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An Energy Efficient Hybrid routing for Wireless Sensor Network using Fuzzy Logic

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***Abstract*— Wireless Sensor Networks is a collection of sensor nodes and base station. The nodes have limited battery power. The efficient utilization of sensor node's energy, clustering is one of the powerful tool. The heterogeneous wireless sensor networks consist of different type of sensor nodes in term of sensing, computation, communication and power. The proposed protocol is An Energy Efficient Hybrid routing for Wireless Sensor Network using Fuzzy Logic provide the multi path routing among the Cluster Head of super node region for transmitting the data to base station. The proposed protocol is efficient for selecting an optimum (cluster head) CH for transmission of data. The proposed Fuzzy Logic Technique, the status of the CH node is verified to transmits the data to base station. The designed fuzzy logic controller determines, best outcome from all the possible combinations of noise, load and residual energy. The CH node with highest Output Membership status will be chosen to send the data to base station . The proposed protocol improved the throughput of network. This increases the stability period of network. The Simulation result shows the improvement of the overall network performance in terms of stability period, alive nodes.**

Keywords – Hybrid Routing; Multipath Routing, Region based clustering, Noise, Load and Residual Energy, Load-balancing Fuzzy Logic.

I. Introduction

Wireless Sensor Networks (WSNs) is a collection of sensor nodes and one or more base station (BS). The deployment of sensor nodes in the wireless environment is preset / random. The sensor networks generally use random deployment. Sensor nodes have used for monitoring and tracking objects in the field of communication. The nodes have limited battery power so they work for limited time. The stability period and network lifetime is limited. Therefore attention is made to improve the lifetime of network by using efficient routing protocol. Clustering is considered to improving the lifetime of WSNs. Clustering is a mechanism in which group the sensor nodes and the highest parameter sensor node act as Cluster Head (CH).[1][2] . Generally, most of the routing protocol focuses on homogenous sensors nodes. The working with different type of sensor nodes is known as Heterogeneous WSNs [2].

There are different types of routing techniques for transmitting the data to BS .The relay nodes techniques is used for single path routing / multiple path routing. In Single path routing, the route between source node and destination node is one hop transmission of data. Multipath routing is an alternative routing technique, which selects multiple paths to deliver the data from source to destination [3].

The proposed Region based Clustering approach is used for large coverage area of network. The area is divided into fixed number of regions and deploying different types of sensor nodes.[9][10] These different types of nodes are normal and super node depending upon their initial energy. The Hybrid routing approach is used for transmits the data to BS. The Fuzzy logic is used for routing purposed.

The rest of the paper is organized as follows: design issue and related work in Section 2, the proposed protocol in Section 3, and simulation result is explained in Section 4 and finally conclusion in Section 5.

II. Design Issues and Related Work

The sensor node deployment is based on pre-deterministic or randomized deployment. The nodes are deployed randomly and create an infrastructure in an ad hoc manner. In, random deployment there is a several issues such as coverage area problem, optimal clustering etc [2]. Aggregation of data in sensor network has been playing an important role for transmission of similar packets. Aggregation is the combination of data from the different sensor nodes according to a certain aggregated function [3].

LEACH (Low-energy Adaptive Clustering Hierarchy) is first and most well known uses energy efficiently hierarchical clustering algorithm used in WSNs has been proposed for power consumption reduction. In LEACH, the task for cluster selection is rotated among the nodes, on basis of duration. LEACH uses single hop communication, here each sensor nodes to their respective CH in a single hop and CH forward data to BS in single hop. Therefore, LEACH protocol prolongs network lifetime. Routing follow single hop count, it is not applicable to a large area of network. In LEACH all nodes

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with same probability to become a CH. Therefore, LEACH is not well suited for heterogeneous environment [4].

