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Cluster Formation using Fuzzy Logic in Wireless Sensor Networks

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Abstract- The biggest challenges faced by wireless sensor networks (WSNs) are the network lifetime and consumption of energy. To reduce the amount of energy used by WSNs, high quality clustering proves to be a crucial approach. There are multiple criteria that need to be evaluated depending on the cluster's quality and incorporating all these criteria will prove to be cumbersome process, leading to high-quality clustering. Hence, in this paper we propose an algorithm that is used to produce high quality clusters. Cluster quality is set as the deciding criterion to determine the quality of the clusters thereby categorizing them as intra- and inter-clusters based on their distances to eliminate error rate. Using fuzzy logic, the optimal cluster head is chosen. Similarly, based on the maximum and minimum distance between the nodes, the maximum and minimum energy present in every cluster is determined. The major advantages of the proposed methodology are large-scale networks with large nodes count, better scalability, independence of key CHs, low error rate and high reliability. Using internal and external criteria, the validity of the clustering quality can be measured. Experimental simulation shows that the proposed methodology will be useful in improving the network lifetime and energy consumption. Hence the proposed node further enhances the death of the last node and first node when compared using other methodology.

Keywords: Reliability, vehicular network, block chain, smart parking, privacy protection

1. Introduction

A typical wireless sensor network is built up of a number of nodes used for recording and monitoring data from the environment. These nodes are distributed in a deterministic or random manner and are commonly used in areas where human access is not possible. There

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are a high number of nodes present within a particular WSN region and they are charged using energy [1]. Hence network lifetime and energy consumption proves to be the biggest challenges faced by the WSNs. The nodes are used to collect information from the environment and sent it to the base station where it is further processing [2-3]. To transmit the information, many algorithms and methodologies are recommended based on single-hop and multiple-hop. Fig.1 depicts the two hops used to transmit data between the WSN node and the base station (BS). Controlling traffic, military areas, status of sensitive patients and monitoring forest fires are some of the major applications where wireless sensor nodes are commonly used [4]. The key factors that have an influence on the WSN design are reliability, hardware limitations, costs, scalability, fault tolerance, energy consumption and transmission environment [5]. Routing and clustering are the two methodologies commonly used to increase the WSN's lifetime. Based on a set of common attributes, a batch of sensors is placed during clustering. One node in every cluster is chosen to be the Cluster Head (CH). A CH is used to gather the data from each node in the cluster and transmit it to the higher level Cluster head or the Base Station (BS), according to the type of transmission it follows. Fig.2 shows the process of clustering in WSN [6].

