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An Improved Gateway-Based Energy-Aware Multi-Hop Routing Protocol for WSNs.

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***Abstract:** In a large scale WSN the nodes which are nearer to sink are always used for forwarding packet from all other distant nodes. Due to this, the nodes which are nearer to sink are out of energy very soon and an energy hole is created near the sink and the sink becomes unreachable, while maximum nodes in the network are still alive. In this research work a gateway based protocol has been proposed, which is an improvement over the M-GEAR protocol. In the proposed work the base station is considered to be located outside the network area. The sensors are randomly based and based on threshold levels are divided into six parts. The sensor nodes below the threshold are in direct communication with the gateway node while those above the threshold level use clustering hierarchy similar to those proposed in LEACH for communication. The results are compared with the existing protocol and fares well in terms of increased lifetime, throughput and residual energy.*
***Keywords:** Wireless Sensor Networks, Network Lifetime, Throughput, Residual Energy, Clustering protocol.*

I. INTRODUCTION

Wireless Sensor Network (WSN) due to its potentially large application area has emerged as an important research topic nowadays. WSN consists of thousands tiny nodes which individually has limited capabilities but collectively they can form a very useful network for various applications like disaster management, forest fire detection, vehicle tracking, habitat monitoring etc. WSN's use mesh networking protocols. The mesh networking connectivity finds any possible communication path to the destination or sinks by hopping data from node to node. These tiny sensor nodes consist of sensing, data processing, and communicating components. The main characteristics of these sensor nodes are in its infrastructure-less and self-organizing capability. The sensor nodes are deployed randomly and they can perform their task in an unattended manner. Another vital feature of sensor network is the cooperation between sensor nodes. Sensor nodes contain on-board processors. Instead of sending raw data sensor nodes transmit partially processed data by carrying out computation within themselves. [4] Usually the WSN once deployed in the network area, works in an unattended manner and each sensor node has limited battery capacity. With usage the sensor nodes keeps losing their energy and the node comes closer to death which finally brings the whole WSN's operation to a halt. Thus, retaining the energy of the nodes is one of the major constraint in the design of the Sensor Network architecture. A number of research work has been in this field, which has led to several approaches of energy efficiency in the usage of the network. The issues related to physical and link layers are generally common for all kind of sensor applications, therefore the research on these areas has been focused on system-level power awareness such as dynamic voltage scaling, radio communication hardware, low duty cycle issues, system partitioning, energy-aware MAC protocols[5]. Several researches find out that the routing protocols for sensor networks must be designed in such a way that the limited power in the sensor nodes is efficiently used. Routing in sensor networks is very challenging due to several characteristics that distinguish them from contemporary communication and wireless ad hoc networks. First of all, it is not possible to build a global addressing scheme for the deployment of sheer number of sensor nodes. Therefore, classical IP-based protocols cannot be applied to sensor networks[6]. Secondly, in contrary to typical communication networks almost all applications of sensor networks require the flow of sensed data from multiple regions to a particular sink. The third consideration, is that generated data traffic has significant redundancy in it since multiple sensors may generate same data within the vicinity of a phenomenon. Such redundancy needs to be exploited by the routing protocols to improve energy and bandwidth utilization. Fourth, sensor nodes are tightly constrained in terms of transmission power, on-board energy, processing capacity and storage and thus require careful resource management. Due to such differences, many new algorithms have been proposed for the problem of routing data in sensor networks. The routing mechanisms have considered the characteristics of sensor nodes along with the application and architectural requirements. Almost all of the routing protocols can be classified as data-centric, hierarchical or location based although there are few distinct ones based on network flow or quality of service awareness.

M-GEAR[1] proposes the idea of dividing into network area into logical regions, to efficiently utilize individual sensor node energies. The network area has been divided into four distinct regions which use different communication hierarchy in different regions. Nodes in one region communicate directly to BS while nodes in region 2 communicate directly to gateway node. Nodes in other two regions use clustering hierarchy and sensor nodes transmit their data to gateway node through their CHs. Gateway node assists in defining clusters and issues a TDMA schedule for CHs. Each CH issues its own TDMA schedule for its member nodes.In this paper, an improvement over M-GEAR protocol has been presented, which divides the network area into six different logical regions based on a threshold level of their energies.