PEGASIS (Power Efficient Gathering in Sensor Information Systems) protocol is better than LEACH protocol, it forms sensor nodes chain so every node transmits as well as receives from their neighbor and only one node from the chain chosen for sent the data to BS. The data is been gather and moves between nodes, then aggregated and sent to BS. PEGASIS also requires dynamic topology change since a sensor needs to identify the energy status of its neighbors to know their order for route its data. Such adjustment of nodes can bring significant overhead particularly for highly utilize the networks [5].

TEEN (Threshold sensitive energy efficient sensor network) protocol is a reactive protocol designed for time critical applications. In TEEN the criteria for selection of CH is same as in LEACH, TEEN introduces hard and soft threshold to minimize the number of transmissions thus saving the energy of nodes. But, TEEN protocol is for homogeneous WSNs that are not fit for heterogeneous environment [6].

SEP (Stable Election Protocol) was introduced for heterogeneous WSNs. It has two level hierarchical protocols where two types of nodes (normal node and super node) are used for data transmission. Super nodes have more Initial Energy than normal nodes. In SEP both nodes have weighted probability to become CH. Chance of super node to become CH is more than normal node due to high energy. The SEP protocol does not guarantee efficient deployment of nodes over the network area. Due to random deployment it may causes coverage hole problem in network. If majority of low level initial energy nodes like normal nodes may be deployed far away from base station so now for transmission it consumes more energy therefore it shortening the stability period and decrease the throughput, so efficiency of SEP also decreases [7].

EEHC(Energy Efficient heterogeneous Clustered) protocol also used for heterogeneous environment which provide three level hierarchy by using three types of nodes such as normal node, advance node and super node on the basis of Initial Energy. CH selection same as LEACH protocol. Super nodes have β times more energy than advance node and advance node have α time more energy than normal node. By using three level hierarchies this protocol able to improve the stability period of Network as compared to SEP. But node deployment is random in it therefore coverage hole problem may be arises [8].

The RBHR (Region Based Hybrid Routing) Protocol deals with sensor node sent their data to their respective CH in single hop and each CH transmitted data to BS in single hop [10]. By using single hop routing, it consumes huge amount of energy therefore stability period of network is reduced. For improve the stability period and lifetime of network we proposed the multipath routing for transmitting the data among CHs of super nodes regions, which improves the stability period, throughput and lifetime of network which shown in simulation result.

III. PROPSOED WORK

The Hybrid Routing Approach for Heterogeneous Wireless Sensor Networks Using Fuzzy Logic Technique used two types of routing techniques. 1) The Normal nodes sent their data directly to BS .2) The super nodes send data using clustering approach. The clusters are formed in super nodes regions using inverted binary tree concept [11] [12]

Let us consider M*M size network area where BS is located somewhere at the center of the network. The total area is divided into regions for the efficiently use of the area of network. The heterogeneity is provided by two types of sensor nodes (super node and normal node) on the basis of their initial energy level. The super node has α times (α > 1) more energy than the normal node. The Normal nodes are placed near the BS and Super nodes are placed far from BS.

The network shown in figure1 is developed on following models

A. Levels into Region Based Deployment

The proposed protocol is provides large coverage area to gathering information from network. The network is divided into regions There are RP region than {R1, R2 …. RP-1} region for super nodes deployment and{ Rp} region for the normal nodes deployment.

The super nodes regions is approximately divided into equal level set $\{L_1, L_2 \ldots L_{Q,}\}$ and form the clusters at each level shown in Figure 1. Level L1 is defined as the nearest region to BS. The Clusters are form at far level to BS using Inverted binary tree concept.

B. Multipath Routing in Super nodes Region

The Super nodes having more energy than normal nodes are deployed at far from BS .The multipath routing approach is used for data transmission. In the multipath routing approach CHs of each level L_Q sends its packet to just it's above level L_{Q-1} CHs and so on. For route discovery among CHs we will take residual energy as parameter, lower level's CHs send its packet to those CHs whose energy is higher than other CHs of its above level. As if distance of route is large than it consume more energy which decrease the lifetime of network therefore we consider distance for route also, CHs of below level sends its packet to just above half levels of CHs and compare energy among them for choosing intermediate CHs so it makes its route to BS. This procedure follows up to level L_Q and CHs at level L_Q will send its packet directly to BS shown in Figure 1.

