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A Fuzzy-Logic Based Clustering Algorithm in WSN to Extend Network Lifetime

Gaurav Srikar, Reshmi TR

School of computer science and Engineering, VIT Chennai, Chennai-600127, India.
Corresponding Author

Abstract

Wireless sensor networks consists of collection of sensor nodes with limited memory to store the sensed data and runs on battery which generates the concept of energy efficiency and energy consumption through routing protocol rather than adjusting physical entities. Clustering is one of the techniques to utilize the energy of network efficiently. Low energy adaptive clustering hierarchy (LEACH) is most famous hierarchical routing protocol where a cluster head is elected based on probabilistic threshold value and the role is rotated among the other nodes in network. And only CHs are allowed to send collected and compressed data to Base station. But simultaneous retrieval results in packet loss and BS are far from field so more energy is consumed to transmit data to BS. To solve these issues, a Super-CH is elected among CHs based n fuzzy logic. Suitable fuzzy descriptors such as remaining battery power, mobility of BS and centrality of clusters are considered. The resultant node collects all data from CHs, aggregate them and transmit the compressed data to BS.

Keywords: Fuzzy, Decision, Sensors, LEACH

INTRODUCTION

Wireless sensor networks (WSN) consists of collection of sensor nodes with battery which generates the concept of energy efficiency and energy consumption through routing protocol rather than adjusting physical entities. Clustering is one of the techniques to utilize the energy of network efficiently. LEACH protocol [2] is the famous hierarchical routing protocol which is proven to be most efficient over traditional routing protocol like direct transmission, static hierarchy, etc. LEACH is a dynamic clustering organizing protocol that uses randomisation to distribute energy throughout the network evenly. Among the nodes in network, they form clusters and a particular node is selected based on probabilistic function to act as cluster head. Each node in cluster senses its environment and transmits the data to CH. The job of CH is to collect data from its cluster members, aggregate it to eliminate duplication of data and compress the amount of data being sent from cluster to BS. Thus enhance system lifetime by reducing energy dissipation when compared to direct transmission or MTE.

The role of CH is randomly rotated among various sensors in the network in order to distribute the energy consumed by nodes during its period of being CH. Nodes are elected themselves based on probabilistic function at a given time. These newly selected cluster heads broadcast their status to other nodes in network. All non-CH nodes switch in its receivers to get advertisement. Each node chooses its CH based on the minimum communication energy required to transmit based on received signal strength. Once after choosing its CH transmits back data to CH as to be a member of that cluster. Till that the CH will switch on the receivers to get request.

After receiving, the CH will create a schedule for the nodes in its clusters. Then the schedule is transmitted back to nodes to set a period to transmit data thus minimizing the energy dissipated in the individual sensors. Once the CH has all the data received from its members, the data is aggregated and then transmitted to BS. Since the BS is far away the field, huge amount of energy need to be used to transmit. However there are only a few CHs and the role of transmission is rotated, the effect is not much on the whole network rather distributed. To become a CH means to get data from its members, aggregate them and transmit the compressed data to BS which is far from field drains outs the battery of the node. So the role of CH is not fixed and will rotate among the non-CH nodes to become CH and this position is self-elected at different time intervals. And a node becomes CH depending upon the amount of battery remained. If the node has more energy then it will perform the energy intensive functions of the network.

The decision to become CH is independent from other nodes in the network so extra negotiations like GPS location, battery of other nodes, etc. will not be required. The optimal number of cluster heads in a network can be determined to reduce the energy dissipation of the system. Let us assume, an optimal number of cluster heads as N. If the number of CH formed is less than N means, if the number of CH formed is 3 but the optimal number is 5 then the nodes of remaining 2 clusters load is handled by these 5 CHs and the distance to transmit data increases resulting in consumption of more data. If the number of CH formed is more than N which means, if the number of CHs formed is 8 but the optimal number is 5 then the distance, the node have to transmit data to reach the CH is not much reducing substance but there are more CHs that have to transmit the data received to BS which is far from field resulting in more nodes dissipate energy and reducing the lifetime of network. The main energy saving of LEACH

protocol is due to combining lossy compression with the data routing. There is clearly a trade-off between quality of output and the amount of compression achieved.

