GWO Algorithm with Fuzzy logic Based Clustering Protocol Using Wireless Sensor Network

Nivedha M
Associate Professor Mr. P. Anbumani
Krishnasamy College of Engineering and Technology,
Cuddalore.

ABSTRACT

Wireless Sensor Networks (WSN) become more popular due to the wide range of applications in various fields. WSN consists of a group of sensor nodes deployed in the region of interest. Energy efficiency is the major challenge while deigning WSN. Clustering is one of the important energy efficient techniques. Clustering is the process of grouping the nodes into clusters. A cluster consists of a Cluster Head (CH) and number of cluster members. CH is responsible for collecting data from cluster members, aggregating it and forwarding the aggregated data to Base Station (BS). So, CH selection plays a vital role to preserve energy in WSN. Many researchers are carried out to select the proper CHs. CH selection influences the overall performance of the WSN. Since LEACH protocol elects CHs in a probabilistic manner, it results in minimum network lifetime. In this paper, a dynamic CH selection using Fuzzy logic and gwo algorithms are proposed. The fuzzy input parameters are residual energy and the distance to BS. The output parameter is the probability of becoming CH. The proposed method is compared to the well known clustering protocol LEACH. Simulation results shows that the proposed method produces better results than LEACH in terms of energy consumption and network lifetime.

INTRODUCTION

Recent advances in sensor devices and wireless technologies have enabled deployments of large-scale wireless sensor networks (WSNs) for a diversity of applications such as

• **Health applications**: Like smart wearable body for patient monitoring, doctor tracking, drug administration in hospitals, and so on;

• **Environmental applications**: These include water level monitoring, reliable forest fire detection, etc.

• **Military applications**: For example, friendly force surveillance, battlefield monitoring, nuclear attack defense systems, and much more;

• **Home applications**: Such as smart home devices for home automation, smart life, etc. In such variety of applications, hundreds or thousands of sensors are deployed over the monitoring field, with sensors intelligently organized into a wireless network, in which each sensor periodically forwards its sensed information to the sink (base station)

In large-scale WSNs, sensors collect data and forward it to a user over the wireless link. Moreover, the sensors are usually powered by limited battery capacity in expectation of surviving for a long lifespan. Thus, routing in WSNs becomes more challenging as compared to wireless ad hoc networks. Keeping the fact in mind that the number of sensors is large in networks, the need of routing algorithms with the capability to convey sensed data along lengthy paths is becoming much more demanding. Regardless of the network size, and all the way through the network setup, some of the engaged sensors may not operate properly due to their energy exhaustion. However, this concern should not have an impact on the ongoing network configuration.

Architecture of Clustering in WSN

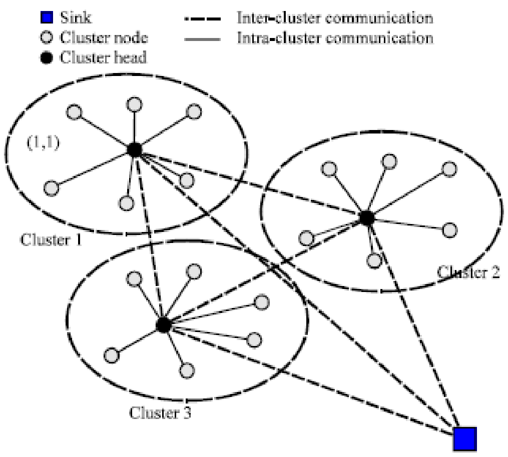

Fig. 1. Architecture of Clustering in WSN

To avoid this data redundancy and to make the network most energy efficient, data aggregation and sensor fusion have been emphasized in the literature [1]. Many routing protocols with many different ideas have been proposed in the literature to make the network energy efficient [14]. Cluster based routing protocol is one of these efficient ideas, where sensor nodes are divided into number of groups and each group is called as a cluster. One group leader is elected in each cluster known as Cluster Head (CH). Data aggregation is obtained at the leader node. The leader node/CH is only responsible for sending the message to the BS. Figure 1 shows the general system model for clustering based WSN.

RELATED WORK

In few recent years, many clustering algorithm-based routing techniques have been proposed for wireless sensor networks (WSNs); some of these ones use the fuzzy logic approach to solve the problems found in the clustering algorithm precisely the CHs selection. However, due to space limitation, only some of these routing protocols are described here. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is one of the clustering algorithms based routing protocols in which CHs are randomly selected. The operation in LEACH consists of the set-up phase and steady-state phase. The set-up state phase contains CHs selection and clusters formation, while in steady-state phase; the nodes send data to sink through CHs. In LEACH the CHs are randomly rotated over time to balance the energy efficiency of sensor nodes.

