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An Improved LEACH Protocol using Fuzzy Logic in Wireless Sensor Network

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Abstract: ***Wireless Sensor Networks are group of low cost and extreme power limited sensor nodes. The various applications of wireless sensor networks include sensing the environment to collect the data and send it to the base station or server in single or multiple hops. The basic target of WSN is to achieve maximum network life using the minimum battery power as limited battery backup is available for any WSN. The first part of this paper presents the comparative study of leach protocol and its types. The second part includes a new improvement in LEACH protocol using Fuzzy Logic.***

Keywords: Wireless Sensor Network, LEACH, Variations of LEACH Protocol, FEEPRP, Fuzzy Logic.

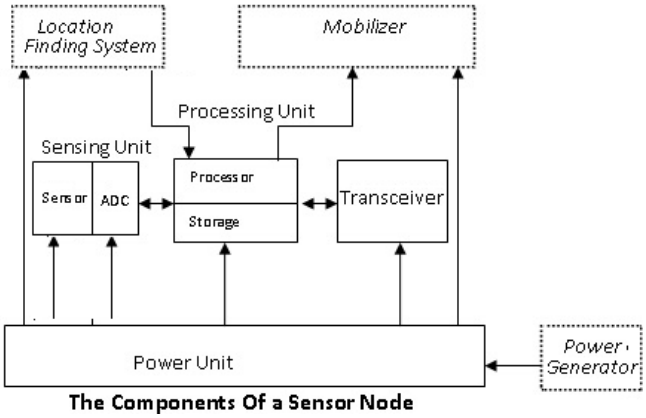
1. Introduction

Wireless Sensor Network [1] is one of the results of the recent developments and advances in micro-electro-mechanical system techniques, digital electronics and wireless communication. The basic idea of these sensor networks are based on the collective efforts of large number of small size, low cost, low power, multi-functioning sensor nodes which sense, collects, process the data and are capable of communicating the base station and other devices in short-range distances. These nodes are deeply deployed near or at the place where phenomenon is taking place. Since the position of theses nodes are not pre-defined therefore they posses the self- organizing and co-operative effort capabilities. Because of these capabilities the responsibility of the wireless sensor network is to send the processed or semi-processed data to the base station. There are many recent improvements in the sensor network over the traditional networks. These improvements can be deployed in two ways [2]:-

- Sensors positioned away from the exact position where actual phenomenon is taking place.
- Sensors are deployed at the same place where the phenomenon is going on.

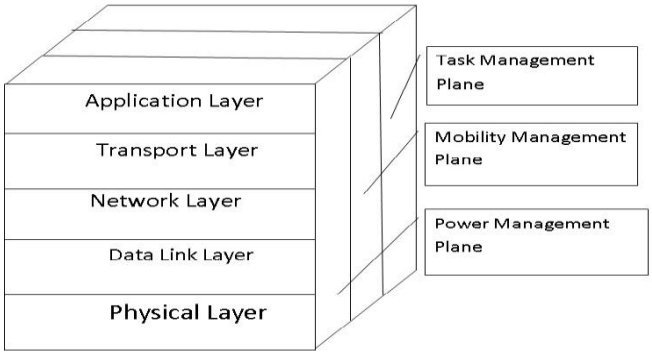
In first situation, large sensors with the capacity of distinguishing data from noise are required whereas in second situation, the sensors deployed perform only the function of sensing and collecting data.

The basic components of sensor nodes includes: - a sensing unit, a data processing unit, a transceiver unit & a power house. Additional components include location finding system, a power generating system & a mobilizing unit. Sensing units sense the environment using sensors, but since the signals are analog in nature, they are converted to digital using ADC [3]. The output of ADC is send to the processing unit, which processes the data and transfers it to the transceiver. The transceiver then connects to the base station and transfers the data to them. All these functions where power which is supported by a power house which contains a power generating unit which contains scavenging units like solar panels.



The Components Of a Sensor Node

Sensor Network protocol architecture contains the following layer: - Application Layer, Transport Layer, Network Layer, Data Link Layer and Physical Layer [4].



The Sensor Network Protocal Stack

2. LEACH Protocol

Low- Energy Adaptive Clustering hierarchy (**LEACH**) [5] is one of the most important and widely used routing approaches for Wireless Sensor Networks. The main concept of this algorithm is to rotate the cluster heads per communication interval among the various sensor nodes, so

that the energy dissipated is distributed among all the sensor nodes during communication with the base station [6]. As this is a hierarchical protocol, its operation is iterative and can be divided into many rounds. Each round is divided into two phases: - a set-up phase and a steady-state phase.

- **Set-Up Phase**:

In this phase every node selects a random number between 0 and 1. The node becomes the cluster head for the current round if it select the number below the threshold value T(n).

$$T(n) = P/1\text{-}P(\mathrm{mod}(1/P)), \begin{cases} \text{if n belongs to G} \\ \text{0, otherwise} \end{cases}$$

Where P is the required percentage of CHs, r is the current round and G is the set of nodes that have not been selected as CH in last 1/P rounds**.** The successfully selected CHs then advertise their selections in the network which are received by the remaining sensor nodes. According to the received signal strengths from various CHs, the sensor nodes select their own Cluster Head and form a cluster for one round of communication with the base station.