But still there is a drawback that the BS will be placed far from field so to transfer data to BS consumes more energy which results in draining of charge in all CHs and another issue is the parallel transfer, the BS cannot receive packets resulting in packet loss. So to reduce dissipation of battery and utilize the bandwidth efficiently we place a Super-CH among CHs. So that after all CH receives data from its members the data is transmitted to SCH rather than BS. The selection of SCH is based on fuzzy logics. Fuzzy logics is used to model human decision making and experience to handle uncertainties of real time applications more accurately than the probabilistic model. And it also overcomes the overhead of collecting energy and location information of each node. Only SCH is allowed to send the message to BS.

LITERATURE SURVEY:

In this section, we are discussing most of the well-known hierarchical routing protocols where the CHs are elected in an energy efficient manner. We have also discussed on some fuzzy logic based clustering protocols. Each cluster head becomes representative for the cluster and gathering information from other nodes, aggregate them and send them to the base station either directly or indirectly. Even though there are many clustering protocols with fuzzy or without fuzzy descriptors are proposed, but very few most important protocols are presented here.

A. Hierarchical Routing Protocols Based on Clustering

1) Low Energy Adaptive Clustering Hierarchy (LEACH):

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol [2], [3], [9] introduced by Heinzelman in year 2000[2] is self-organizing, adaptive clustering protocol which does distribute energy load equally in all nodes in a cluster.

LEACH consists of 2 phases,

- Setup phase: Nodes form clusters.
- Stead state phase: data is sensed and transmitted.

A. Setup Phase:

Initially each node decides to become CH or not based on probabilistic function and number of times the node has been a CH so far. The node chooses a random number (no) between 0 and 1. If the number is less than threshold value T(n), then that node becomes CH for the current round.

The threshold value would be,

$$T(n) = \begin{cases} \dfrac{P}{1 - \left(P * \left(r \bmod \left(\frac{1}{P}\right)\right)\right)}, & if\ n \in G \\ 0, & Otherwise \end{cases} \quad \text{(Eqn. 1)}$$

Where P is the desired percentage to become CH, Eg. P = 0.05 (5% as mentioned in [2]). R is the current round and G is the set of nodes that haven't been cluster heads in last 1/P rounds.

After electing CHs, it will start broadcasting "Hello" message to its neighbourhood nodes by using CSMA MAC protocol. Energy used to broad cast message is equal for all CHs. All non-CH nodes should keep their receivers on till it receive broadcast message. And the non- CH node chooses the cluster based on received signal strength and after each node decides to become member of that cluster, it will acknowledge CH that it will be a member of cluster. At that time, all CH nodes must keep their receivers on. After receiving all the acknowledgement messages from nodes, the CH creates a TDMA schedule allotting at which period the node should transmit data. And the schedule is broadcasted back to the nodes in the cluster.

B. Steady State:

Each node will switch off the transmitter and start sensing environment. The sensed information is stored and at particular period of time, when its turn to transmit comes, the stored data is transmitted to CH. In CH, all data is collected, aggregated and finally transmitted to BS.

2) LEACH–C:

In LEACH-C [3] is a centralized protocol where the complete setup phase like CH formation, cluster formation and distribution of information into network is performed on base station. BS knows the location and energy information of each node. So, it can produce better clusters by exactly forming optimal cluster head nodes throughout the network. The main drawback of this centralized protocol is that the position of all the nodes must be known which makes the node to be expensive and provide overhead.

As the projects mainly interested on fuzzy logic based clustering protocols, so few of them are highlighted below.

B. Fuzzy Logic Based Clustering Protocol

Many researchers have worked on how Fuzzy Logic can be utilized to elect the proper and efficient CH so that efficient life time can be accomplished.

Some of the well-known fuzzy logic based clustering algorithms are discussed below.

