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Fuzzy Logic Based Smart Routing Algorithm for WSN

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Abstract: For a WSN systems moving packets is just a medium to access an end but not the actual purpose. Rather Wireless Sensor Networks is useful if they provide meaningful information and actions for fulfilling a given task. This work focus on utilizing node characteristics with fuzzy logic based intelligent decision mechanism for mitigate the major challenges of the nodes selection for establishing the multi hop routing of the wireless sensor networks. The node characteristics are considered in terms of nodes data forwarding success rate probability evaluation by simple and flexible fuzzy rules.

Keywords: Fuzzy Logic, WSN, Routing Protocol, Sensor Nodes

1. Introduction:

Wireless Sensor Networks possess a large number of sensor nodes with limited resources in terms of energy, computation and memory. They are operated by a small battery attached to it. This battery possess some initial energy, and in every communication it dissipates a fraction of the energy. Many such communications take place during the network lifetime, and every time sensor node consumes some energy which makes battery exhaust eventually. When nodes are deployed in harsh environment, where it is hard to reach, in most of the cases there is no way to recharge these batteries [1].

Sensors are considered as significant components of electronic devices. Important and critical information must be delivered to the sink in a multi-hop and energy-efficient manner in most applications of wireless sensor networks (WSNs). In as much as the energy of sensor nodes is limited, prolonging network lifetime in WSNs is considered to be a vital issue. Therefore, researchers should consider energy consumption in routing protocols of WSNs in order to extend the network lifetime

Recent advances in micro-electro-mechanical systems (MEMS) and wireless communications have highlighted the importance of WSNs as significant reporting devices. Indeed, sensor nodes in WSNs are deemed to be resource constrained in terms of energy, communication range, processing capability and memory capacity. WSNs are used in applications such as target tracking, environmental monitoring and battlefield applications. The main purpose of WSNs is to disseminate the information from the source to the sink in multi-hop scheme [6]. Figure 1 shows a typical WSN.

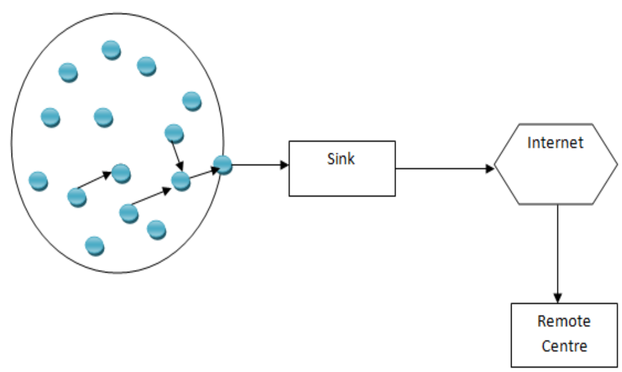

Fig. 1. Architecture of WSN

A sensor node typically consists of five main components: One or more sensors gather data from the environment. The central unit which is in the form of a microprocessor manages the tasks. A transceiver communicates with the environment and a memory is used to store data generated during processing or temporary data . The battery provides energy to all parts. Energy efficiency in all parts of the network is crucial in order to assure a sufficiently long network lifetime . To fulfil this need, data processing tasks are often spread over the network, i.e. nodes co-operate in transmitting data to the sinks. In spite of the fact that most sensors have a traditional battery there is some early stage research on the production of sensors without batteries, using similar technologies to passive RFID chips without batteries.

2. Related Work:

With the recent technological advances in wireless communications, integrated digital circuits, and micro electro mechanical systems (MEMS); development of wireless sensor networks has been enabled and become dramatically feasible. Wireless sensor networks (WSNs) are large networks made of a numerous number of sensor nodes with sensing, computation, and wireless communications capabilities. Many various routing, power management, and data dissemination protocols have been designed for wireless sensor networks (WSNs) dependent on both the network architecture and the applications that it is designed for. In this work, **Samira Kalantary, and Sara Taghipour, (2014),** [9], presented the state of the art of wireless sensor networks' architecture and design features. Also, in this work, we introduce recent work on routing protocols for WSNs and their design goals and challenges. Also, an overview of the application that WSNs assist in is presented. Finally, several open research questions of wireless sensor networks management and issues are suggested and put forward.

