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Load Balancing of Intermediate Nodes to Extend Network Lifetime

Tanuj Kumar Mishra[1] and Raj Kumar Paul[2]

[1]Student, Department of Computer Science and Engineering, Vedica Institute of Technology, Bhopal (M.P.)
[2]Assistant Professor, Department of Computer Science and Engineering, Vedica Institute of Technology, Bhopal (M.P.)

***Abstract*—Abstract: Wireless sensor network is energy constraint network. The lifetime of a network is defined by the life of first specified percentage of dying nodes. Load balancing is a method to equalize energy consumption of all nodes and this way all nodes will degrade together. By load balancing, the lifetime of the network does not depend only on the life of weak node but depends on the life all nodes in the network which helps to increase the life of the network. In this paper, a distributed multi-hop routing algorithm for Load Balancing of Intermediate Nodes (LBIN) has been proposed to extend network lifetime. The objective of the proposed protocol is choose forwarded node in such a way, so they deplete their energy at approximately the same time, which is achieved by addressing the load balance problem at the node levels. At the node level, a predefined threshold is used to select the best node to balance the load in the selected subregion. This approach is shown to be an effective solution for load balancing and extending network lifetime in large multi-hop networks. This paper shows that the use of LBIN offers significant improvement over existing protocols in extending network lifetime.**

***Index Terms*—Wireless sensor network, data precision, residual energy, network lifetime, load balancing.**

I. Introduction

In todays world of computing, information gathering is a fast growing and challenging field in the different area such as inhospitable and low-maintenance areas where conventional approaches prove to be very costly [1]. Sensors provide a low-priced and straightforward solution to these applications. These physical devices are small in size that is capable of gathering environment information like heat, light or motion of an object. Sensors are deploying in a simple model in the area of interest to monitor events and gather data about the surroundings. Networking of these unattended sensors is expected to have a major impact on the effectiveness of many military and civil applications, such as combat field observation, security and adversity management. Sensor motes in such systems are typically throwaway and expected to last until their energy drain. Therefore, for sensor networks power is a very inadequate resource and for the duration of a particular mission. It has to be managed wisely to extend the life of the sensor motes. The sensor networks pursue the model of a base station, where sensors relay streams of data to the base station either like periodically or based on actions. The control node/ base station may be statically allocated in the surrounding area of the sensor, or it may be mobile so that it can move around the field and collect data from the network. In either case, the base station cannot be reached strongly by all the sensor motes in the network. The motes /nodes that are located far away from the base station will consume more energy to transmit data than other nodes and therefore will die sooner [2].

In Wireless Sensor Network (WSN), it consists of a potentially large number of resource constrained sensor nodes and few relatively powerful relay nodes. The sensor node has a battery and a low-end processor, a limited amount of memory, and a low power communication module capable of short range wireless communication [3]. As sensor nodes are deployed randomly and have very limited battery power, it is impossible to recharge the dead batteries. Thats why battery power is considered as a limited resource in WSN and should be efficiently used. Sensor node consumes battery in sensing data, receiving data, sending data and processing data [4]. A sensor node doesnt have enough power to send the information directly to the far away from the base station. Therefore, along with sensing data the sensor node act as a router to promulgate the data of its neighbor. The sensor nodes can be grouped into small clusters in a large sensor network. Each cluster has a cluster head to coordinate the nodes in the cluster [5]. However, clustering technique has a large delay than direct and multi-hop routing. Normally it is supposed that the nodes in wireless sensor networks are homogeneous, but in actuality, homogeneous sensor networks hardly subsist. Even homogeneous sensors have different capabilities like different levels of initial energy, depletion rate, etc. [6].

In this paper, a load balancing protocol is proposed to balance the load on intermediate nodes in the multi-hop path. It provides an energy efficient network retain a long time with data dissemination reliability. In this approach, forwarded nodes are selected for data relaying. The forwarded nodes are selected through a predefined threshold. It has been observed that the proposed approach equalize the energy consumption in data forwarding. It saves a lot of energy by reducing retransmission path and increase stability period of the sensor network. It was found that the LBIN enhances the network lifetime significantly than existing techniques.

