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An Energy Efficient Fuzzy Logic based Hybrid Routing Protocol in Wireless Sensor Networks

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Abstract –**Wireless sensor networks are the collection of several small, battery operated electronic devices known as sensors in order to monitor physical phenomena such as temperature, pressure or humidity. Furthermore, these sensor nodes are usually operated by the battery which is normally not easy to replace. Till now many routing protocols have been proposed for energy efficiency of both homogeneous and heterogeneous environments. We propose here a Fuzzy-based hybrid protocol for some nodes to transmit data directly to the base station. The proposed approach is based on fuzzy level information which minimizes the time for the selection of cluster head.**

Keywords – **Fuzzy, LEACH, Routing, WSN.**

I. Introduction

Technological and technological advances in the field of wireless networks, micro-manufacturing, and microprocessor integration have resulted in a new generation of networks of large-scale sensors suitable for a wide range of applications [1]. Let us imagine a set of small, stand-alone electronic devices, equipped with sensors and capable of communicating with one another wirelessly. Together, they form a network of wireless sensors capable of supervising a region or a phenomenon of interest, providing useful information by combining the measures taken by the different sensors and then communicate them via the wireless medium.

This new technology promises to change the way we live, work and interact with the physical environment around us. Wireless communicating sensors with computational capabilities facilitate a series of applications that were ineffective or too low a few years ago. Today, tiny and cheap sensors can be scattered on roads, structures, walls or machines, creating a kind of second digital skin capable of detecting a variety of physical phenomena. Many areas of application are envisaged, such as disaster detection and monitoring, environmental monitoring and biodiversity mapping, intelligent building, Monitoring, and preventive maintenance of machinery, medical and health, logistics and intelligent transport. Wireless sensor networks are often characterized by dense deployment on a large scale in resource-constrained environments. The limits imposed are the limitation of the processing, storage and above all energy capacity because they are supplied by batteries. Recharging the batteries in a sensor array is sometimes impossible due to the location of the nodes, but most often for the simple reason that this operation is practically or

Economically unfeasible. It is therefore widely acknowledged that energy limitation is an unavoidable issue in the design of wireless sensor networks because of the stringent constraints imposed on network operation. In fact, the consumption of sensor energy plays an important role in the life of the network, which has become the preeminent performance criterion in this field. If we want the network to function satisfactorily for as long as possible, these energy constraints require us to compromise between different activities at both the node and network.

Several research projects have emerged to (or “intending to”) optimizing consumption

'Node energy' through the use of innovative conservation techniques to improve network performance, including maximizing its lifetime. Generally speaking, saving energy ultimately means finding the best compromise between the different energy-consuming activities. The wireless sensor network literature recognizes that radio is an outstanding energy consumer [2, 3].

The research community has proposed a large number of protocols at all levels, from the physical layer to the application layer, and naturally, fall into two categories. The first class of protocols in the field of ad hoc networks, but the application of these protocols to wireless sensor networks, generates, surprisingly, complexity and energetic energy costs.

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The second class of protocols are specific to sensor networks; they are often directed and personalized for a precise application. As a result, they cannot be applied and appropriately deployed to any application context, and many of them have been largely deployed due to disadvantages related to the sustainability of the network. Energy efficiency protocols are needed to extend the life of the network. On the other hand, there is a high degree of freedom to set up, requiring the complete design of the infrastructure, mechanisms, and protocols to be applied in the intended application, as it is the sustainability which is at stake.

For all of these reasons, we largely devote this paper to the energy efficiency of communications in the network, and we are doing energy conservation, the guideline of our work. To resolve this problem, we choose a precise application context, and we propose to design a complete and original protocol solution. The design of such a solution must take account of the constraints of energy. It involves the implementation of an effective and efficient network architecture on the one hand, and then a relevant choice among existing energy conservation techniques and improvements in their performance. All the phenomena of overconsumption of energy. It is also necessary to consolidate this work with a detailed analytical study to facilitate the understanding of the dissipation of energy in the network and to make the necessary improvements the proposed mechanisms.

Similar to other communication networks, scaling is one of the main design attributes of sensor networks. A single-level network can cause the gateway to overload by increasing the density of the sensors. This overload can cause latency in communication and inadequate tracking of events. In addition, the single-gateway architecture is not scalable for a larger set of sensors covering a wider area of interest because sensors are generally unable to communicate at long distances. To allow the system to cope with the additional burden and to be able to cover a wide area of interest without degrading the service, cluster network division has been continued in some routing approaches.

The main objective of the routing is to efficiently maintain the energy consumption of the sensor nodes by involving them in multi-hop communication in a particular cluster and by aggregating and merging data in order to decrease the number of messages sent to the sink. The cluster formation is generally based on the energy reserve of sensors and the proximity of the sensor to the cluster head (CH) [4, 5]. LEACH [6] is one of the first hierarchical routing approaches for sensor networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols [7, 8, 9], although some protocols have been developed independently [10, 11].

