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An Efficient Unequal Clustering Approach for Hot-Spot Removal in Wireless Sensor Networks

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***Abstract*— The Wireless Sensor Networks (WSN) are partitioned into clusters to gather information. Each cluster consists of cluster-heads and it transmits the gathered information to the base station. The cluster-heads which are closer to the Base Station (BS) spend more energy on transmitting complete information of its nearest clusters information which in turn reduces the lifetime of the cluster close to the BS. This problem is referred as hot spot problem. This destructs the whole network within a short span of time. This leads to wastage of energy. To overcome these disadvantages, unequal clustering approaches have been implemented to manage inner-traffic and intra-traffic. Moreover, the proposed algorithm includes the fuzzy energy-aware algorithm to determine cluster-head. The observed result reveals that it improves the lifespan of cluster closer to the BS and reduces intra-cluster traffic. Further, the proposed method balances the traffic and energy of network.**

***Index Terms*— Clustered WSN, Cluster heads, Fuzzy logic, Inter-cluster traffic, Intra-cluster traffic, Unequal clustering.**

I. INTRODUCTION

A WSN is a group of sensors grouped together to monitor and to pass the sensed values through the network to a sink or base station. In many WSN applications, the sensor nodes are battery driven and they are often very difficult to recharge or to change their batteries, prolongs network lifetime and is a critical issue [1]. Sensors often have long period between transmissions (e.g., in seconds). Thus, a good WSN design needs to be energy efficient.

Network lifetime is a key characteristic for evaluating sensor networks. The lifetime of a WSN, are calculated based on the following three metrics: 1. First Node Dies (FND), 2. Half of the node Alive (HNA), 3. Last Node Dies (LND).

The network structure is designed based on flat and hierarchical or cluster based networks. Due to many advantages in clustering it is used now a days in WSN.

A. *Problem definition*

In WSN, the base station and cluster of sensor nodes are grouped together. Each cluster has bunch of sensors, any one of the sensor acts as cluster-head. Based on cluster-head selection algorithm it transmits the data to base station. If cluster-head is far away from base station, it transmits data to other cluster-head closer to base station. But cluster-heads near to the base station have to forward more data, which are from the far away cluster-head [8].

Due to this, cluster-heads near to the base station lose more energy in addition to energy expenses involved in intra-cluster task. This imbalance in energy consumption makes the node die prematurely causing the hot spot problems. This hot spot problem can be effectively dealt by unequal clustering algorithms.

B. *Unequal clustering*

In the unequal clustering algorithm, the clusters close to base station have smaller size than cluster far away from base station in order to balance the energy. The cluster-head closer to base station concentrates mostly on the transmitting its nearest cluster-heads information (inter-cluster work) and cluster-heads far away from base station concentrates on intra-cluster works with the Base station. The reduced clusters in it would be placed in the cluster which is very far away from the Base station, since it has very less duty of transmitting and spends small amount of energy.

C. *Fuzzy logic*

Fuzzy logic can also be utilized for making a decision based on different environmental parameters by blending using predefined rules [9]. The proposed clustering algorithm employ fuzzy logic to handle uncertainties in the wireless sensor networks.

To manage the imbalance in energy consumption and to control the packet transmission unequal clustering and fuzzy logics are used. The proposed network model transmits the packet and provides a solution to the aforementioned problems. The main attempt of this paper is summarized as follows:

- Hot-spot problem is removed
- Energy consumption is reduced
- Increases network lifetime

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The remaining part of the paper is organized as follows:

In section II, various algorithms found on clustering, unequal clustering and fuzzy logics are explained. Section III explains about the proposed model. Section IV deals with simulation and results. Section V examines various scenarios with the modelled results. Conclusions and future direction of the proposed work are discussed in Section VI.

II. CLUSTERING MODELS

A lot of algorithms are available on equal and unequal clustering techniques for wireless sensor networks. In the following some work on equal clustering algorithms and some unequal size algorithms are discussed

A. *LEACH*

LEACH utilizes an equal clustering algorithm. The network is divided into clusters. LEACH elects the CH node based on local decisions [2]. CH has been chosen at random based approach with some threshold value. Based on the threshold value, on every round the CH nodes have been chosen. The CH node collects the information from the end nodes in its cluster. CH group the data before forwarding to BS. In LEACH, there may be a chance of selecting a lower energy node as CH node.