1) CHEF:

In CHEF [5], CH is elected based on two descriptors which are proximity distance and energy. The fuzzy based approach elects CH with high energy and locally optimal node among the other nodes in network. In [4], the author has considered three fuzzy descriptors such as remaining battery, concentration of network, and centrality among neighbourhood nodes. These three descriptors are the key points to calculate the chance to become the CH which can improve the network

lifetime. Energy level is defined as remaining energy at each node, concentration is number of neighbourhood nodes and centrality is a value based on how centre the node to the cluster. But the main drawback with this protocol is that all the nodes are not equipped with GPS trackers and they might not be able to provide location information in some regions.

2) F-MCHEL:

In F-MCHEL [8], cluster head is elected by applying fuzzy rules based on energy and proximity of distance. The node which has the maximum remaining energy among the cluster heads is elected as a Master Cluster Head (MCH), aggregated data and transmits optimal data to the base station. F-MCHEL is an improvement of CHEF. It provides much network stability when compared with LEACH and CHEF. In F-MCHEL, base station is considered to be static. In [16], we proposed a protocol which considers three fuzzy descriptors such as remaining battery power, mobility, and distance to base station for electing a MCH. But the main drawback of this protocol is that when mobility increases or decreases, the lifetime of the network remains constant. Because, mobility is indirectly proportional to the distance to base station.

PROBLEM STATEMENT:

BS will be placed far from field so to transfer data to BS consumes more energy which results in draining of charge in all CHs and another issue is the parallel transfer, the BS cannot receive packets resulting in packet loss

MOTIVATION:

So to reduce dissipation of battery and utilize the bandwidth efficiently we place a Super-CH among CHs. So that after all CH receives data from its members the data is transmitted to SCH rather than BS. The selection of SCH is based on fuzzy logics. Fuzzy logics is used to model human decision making and experience to handle uncertainties of real time applications more accurately than the probabilistic model. And it also overcomes the overhead of collecting energy and location information of each node. Only SCH is allowed to send the message to BS.

PROPOSED WORK:

WSN are densely deployed in a region to sense environment parameters. There are various types of environmental parameters such as motion, temperature, humidity, pressure, seismography, gas and so on. WSN are deployed in hazardous region where battery replacement or recharge is nearly not possible. There are many typical constraints such as power, limited processing capacity, radio connectivity, geographical location makes the sensor node's battery dissipate. Once the network is deployed, nodes keep on sensing the environment and the battery power drains exponentially.

Whenever a node detect any event, it will send the information to CH or if it is a CH then will send information to the base station. Sometimes it happens like, the same information sensed by nearby sensor node can be sensed by the CH, which makes the network inefficient. To avoid this data duplication and to make the network more energy efficient, data aggregation is used.

Cluster based routing protocol is one of the efficient ideas to solve this issue, where sensor nodes are extended into number of groups and each group is called as a cluster. One node is elected among other nodes in each cluster and is named as Cluster Head (CH). Data aggregation is obtained at the CH. The CH will take the responsibility for sending the message to the BS.

Figure 1. Network formation

LEACH is a hierarchical routing protocol which elect cluster heads based on probabilistic model and initially assumed that each sensor node has equal chance to become a CH. This protocol operates in two phases. They are set up phase and steady state phase.

In set up phase, a node is elected as cluster head and forms the cluster among its neighbour nodes and actual data is transmitted is performed in the steady state phase. Each node chooses a random number between 0 and 1. If the number is less than the threshold value, the node gets the chance to be the cluster head for the current round. Probability of the nodes to become CH and set of nodes which have never been cluster head in the last few rounds is elected as cluster head. After electing CHs, it will start broadcasting "Hello" message to its neighbourhood nodes by using CSMA MAC protocol. Energy used to broad cast message is equal for all CHs. All non-CH nodes should keep their receivers on till it receive broadcast message. And the non- CH node chooses the cluster based on received signal strength and after each node decides to become member of that cluster, it will acknowledge CH that it will be a member of cluster. At that time, all CH nodes must keep their receivers on. After receiving all the acknowledgement messages from nodes, the CH creates a TDMA schedule allotting at which period the node should transmit data. And the schedule is broadcasted back to the nodes in the cluster.