A sensor is a device for detecting and signalling a changing condition. The "changing condition" is simply the presence or absence of an object or material (discrete sensing). It can also be a measurable quantity like a change in distance, size or colour (analog sensing). This information, or the sensor's output, is the basis for the monitoring and control of a manufacturing process. In a wireless sensor network (WSN), event detection and tracking are significant for several applications. Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. WSNs have great potential for many applications in scenarios such as military target tracking and surveillance, natural disaster relief, biomedical health monitoring and hazardous environment exploration and seismic sensing. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user. The goal of **G. Sasikumar, H. Vignesh Ramamoorthy, and S. Natheem Mohamed, (2014),** [10] survey was to presented a comprehensive review of the recent literature on sensor networks especially in Animal Tracking.

A wireless sensor network (WSN) is a network consisting of wireless computing devices called sensors that sense environmental conditions like motion, sound, etc in an area. These networks collect the information from the environment and send it to the sink node. The main constraint in these networks is the energy of the nodes. As these sensors have limited battery life, routing protocol should be designed appropriately so that minimal energy is used. Long communication distances between the sensors and the sink in the WSN drain the energy of the sensors and reduce the lifetime of the network. Clustering reduces energy consumption. By clustering a sensor network they can help minimize the total communication distance, thus increasing the network lifetime. In this work, **Tripti Sharma, G. S Tomar, Radhika Gandhi, Srishti Taneja and Kiran Agrawal, (2015),** [11], an algorithm based on LEACH (Low Energy Adaptive Clustering Hierarchy protocol) using genetic algorithm has been proposed in order to achieve increased lifetime of the network and energy efficiency in WSN. The genetic algorithm is used to select the cluster heads for the WSN and hence create the energy efficient clusters for transmission of data in the wireless sensor network. The fitness function proposed in this algorithm considers both the distance of the nodes from the sink and their energies. The simulation results show that the proposed protocol results in prolonged network lifetime and optimal energy consumption of the wireless sensor network.

Sensors are regarded as significant components of electronic devices. In most applications of wireless sensor networks (WSNs), important and critical information must be delivered to the sink in a multi-hop and energy-efficient manner. Inasmuch as the energy of sensor nodes is limited, prolonging network lifetime in WSNs is considered to be a critical issue. In order to extend the network lifetime, researchers should consider energy consumption in routing protocols of WSNs. In this work, a new energy-efficient routing protocol (EERP) has been proposed for WSNs using A-star algorithm by **Ali Ghaffari, (2015),** [12],. The proposed routing scheme improves the network lifetime by forwarding data packets via the optimal shortest path. The optimal path can be discovered with regard to the maximum residual energy of the next hop sensor node, high link quality, buffer occupancy and minimum hop counts. Simulation results indicate that the proposed scheme improves network lifetime in comparison with A-star and fuzzy logic(A&F) protocol.

3. Methodology:

In this study, we used A* algorithm to find the optimal path from the source node to the destination node (base station) with regard to some parameters of sensor nodes such as residual energy, packet reception rate (PRR) and node buffer state. In order to find the optimal path, the sink node should be aware of the criteria of each node. Thus, at the initial phase, each node must send its aforementioned parameters to the sink node. In the remaining round, if the sensor node has data to send toward the sink node, it will append its parameters to the data packet. Based on the gathered parameters, the sink node must determine and broadcast the routing schedule to each sensor node [9]. Then, A* algorithm will search for the optimal path from the source node to the destination node. If the residual energy of sensor node is less than the energy threshold value, that node cannot participate in the routing process and hence will not send its parameters to the base station. The network load will be balanced with regard to the threshold value of the energy, and as a result, the network lifetime

will be enhanced. A* algorithm uses the method of best-first search and finds an optimal path from the initial node to the destination node[14]. It includes two lists, an OPEN list and a CLOSED list. It creates a tree structure of sensor nodes. The OPEN list is a priority queue and keeps track of those nodes that need to be examined while the CLOSED list keeps track of nodes that have already been examined [14]. A* algorithm uses a distance-pluscost heuristic function of node n, f(n) to determine the order in which the search visits nodes in the

tree. This heuristic function is a sum of two functions as follows [14].

