delay of information and the information keeps updating as per the requirements. Through this, the important information is also achieved at very less time duration to the users.

Due to the less power present within the nodes of WSNs the node failure is very frequent here. For providing secure environments within these networks, the properties of the nodes should be maintained along with providing reliable services for controlling the power consumption [22]. Due to less battery life time, the node might die easily and failure might occur. In order to prevent such failures and keep the working of network proper, there is a need to develop proper network protocols.

Due to the various physical constraints of the nodes, the lifetime of these nodes is less and they need to be replaced. As per the nodes present within the network, the architecture and protocols of the sensor nodes must work and adjust [23]. The communication that is to be provided within these networks is also to be handled through the extension of battery lifetime of the nodes.

6. Clustering of Sensor Nodes

There is a need to implement the clustering methods for saving energy within the WSNs. Each node present within the network can be divided into various groups known as the clusters as per the network organization. There is a CH for each cluster and the other nodes are completely different from that cluster [23]. There are two levels within the clustering process. The higher level holds the CHs and the lower level comprises of the nodes.

The nodes are clustered into groups and the selection of cluster heads is done in periodic manner. The communication of cluster heads with their nodes is required and so the cluster heads are selected on the basis of this factor. The CHS further send the gathered data to the BS. The CH depletes more energy as the data has to be sent at regular intervals from the clusters to the BS. The consumption of energy is higher is the cluster heads as compared to the other nodes. In order to minimize this consumption of energy, the clustering process is developed. The packet collisions as well as channel congestion are minimized through the clustering procedure. However, the throughput of the overall network is increased when there is high load in the network. The lifetime of the sensor networks thus increases with the help of this clustering process.

The execution of the sensor networks can only be assessed if the lifetime of the network is increased [24]. There are different deployment types and operational qualities of the various clustering methods. Thus, they cannot be utilized in all types of WSN applications. When there are large numbers of nodes present, the data is sent in an ad hoc manner in these networks. The location of the nodes is not known within this type of scenario [25]. The clustering protocols that are dependent on the information related to the neighboring nodes are taken as priority for these networks.

- **In heterogeneous sensor networks:** There are two types of sensors nodes which are the ones that have higher processing capabilities and the other are that are complex hardware. The sensor nodes that are to be chosen as CHs and the ones that are to be presented as data collectors are important within the WSNs. The rest of the nodes process the rest of the data gathered from the sensors. The required attributes within the field are sensed with the help of the common sensors that do not have much higher abilities of sensing. There is similar quality, hardware as well as creating capacity for the homogeneous types of networks which is the average environment that is provided further. Each sensor present within the network can be chosen as a CH. As per the periodic changes, the CHs can be changes and chosen as per the scenario of the network or as per the requirement. This also helps in providing a proper load balancing within the network and the energy consumed within it is very uniform.
- **In homogeneous sensor networks:** The quality of nodes present within the network is to be changed for providing flexibility and providing faster execution within the network. this is basically provided with the help of distributed CH selection and the method that is utilized for forming clusters within the network as per the requirements. There are numerous methods being proposed for this. The complete network is to be divided with the help of the central controller or the base station within the network. The cluster involvements and actions are also handled and monitored by the central controller only. The highly established WSN applications are not easily handled here however. The applications that have limited scale applications and excellent connectivity and network division are presented and applied here.

6.1 Clustering parameters

It is necessary to validate all the important conditions that are needed for forming clusters within the clustering algorithms. Various parameters are important for the establishment of clustering process within

the WSNs. The generation of clusters is done in a proper manner through these parameters. The various parameters are given below:

- **Number of clusters:** There are numerous clusters generated through the recently provided probabilistic and randomized clustering algorithms. They also define the CH selection process and the formation process within these networks. The cluster heads to be elected are predefined in some cases along with the number of clusters. The numbers of clusters to be present are very important here for providing the total routing protocol.
- **Intra-cluster communication:** Within the initial clustering methods, the one-hop communication is required in which the cluster head as well as sensor node communicate in direct manner. There is a need of multi-hop intra-cluster communication for providing communication amongst the sensor nodes and the cluster head when there are numerous sensor nodes involved and there is limited communication range within the particular network.
- **Nodes and cluster head mobility:** If in any case, the nodes and CH is assumed to be static there are static clusters generated that have intra clusters as well as inter-cluster network management processes. In case the CHs and nodes are movable, the number of clusters as well as the CH as also dynamic. The positions of these nodes change in dynamic manner and the modifications thus also will be dynamic. The clusters that change dynamically need to be updated at different time intervals as well within these networks.
- **Nodes types and roles:** The capabilities of the cluster head are higher as compared to rest of the nodes and various activities that have communication resources and computations are thus involved. There is a need to provide equal capabilities to all the nodes present within the network within a homogeneous scenario.
- **Cluster formation methodology:** There is a formation of random type of cluster which does not have any coordination when the chosen cluster head is a random sensor node and the time efficiency is important in that situation.
- **Cluster-head selection:** There is a pre-assignment of the header nodes within the heterogeneous types of networks. The cluster head is chosen from the pre-assigned nodes only. However, within the homogeneous scenarios, amongst the deployed set of nodes, the CHs are chosen either in probabilistic or random manner or also on the basis of any other specified criteria.
- **Algorithm complexity**: The quick termination of any executed protocol is the prior objective of the latest algorithms proposed. There is a constant time complexity or convergence rate within the cluster generation methods these days. The numbers of CHs present on the number of hops are also important factors that can be considered here. The total number of sensors present within the network is important to determine the complexity of network within some of the earlier designed protocols.
- **Multiple levels:** A multi-level cluster hierarchy is proposed within various clustering methods for providing better energy distribution and providing total energy consumption. There is no utilization of one cluster level here. In the scenarios that have huge networks and higher inter-CH communication efficiency, the enhancements of such multi-level clusters is provided.
- **Overlapping:** Due to various causes, the sensor nodes are overlapped amongst each other. There is in some cases the need of having better routing efficiency and protocol execution is required for forming execution of protocols within other cases. There is minimum overlap within most of the known protocols and some of them do not support overlapping is any aspects.

6.2 Classification of Clustering Techniques

There are two principle classifications of the clustering algorithms in WSNs on the basis of the arrangement of clusters and the parameters that are utilized for selecting the cluster head:

- Probabilistic (random or hybrid) clustering algorithms: LEACH, EEHC, HEED, etc.
- Clustering in WSNs involves grouping nodes into clusters and electing a CH such that:
- There is direct communication between the members of clusters and the CHs.
- The aggregated data is forwarded to the base station with the help of other CHs with the help of the respective CH.
- There are number of techniques that are used in clustering these are LEACH, and many more improved forms of LEACH like E-LEACH, LEACH-SM, multi-hop-LEACH, ENCM and so on. LEACH protocol contains two phases:

Cluster set up phase: It is displayed by each node whether to select the CH for the specific round or not. An arbitrary number between zero and one is chosen for each node to make a decision. There is value of threshold setup here and in any case if the value of the node is less than the threshold value, the sensor node is chosen to be the CH for that particular round in that network.

Steady phase: If the time taken the CH exceeds the time divided for each sensor node, the network will enter to a stead stage. Here the TDMA mode is activated. This scenario is moved into a frame in which the sensor nodes send the data to the cluster head one by one as per the frame. The data is forwarded as per the assigned transmission division.

There are various issues faced when the Ch node is to be selected in the case of LEACH protocol. Some of these issues are given below:

- There are big as well as smaller clusters present within the networks at similar durations.
- Even when there is different energy for each node, there is un-required CH selection.
- Once the CH is dead, the cluster member depletes its energy also.
- The locations of the nodes are not considered here.
- The common information that involves residual energy, geographic location as well as other information that will lead to the failure of cluster head node.

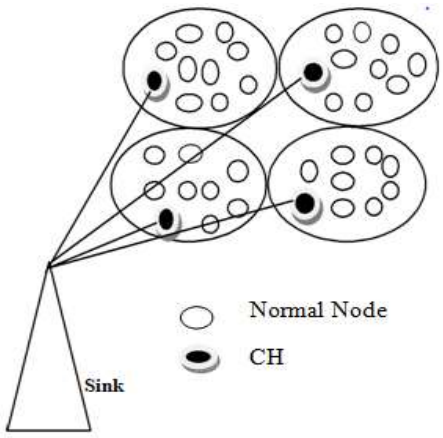

Figure 3. Clustering with single hop

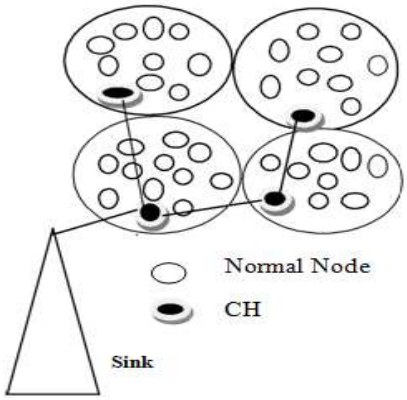

Figure 4. Clustering with multi hop

Within the above given figures 3 and 4, the clustering process is explained. Single-hop with clustering is depicted within the figure 3 and the multi-hop clustering scenario is provided in figure 4. There is the division of LEACH into three different clusters as shown within these above figures. The cluster is represented here in which the black node is the CH. The white members are the common nodes of that particular cluster. With the help of any clustering protocol, the CH can be changed within the cluster. The network load is distributed when the CH is changed for each of the cluster nodes. The performance of the complete network is thus enhanced due to this manner and thus the energy consumption is reduced.