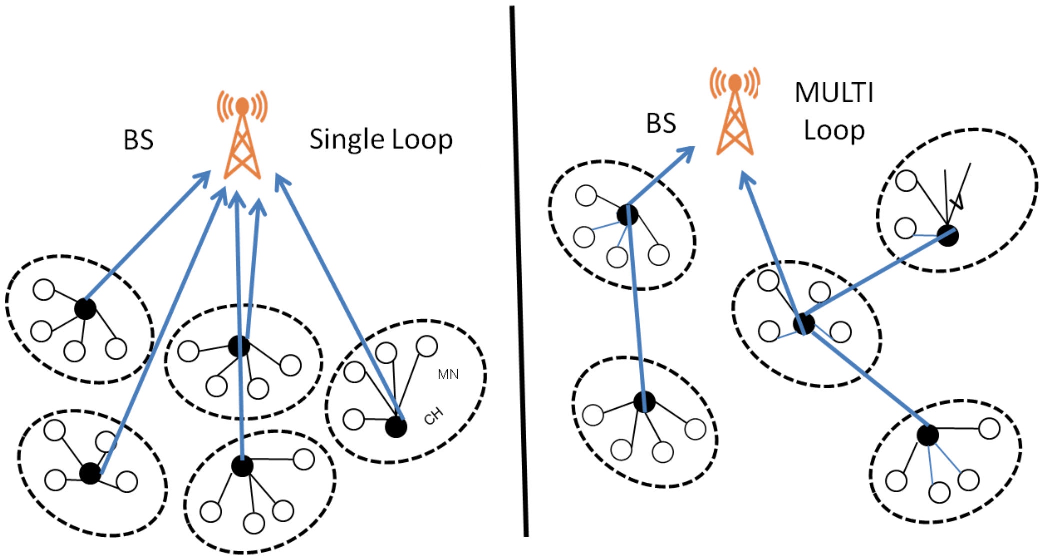

Fig.1. Single Loop and Multi Loop Data Transfer in WSN

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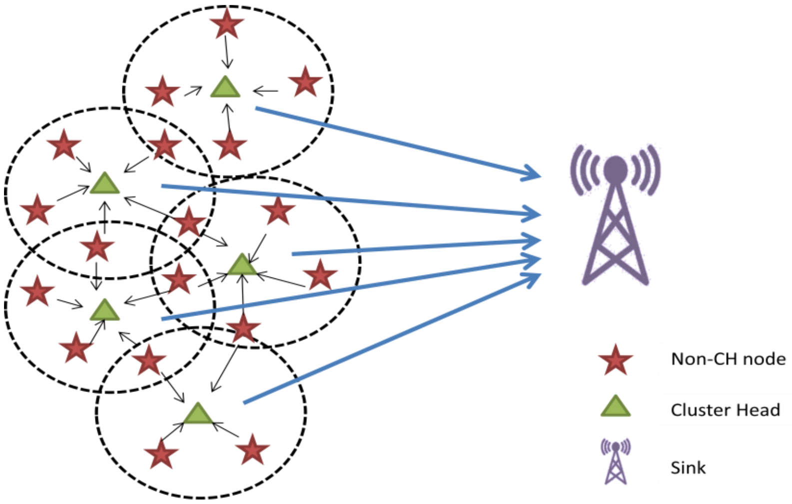

Fig.2. Clustering in a WSN

The quality of clusters present in a cluster is the crucial challenge faced during clustering. In a cluster, the data present must be close to each other such that the clusters are adequately separated in order to reduce overlapping. Clustering can be accomplished by a number of methods such as density-based clustering, grid-based clustering, spectral clustering, partition-based clustering and hierarchical clustering. Single-hop transmission and multiple hop transmission have an effect on energy constraint. The proposed work has a number of advantages that overcome the drawbacks of the previously existing methods. Using the proposed methodology, LND and FND parameters are improved along with increased network lifetime and reduced energy consumption. Similarly, improvement in selection of cluster sensors, C-means clustering and intra-cluster and inter-cluster distances are also observed. To identify and segregate clusters in high and low-density areas, new criterion is established which can be used to strike a balance in the energy consumption utilized by the clusters of a particular node [7]. The proposed work can be used in large-scale networks where a high count of nodes is used. The rest of this paper is organised as follows: the related work is summarized in Section 2 and Section 3 explains the working of the proposed work. Section 4 shows analysis of the results recorded and a conclusion is drawn in Section 5, along with future scope for the proposed work.

2. Related Work

The LEACH [8] protocol is one of the biggest WSN clustering methods that is used to improve the network lifetime of the node. It is a single-hop, distributed, probabilistic and hierarchical protocol that will work on power distribution across all the nodes associated with

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the WSN. Data aggregation is used to reduce the amount of energy used by reducing the messages that are transmitted. The advanced version of LEACH is PEGASIS [9] which uses the method forming a chain of connection between the sensors. Here, every node in a particular chain is connected to a particular chain and only one node in the chain is used to transfer data to the base station. Another energy-efficient clustering protocol is TEEN clustering protocol which operates on multi-hop transmission. The drawback with this approach was that it did not optimize energy consumption using the appropriate distribution. In this methodology, energy consumption is not distributed accurately. There are many other similar protocols such as HUCL, PECRP, SONS, CBL, PSO-C, O-LEACH, LEACH-SWDN, BARC [10], CACH, LLACA and EECF [11] which show an increase in network lifetime and reduction in power consumption. Another algorithm is ERA which uses inter-cluster distance and residual node energy to form clusters. Genetic algorithm is implemented in GADA-LEACH and multi-hop data aggregation [12] is used as the clustering protocol in CBCCP [13]. It shows significant reduction in energy consumption and data transmission. To obtain better topology, to increase load balancing, data aggregation, scalability, error tolerance and network lifetime, clustering proves to be an efficient algorithm [14-15].