In steady state phase, each node will switch off the transmitter and start sensing environment. The sensed information is stored and at particular period of time, when its turn to transmit comes, the stored data is transmitted to CH. In CH, all data is collected, aggregated and finally transmitted to BS.

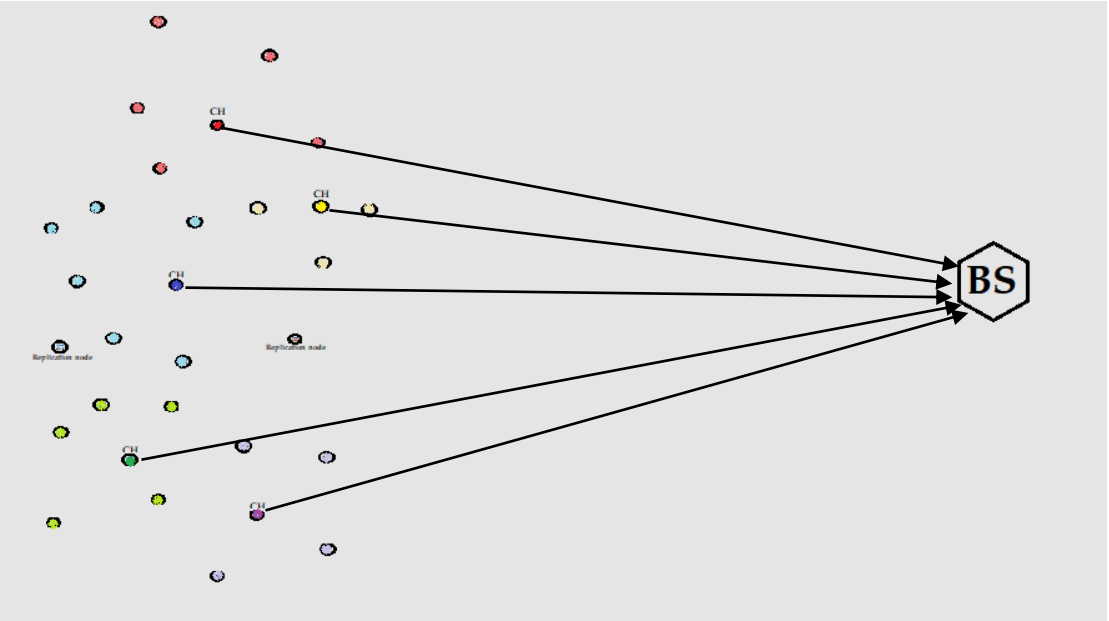

Figure 2. LEACH protocol

In the proposed model, fuzzy logic [10]-[15] is used in order to handle the uncertainties occurred for electing the SCH. The main benefit of using fuzzy logic is to overcome the overheads caused by collecting and calculating energy and location data of each node. Most of the fuzzy based clustering algorithms consider the BS as static but if we made BS to be mobile then that can relieve the network traffic, reduces delay and enhances energy efficiency.

The proposed clustering protocol follows the basic principle of LEACH protocol. The cluster is formed in each round and in every round, each node generates a random number between 0 and 1. If the random number generated for a particular node is smaller than the threshold value T(n), the node becomes the cluster head.

In basic LEACH protocol, the cluster formation algorithm was defined to assume that the number of cluster per round is k. The optimal value of k in LEACH protocol can be determined analytically by simulating a graph plotted between normalized total system energy dissipated and the percent of nodes that are cluster-heads [3]. For instance, if there are N nodes deployed randomly over X×Y region, and k clusters are been assumed, then there are N/k nodes per cluster.

Each CH consumes energy by receiving the data, aggregates it and sends the compressed data to base station. To save some

energy, one Super cluster head [16] among the CHs can be elected to send the data to BS to reduce energy consumption of each CH and to utilize the bandwidth efficiently instead of multiple CHs which can reduce energy consumption and enhances network lifetime.