C. Region based Clustering using Fuzzy Logic Techniques

Cluster based routing protocol consists of four stages: CH selection, Cluster formation, data aggregation and data communication. The setup state starts by election of head selection stage, which is followed by the steady state in this transmission state it is subdivided into data aggregation and data transmission phase. We have proposed Fuzzy based

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decision making techniques for selection of CHs. The fuzzy decision rules set ranked the Super node's status on the basis of memberships input functions. Initially, all the Super nodes are deployed in the Region (R_1, R_2,…. , R_{P-1}) and all the super nodes have same initial energy. Each Super node contains its ID and the value of Residual Energy (RE).

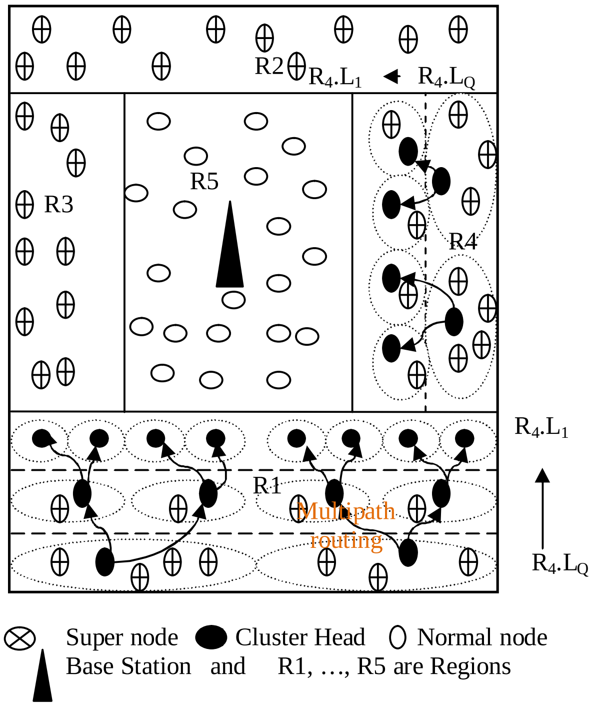

Figure 1. Multipath routing among CHs of each level in Super nodes Regions

D. Proposed Algorithm for multipath and hybrid routing and optimal clustering using inverted Binary Tree

The proposed algorithm for data transmission using hybrid routing and optimal clustering in each region using inverted Binary tree described in Figure 2:

CH= Cluster Head; CM= Cluster Member;
BS= Base Station
1. Start,
a) Total area= M*M,
b) Total number of nodes= n,
c) m = Fraction of total number of nodes (number of super nodes having α (α>1) times more energy)
d) n * (1-m) = number of Normal nodes
e) All the sensor nodes set in Regions.
f) Each node contains its ID and value of energy that it retains RE.
g) Network has R_1, R_2, R_3…. R_P regions.
h) Normal nodes deployed in Region R_p.
i) Super nodes deployed in Region R_1, R_2…R_{P-1}
2. If, node = normal
3. Node sense data
4. Data → BS
5. End if.
6. Else, node= Super
7. Formation of Levels into Regions
8. Apply, for f= 1to (P-1) for regions
9. for g=1 to Q for levels
10. $R_f.L_1 = R_f.L_2 = …… = R_f.L_Q$
11. End.
12. Set L_1 near to BS of each region R_1…. R_{P-1}.
13. Cluster formation in each level done by using inverted Binary Tree concept.
14. Number of cluster at each $level_x=2^y$
Where x= Q to 1 and y= 1 to Q.
15. Total number of cluster in each Region
$= 2^1+ 2^2+ 2^3+……. + 2^y$
Where y= 1, 2… Q.
16. Selection using Fuzzy logic technique Cluster formation.
17. CM sense data
18. Data → CH
19. Data aggregation by CH
20. CH uses multipath routing among inter clusters in between levels for transmitting the data.
21. for u= Q,Q-1, ….. 1 levels
22. If level L_Q CHs transmit their aggregate data to L_{Q-1} CHs until L_1
23. For route discovery CHs at L_Q take energy as constrained.
24. If CHs at level L_Q, first CH of L_Q, send its data to first two CHs of above levels L_{Q-1}
25. Find MAXENERGY (first half CHs at level L_{Q-1}) and CH at L_Q send its data to highest energy CHs at L_{Q-1}, makes the route among CHs of inter levels.
26. End if.
27. Else, at level L_1 sends its aggregate data directly to BS.
CHL_1 → BS
28. End Else.
29. End Else
30. End.