- **Steady-State Phase**

After this phase, the nodes collect and send the data to their respective CHs. CHs then process the data and send them to the BS. After each round, the cluster again return back to the set-up phase and CHs are again formed from the remaining sensor nodes which were not selected earlier. Leach uses TDMA and CDMA protocols for inter-cluster and intra-cluster communication for avoiding collisions [1].

3. Variations in LEACH Protocol

Different types of Leach protocol are as follows:-

3.1 E-LEACH

This improved multiple hops energy balanced routing protocol called Energy LEACH [8] can be characterized as: -

- Direct communication will take place between cluster heads and base station, if BS is close to them
- When BS is far away from CHs, the communication will take place in multiple hops and the shortest transmission distance will be covered. For different areas different frequencies will be used by sensor nodes for communication.

3.2 Two Level LEACH (TL-LEACH)

This leach variation works on two-level architecture [7], [8], [9] for communicating the BS. In original leach every cluster head is responsible for sending their data to the base station. If there lays a cluster head which is far away from the base station then it will loose maximum of its energy while communicating to the base station. The solution to this problem is TL-Leach forms a head of all cluster heads whose only function is to collect data from all cluster heads and then send it to base station. This algorithm helps mainly those cluster heads which lie far away from the base station hence increasing the overall life time of sensor network.

3.3 Multi-Hop LEACH

This variant of leach protocol work on multi hops way to reduce the energy consumption of overall sensor network and of cluster heads [7], [8]. It follows the same round concept for initial communication between cluster heads to their clusters but the difference lies in the communication method when it comes to the communication between cluster heads and to the base station. Those cluster heads which lie far away from the base station send their data to the nearest cluster head and so on until the data reach to the cluster head which is near to the base station who ultimately send the data to the base station. This way helps to maintain the energy level in the entire network.

3.4 Centralized LEACH

C-LEACH was introduced to clarify the ambiguous count of number of cluster heads formed during the implementation of original Leach [7],[8]. It is different from Leach in the formation of clusters. In Leach-C, BS decides the cluster head according to the information received by it about the residual energies of nodes and their current location. Candidate set are determined by BS for cluster head node using the residual energy of the nodes. BS finds the clusters by this candidate set using the annealing algorithm which minimizes the total energy used by the non cluster head nodes by minimizing the total sum of squared distances between cluster head nodes and other nodes. CHs are broadcasted by the BS as CHs are formed [12].

3.5 Cell LEACH

In this method, the group of sensors called CELL is formed by divided the sensor network. From each cell, head is selected. The near seven cells form a cluster and then among the heads of all seven clusters, a CH is formed. The cluster formed will remain the same, only cell heads and cluster heads are changed using TDM. The nodes of cell sends their data to the cell head which then sends the data to the cluster head which then transfer the data to the base station. The time duration is fixed for send the data between cluster head and cell head to save the energy to the maximum. The cell heads and cluster heads are changed according to the residual energy left thus increasing the overall time of the network [7].

4. Improved Leach Algorithm Using Fuzzy Logic

The concept of Fuzzy Logic centers on the idea of partial set membership, instead of crisp or discreet set membership [10]. Initially, it was introduced as an alternative approach to processing data that has behavior defined by a “fuzzy” set , which contains elements whose degree of membership vary in the set. Fuzzy Logic varies from conventional control methods by the fact that it incorporates simple *if- then* structure, rather than complicated mathematical model. It is fundamentally dependent on the experience of an operator in cooperating human reasoning process rather than the technical understanding of the system.

A fuzzy control system consists of three basic components: a Fuzzifier, an Inference System governed by a rule base, and a Defuzzifier. The Controller takes input in the crisp/discrete form and feeds it to the Fuzzifier, which converts the crisp inputs into fuzzy variables using membership functions, which, in turn,map the crisp input into fuzzy variables and calculates the degree of membership of those variables. Fuzzy variables are conceived to be objects or words rather than numbers and are expressed as adjectives such as "high", "low", "medium", "very high" and "very low". The Fuzzifier normalizes the fuzzy variables in the range between 0-1 depending on the crisp input and is termed as the degree of membership. The fuzzy input is then fed into the inference system governed by a rule base in which the fuzzy variables are mapped to fuzzy output. The mapping of the fuzzy variables to the inference system is not discrete and can be partial or overlapping. The set of fuzzy outputs is combined together and is applied to the Defuzzifier, which reverses the effect of fuzzification. Different techniques can be used to obtain the crisp output from the fuzzy output, after applying them to the membership function. The transformation of this set to a crisp number is termed as defuzzification. The basic defuzzification methods include: Centroid method, Mean of maximum and Centre of sums [11].