3. Proposed Methodology

3.1. Network model

In a square area of dimensions n*n, there are N sensor nodes in the proposed high quality clustering algorithm. Each sensor has a different energy which will not be able removed or added on deployment. Once the sensors have drained their energy, they can be recharged. The location of these sensors is identified by the BS. When a message is being transmitted, media access control (MAC) is used to prevent interruptions from occurring. The following assumptions are made in this work:

- Global positioning system is used to determine the positions of the node using positioning algorithms
- The power, memory and energy of the BS are infinite.
- Wireless communication is found to be symmetrical between the nodes
- BS is situated away from the node’s location which is different for different situations.

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3.2. Radio model

Depending on the distance between receiver and transmitter, the radio model locates the shortest distance which is known as the crossover distance, in the proposed method. The transmission power can be represented as:

$$p_{tr} = \frac{P_t G_t G_r \lambda^2}{(4\pi\lambda)^2} \tag{1}$$

where G_t, P_t and λ are the transmission antenna gain, power and wavelength of the signal. When the receiver is located at a greater distance when compared with the crossover distance, the transmission power is represented as:

$$P_{tr} = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4} \tag{2}$$

where h_r and h_t indicate the receiver and transmitter antenna heights.

3.3. Energy model

To determine the energy consumption, Heinzelman energy model is used to get 'n' bit message at 'd' meters distance as represented below:

$$\begin{cases} E_c(n,d) = n\left(E_{energy} + \varepsilon_{fs} d^2\right), d < d_c \\ E_c(n,d) = n\left(E_{energy} + \varepsilon_{mp} d^2\right), d < d_c \end{cases} \tag{3}$$

The energy consumption that is necessary to obtain a m-bit message at a distance of d meters as shown in the equation:

$$E_c = mE_{elect} \tag{5}$$

where ε_{mp} and ε_{fs} vary according to the sender's noise shape and sensitivity.

In C-means algorithm, choosing the C-parameter is the crucial challenge. In [15] a methodology where Fuzzy logic is used to choose the CH based on unequal clustering. There are three criteria that play a crucial role they are degree of the node, distance to the BS and residual energy of the node. Using fuzzy interference system, the final CH is chosen. There are many methodologies based on fuzzy logic to determine optimal CH selection. When compared with previously existing traditional method, there is significant improvement in the development of these methodologies. However the purpose of the proposed work is to take into consideration the cluster density of both intra and inter- cluster along with the other criteria. Hence the routing process will commence after quality and accuracy of the clusters are determined. In order to optimize cluster quality and network lifetime, a high-quality clustering algorithm using fuzzy logic is proposed in this paper. There are a number of

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qualities to measure the cluster quality. Both the intra-cluster and inter-cluster will be better when the criteria is low. Hence in our criteria, the nodes are initially arranged in clusters as shown in Fig.3.

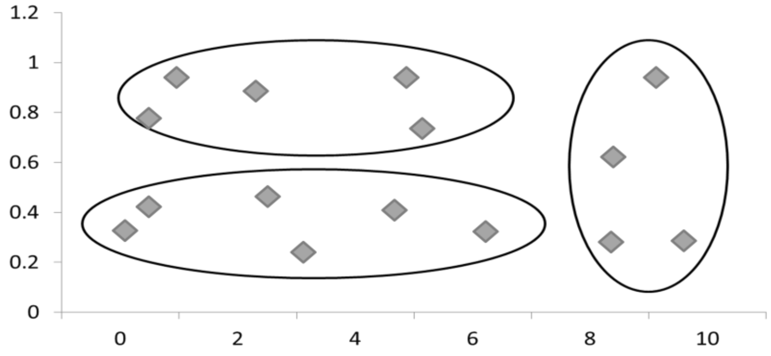

Fig.3 Node Distribution in Clusters

4. Results and Discussion

A comparison of the proposed work with previously existing methodologies is observed in Fig.4. It is observed that LND and FND metrics are improved significantly using the proposed high quality cluster selection methodology. To reduce the energy consumption, it is important to choose the right CH in a WSN. This is especially the case when selecting a CH in an overall cluster coverage and an area of high density resulting in reduced energy consumption and increased network lifetime. When a CH is chosen from a high-density area, it indicates that the distance between the CH and sensors will improve the network efficiency. Fig.5 indicates a typical random distribution of nodes which shows that there is higher number of nodes in certain areas of the network when compared with other areas. Hence it is a wiser option to pick a node from high density area.