II. RELATED WORK

Several routing protocols have been suggested in the recent years. These can be broadly categorized into flat based, hierarchical or clustering based and location based. Flat based routing protocols assign same characteristics to each node and use flood based data transferring for packet transmission. The hierarchical or clustering based protocols clusters are created and a head node is assigned to each cluster. The head nodes are the leaders of their groups having responsibilities like collection and aggregation the data from their respective clusters and transmitting the aggregated data to the base station. Location-based protocols utilize the position information to relay the data to the desired regions rather than the whole network. In this kind of routing, sensor nodes are addressed by means of their locations [7]. Heinzelman. et. al [2002] have presented one of the most popular hierarchical cluster-based routing protocols which include distributed cluster formation called Low Energy Adaptive Clustering Hierarchy (LEACH)[8]. The main idea is to form clusters of the sensor nodes based on the received signal strength and use a local cluster head (routers) to the sink. Energy is saved from this protocol since transmission will only be done by cluster heads rather than the all sensor nodes. LEACH uses a TDMA/code-division multiple access (CDMA) MAC to reduce inter-cluster and intra-cluster collisions. LEACH-C is a modified version of LEACH in which cluster heads are selected by the base station randomly. All the nodes having the energy above average are eligible to be cluster heads. Base station runs a simulated annealing algorithm to find the optimal solution with better positions to reduce the energy consumption of cluster heads. Mao Ye. et. al [2005] has proposed and evaluate an energy efficient clustering scheme (EECS) for periodical data gathering applications in WSNs. In the cluster head election phase, a constant number of candidate nodes are elected and compete for cluster heads according to the node residual energy. The competition process is localized and without iteration, thus it has much lower message overhead. The method also produces a near uniform distribution of cluster heads. Further in the cluster formation phase, a novel approach is introduced to balance the load among cluster heads. EECS is fully distributed and more energy efficient and the simulation results show that it prolongs the network lifetime as much as 135% of LEACH. M. Tripathi et. al [2013] have presented an Energy Efficient LEACH-C (EELEACH-C) protocol, in which base station runs a sorting algorithm to obtain a list of candidate cluster head nodes sorted in descending value their residual energy. After examining the candidate cluster head nodes it selects those with maximum residual energy and then calculate the quadratic sum of the distances from each cluster heads to its member nodes to find the optimal solution. Experimental result attests that the proposed protocol improves network longevity. B. Manzoor et. al [2013] have presented Q-LEACH protocol According to this approach sensor nodes are deployed in the territory and in order to acquire better clustering the network is portioned into four quadrants. Doing such sort of partitioning better coverage of the whole network is achieved. Additionally, exact distribution of nodes in field is also well defined. Portioning of network into quadrants yields in efficient energy utilization of sensor nodes. Through this division optimum positions of CHs are defined. Moreover, transmission load of other sending nodes is also reduced. In conventional LEACH cluster are arbitrary in size and some of the cluster members are located far away. Due to this dynamic cluster formation farther nodes suffers through high energy drainageand thus, network performance degrades. Whereas, in Q-LEACH network is partitioned into sub-sectorsand hence, clusters formed within these sub-sectors are more deterministic in nature. Therefore, nodes arewell distributed within a specific cluster and results in efficient energy drainage[10]. Q. Nadeem et. al [2013] has proposed an energy-efficient multi-hop routing protocol (M-GEAR) using gateway node to minimize energy consumption of sensor network. The authors propose dividing the network into logical regions. Each region use different communication hierarchy. Two regions use direct communication topology and two regions are further sub-divided into clusters and use multi-hop communication hierarchy. Each node in a region elects itself as a CH independent of other region. This technique encourages better distribution of CHs in the network. Simulation results shows that this protocol performs well compared to LEACH in terms of the three performance metrics: Network lifetime , Residual energy and throughput. Samayveer Singh et.al [2016] has presented a 3-level heterogeneous network model for WSNs to enhance the network lifetime, which is characterized by a single parameter. Depending upon the value of the model parameter, it can describe 1-level, 2-level, and 3-level heterogeneity. The network model presented by the authors also helps to select cluster heads and their respective cluster members by using weighted election probability and threshold function[11].