6.3. Disadvantages of the LEACH Protocol

Apart from the plane multi-hop routing and static routing, there are some issues within the LEACH protocol. There is the selection of cluster head in a random manner here and thus all the nodes cannot be chosen as cluster heads. There is no confirmation whether the distribution of CHs is possible or not. There is similar priority for all the nodes within the cluster and so any of them can be chosen as the cluster head in spite of its high or low energy. In case the nodes that have less energy, left are chosen as CHs, those nodes will die first within the sensor networks.

6.4. Need of clustering

- **Load balancing:** For the purpose of aggregating data from the nodes of the network, there is a need of higher energy within the cluster heads. They also need energy to transmit the gathered data to the BS. The base station is not located within the network and is distant from it. The cluster heads are chosen randomly and are not fixed due to which the load of the network is reduced and shared amongst all the nodes of the network.
- **Optimal number of cluster heads:** Within some networks the selection of CH is considered to be a priority. There is less quantity of energy consumed by the network is optimal number of CHs are chosen. This reduces the power consumption of the network and increases the overall network-lifetime.
- **Maximum network lifetime:** As per the resource constraint and batteries, the sensor nodes have their lifetime. Thus, it is important to provide lifetime consideration for the deigning of network topology.

7. Fuzzy Logic Approach

Fuzzy approach is preferred, when a lot of uncertainties are there for a single parameter. It checks a single parameter for different number of conditions accounting all the least minimum possibilities. It uses different techniques such as fuzzy ant colony optimization and Neural networks. It has four unit fuzzifier, defuzzifier, fuzzy rules and an interface engine as shown in Fig. 5. A crisp value is given to fuzzy system as input. It is further changed to fuzzy input set value using Fuzzifier. To get back a crisp value at the output, a defuzzifier is used. An Interface engine is used to provide output. Output is obtained based on the rules that are defined for CH selection

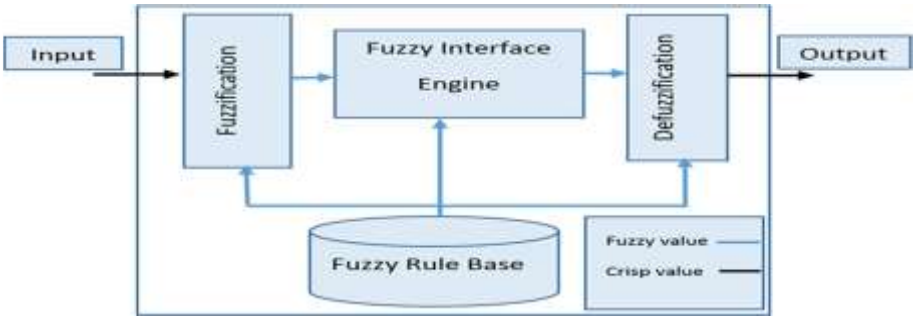

Figure 5. Fuzzy Inference Systems

FIS Editor display general information about a fuzzy inference system in which edit containing different editor and view containing different viewer are present for application use as shown in Fig. 6.

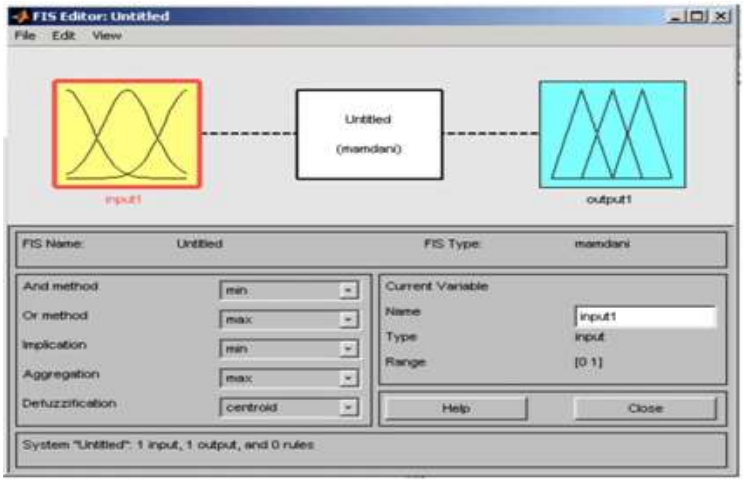

Figure 6. Fuzzy Logic Toolbox

8. Challenges of WSN and Proposed Solution

The challenging task in WSN is the limited battery sources, more consumption of energy and delays in the transmission of data. Limited battery supply provides a short lifetime network and ultimately forces to think about the energy conservation for an efficient prolonged lifetime network. Apart from this, in real time applications, timely delivery of data is also important. It means transmission of data should occur without any delay, while keeping energy consumption to minimum level. The key challenge in the