II. Low-Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [6] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form groups of sensor nodes based on the strength of the received signal and use the local clusters heads (CHs) as routers to the sink (see Figure 1). This will save energy because the transmissions will only be made by CHs rather than all sensor nodes. The optimal number of CHs is estimated to be 5% of the total number of nodes.

All data processing such as merge and aggregate data is local to the cluster. The CHs change randomly over time in order to balance the energy dissipation of the nodes. This decision is taken by the node by choosing a random number between 0 and 1. The node becomes a CH for the current cycle if the chosen number is less than the following threshold:

$$T(n) = \begin{cases} \frac{p}{1-p^*(r \, mod \frac{1}{p})} & if\ n \in G \\ 0 & otherwise \end{cases} \qquad (1)$$

III. Cluster-Head Selection using Fuzzy Logic

The Hybrid Routing Protocol (HRP) takes various parameter to elect CH as a random value, which causes poor balancing of energy in the network. The Fuzzy logic approach is used to make energy level stable (improve balancing of energy) in the network [12, 13]. The proposed protocol is a fuzzy logic based protocol for the selection of cluster head. Hence we call it as Fuzzy based hybrid routing protocol [14]. In the process of cluster head selection, two input functions such as distance and residual energy of sensor node are transformed into fuzzy sets. A fuzzy set consists of degree of membership. The distance and residual energy Fuzzy sets are defined as:

$$A = \{(d, \mu_A(d))\},\ d \in D$$
$$B = \{(e, \mu_B(e))\},\ e \in E \qquad (2)$$

Where, D is a universe of discourse for Distance and E is a universe of discourse for residual Energy, d and e are particular element of D and E respectively. $\mu_A(d), \mu_B(e)$ are membership functions, the degree of membership of the element in a given set. Membership functions for distance and residual energy are as follows.

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$$\mu_A(d) = \begin{cases} 1 & if\ d \le TH_1 \\ (TH_1 - d)/TH_1 - TH_2 & if\ TH_1 < d < TH_2 \\ 0 & if\ d \ge TH_2 \end{cases} \quad (3)$$

$$\mu_B(e) = \begin{cases} 0 & if\ e \le TH_1 \\ (e - TH_1)/TH_2 - TH_1 & if\ TH_1 < e < TH_2 \\ 1 & if\ e \ge TH_2 \end{cases} \quad (4)$$

Where,
TH_1= Threshold to activate system
TH_2 = Threshold which identifies the level of activeness

A fuzzy relation is a relationship between elements of D and elements of E, described by a membership function, $\mu_{D\times E}(d, e)$, d € D and e € E.

The fuzzy operator AND (∧) is used to find the fuzzy relation,

$$\mu_A(d) \wedge \mu_B(e) = \min(\mu_A(d), \mu_B(e)) = \begin{cases} \mu_A(d), & if\ and\ only\ if\ \mu_A(d) \le \mu_B(e) \\ \mu_B(e), & if\ and\ only\ if\ \mu_A(d) \ge \mu_B(e) \end{cases} \quad (5)$$

The maximization of lifetime can be formulated as an optimization problem. The variables of this optimization problem are routing parameters at nodes. When having sensed or asked to relay a data packet, each node needs to transmit this packet to a sink. However, it cannot send the packet directly to sinks except that it is a sink's neighbour. So normally a node needs to choose a neighbouring sensor as its next hop. When nodes are chosen as the next hops they will influence the energy consumption of the network as well as the lifetime. The process of Cluster Head selection consists of distance and residual energy of a super node.

Distance: A routing protocol prefers the route that has the largest total energy capacity from source to destination. The process of cluster head selection depends upon the distance to base station.

Residual Energy (RE): Undoubtedly the most crucial aspect of routing in WSNs is the energy efficiency. Under this criterion, the focus is on the energy capacity (i.e. the current battery charge level) of the nodes. A routing protocol that uses this metric would then favour routes that have the largest total energy capacity from source to destination. In other words, nodes having greater remaining energy participate more than the nodes with limited power.

Traffic Load (TL): The traffic load (or intensity) of a node is defined as the pending amount of traffic in a node's queue. This includes the application traffic and also the traffic that a node has already committed to forwarding. In the case that concentration of events in some particular sub-areas is more than that of areas, using shortest path will cause implosion along the path. The high traffic load causes a data queue overflow in the sensor nodes, resulting in loss of important information. In addition, since the battery energy of the sensor nodes is quickly exhausted, the entire lifetime of wireless sensor networks would be shortened.