PROPOSED METHOD

Fuzzy Logic and GWO Algorithm is proposed to improve the lifetime of WSNs. This approach uses fuzzy logic for CHs selection and clusters formation processes by using residual energy and closeness to the sink as fuzzy inputs in terms of CH selection, and residual energy of CH and closeness to CHs as fuzzy inputs in terms of clusters formation. Simulation results justify its efficiency.The proposed method is compared to the well known clustering protocol LEACH (Low-Energy Adaptive Custering Hierarchy) Simulation results shows that the proposed method produces better results than LEACH interms of energy consumption and network lifetime.

GWO ALGORITHM

The **Grey Wolf Optimizer** **(GWO)** Algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature. Four types of grey wolves such as alpha, beta, delta, and omega are employed for simulating the leadership hierarchy. In addition, three main steps of hunting, searching for prey, encircling

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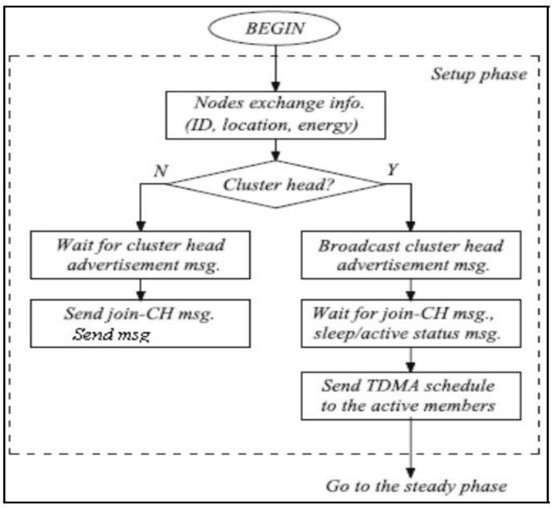
prey, and attacking prey, are implemented to perform optimization.

LEACH Protocol Architecture

LEACH is the first and most popular hierarchical based clustering protocol in WSN. It has been proposed to reduce the energy consumption and lengthen the network lifetime. Cluster Head Selection Algorithms It is a distributed; probability based clustering protocol without any central control. It does not need any global information of the sensor nodes (energy, distance, etc.) Additionally, each node independently takes decisions of becoming CH. LEACH works in two phases: setup phase and steady state phase. In setup phase, each node determines the probability of becoming CH by choosing a random value between 0 and 1. The node becomes a CH in the present round, when the random number is less than the predefined threshold value:

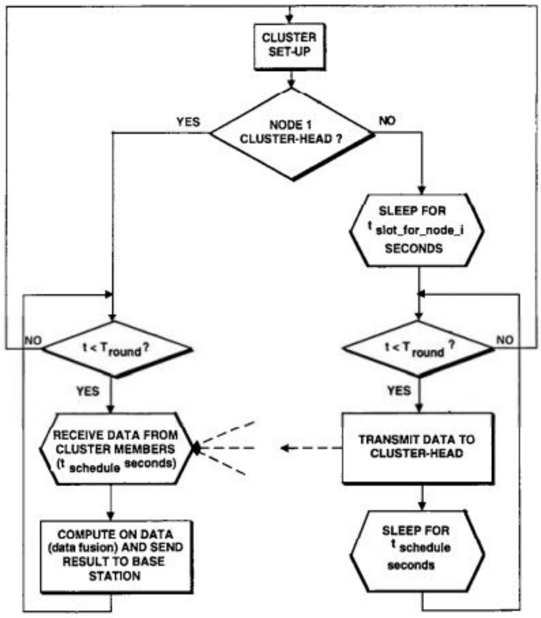
$$T(n) = \begin{cases} p \Big/ \left(1 - p\left(r \bmod \frac{1}{p}\right)\right), n \epsilon G \\ 0 \qquad\qquad\qquad\qquad\quad , n \epsilon G \end{cases} \qquad (1)$$

where p is the desired percentage of CHs, r is the number of rounds and G is the set of all nodes which is not elected as CH in the past 1/p rounds.