operation of WSN is to increase network lifetime with less energy consumption. Many researchers have made variety of changes to minimize the energy consumption in WSN. LEACH is the main motivated protocol for many researchers to extend the network lifetime. LEACH is probability-based protocol in which CHs are selected periodically in different rounds to minimize the energy consumption of the network. but due to probability approach, there may be chances of wrong selection of CH and even node with less residual energy gets elected as CH then it may die quickly resulting short lifetime network and if elected CH is located at large distance from BS then it needs large amount of energy for data transmission. To overcome the limitations of probability approach, fuzzy approaches in clustering is recently followed by different researchers for selection of CH. In fuzzy approach, CH are selected based on the fuzzy parameters such as residual energy, distance between BS and CH that effects the energy consumption during simulations as in case of MOFCA algorithm. Selection using fuzzy approach provides better selection of CH giving energy efficient and long lifetime network but to further improve the energy efficiency of network, some more due to Selection of CHs for such rotation influences the energy efficiency of the network.

A WSN consists of different sensor nodes with different sensors to investigate the environmental conditions like temperature and speed etc. The nodes in the WSN are battery powered, so the important challenge in WSN is the use of limited battery power within network. Second major challenge is the small network lifetime due to more energy dissipation. For maximizing network lifetime, minimum energy dissipation is required.

In order to overcome these difficulties, direct communication between BS and sensor nodes is used. During direct communication, sensor nodes placed at larger distance from the BS needs more energy for the data transmission. As a result of more energy consumption, nodes die earlier providing short network lifetime. Such type of problem in WSN is known as hot-spot problem. Most of the WSN prefer clustering process to overcome the hot-spot problem.

Clustering is a process in which nearby sensor nodes are grouped together and a cluster- head is selected among the grouped sensor nodes in a network. Energy consideration is mainly involved in CH selection process. Selected CH sends a notification message to the sensor nodes of communication area to create a cluster network. Sensor nodes of cluster network send their data to the selected CH. CH send that data to the base station consuming less energy and minimizing hot-spot problem. In clustering, different techniques such as LEACH, HEED, CHEF etc. are used for the selection of CH. All these techniques are based on probability approach for CH selection. Due to probability approach, there may be chances of wrong selection of CH.

To overcome the limitations of probability approach, fuzzy approaches in clustering is recently followed by different researchers for selection of CH. In fuzzy approach, CH are selected based on the fuzzy parameters such as residual energy, distance between BS and CH that effects the energy consumption during simulations as in case of MOFCA algorithm. Selection using fuzzy approach provides better selection of CH giving energy efficient and long lifetime network but to further improve the energy efficiency of network, some more different parameters like mobility etc. can be used for more better and optimal selection of CH.

Mittal et al. proposed a stable, energy-efficient, threshold-sensitive Fuzzy cluster-based routing protocol called FESTERP using enhanced FPA (EFPA) [38] and enhanced GWO (EGWO) [39] for forest fire detection, such as applications suitable for event-driven purposes. In the protocol to select the relevant

CHs, the remaining power, node centrality, and distance to sink are considered. CHs are elected using FIS as an objective method, using EFPA or EGWO. In this method, an energy-based heuristics achieve a longer period of stability.

Mittal suggested a Fuzzy type-2 cluster-based routing protocol called FBFPSTERP for event-driven applications using Bat Flower Pollinator (BFP) [40]. The parameters considered for selection of CHs are residual energy, node centrality, and distance to sink. CHs are chosen using BFP as an objective function, using the Fuzzy type-2 logic. The main aim of FBFPSTERP is to use energy-based heuristics to achieve a longer period of stability.

9. Conclusion

Two issues for wireless sensor networks are considered in this paper, namely load balancing and minimizing the energy dissipation. Cluster head selection is done with the goal of reducing network energy dissipation and balancing the load between the nodes. Fuzzy logic for choosing the cluster heads is engaged here. Using fuzzy-logic, a major increase in network-life is observed. The protocol can be tested in future works by integrating the mobility of nodes and obstacles in the field of interest. This can be further applied by considering various other IoT-based WSN scenarios.

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