III. MOTIVATION

Wireless Sensor Network (WSN) due to its potentially large application area emerged as a premier research topic. Usually the WSN once deployed, works in an unattended manner and each sensor node has limited battery capacity. So after each operation a node comes closer to death which finally brings the whole WSN's operation to a halt. So energy is the main constraint for any application using WSN. In a large scale WSN the nodes which are nearer to sink are always used for forwarding packet from all other distant nodes. Due to this, the nodes which are nearer to sink are out of energy very soon and an energy hole is created near the sink and the sink becomes unreachable, while maximum nodes in the network are still alive. Sensor node are densely deployed in wireless sensor network that means physical environment would produce very similar data in close by sensor node and transmitting such type of data is more or less redundant. If sensor nodes of same application and at minimum distance between them alternatively perform data collecting, processing and communication then we can able to transmit information to the base station for longer time. Thus network lifetime will be improved.

IV. NETWORK MODEL

The first order radio model is used in many researches on wireless sensors networks. Energy dissipation takes place, while transmitting and receiving the data and energy consumption for short distance communication is 'd^2' when propagation is done in line of sight and 'd^4' when transmission is done for the long distance due to multipath fading propagation. It works on the route measurements and sensing takes place constantly resulting in steady volume of data being transmitted to the sink. The following assumptions are considered in an analytical implementation:

A. *Base station remains fixed*: Wireless sensors are densely populated in the network area and are static. Number of clusters according to the network is predetermined for the network. The nodes will pass the data on the predefined paths, in which clusters and the cluster heads are numbered according to the distance based on received signal strength.
B. Some sensors are located farther away from the base station due to which, the cluster head will consume the 'd^4' energy for transmitting l bit data for direct transmission. Thus, data is transmitted through multiple hops and finally reach the base station by clusters very near to the base station
C. Links in the path are symmetric i.e. same power is required for the communication between any two nodes. No changes in the topologies and the loads are considered.
D. Thus, to transmit a message of length to a distance d, the transmitter energy is given as:

$d_0 = \mathrm{sqrt}(E_{mp}/E_{fs})$ (1)

if $d < d_{0,}$

$Et_x(k,d)=E_{elec}*k+E_{mp}*k*d_4$ (2)

If $d > d0$

$E_{tx}(k,d)=E_{elec}*k+Emp*k*d_4$ (3)

Receiver Energy:

$E_{rx}(k)=E_{ele}c*k$ (4)

Where E_{elec} is the energy dissipated in transmission and reception, Efs and Emp are free space and amplifier energy respectively.

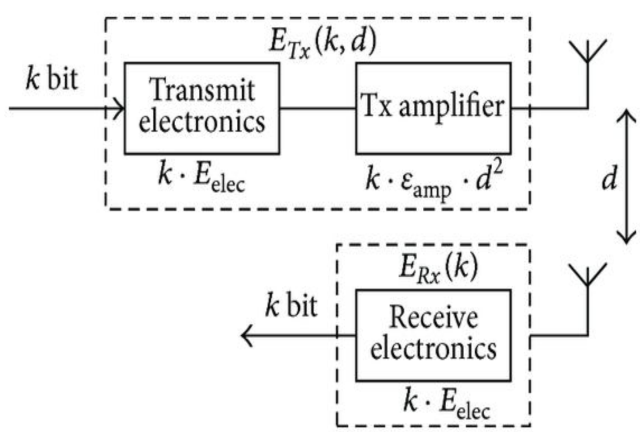

Figure 1: First Order Radio Model

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The above diagram shown in Figure 1, shows a graphical representation of a first order radio model. The transmitter and receiver use the same kind of electronic circuitry and thus their energies are accumulated as Eelec, for each data bit transmitted. The sensor nodes are thus symmetric to each other.