$$f(n) = g(n) + h(n) \quad (1)$$

Where, *g(n)* is the cost from the source node to the current node n and *h(n)* is an admissible heuristic estimate of the distance from n to the destination node.

In the proposed scheme, the value of *g(n)* function is equal to the node cost of node n. Our intention is to forward data packets to the next neighbour node which has higher residual energy, higher free buffer, and higher packet reception rate. To achieve this, we made use of aggregated weight of the above-mentioned routing parameters. Here, we define the aggregated weight of a next neighbour node as the sum of normalized weights of its routing metrics as follows:

$$g(n)= Max\{\alpha(Eres(n)/Eini(n) + \beta(Nr(n)/Nt(n)) + \delta(Bf(n)/Bini(n))\} \quad (2)$$

Where, $E_{res}(n)$ and $E_{ini}(n)$ are residual and initial energy of node n respectively. In addition, $N_t(n)$ and $N_r(n)$ are the number of transmitted and received packets respectively. $B_f(n)$ and $B_{ini}(n)$ referred to the number of free and initial buffer of node *n* respectively. In "Eq. 2", α, β and δ are weight parameters and $\alpha + \beta + \delta = 1$. The results of our extended simulation, performed in MATLAB 7.10, indicated that setting including $\alpha=0.6$, $\beta=0.2$, and $\delta=0.2$ produces the best possible results. The parameter of node cost is related to the linear combination of three normalized metrics. The first parameter is includes normalized residual energy which illustrates the residual energy of the next neighbouring node *n*. This parameter is aimed to ascertain that the sensor nodes' energy consumptions are balanced. Energy load must be evenly distributed among all the sensor nodes in order to prolong the network lifetime. The second parameter is called normalized number of received packets in *n* node. This metric corresponds with the packet reception rate of the next node. In other words, maximizing this metric is equal to maximizing the packet transmission efficiency. As a result of taking this metric into account, the majority of the probability and hence this will prevent the retransmission of data packets which will significantly reduced the amount of energy consumption in the node. The third parameter stands for the magnitude of the available free buffer at the next neighbouring candidate, node *n* this parameter plays the remarkable role in the proper distribution of traffic load. The packet will be sent to the next node which has the maximum free buffer. Each source or intermediated node needs to know its neighboring nodes and their current parameters, e.g., position, battery state, free buffer, link quality, etc. This can be ensured via the execution of a HELLO protocol such as in [15, 16]. We assume that each node knows the position of sink node. The sink node broadcast its position to all sensor nodes in the network.

For updating packet reception rate-

$$PRR(t+1) = \theta(PRR(t)) +(1-\theta)(N_r(t+1)/N_t(t+1)) \quad (3)$$

Where, θ is waiting parameter and the value for h(n) function can be calculated as follows:

$$h(n)= 1/Min(hc_n^s) \quad (4)$$

Where, $Min(hc_n^s)$ is the minimum hop count from node *n* to the destination node. In order to compute the minimum hop count from node *n* to the sink node, we must calculate the distance between node *n* and sink node via euclidean distance formula as follows:

$$d(n,s)= \sqrt{(xn-xs)^2 +(yn-ys)^2} \quad (5)$$

Where, *d(n,s)* is equal to the Euclidian distance between the node *n* and sink node. Moreover, the hop count from node *n* to the sink node can be calculated as follows:

$$hc_n^s = d(n,s)/avg\ d(n,j) \quad (6)$$

Where, *avg(d(n, s))* is the average distance between the node *n* and its one hop neighbouring nodes (*j*). On the basis of "Eqs. 3.2 and 3.6", we can calculate the value of evaluation cost function, *f(x)* Thus, for choosing the optimal path, we will select that node *n* which has the maximum evaluation function. The value of *f(x)* can be used to obtain the optimal path.