IF-ELSE Rule Set

The rules are designed as follows:

Table 1: If-else rule set

IF	DISTANCE	RESIDUAL ENERGY	LOAD	THEN	OUTPUT
IF	Reachable	Low	Less	THEN	18
IF	Reachable	Low	Medium	THEN	9
IF	Reachable	Low	Heavy	THEN	19
IF	Reachable	Adequate	Less	THEN	3
IF	Reachable	Adequate	Medium	THEN	6
IF	Reachable	Adequate	Heavy	THEN	17
IF	Reachable	High	Less	THEN	1
IF	Reachable	High	Medium	THEN	2
IF	Reachable	High	Heavy	THEN	11
IF	Considerable	Low	Less	THEN	16

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IF	Considerable	Low	Medium	THEN	20
IF	Considerable	Low	Heavy	THEN	24
IF	Considerable	Adequate	Less	THEN	7
IF	Considerable	Adequate	Medium	THEN	8
IF	Considerable	Adequate	Heavy	THEN	21
IF	Considerable	High	Less	THEN	4
IF	Considerable	High	Medium	THEN	5
IF	Considerable	High	Heavy	THEN	10
IF	Far	Low	Less	THEN	25
IF	Far	Low	Medium	THEN	26
IF	Far	Low	Heavy	THEN	27
IF	Far	Adequate	Less	THEN	13
F	Far	Adequate	Medium	THEN	15
IF	Far	Adequate	Heavy	THEN	23
IF	Far	High	Less	THEN	12
IF	Far	High	Medium	THEN	14
IF	Far	High	Heavy	THEN	22

The Rule Viewer displays the whole fuzzy inference process. It is based on the fuzzy inference diagram described with small plots nested in it. The four small plots in each row represent the antecedent (IF) and consequent (THEN) of the rule. Each rule is a row of plots, and each column is a variable. The first three columns of plots (the yellow plots) show the membership functions referenced by the antecedent, or the if-part of each rule.

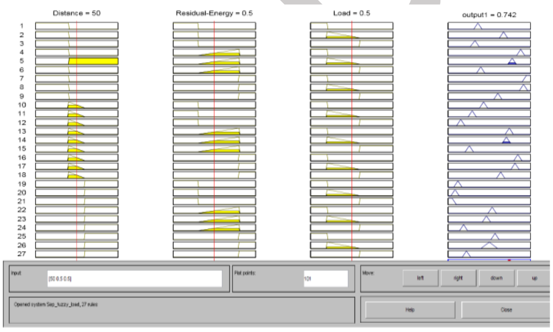

Figure 1: MATLAB Rule Viewer

The fourth column of plots (the blue plots) shows the membership functions referenced by the consequent, or the then-part of each rule. The last plot in the fourth column of plots represents the aggregate weighted decision for the given inference system. This decision will depend on the input values for the system.

Figure 2: Graph showing membership functions for input variable “Distance”

Figure 3: Graph showing membership functions for input variable “Residual Energy”

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A fuzzy relation is a relationship between input variables, described by a membership function. Triangle and Trapezoidal membership functions are used because their degree is more easily determined. When we double click on any of the input (yellow plot) of FIS variables, the membership function opens up.

Figure 4: Graph showing membership functions for input variable "Load"

We can adjust the desired input by clicking anywhere in the plot. This will let changed value be highlighted with red index line. Same procedure is followed to modify other input values. When we release the line, a new calculation is performed and we can see the fuzzy process takes place.

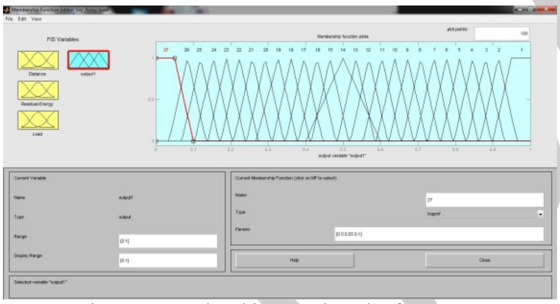

Figure 5: Membership Function plot for Output

For example if we follow rule 1 across the top of the diagram, we can see the consequent "output1 is 18" has been truncated to exactly the same degree as the (composite) antecedent–this is the implication process in action. The aggregation occurs down the fourth column, and the resultant aggregate plot is shown in the single plot to be found in the lower right corner of the plot field. The de-fuzzified output value is shown by the thick line passing through the aggregate fuzzy set. The graph of various probabilities of output functions are shown in Figure 5.

IV. Simulation And Results

The performance of the network is analysed through simulation results obtained through MATLAB software.