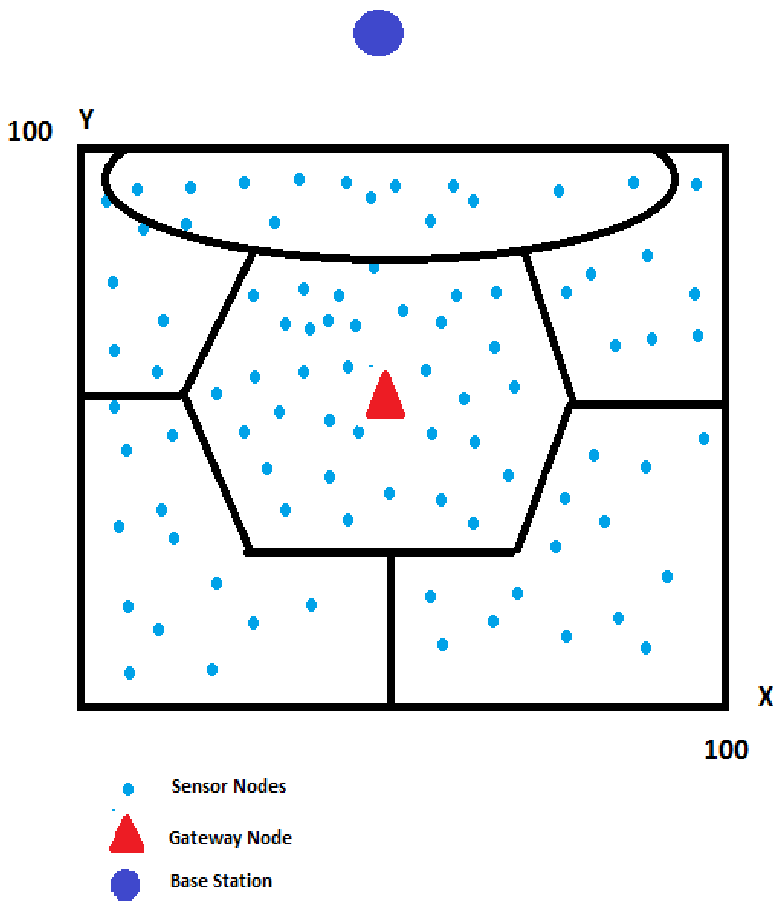

Figure 2: Network Model

The network model used in this research work is as shown in the figure 2. S sensor nodes which are deployed randomly in the network area. The *i-th* sensor node is represented by si and consequent sensor node set S= s1,s2,....., sn. All the sensor nodes are assumed to be homogenous. The gateway node is placed at the center of the network of the network and is rechargeable. The Base station is placed outside the network area.

V. PROPOSED WORK

The proposed work is takes into account geographical positioning of the network area. The network area consists of homogenous sensor nodes are used that are distributed randomly in the network area. After deployment of nodes, every node forwards its location to the base station. The base station calculates the distance of each node and save all information of the sensor nodes into the node data table. The node data table consists of distinctive node ID, Residual energy of node, and its distance to the BS and gateway node. The same topology is being used in this proposed work. The algorithm has been shown below.

A. Set Random Position of Nodes.

1) *Set Position of gateway node:-* At the center of Network area. X-co-ordinate- M/2, Y-Co-ordinate-M/2;
2) *Set Position of Base Station:-* X-Co-ordinate- M/2; Y-Co-ordinate-M+M/10.
3) Calculate Distances of each nodes from base station and gateway node.

B. Set up Phase.

1) *Network Division:-* Set Threshold Distance for selection of nodes in a particular zone:

$$d0=E_{f0} / E_{fs} \quad (5)$$

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2) Define the node region:-

Region 1 nz1=(dBS<=d0).*id
Region 2 nz2=(dGS<=d0).*id
Region 3 nz3=(y>=yg & dBS>d0).*id;
Region 4 nz4=(y<yg & dGS>d0).*id;
Region 5 (dGS<=d0).*id& n_{dist} =< d0
Region 6 (dGS<=d0).*id& n_{dist}> d0

C. Running Phase

1) Initially every node has probability to be elected has cluster head.
2) Initialize the rounds. Simulation is carried out for 7000 rounds.
3) The selection Probability is given as:

   T=p/(1-p*mod(r,1/p))’ (6)

4) Where T is threshold probability, p = the desired percentage of CHs and r = the current round, C = set of nodes not elected as CH in current round.
5) Calculate node distance to cluster head.
6) For every round calculate energy and threshold for cluster head selection.