Energy Efficient Routing Algorithm

- We use A* algorithm to find the optimal path from source node to destination node.
- At the initial stage each node sends its parameters: residual energy, packet reception rate, node buffer state.
- Based on these parameters the sink node determine the routing schedule.
- If the energy of the node is less than the threshold energy it do not participate in the process and network load is balanced.
- A* algorithm uses distance plus cost heuristic function to determine the order of search in order to find optimal path:

$$f (n) = g (n) + h (n)$$

Where, g (n) = cost from source node to node n.
h (n) = distance from node n to destination node

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- Our intention is to forward data packets to the next neighbour node which has high residual energy, high packet reception rate, and high free buffer.
- To achieve this we use aggregated weights of the above mentioned parameters which is the sum of the normalised weights given as:

g(n)= Max{α(Eres(n)/Eini(n) + β(Nr(n)/Nt(n)) + δ(Bf(n)/Bini(n))}

Where, Eres (n) = residual energy of node n
Eini (n) = initial energy of node n
Nr (n) = number of received packets
Nt (n) = number of transmitted packets
Bf (n) = fixed free buffer
Bini (n) = initial free buffer

And α, β, δ = weight parameters,
α + β+ δ= 1

- The value of h(n) is calculated as:
  h (n) = 1/Min (hcns)
  Where, Min (hcns) = minimum hop count from node n to the sink node.
- To compute the minimum hop count we must calculate the distance from node n to sink node:
  d (n, s) = √ (xn-xs) ^2 + (yn-ys) ^2
- To calculate the minimum hop count:
  hcns= d (n, s)/avg d (n, j)

where,
avg d (n, j) is the average distance between node n and its immediate neighbour node j.

Performance Evaluation:

- The energy consumed for transmitting and receiving k bit data can be evaluated as-

ETx (k) = k (Eelec+ εamp.d^2)
Erx (k) = k (Eelec)

Where, Eelec= per bit energy dissipated in transmitting and receiving circuitry
And, εamp= energy required per bit per meter square for the amplifier to achieve acceptable S/N Ratio.

- Total energy= Etx+ Erx
  =k (2Eelec+ εamp.d^2).

4. Result and Discussion:

We have considered a network consisting of N nodes randomly distributed in an area of length MxM meters having an initial energy E_0 and they have a destination D which is to be accessed by establishing route from various source nodes to the destination for example the algorithm considers an area length (M) in meters of 200 with number of nodes (N) = 10.The x y coordinates of the nodes are generated randomly as shown below:

Table 1 : x y coordinates for sensor nodes network

x coordinates	y coordinates
162.9447	31.5226
181.1584	194.1186
25.3974	191.4334
182.6752	97.0751
126.4718	160.0561
19.5081	28.3773
55.6996	84.3523
109.3763	183.1471
191.5014	158.4415
192.9777	191.8985

After initialization of nodes the sensors sensor sends the data packet by multihop routing and at every transmission and receiving the nodes consumes enrgy as a result the initial energy E_0 reduces and the residual energy becomes lower than initial energy.For example on set up of network as nodes exchanges the hello packets the $E_{residual}$ of the nodes are-
(etxres) = [4.9516 4.9986 4.9503 4.9818 4.9880 4.8999 4.9445 4.9856 4.9963 4.9990].