The rest of the paper is organized as follows. Section 2 discusses the previous load balancing protocols. Section 3 describes the proposed approach. Section 4 provides an overview of simulation and results. Section 5 briefly summarized the conclusion and future work.

II. Related Work

Recently, a large number of load balancing techniques and algorithms have been proposed for WSNs, and simultaneously many studies have been done to analyze existing routing techniques and algorithms. For example,

In [2], authors select the cluster member by considering the maximum transmission power of the nodes; its membership depends on the communication cost. In this method, backup recovery is not to be considered. In paper [7], author improves the choice of the cluster member by using comprehensive weight value composed of distance between the cluster head and the member and the residual energy. To avoiding the load imbalance, it uses optimization threshold value too. For developing the balanced cluster, the algorithm considers load equalization.

In this paper [8], for intra and inter-cluster communication layered approach is used. This algorithm considers similar network. In this paper [9], fairly distributed cluster heads increase the network lifetime. The cluster heads used the transmission range reconfiguration to balance the clusters that based on the number of general nodes in the cluster and the number of cluster heads. The algorithm provides effective data aggregation.

In this paper [10], for packet forwarding uses optimal scheduling algorithm in which determines the time slot for sending the packets for the nodes. The algorithm provides uniform packet loss probability for all the nodes. The algorithm uses balanced cost objective function for optimum scheduling. In this research [11], for improving data accuracy and use of bandwidth WSN to increase network lifetime, pseudo-sink protocol is introduced. In this paper [12], handles the hot point problems which use the pruning mechanism in the cluster to balance the load in the network. Evaluation function in the algorithm is based on pruning mechanism and uses nodes location, residual energy and count of cluster nodes as its parameter to find its cost.

In this paper [13], by dividing the sensor network nodes into subsets, the algorithm consider sensing coverage & network connectivity. To ensure the network connectivity, it turns on some extra nodes in each subset. The problem with this approach is to find the existence of critical nodes. These nodes may be on all the time and if these nodes die the network will be partitioned In this paper [14], provides possible in-network method for adaptive distributed control of energy consumption. In this, some other methodologies like a market-based algorithm or game theoretic algorithm are used. The algorithm assumes complete connectivity.

In this paper [15], density as a key parameter, the load balancing algorithm is proposed for cluster heads in wireless sensor networks by considering the traffic load. It is supposed i.e. the traffic load supplemented by entire sensor nodes is same, which is the special case of this algorithm. It is an NP-hard method. It uses centralized approach and assumes that each node is aware of the network. In this research [16], in this paper, an algorithm is proposed that accounts the problem of positioning mobile cluster heads and balancing traffic load in hybrid sensor network which abides of static and mobile nodes. It has shown that the location of the cluster head could affect network lifetime significantly, by moving cluster head to better location network load can be balanced and lifetime is increased. In this paper [17], load balanced group clustering to balance the battery power by implementing dynamic route calculation according to the condition of energy distribution in the network.

In this paper [18], in this paper fuzzy based approach is used in distributing database for load balancing on sensor network that extends the lifetime of the network. A new approach vertical partitioning algorithm for distributing a database on sensors is used in this paper. In this approach, first clusters are formed and then distribute partitions on clusters. In this paper [19], a new clustering protocol of load balancing which isolates the entire network to the virtual circle with variable radiuses is proposed. This protocol used in such a fashion that radius of every virtual circle and the size of every cluster will rise with the augmenting distance from the base station, in such a way that cluster size of every circle would be distinct with the clusters of the other circles.In this study, the prospective protocol, network coverage after the initial node dead, first node dead, decreases harmonically and uniformly. It also raised network lifetime incomparably in such a way that the lifetime of the network increased.

In this paper [20], planned to deal with the lifetime expansion problem, then improves a novel load balancing scheme by load balancing applying to the sub-network management in wireless sensor networks that balance the energy consumption of the sensor nodes and utmost network lifetime. In this study a scheme using analytical models and compare the results with the earlier researchers. This scheme takes into account the load balancing of individual nodes to maximize the system lifetime. In this paper [21], authors proposed a clustering approach to providing the balanced cluster by considering thresholds for cluster formation and also address to reduce cluster unevenly and load unbalanced. It shows that it reduces the death rate of nodes when it compares with the other traditional approaches with a better lifetime of the network. It provides us an impartial cluster and better quality cluster.