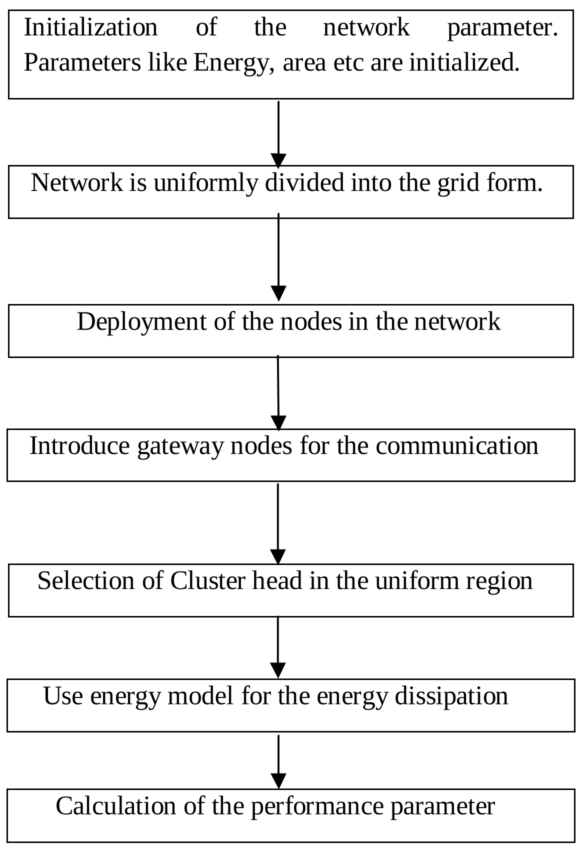

Figure 3: Flow chart of the proposed work

VI. PERFORMANCE EVALUATION

A. Simulation Setting

In order to evaluate the performance of the proposed protocol it has been implemented and simulated using MATLAB. A wireless sensor network with 100 nodes distributed randomly in 100m X 100m field. A gateway node is deployed at the center of the sensing field. The BS is located far away from the sensing field. Both gateway node and BS are stationary after deployment. The table 1 below shows the simulation parameters.

Parameters	Values
Network Area	100m *100m
Threshold distance, d0	sqrt(E_{fs}/E_{mp})
Energy consumed in the electronics circuit to transmit in 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, Emp	0.0013 pJ/bit/m_4
Data Aggregation Energy, EDA	5 nJ/bit/signal
Message Size	4000 bits
Initial Energy, E0	0.5 J
Numbers of rounds	7000

Figure 4: Network parameters

B. Performance Parameters:-

1) Network Lifetime:- It is the time interval from the start of the network operation till the last node die.

2) Throughput:- To evaluate the performance of throughput,the number of packets received by BS are compared with the number of packets sent by the nodes in each round.

3) Residual Energy:- The residual battery energy of network is considered in order to analyse the energy consumption of nodes in each round.

C. Simulation Result and Analysis

In this sub-section we show the simulation results.We compare our results with M-GEAR and LEACH protocols as shown in below figures.

1) Network Lifetime:- In fig 5, we show the results of the network lifetime. Our proposed protocol obtains the longest network lifetime. This is because the energy consumption is well distributed among nodes and network is divided into logical regions. Proposed topology balance energy consumption among sensor nodes and increased the network lifetime. On the other hand, in M-GEAR and LEACH, nodes die quickly as stability period of network ends.