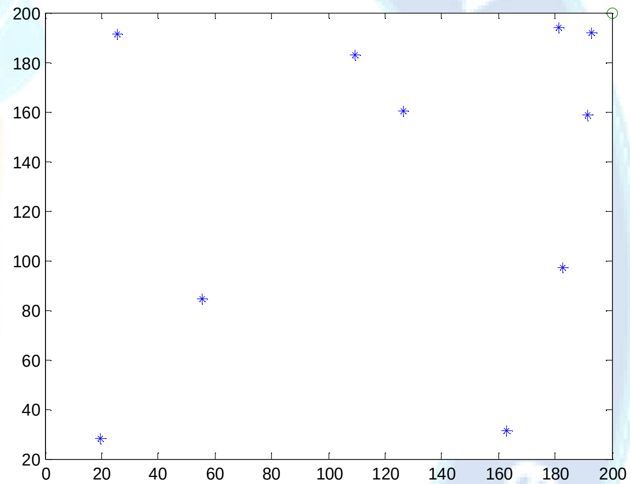

Fig. 2. Distribution of nodes wrt to table 1.1 keeping sink at corner(x=M,y=M).

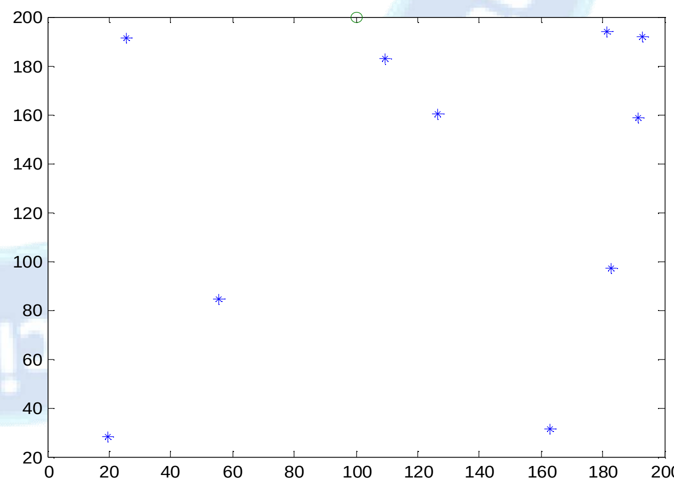

Fig. 3. Distribution of nodes wrt to table 4.1 keeping sink at center (x=M/2,y=M).

We have considered buffer size of 10 packets. Initially buffer status is assumed to be randomly filled and on each round the nodes packets are dispatched and received to vary the buffer size.

We have used the fuzzy inference system to develop the node status evolution system to select the neighbour node best fit for packet transmission as next hop. The details of fuzzy inference system are given below:

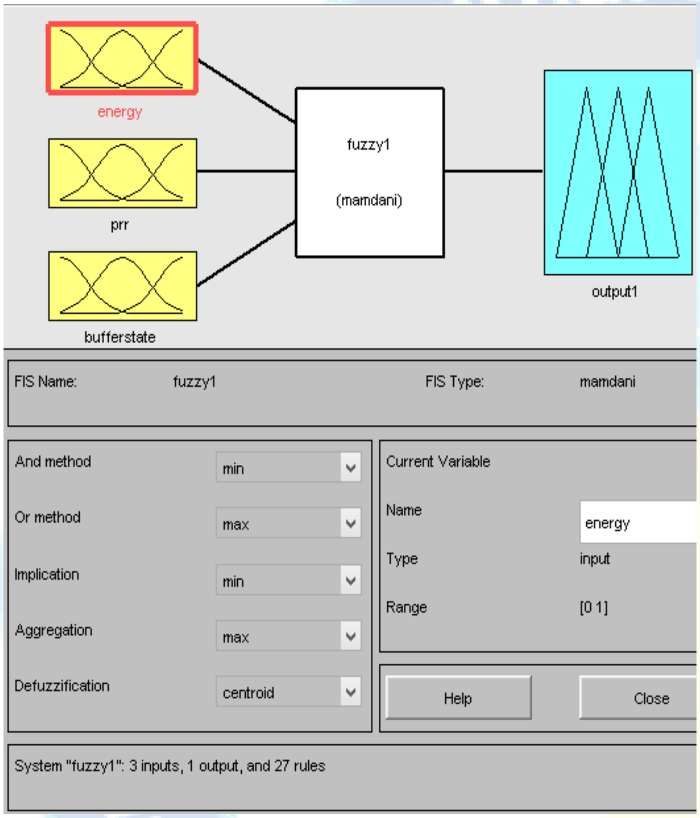

Fig. 4. Fuzzy inference system for evaluation of node status.