Figure2. Algorithm for Proposed Protocol.

F Proposed Model for Optimal CH Election using Fuzzy Logic

The proposed protocol uses Fuzzy based decision making technique to verify the status of a node. As an outcome of fuzzy decision rules, the node's status has been ranked on the basis of the memberships of input functions. Before a node transmits the data to the next node, it checks the status of that node. This estimated decision is exchanged among all neighbors using a status flag with RREQ message. If the ranking of node's status has lower priority then the sending node does not transmit the packet to that node, if the ranking of node's status has average priority then that node is considerable for receiving the packet from sender node but if the ranking of node's status has higher priority then the sending node will choose this node for efficient data packet transmission [4]. The process of node selection consists of three input functions that transform the system inputs into fuzzy sets such as Noise Factor, Load and Residual Energy of paths between any two nodes. A, B and C are fuzzy sets for Noise Factor, Load and Residual Energy in the protocol that can be defined as,

$$\mathbf{A = \{(n, \mu_A(n))\}, n \in N}$$

$$\mathbf{B = \{(l, \mu_B(lo))\}, l \in L}$$

And $$\mathbf{C = \{(e, \mu_C(e))\}, e \in RE}$$

Where,N is universe of disclosure for Noise Factor, L is universe of disclosure for Load and RE is a universe of disclosure for Residual Energy.

n, *lo* and *e* are particular elements of N, L and RE respectively,

$\mu_A(n)$, $\mu_B(lo)$, $\mu_C(e)$ are membership functions that are used to find degree of membership of the elements in a given set.

Membership functions for Noise, Load and Residual Energy are defined from Figure 1, as follows:

$$\mu_A(n) = \begin{cases} 0, & \text{if } n > TH_2 \\ (n - TH_1)/\ TH_2 - TH_1, & \text{if } TH_1 \geq n \geq TH_2 \\ 1, & \text{if } n \leq TH_1 \end{cases}$$

$$\mu_B(lo) = \begin{cases} 0, & \text{if } lo > TH_2 \\ (lo - TH_1)/\ TH_2 - TH_1, & \text{if } TH_1 \geq lo \geq TH_2 \\ 1, & \text{if } lo \leq TH_1 \end{cases}$$

$$\mu_C(e) = \begin{cases} 0, & \text{if } e \leq TH_1 \\ (TH_1 - e)/\ TH_1 - TH_2, & \text{if } TH_1 < e < TH_2 \\ 1, & \text{if } e \geq TH_2 \end{cases}$$

Where,

TH_1= Threshold to activate system

TH_2 = Threshold which identifies the level of activeness

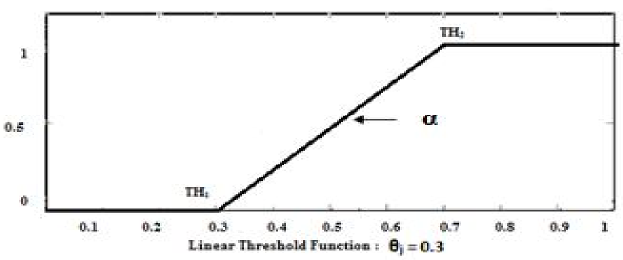

FIGURE 1: GRAPH SHOWING MINIMUM AND MAXIMUM THRESHOLD FOR ANY INPUT VARIABLE

A fuzzy relation is a relation between elements of N, L and RE, described by a membership function,

$$\mathbf{\mu_{N \times L \times RE}\ (n, lo, e), n \in N, lo \in L \text{ and } e \in RE}$$