A Fuzzy Logic Based Energy Efficient Packet Loss Preventive Protocol (FEEPRP):

This algorithm works on fuzzy logic to decide appropriate path by using certain parameters whose values are extracted from nodes. The values are then analyzed and fuzzy logic is implemented to decide a path. The Concept of this algorithm contains two phases: - **Route Discovery** & **Choice of Route [11].**

- **Route Discovery**

For sending information to a particular destination node, a source node requires to find a route to the destination. For this purpose, source node advertises the request packet in the network which contains the source address and the destination address, a sequence number and some vacant space for saving the addresses of intermediary nodes, residual energy, hop counts and packets dropped. In this algorithm, after advertising the request packet by the source node, the sequence number of all the intermediary nodes are maintained which help in avoiding the loop formation and short route distances. After finding all the routes, the route selection algorithm is run to finalize a route.

- **Choice of Route**

After getting all the routes, a route from source to destination node is finalized using the fuzzy logic algorithm [11]. Since we use a fuzzy logic, it become unpredictable for an outsider to know which route is finalized which adds a security aspect to the information transmitted. Along with the probability of selection of same route is also very low which adds energy efficiency in the network as different nodes will be used every time. The final route is selected on the basis of membership graph and a rule base.

- **Membership Graph**

Membership graph is constructed for all the nodes on three metrics: "residual energy", "packets dropped" and "hop count". On these metrics, the nodes are given values as "LOW","HIGH" and "AVERAGE". As this algorithm is based on the concept of energy efficient, packet loss preventive route discovery, the routes are determined after monitoring the values from all the three metrics for all the intermediary nodes.

- **Rule Base**

This is an intuitive output that is based on the previous experiences of an operator. Along with the experiences, it also incorporates the human reasoning process. The fuzzy input to the rule base includes Low, High and Average for hop count, residual energy and packets dropped, which gives the fuzzy output as "very low", "very high", "average", "low", "high" and "medium".

- **Defuzzification**

After getting inference from the rule base, again a membership graph for deffuzification is generated to get the crisp output. This output is generated using the centroid method and the areas defined in the membership graphs [11].

5. Results and Discussions

Simulation tool used in this approach is Matlab. Platform is windows on which this tool has been installed. To run this simulation firstly we have to configure the installation. The Graphs are representing the energy dissipation of nodes during the communication. The blue line is representing energy dissipation of nodes in the original Leach Protocol. The red line is presenting the FEEPRP algorithm.

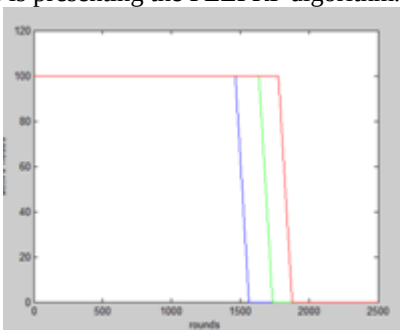


Figure 1: The result of simulation (red line) in number of rounds vs node graph (test 1)

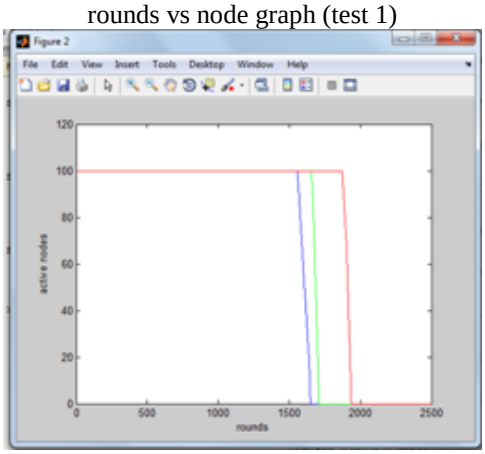


Figure 2: The result of simulation (red line) in number of rounds vs node graph (test 2)

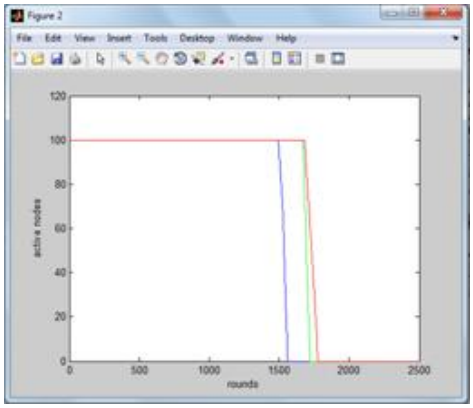


Figure 3: The result of simulation (red line) in number of rounds vs node graph (test 3)

6. Summary and Conclusion

In this paper, we analyze an energy awre packet loss preventive routing protocol, for WSNs using a Fuzzy control mechanism. Applications of Fuzzy Logic in WSN have been encountered in interesting ways in various other pioneering works. Contemplating with the restraints of sensor nodes, FEEPRP is designed to impart security to the network to some extent in terms of avoiding malicious nodes, prevent data loss, control congestion and save energy at the same time. Different from leach, FEEPRP designs a fuzzy control to monitor the past records of the residual energy, packets dropped at each node and hop count to decide which route to select for sending messages. A different route is selected each time according to the output given by the fuzzy logic. As residual energy of each route is given as one of the inputs in the fuzzy control to assure energy conservation and nodes are let to sleep when idle. The graphs above show that energy conservation is much higher in FEEPRP as compared to LEACH protocol.

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