Figure 4 shows the fuzzy inference system for evaluating the node status. It has three input known as energy ratio , packet receive rate and buffer state and the output is the node status. The inputs are partitioned using membership functions as shown in figure 5 (a,b & c).

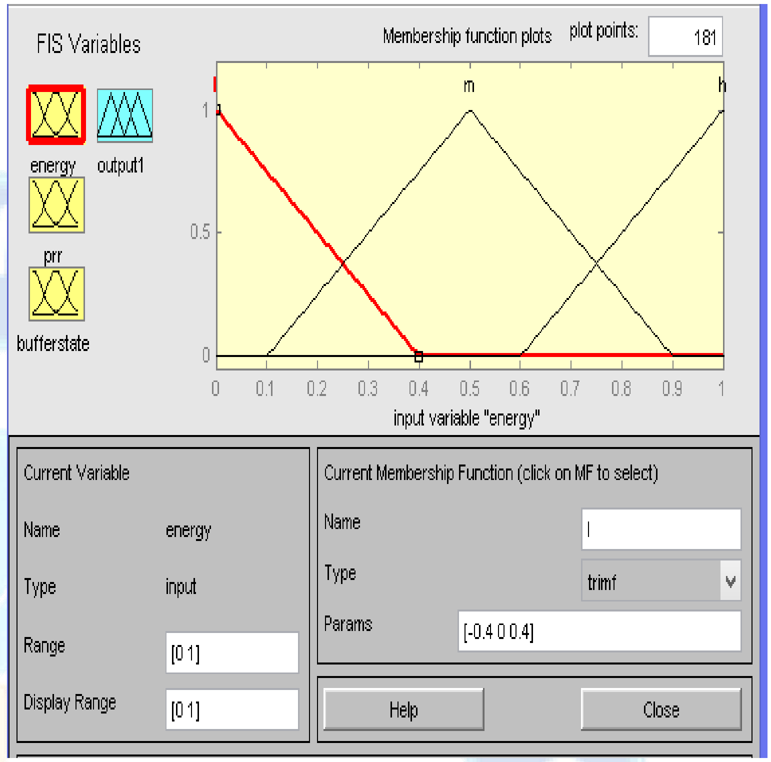

Fig 5a: Member ship function for input 1 energy ratio.

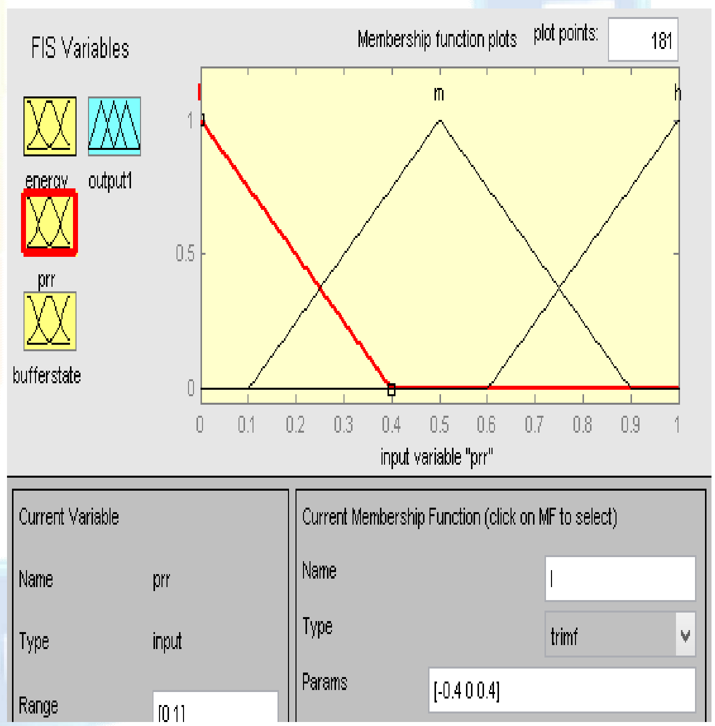

Fig 5b: Membership function for input 2 packet receive ratio.