Then we are applying AND fuzzy operator i.e. min (Λ) on fuzzy relation,

$$\mathbf{\mu_A(n) \wedge \mu_B(lo) \wedge \mu_C(e) = \min(\mu_A(n), \mu_B(lo), \mu_C(e))}$$

$$= \begin{cases} \mu_A(n), \text{ if and only if } \mu_B(lo) \geq \mu_A(n) \leq \mu_C(e) \\ \mu_B(lo), \text{ if and only if } \mu_A(n) \geq \mu_B(lo) \leq \mu_C(e) \\ \mu_B(e), \text{ if and only if } \mu_A(n) \geq \mu_C(e) \leq \mu_B(lo) \end{cases}$$

3.1 Rule Evaluation

The proposed protocol is a fuzzy logic based protocol for the selection of Cluster Head. The process of Cluster Head consists of three input functions that transform the system inputs into fuzzy sets such as Noise Factor, Load and Residual Energy of CH nodes. The Table 1 of Input Function uses three membership functions to show the varying degrees of input variables.

Table 1: Input Function

Input	Membership		
Noise Factor	Light	Considerable	Heavy
Load	Less	Medium	Heavy
Residual Energy	Low	Adequate	High

Preceedence order for input functions are as follows.

Residual Energy > Load > Noise Factor

In Table 2, 27 rankings are defined to represent the varying Output Memberships of the fuzzy outputs defined for each of the rules in the rule set. Aggregations of these fuzzy probabilistic values into a single fuzzy output are represented in detail in the rule-set defined in Table 3.

Table 2: Output Function

Output	Membership
Output Member-ships	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27

Preceedence order for ranking of output memberships is:

R1 > R2 > ------- > R26 > R27.

3.2 The Proposed Rules set

The given protocol defines all the possible combinations of the different membership functions for the three input variables that results in 27 rules for the fuzzy inference shown in Table 3.

Table 3: Rule Set Table

Noise factor	Load	Residual Energy	Output Memberships
Light	Less	Low	R11
Light	Less	Adequate	R3
Light	Less	High	R1
Light	Medium	Low	R15

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Light	Medium	Adequate	R6
Light	Medium	High	R5
Light	Heavy	Low	R19
Light	Heavy	Adequate	R18
Light	Heavy	High	R12
Considerable	Less	Low	R13
Considerable	Less	Adequate	R7
Considerable	Less	High	R2
Considerable	Medium	Low	R14
Considerable	Medium	Adequate	R8
Considerable	Medium	High	R4
Considerable	Heavy	Low	R20
Considerable	Heavy	Adequate	R17
Considerable	Heavy	High	R16
Heavy	Less	Low	R23
Heavy	Less	Adequate	R10
Heavy	Less	High	R9
Heavy	Medium	Low	R24
Heavy	Medium	Adequate	R22
Heavy	Medium	High	R21
Heavy	Heavy	Low	R26
Heavy	Heavy	Adequate	R27
Heavy	Heavy	High	R25