Another assumption made is that the BS mobility that can relax collision avoidance caused by concurrent data transmission by collecting the data from SCH. Other sensor nodes including cluster heads and super cluster head are remained static. Base station can adopt any path to collect the information from the Super-CH. Further assumption would be made that remaining battery power, BS mobility, and Centrality of the cluster heads to be the three fuzzy descriptors [1], [14] suitable to calculate the chance to become the Super-CH that can deliver the message to the base station.

Assuming that in each round, battery level of each CH gets reduced so considered as a metric. Centrality is considered as another metric because centrality focuses on the location of Super-CH among CHs. Mobility implies that when base station moves in a particular direction, the distance between BS and Super-CH increases or decreases with respect to the speed and direction of moving BS.

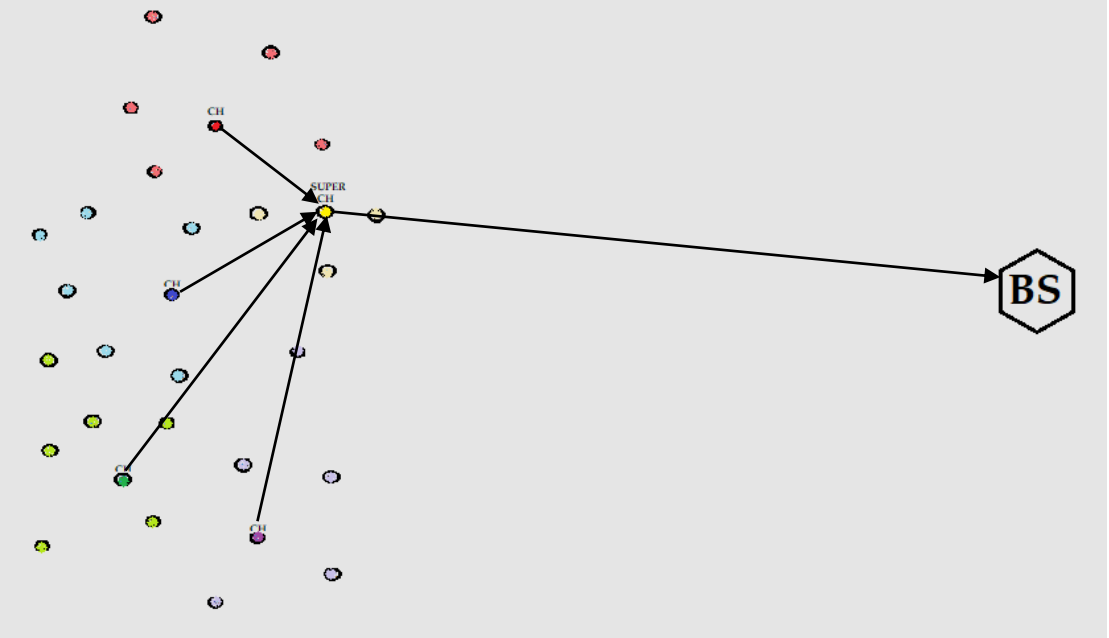

Figure 3. The proposed fuzzy descriptor LEACH protocol

PERFORMANCE EVALUATION:

1. Simulation environment:

In this experiment, I have simulated using NS2.35 in Ubuntu 12.04 and considered 30 nodes randomly deployed over the area between (x=0, y=0) and (x=1141, y=652) with BS location (x=527.227, y=114.155). We assume six no. of clusters. Each round duration is 20s. The bandwidth of the channel is 1 Mbps. Each data message is 500 bytes long; packet header length is 25 bytes. We have used a simple energy model. We run the simulation for 20000s.

Simulation parameters:

Table 1. Simulation parameters

No. Item	No. Item Description Specification	Values
1	Simulation area	1141 X 652
2	No. of nodes	30
3	Transmitter amplifier Energy dissipation (a) $E_{fs\ amp}$ (b) $E_{two\ ray\ amp}$	 10 pJ/bit/m^2 0.0013 nJ/bit/m^4
4	Radio bit rate-Rb	1mbps
5	Channel type	Channel/Wireless channel
6	Radio propagation model	Two ray ground
7	Simulation time	200.0
8	Antennae model	Antenna/Omniantenna
9	Energy model	Battery
10	Interface queue type	Queue/Drop tail/prequeue
11	Link layer type	LL
12	Communication model	Bi-direction
13	Min packet in ifq	50

2. Performance metrics:

a. Energy consumed:

We assume a simple model [6] for the radio hardware energy dissipation where the transmitter consumes energy to run the radio transmitters and the power amplifier, and the receiver consumes energy to run the radio receiver, as shown in Fig. 4.