In this paper [22], a data aggregation methods are used which are the combination of two methods for load balancing. In the primary method, nodes which are away from the sink consume additional energy and load balancing is concluding by rising the interval of communication-based on remaining energy of these nodes. In the secondary method, load balancing is concluded by tolerating the superiority of data when data is sufficient diverged from previous data.Nodes which have less energy send data only. The quality of data is based on deviation control function, and this deviation control function is based on remaining energy of nodes. This method shows radically increases the lifetime of wireless sensor network. In this research [23] by using some backup nodes, a clustering technique will balance the load among the cluster. The backup high energy and high processing power nodes replace the cluster head after the cluster reaches its threshold limit. It provides high network lifetime and maximum throughput. The

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performance of the algorithm is compared with the original LEACH algorithm regarding the number of rounds and the dead nodes using the parameter like energy dissipation in each round per node. The result shows that it provides effective results in prolonging the network lifetime.

In this paper [24], a decentralized routing algorithm, known as a game theoretic energy balance routing protocol. It is planned to expand the network lifetime through balancing energy consumption in a larger network area with geographical routing protocols. The goal of the proposed protocol is to make sensor nodes decreases their energy at approximately the same time, which is accomplished by addressing the load balance problem at both the region and node levels. In the region level, evolutionary game theory (EGT) is used to balance the traffic load to the available subregion. In the node level, classical game theory (CGT) is used to select the best node to balance the load in the selected subregion. The combination of evolutionary and classical game-theoretic with geographical routing is shown to be effective improvement in lifetime of the network

In this research paper, we investigate the load balancing techniques that is based on energy consumption of nodes and region density, cluster size, network traffic, etc. It has been found that the load balancing can be used to expand the lifetime of a sensor network. Load balancing using clustering can also increase network scalability. However, it does not fit for the real-time application. With respect to energy requirements, a real-time energy efficient multi-hop routing protocol is needed for sensor networks.

III. PROPOSED MECHANISM:LBIN

A. Assumptions

In this section assumption about the network, model is described.

- Sensor nodes and base station are static.
- The base station does not limit by energy.
- Sensor nodes are aware of their geographic location.
- The distributions of sensor nodes are random over the sensing area.
- The sensor nodes are densely deployed in the sensing area.
- Sensor nodes are homogeneous in energy level.
- Multi-hop communication is used for data transmission.
- Sensor nodes do not use any data aggregation technique.

B. Load Balancing in Intermediate Nodes

The proposed LBIN protocol is designed to provide energy balance to uniformly and randomly deployed multi-hop WSNs with homogeneous nodes where the transmission range is γ. The LBIN protocol considers geographical routing in a stationary network. If the node is equipped with GPS, the GPS needs to only run in the initialization phase to acquire the location of the node; then it can be turned off. That is why the energy cost of this initialization is not included in this paper. In the network, any node can be a source and can report events periodically or at the instant, they occur. Initial,

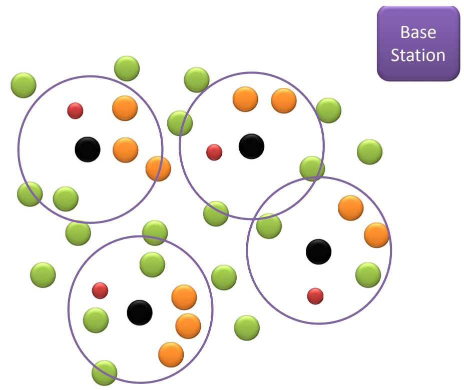


Fig. 1: Potential candidates selection.

sensor nodes determine their neighbor's positional information by exchanging a HELLO packet as soon as it observes an event. The Reply message contains the location coordinate of the node with its remaining energy. The energy cost of this process incurs a one packet transmission cost for each neighboring node and one overhearing cost. The problem of achieving a network-wide energy balance is broken down into the following two sub-problems: i)determine potential candidates (neighboring sensor nodes) for data forwarding and ii) determine a node in the potential candidates. The energy balance at the region level is achieved using the density of the nodes in particular region and the angular and energy balance at the node-level is achieved using distance computation with the base station.