The Rule are define as follows

Rule 1
IF Noise Factor is Light AND IF Load is Less AND Residual Energy is High
THEN Output Membership is R1
Rule 2
IF Noise Factor is Considerable AND IF Load is Less AND Residual Energy is High
THEN Output Membership is R2
Rule 3
IF Noise Factor is Light AND IF Load is Less AND Residual Energy is Adequate
THEN Output Membership is R3
Rule 4
IF Noise Factor is Considerable AND IF Load is Medium AND Residual Energy is High
THEN Output Membership is R4
Rule 5
IF Noise Factor is Light AND IF Load is Medium AND Residual Energy is High
THEN Output Membership is R5
Rule 6
IF Noise Factor is Light AND IF Load is Medium AND Residual Energy is Adequate
THEN Output Membership is R6
Rule 7
IF Noise Factor is Considerable AND IF Load is Less AND Residual Energy is Adequate
THEN Output Membership is R7
Rule 8
IF Noise Factor is Considerable AND IF Load is Medium AND Residual Energy is Adequate
THEN Output Membership is R8
Rule 9
IF Noise Factor is Heavy AND IF Load is Less AND Residual Energy is High
THEN Output Membership is R9
Rule 10
IF Noise Factor is Heavy AND IF Load is Less AND Residual Energy is Adequate
THEN Output Membership is R10
Rule 11
IF Noise Factor is Light AND IF Load is Less AND Residual Energy is Low
THEN Output Membership is R11
Rule 12
IF Noise Factor is Light AND IF Load is Heavy AND Residual Energy is High
THEN Output Membership is R12
Rule 13
IF Noise Factor is Considerable AND IF Load is Less AND Residual Energy is Low
THEN Output Membership is R13
Rule 14
IF Noise Factor is Considerable AND IF Load is Medium AND Residual Energy is Low
THEN Output Membership is R14
Rule 15
IF Noise Factor is Light AND IF Load is Medium AND Residual Energy is Low
THEN Output Membership R15

Rule 16
IF Noise Factor is Considerable AND IF Load is Heavy AND Residual Energy is Low
THEN Output Membership is R16
Rule 17
IF Noise Factor is Considerable AND IF Load is Heavy AND Residual Energy is Adequate
THEN Output Membership is R17
Rule 18
IF Noise Factor is Light AND IF Load is Heavy AND Residual Energy is Adequate
THEN Output Membership is R18
Rule 19
IF Noise Factor is Light AND IF Load is Heavy AND Residual Energy is Low
THEN Output Membership is R19
Rule 20
IF Noise Factor is Considerable AND IF Load is Heavy AND Residual Energy is Low
THEN Output Membership is R20
Rule 21
IF Noise Factor is Heavy AND IF Load is Medium AND Residual Energy is High
THEN Output Membership is R21

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Rule 22
IF Noise Factor is Heavy AND IF Load is Medium AND Residual Energy is Adequate
THEN Output Membership is R22
Rule 23
IF Noise Factor is Heavy AND IF Load is Less AND Residual Energy is Low
THEN Output Membership is R23
Rule 24
IF Noise Factor is Heavy AND IF Load is Medium AND Residual Energy is Low
THEN Output Membership is R24
Rule 25
IF Noise Factor is Heavy AND IF Load is Heavy AND Residual Energy is High
THEN Output Membership is R25

Rule 26
IF Noise Factor is Heavy AND IF Load is Heavy AND Residual Energy is Low
THEN Output Membership is R26
Rule27
IF Noise Factor is Heavy AND IF Load is Heavy AND Residual Energy is Adequate THEN Output Membership is R27

Based on the analytical work described above simulations are carried out in MATLAB. We simulate a multipath routing in load balancing region based clustered for heterogeneous wireless sensor network using fuzzy logic in a field with dimensions 300x300 m^2. The total number of sensors nodes (n) = 400. The nodes, both normal and super, are randomly distributed over the field which make infrastructure of network. For simulation we have following node settings:

We deployed 80% (m) nodes of total no. of nodes as super nodes and rests are as the normal node. The simulation parameters are shown in Table-V and deployments of nodes in different respective regions according to their energy level are defined in Table-VI.