B. *HEED*

Hierarchical Energy Efficient Distributed Clustering considers the remaining energy level of cluster node for the selection of CH nodes. The degree of the CH nodes or average distance to its nearby neighbor nodes is used to calculate the cluster-head, when two nodes are competing for CH [3]. HEED provides a better performance than LEACH.

C. *EEUC*

Energy Efficient Unequal Clustering uses a probabilistic approach to choose the tentative CH [4]. Tentative CH nodes participate in the CH competition. EEUC considers the node's residual energy for CH selection.

D. *CHEF*

CH nodes Election using Fuzzy logic is an unequal clustering algorithm which selects the cluster in a centralized manner. BS is involved in the selection process. In [5], algorithm uses three fuzzy descriptors such as node concentration, residual energy and node centrality for electing the CH. BS creates fuzzy rules and computes the crisp output representing the chance for CH.

Solution to above mentioned problems is as below

III. PROPOSED MODEL

The proposed cluster model is a distributed competitive unequal clustering algorithm similar to EEUC. It makes local decisions to determine competition radius and to elect cluster-heads. The main difference between EEUC and the proposed model is cluster head selection method. EEUC only considers distance to the base station parameter to calculate competition radius. However, the proposed model employs both residual energy and distance to the base station parameters of the sensor node.

Moreover, the proposed model takes advantage of using

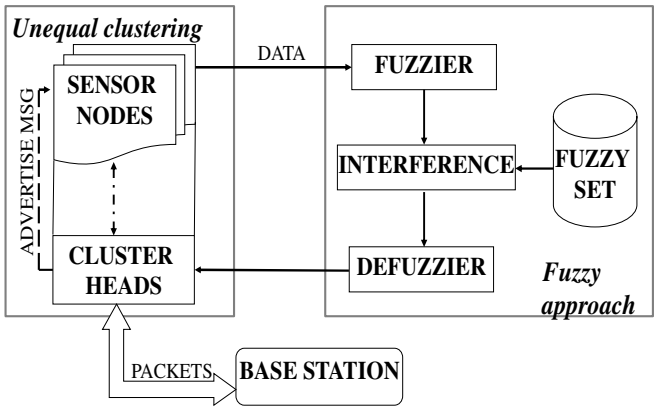

Fig. 1. Architecture for proposed model

fuzzy logic to calculate competition radius. CHEF is also a fuzzy approach, but it utilizes fuzzy logic for assigning cluster-head chances to tentative cluster-heads. LEACH protocol rotates the cluster-heads periodically in each round by using a probabilistic model. The proposed model does not elect the final cluster-heads by just depending on probabilistic model. It elects the tentative cluster-heads using the model like CHEF and reduces the cluster traffic using model like EEUC.

A. *Main flow of algorithm*

In every clustering round, each sensor node generates a random number between 0 and 1. If the random number for a particular node is smaller than the predefined threshold T, which is the percentage of the tentative cluster-heads, then that sensor node becomes a tentative cluster-head.

The competition radius of each tentative cluster-head changes dynamically in proposed model, because the proposed model uses residual energy parameter with distance to the base station metric of the sensor node to calculate competition radius. It is logical to decrease the inter-cluster work of a cluster-head while its residual energy is decreasing. If the competition radius does not change as the residual energy decreases, the sensor node runs out of battery rapidly.

The proposed algorithm takes this situation into consideration and decreases the competition radius of each tentative cluster-head as the sensor node battery level decreases. Radius computation is accomplished by using predefined fuzzy if-then mapping rules to handle the uncertainty.

These fuzzy if-then mapping rules are given in Table 3.1. A fuzzy inference technique is used, because it is the most

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frequently used fuzzy technique.

B. *Fuzzy logic approach for selection of cluster head*

In the proposed model for the cluster-head competition radius calculation, two fuzzy input variables are used. The first one is the distance to the base station of a particular tentative cluster-head. The linguistic variables for this fuzzy set are close, medium and far.