Flow chart of setup phase – LEACH

In Steady State Phase, TDMA schedule is used to send data from node to cluster head. Cluster head aggregates the data received from nodes in the cluster. Then, communication takes place via direct-sequence spread spectrum (DSSS) and each cluster uses a unique spreading code to reduce inter-cluster interference. The data is sent from the cluster head nodes to the using a fixed spreading code and CSMA.



Flow chart of steady state phase – LEACH

LIMITATIONS OF LEACH

LEACH protocol has some limitations. It does not consider the present state of the sensor nodes (e.g. residual energy, distance to sink, etc.). When the node with less residual energy becomes CH, it will die soon. And the distance to BS is also not considered. The nodes located far from BS become CH; the energy consumption is increased enormously. It is not suitable for large scale WSN where the distance between the sensor node and BS is high. LEACH does not employ use multi-hop communication even for longer distances. This makes the CH spends more energy and exhausts its battery soon. To overcome the above limitations, we propose a fuzzy logic based clustering protocol to extend the lifetime of WSN by reducing the energy consumption.

Cluster Heads Selection Using FIS

In CHs selection process, FIS has been used for the chance calculation of each sensor node. As in Figure 1, two input parameters for FIS are the residual energy of sensor node and closeness to the sink, and one output parameter is the chance value of a sensor node to be selected as a CH. The largest chance value means that the sensor node has more chance to be a CH. In this case, these input parameters have been chosen because of their importance for the network lifetime.

The linguistic values for membership function of closeness to the sink are close, medium and far. A trapezoidal membership function is used for close and far, whereas a triangular membership function is used for medium. Another input parameter is a residual energy of sensor node. The membership functions that describe the residual energy of sensor node input parameter is depicted. The linguistic values of this membership function are represented as very low, low, rather low, medium, rather high, and high. A trapezoidal membership function represents very low and high, whereas a triangular membership function represents other linguistic values.

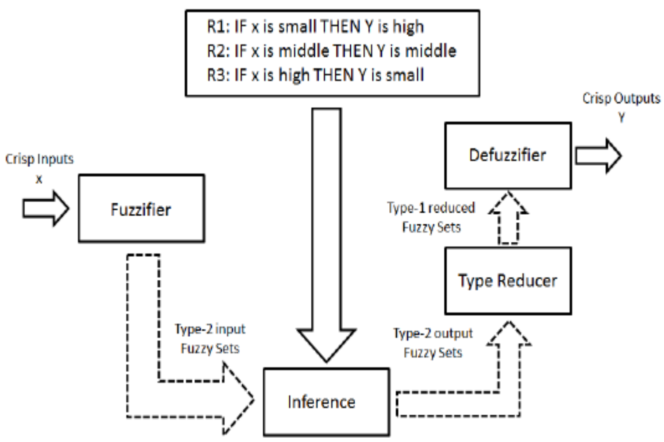


Fig . 2 . Cluster Head selection and formation

Clusters Formation Using FIS

In clusters formation process, the residual energy of CH and the distance between the non-CH nodes and CH (closeness to CH) have been employed. Figure 3 illustrates FIS for clusters formation using two input parameters which are the residual energy of CH and closeness to CH and one output is the chance value of a sensor node to join CH. The maximum chance means that the sensor node has more chance to join CH. The linguistic values for these membership functions of closeness to CH are close, medium and far. Trapezoidal membership functions are employed for close and far, while a triangular membership function is employed for medium. Another input parameter is the residual energy of CH.

SIMULATION RESULTS AND DISCUSSIONS

Parameter Settings and Simulation Metrics

The objective of this work in conducting simulations is to analyze the performance of CAFL protocol by comparing it with LEACH, CHEF, and LEACH-ERE. This proposed clustering algorithm is designed for WSNs that have static sensor nodes. The sensor nodes are randomly distributed in the network field of 100 m2 and the sink is installed at a point (50, 50). Average results showed in this section are obtained after running the simulation 5 times. Moreover, the values of the first order radio model in this simulation are described in Table 1. In order to evaluate CAFL protocol,

- **Network lifetime**: The time duration from the start of WSN operation until the death of the last alive sensor;

- **Stability period**: The time duration from the start of WSN operation until the first sensor dies;

- **Throughput:** The average of successfully received packets per round;

- **Node density:** The number of sensor nodes in a given network area.