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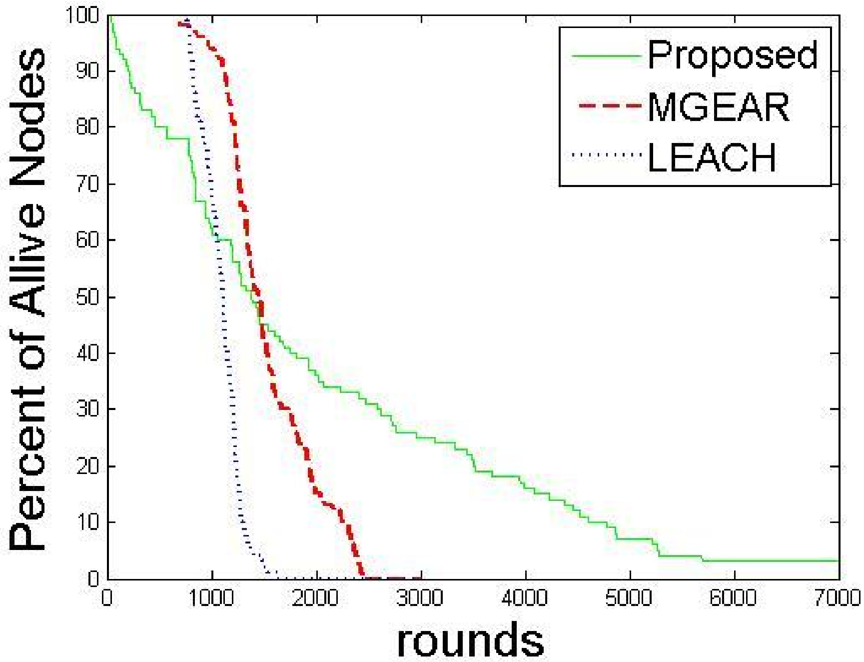

Figure 5: Percent of Alive nodes v/s rounds

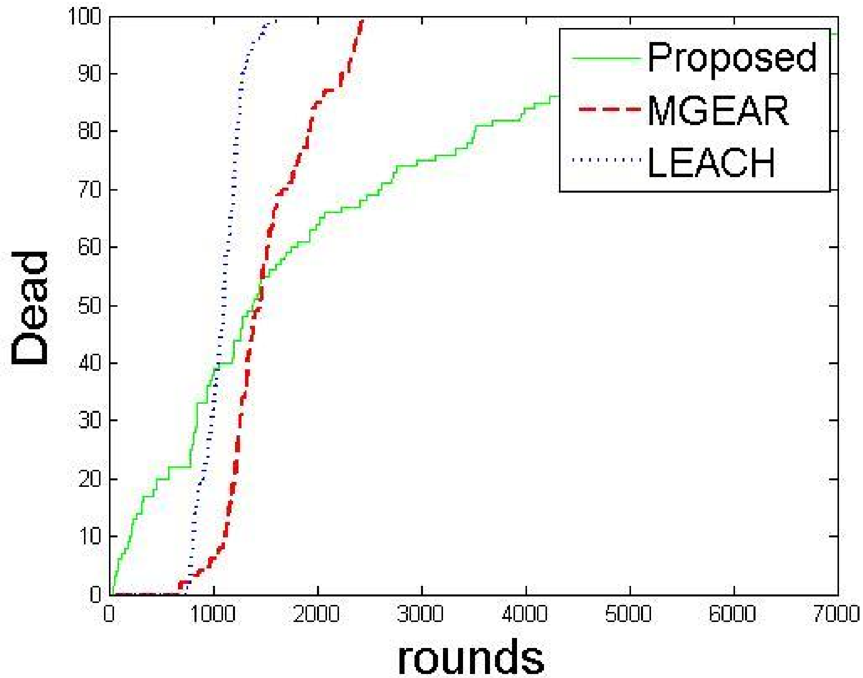

Figure 6: Dead Nodes v/s Rounds

The dead nodes are shown in figure 6. As can be seen from the figure, the dead nodes in the proposed protocol reach maximum after a longer duration as compared to LEACH in which all 100 nodes die at 1500 rounds and those of M-GEAR die at around 2500 rounds.

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2) Throughput: Average packet sent to BS are assessed through extensive simulations. Simulation results of our proposed protocol illustrate increased throughput. Sensor nodes near gateway send their data directly to gateway, similarly nodes near BS transmit data directly to BS.