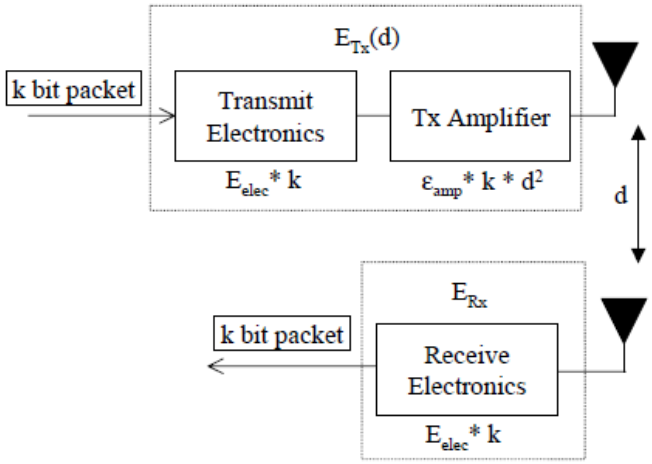

Figure 4. The simple energy model

For this protocol, both the free space (d^2 power loss) and the multipath fading (d^4 power loss) channel models were used, depending upon the distance between the transmitter and receiver. Power amplifier—if the distance is less than the threshold value, the free space (ε_{fs}) model

is used. Otherwise, the multipath (ε_{mp}) model is used. Therefore, to transmit an l-bit length message for a distance, the radio expends

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}(l,d) = \begin{cases} lE_{elec} + l_{\varepsilon_{fs}} d^2, & d < d_0 \\ lE_{elec} + l_{\varepsilon_{mp}} d^4, & d \geq d_0 \end{cases} \quad \text{(Eqn. 2)}$$

and to receive this message, the radio expends:

$$E_{R_x}(l) = E_{R_{x-elec}}(l) = lE_{elec} \quad \text{(Eqn. 3)}$$

The electronics energy E_{elec}, depends on factors such as the digital coding, modulation, filtering, and spreading of the signal.

Whereas the amplifier energy, $\varepsilon_{fs}d^4$ or $\varepsilon_{mp}d^4$, depends on the distance to the receiver and the acceptable bit-error rate.

b. Packet Loss:

Packet loss in a communication is the difference between the number of packets generated and number of packets received. Packet Loss is calculated using AWK script which processes the trace file and produces the result by plotting a graph which indicated the amount of packet loss at particular time.

Based on the trace file generated, the graph is plotted.

The main cause for packet loss could be high latency due to slow network or bandwidth, simultaneous retrieval of data, inconsistent jitter causing spacing between packets or hardware/software failure.

c. Overhead:

To stay up with the latest data about network routes, routing algorithm create small sized packets, called routing packets. One case of such packets is Hello packet, which is utilized to check whether the neighbour node is active. Note that routing packets don't convey any application content, different from what data packets do.

Both, most of the times the routing and data packets need share the same network bandwidth, and thus, routing packets are thought to be an overhead in the system. This overhead is called routing overhead. A good routing protocol ought to bring about lesser routing overhead.

RESULT ANALYSIS:

A graph is plotted among the proposed and existing system's energy consumption where it is shown that proposed system's lifetime is increased when compared to the existing system's lifetime. So the energy consumed by each node while being the role of CH is less when compared to existing system.