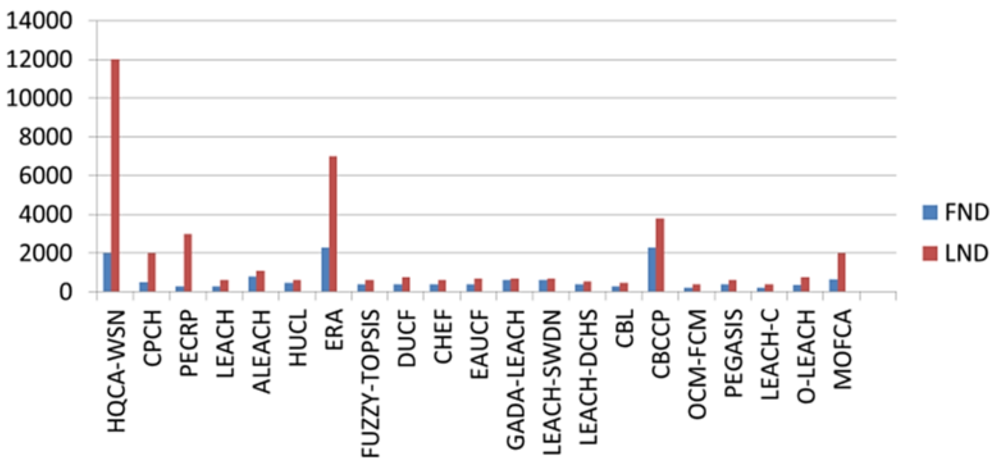

Fig.4. LND and FND metrics for various Methodologies

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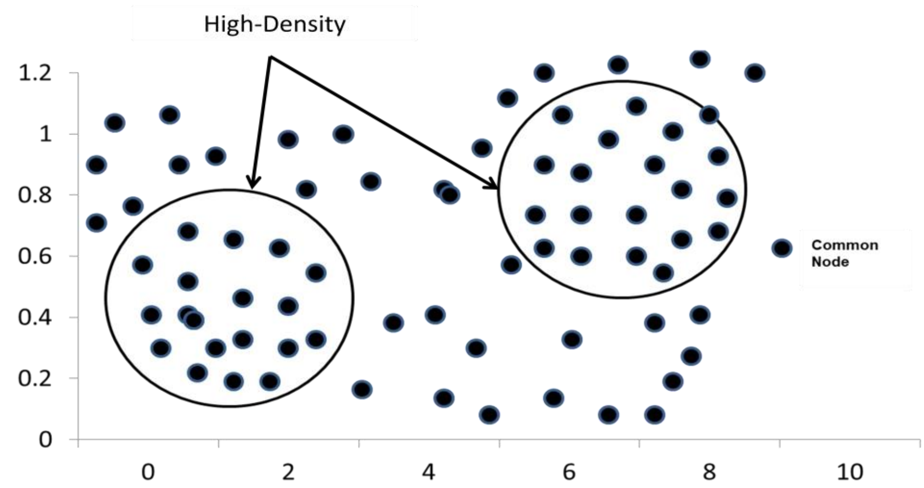

Fig.5. Random Distribution of Nodes

5. Conclusion

Decreasing the energy consumption and simultaneously improving network lifetime are the two challenges that shake WSNs. In the proposed work, cluster quality is used as the defining factor to analyse and segregate the nodes. Depending on the highest quality of clusters and two methods based on many criteria, the nodes are classified. Evaluation of cluster quality depends on distribution of nodes, intra-cluster and inter-cluster intervals. Based on this evaluation, we have also introduced a method for error identification. Using confidence level as the criterion, the number of clusters is determined. It is also possible to choose multiple clusters in areas of high node distribution as well as in dense areas. The cluster heads in the proposed algorithm are chosen based on the distance to the BS, distance between the neighbouring nodes, number of neighbouring nodes, energy consumption of the nodes and the residual energy. Experimental observations indicate that it is possible to improve LND and FND network lifetime when compared with other methods. The average total energy of the network can be reduced at the starting phase while it is also possible to improve the average energy consumption. The major advantages of this work are better selection of primary centres for clustering and improvement in the clustering process. In processes like C-means, the primary selection will have a high impact on cluster quality. In large scale networks, high scalability is achieved using the propose method. As future scope, the proposed method can be further elevated by taking into consideration more parameters like peripheral density of individual nodes, optimal cluster estimation using density and new energy model.

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