The second fuzzy input variable is residual energy of the tentative cluster-head. Low, medium and high are the linguistic variables of this fuzzy set.

The only fuzzy output variable is the competition radius of the tentative cluster-head. We have 9 linguistic variables which are very small, small, rather small, medium small, medium, medium large, rather large, large and very large.

Distance to base	Residual Energy	Competition Radius
Small	*Low*	***Very large***
Small	*Medium*	***Large***
Small	*High*	***Rather large***
Medium	*Low*	***Medium small***
Medium	*Medium*	***Medium***
Medium	*High*	***Medium large***
Far	*Low*	***Rather small***
Far	*Medium*	***Small***
Far	*High*	***Very Small***

Table 1. Fuzzy forms based on 9 variables

The cluster head selection is based on competition radius. It is described briefly in below steps.

C. *Clustering Algorithm Steps*

1. Initialize probability value to become cluster-head and let x is the random value between 0 & 1.

2. Check if the x value is less than the probability to become cluster-head.

3. Calculate radius competition using fuzzy if-then mapping rules.

4. Receive cluster-head message from node that consists of ID, competition radius and residual energy.

a. If cluster-head residual energy is less than node residual energy, it is terminated from cluster-head election and advertise quit election message (ID).

b. If cluster-head residual energy is greater than node residual energy, it is selected as cluster head and advertise message. And add nodes to cluster member list.

5. After receiving all cluster-head messages, repeat step 4 and exit.

IV. SIMULATION AND RESULT

OMNeT++ simulation tool is used to simulate clustering environment. It is a public-source, component-based network simulator. Most of the other wireless sensor network simulators do not provide a graphical user interface (GUI).

The major capabilities of our simulation tool is listed below:

- The simulation tool provides an interactive interface which enables pausing, accelerating, etc. to understand the clustering simulation process.
- Several number of clustering simulation scenarios can be defined by using this interface.
- Provides a detailed results screen that includes detailed charts for visualizing the experimental results.
- Allows to deploy hundreds of sensors which are located randomly.
- Supports sequential simulation of any number of different types of algorithms.
- Supports two different radio models for simulating energy dissipation
- Displays the currently running clustering simulation with an interactive user interface.
- Represents the results using FND, HNA and energy-efficiency metrics.
- Displays the results of the performed simulations together for comparing different simulation results.
- Displays the logs of the simulations in the log window.
- Saves the results of the simulations.
- Modules are reusable and can be combined in various ways.
- OMNET++ gives better feel of work, as it supports interactive GUI.

A. *Fuzzy Logic Testing*

The change of competition radius based to residual energy and distance to the base station parameters is demonstrated by the examples in Table 2. In these examples, the maximum distance to base station is 127 m and the maximum competition radius is set to 60 m.

Example	Distance to base	Residual Energy	Competition Radius
1	112.90	1.0	***45.31***
2	20.12	1.0	***20.61***
3	65.92	1.0	***31.61***
4	84.31	0.999	***38.88***
5	84.31	0.999	***38.88***
6	103.77	0.50	***36.65***
7	112.80	0.64	***46.02***
8	112.89	0.59	***41.08***
9	99.30	0.29	***34.63***

Table 2. Examples of fuzzy based variables determined

In example 1, 2 and 3, the residual energy levels of the

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nodes are identical i.e., equal to 1J but their distances to the base station are different. When the base station is closer, the competition radius of the sensor node decreases. In example 4 and 5, the distance to the base station is identical, but energy levels are different. The node which has a lower energy has a lower competition radius.

To clarify how we use fuzzy logic to determine cluster-head competition radius for each tentative cluster-head, we give a detailed example here by using if-then mapping rules which are listed in Table 3.1.

V. CONCLUSION

The network intra-cluster traffic is reduced using unequal clustering approach. Also fuzzy approach is used to select cluster head which helps in distributing packets among all sensor nodes evenly. The simulation findings reveal that the proposed algorithm can put in a more proper performance and prolong the network life as compared with similar algorithms in literature. It can also be used in mobile sensor networks in future.

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