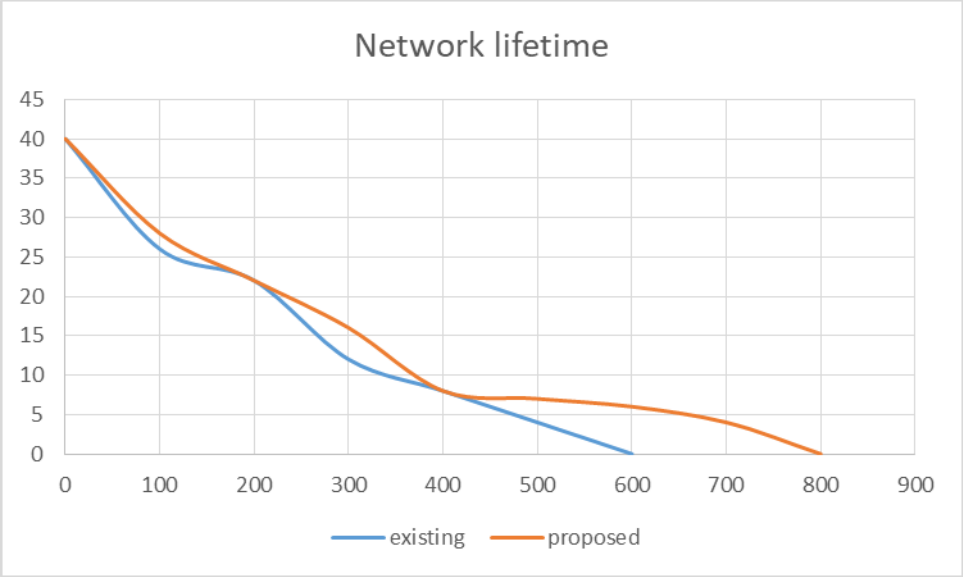

Figure 4. Network lifetime graph

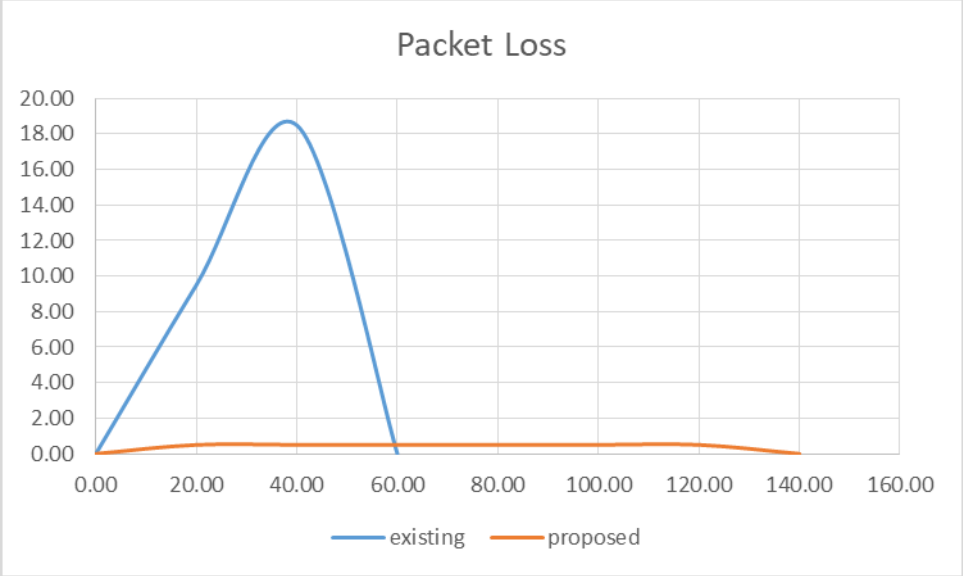

Figure 5. Packet loss graph

In Fig.5, a packet loss graph is generated between time and packet lost in bytes. Because of concurrent communication with all CHs at a time to BS, data is lost and caused the graph to elevate.

CONCLUSION:

While LEACH protocol seems to be saving energy of nodes, with some modifications this protocol can be more alluring and widely applicable. In this paper, an energy effective clustering protocol has been proposed for WSN utilizing fuzzy logic. By choosing suitable fuzzy descriptors, one Super Cluster Head is elected among the CHs who is the agent for delivering the message to a far base station. It is expected that it would be more important in various practical applications like health care, disaster prone areas, military applications, agriculture and so on.

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