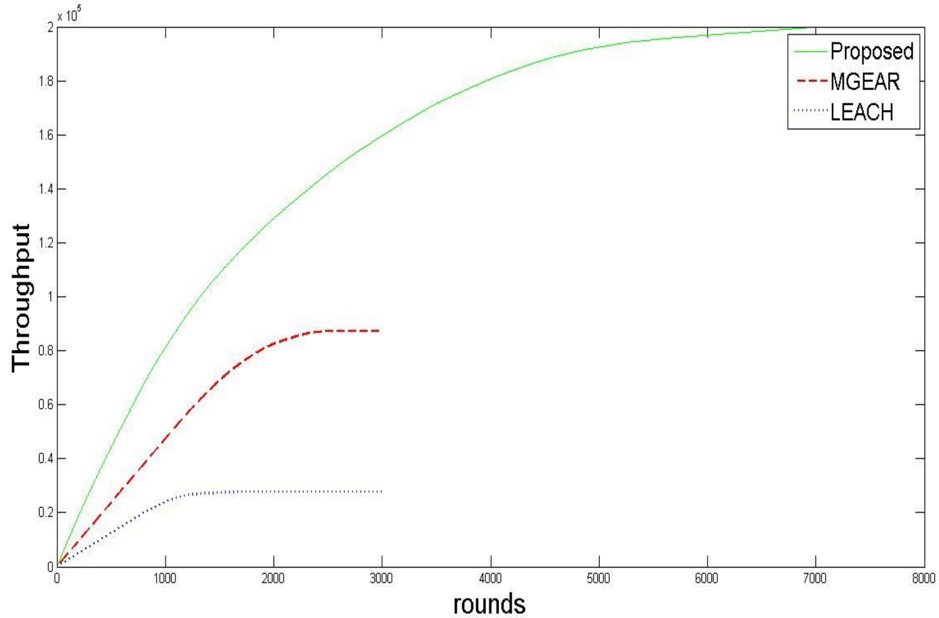

Figure 7: Throughput v/s rounds

3) Residual Energy: Figure 8, shows average residual energy of network per round. It shows number of packets of data transferred between sensor nodes and the base station. In this comparison as well, the proposed protocol shows the minimum energy consumption as compared to LEACH and M-GEAR.

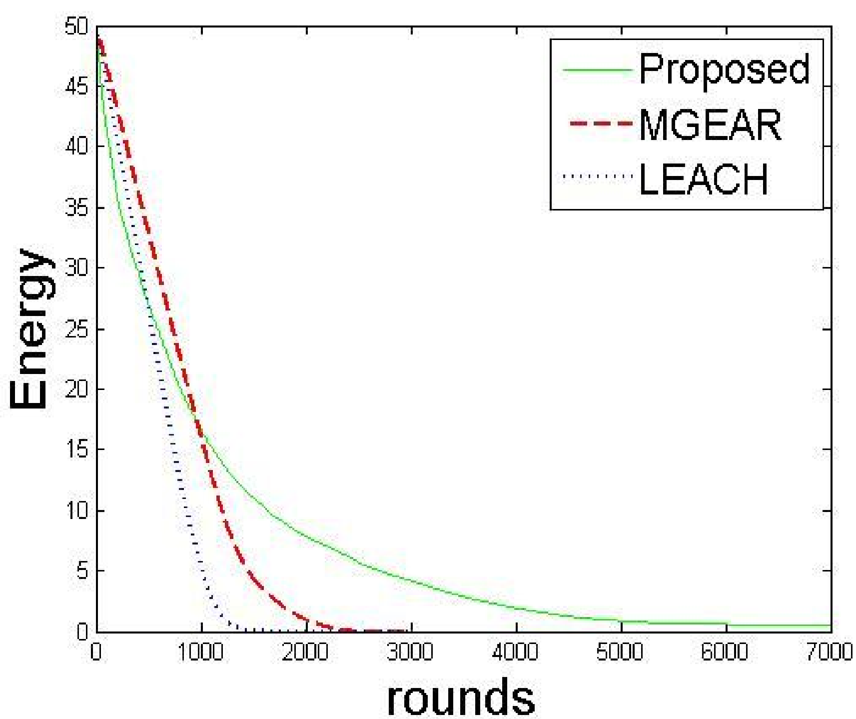

Figure 8: Residual Energy v/s rounds

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Residual energy resembles energy remaining in the sensor nodes after each round. The proposed protocol is able to maintain a considerable residual energy for operations upto 7000 rounds as compared to LEACH and M-GEAR which spent out the energy after 1500 and 2500 rounds approximately.