Type of parameter	value
No of sensor node	100, 200, 300, 400, 500
Transmitter/receiver electronics	50nJ/bit
Transmit Amplifier (if d to BS <=do)	10pJ/bit/m2
Transmit Amplifier (if d to BS >do)	0.0013pJ/bit/m4
Data Aggregation	5nJ/bit/message
Data packet size	2500 bytes
Broadcast packet size	25 bytes

Table 1. Configuration parameters

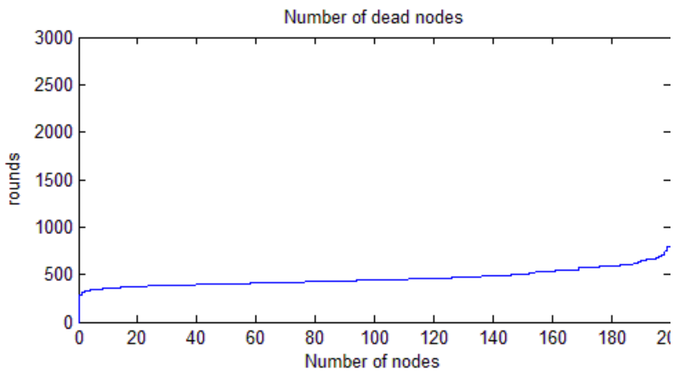


Fig.3number of dead nodes

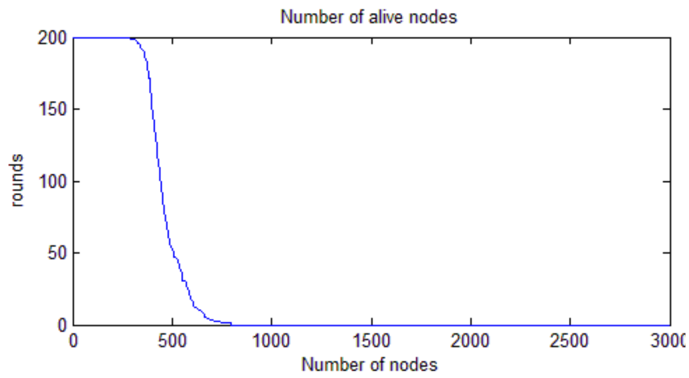


Fig. 4 Number of nodes

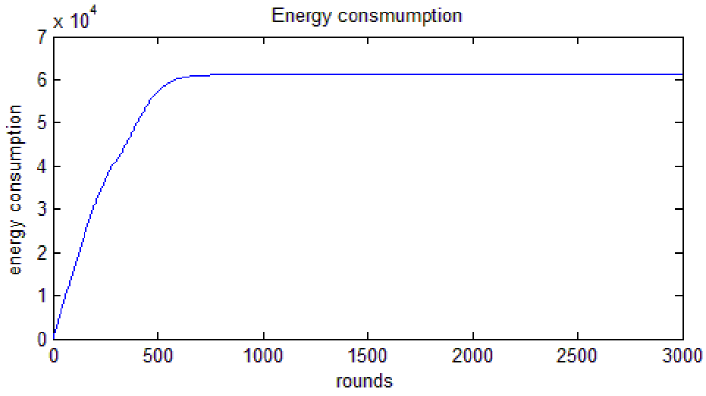


Fig. 5 Number of rounds and energy consumption

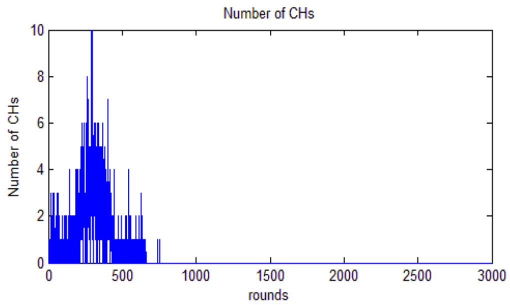


Fig 6 Number of CHs

CONCLUSION

Energy efficiency is the significant factor in designing routing protocol algorithms for WSNs. To carry out this factor, many routing protocols are proposed and hierarchical protocols are representative ones. The hierarchical protocols employ the probability to select CHs and alternate the CHs periodically in order to distribute energy consumption. However, the energy efficiency of WSNs is not extended. In this paper, a new routing algorithm is proposed for the WSNs that have immobile sensor nodes. It is expected that it could be more useful in many practical applications of WSNs such as agriculture field monitoring, forest fire detection, health care etc. As further direction, this work can be extended in terms of mobile sensor nodes.

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