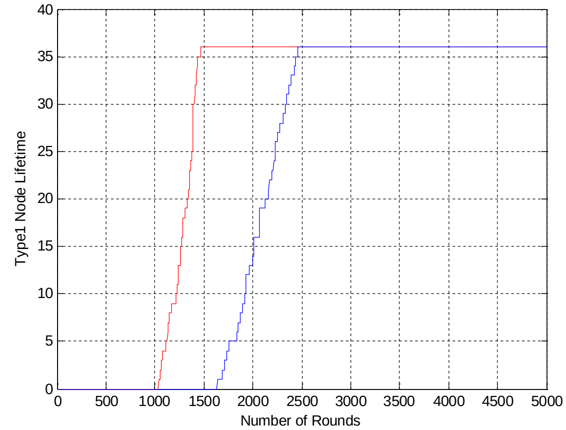
TABLE V: SIMULATION PARAMETERS

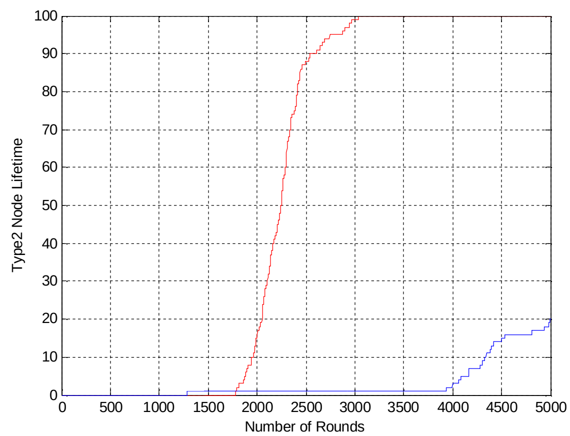
Parameters	**Value**
Initial Energy	0.5J
Energy factor **α**	1
Energy consumed in the electronics circuit to transmit or receive the signal E_{elec}	50 nJ/bit
Energy consumed by the amplifier to transmit at a short distance E_{fs}	10 pJ/bit/m^2
Energy consumed by the amplifier to transmit at a longer Distance E_{amp}	0.0013 pJ/bit/m^4
Data aggregation energy E_{DA}	5 nJ/bit/report

TABLE VI: NODE DEPLOYMENT

Node Types	**Total number of nodes**
Super node in Region 1	100
Super node in Region 2	100
Super node in Region 3	60
Super node in Region 4	60
Normal node in Region 5	80

In this simulation1 section, for 5,000 rounds we compare the performance of our proposed protocol under distance and energy parameter with RBHR protocol. In below given figure 3 L Bin RBHR label is proposed protocol.





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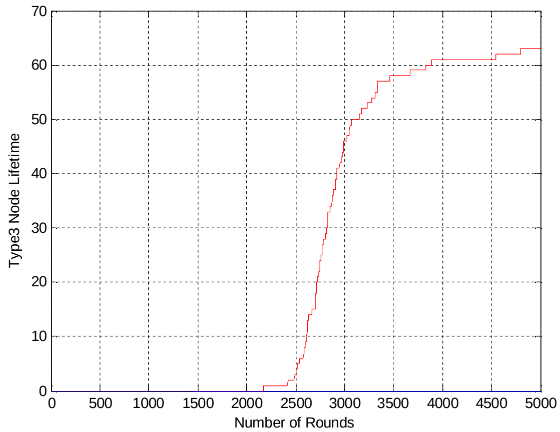

Figure 3: Comparative behavior of proposed protocol with RBHR protocol.

The proposed protocol performance is compared with RBHR protocol under distance and residual energy parameter given in Table VII. The performance of proposed protocol is better than RBHR protocol in term of stability period, scalability, throughput and network lifetime.

IV. CONCLUSION

The proposed protocol is efficient for selecting an optimum (cluster head) CH for transmission of data. The proposed Fuzzy Logic Technique, the status of the CH node is verified a node transmits the data to base station. The designed fuzzy logic controller determines, best outcome from all the possible combinations of noise, load and residual energy. The CH node with highest Output Membership status will be chosen to send the data to base station .When compared with the previous RBHR protocol, the proposed protocol gives a good simulation result. The proposed protocol uses inverted binary tree concepts for optimal number of clusters in levels of region which balance the load of network and provide scalability to the network. The proposed protocol due to multipath routing it gets more paths for data transmission to BS. Since simulation result shows performance of proposed protocol is improved as compared to RBHR protocol.

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