VII. CONCLUSION

The work presented here examines the routing capability of a wireless sensor network in a constrained environment. An energy efficient protocol which uses gateway based multi hopping technique has been implemented. The network area is divided into six logical regions based on the threshold value. Network lifetime , Residual energy and throughput are the various performance metrics which has been used to evaluate the performance of the protocol. The simulation result show better results in comparison to existing LEACH and M-GEAR protocols.

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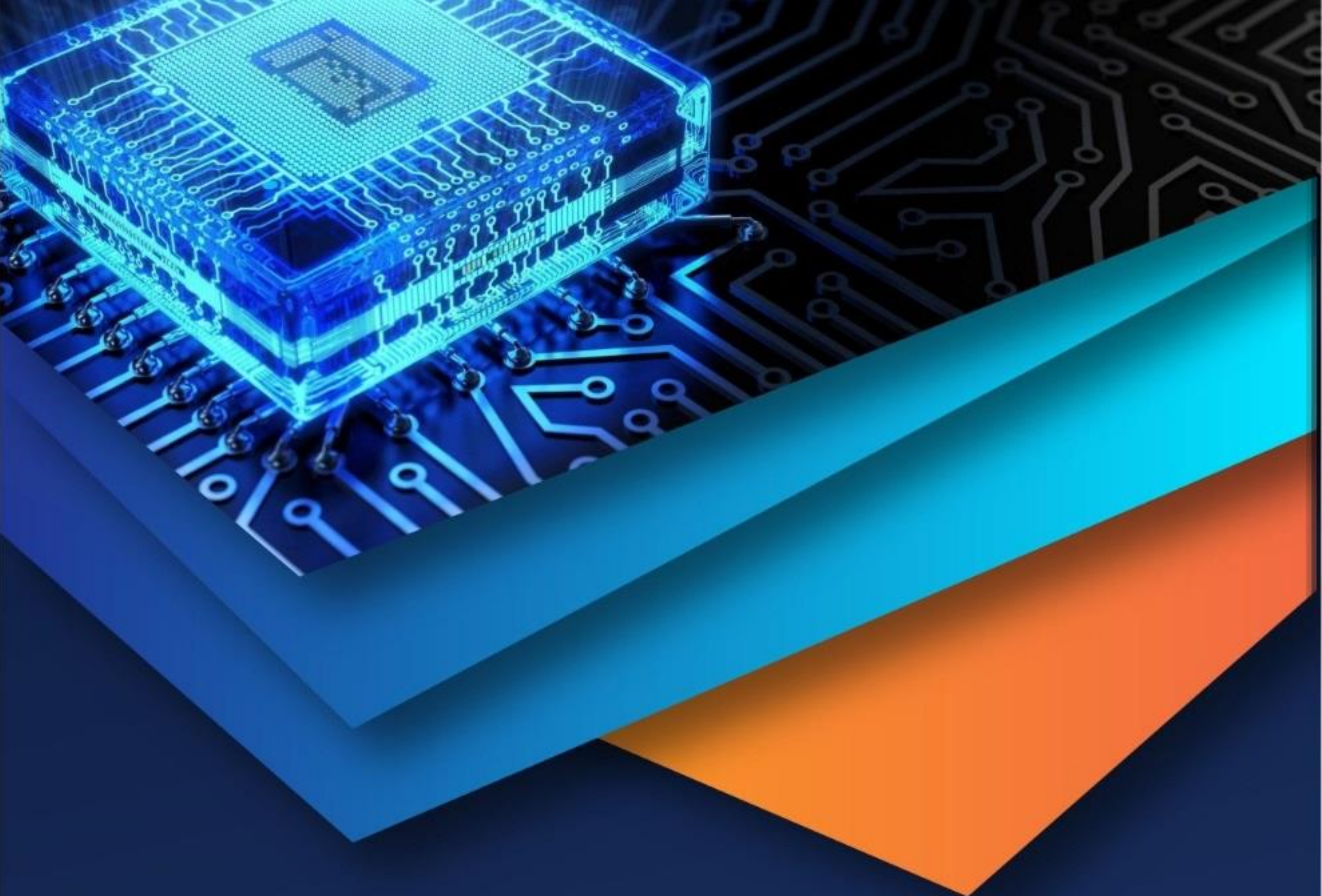

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