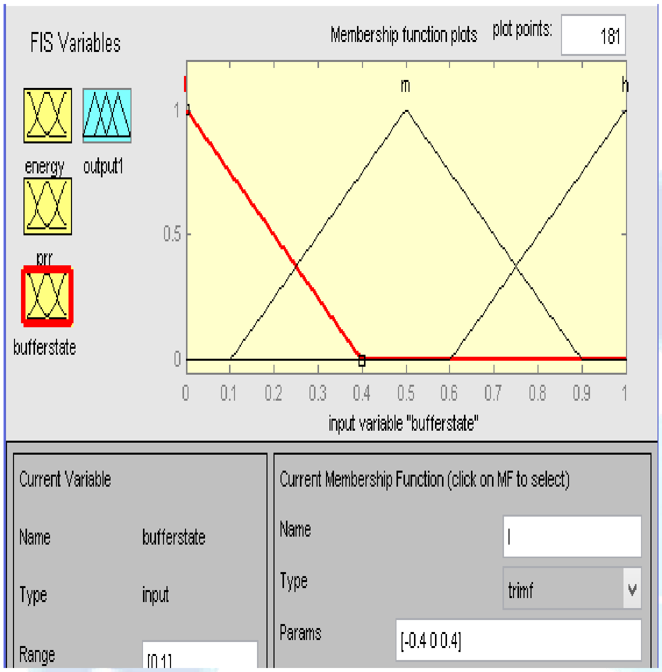

Fig 5c: Membership function for input 3 buffer state ratio.

We can see in fig 5 (a to c) that all three inputs are ratios hence the are varying from 0 to 1 and each input is divide into three equally spaced partitions allotted for LOW,MEDIUM and HIGH values of the input range.

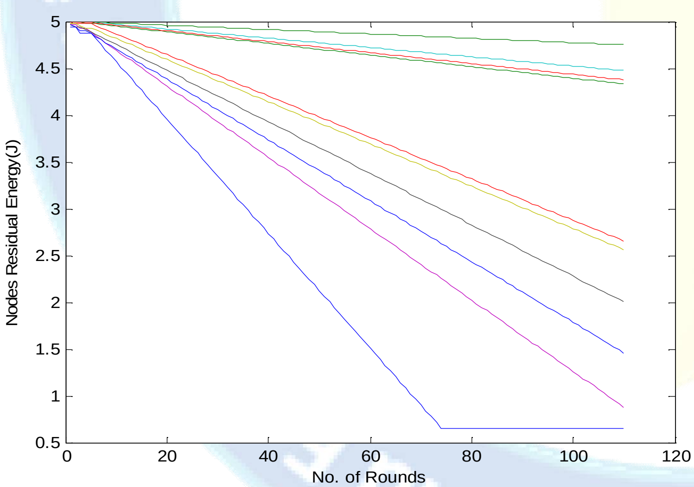

Fig. 6. Residual Energy of all the Nodes at different rounds when sink is at centre.

5. Conclusion: In this work sensor network on large-scale transmission networks is implemented. The nodes are initially powered by limited energy. An algorithm for sensor node is shows the architecture of a WSN. Each node decisions as per the information it currently has, knowledge of its computing, communication, and energy resources. The node have capability to collect and forward propagate data by systematic routing approach to other neighboring nodes and consequently to base station. The algorithm decides the best neighbour on the basis of surrounding nodes parameters by simple fuzzy rules The performance of algorithm are validated in terms of nodes residual energy and it has been observed that the fuzzy based nodes status evaluation and propagation to most suitable node is work better In future more input parameters can be considered which can help in energy consumption better managed to maximize the network lifetime.

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