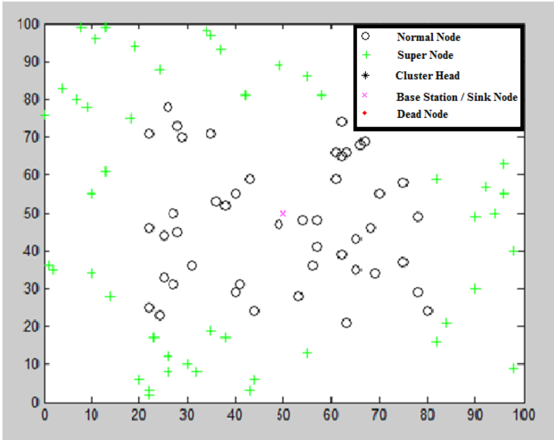

Figure 6: Network field on first round

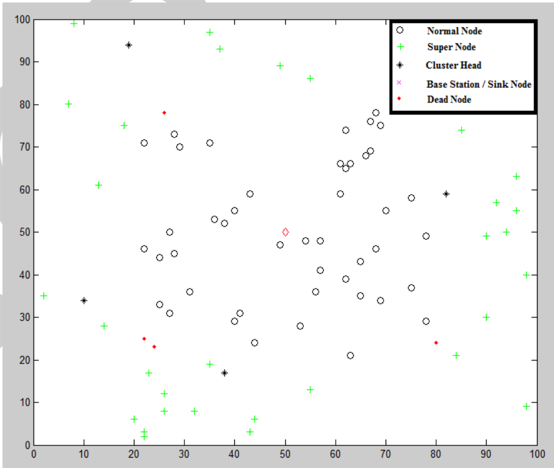

Figure 7: Network field on completion of around 2000 rounds

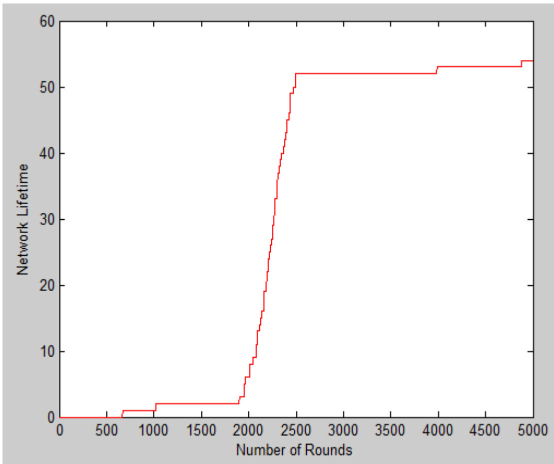

Figure 8: Graph between network lifetime and no. of rounds for proposed approach

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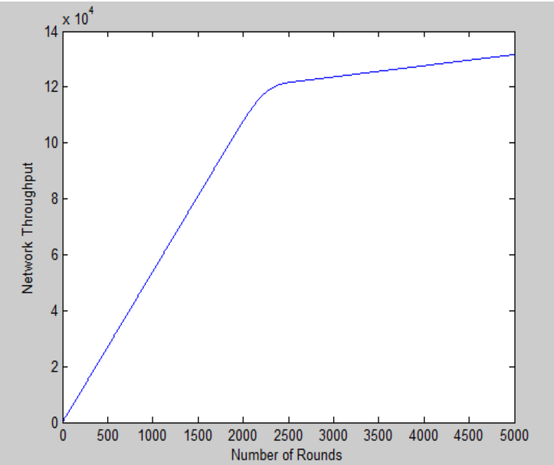

Figure 9: Graph between Network Throughput and no. of rounds for proposed approach

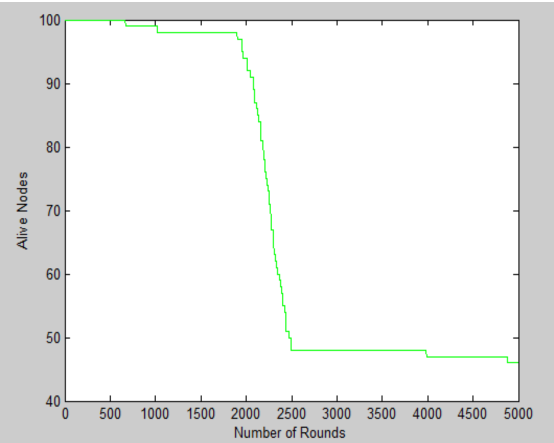

Figure 10: Graph between alive Nodes and no. of rounds for proposed approach

V. Conclusion

The proposed protocol uses the fuzzy data for the choice of cluster head to reduce the time consumed for cluster head election. To address problem of energy efficiency, we have designed FUZZY based hybrid routing protocol implementing fuzzy logic, and presented our approach via a simulation study. This method minimizes overall utilization of energy in course while cluster head election process. So it prolongs the lifetime of system. The hierarchical clustering and organization of the nodes in diverse locations depending upon their energy level optimizes the stability period and throughput of the system.

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