1) Determine a potential candidates: In this phase, sensor node i has data to forward it to the base station. For that node i need to determine nodes that can be relay node. Firstly, determine the potential candidates of neighborhood that belong in a dense region. For this, node i compute degree of each neighbor. Node with higher degree can be in dense region. Using the node densities, node i determines the potential candidates nodes that belong to the dense region as shown in fig. 1.

2) Determine a node in the potential candidates: Node i can have more than one potential candidate for data forwarding but need only one node for data forwarding. For this, Node i compute fitness value (F_v) using fitness function for each potential candidate. The fitness value can be computed as

$$F_v = \sqrt{2}\frac{A_x}{D_{i-BS}} \times \theta^{-1}\frac{E_c}{E_I} \quad (1)$$

where A_x is an edge of the deployed area, D_{i-BS} is the distance between sensor node i to base station (BS). E_c is the current energy level of node and E_I is the initial energy of the node. The θ is an angle among the node i, neighbor node j and BS. The θ can be computed as

$$\theta = \arccos(\frac{a^2 + b^2 - c^2}{2 \times a \times b}) \quad (2)$$

where a,b and c are the distances between node i to node j, node j to BS and node i to BS respectively. Node with higher fitness value is selected as the forwarded node for this

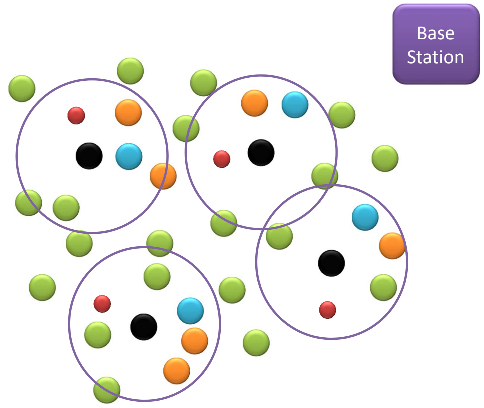


Fig. 2: Forwarded node selection.

TABLE I: Simulation Parameters

Parameters	Values
Area	$250 \times 250\ meter^2$
Base station position	$(250m, 250m)$
Total sensor nodes (n)	100
Initial energy (E_I)	0.5 J
Transmitter/Receiver electronics (E_{elec})	50 nj/bit
Reference distance (d_0)	87 meters
Transmit amplifier (ϵ_{fs})	10 pJ/bit/m^2
Transmit amplifier (ϵ_{mp})	0.0013 pJ/bit/m^4

round as shown in fig. 2. Each sensor node follow the same process as soon as it get data as shown in flowchart (Fig. 3).

IV. Simulation and Results

The performance of the proposed protocol, LBIN, was analyzed for network lifetime, energy consumption per round and packet delivery per round. Network lifetime is defined as the duration until all sensor nodes in the network becomes inoperative due to the depletion of energy [5], [12]. Energy consumption per round is defined as the average energy that is required to transmit all packet successfully in a round. The packet delivery is defined as the number of delivered packets in a given duration. The proposed routing protocol has been evaluated using MATLAB simulator [34]. The simulation parameters are given in Table I. The analysis of sensitivity in LBIN protocol has been done regarding length of network lifetime, energy consumption and packets delivered for three parameters: the initial energy of sensor node, the number of sensor nodes and the number of events.

A. Number of Sensor Nodes

The effect of a different number of sensor node (within the same field) on network lifetime and data dissemination is analysed. We take five values for sensor nodes. The number of events is taken as 12, initial energy of sensor node is taken as 0.5 J. Sensor nodes are deployed in $250 \times 250m^2$ area of sensing field with 50 meters communication range. Figure 4 shows that the stability period and network lifetime varies with number of sensor nodes. It is found that the network

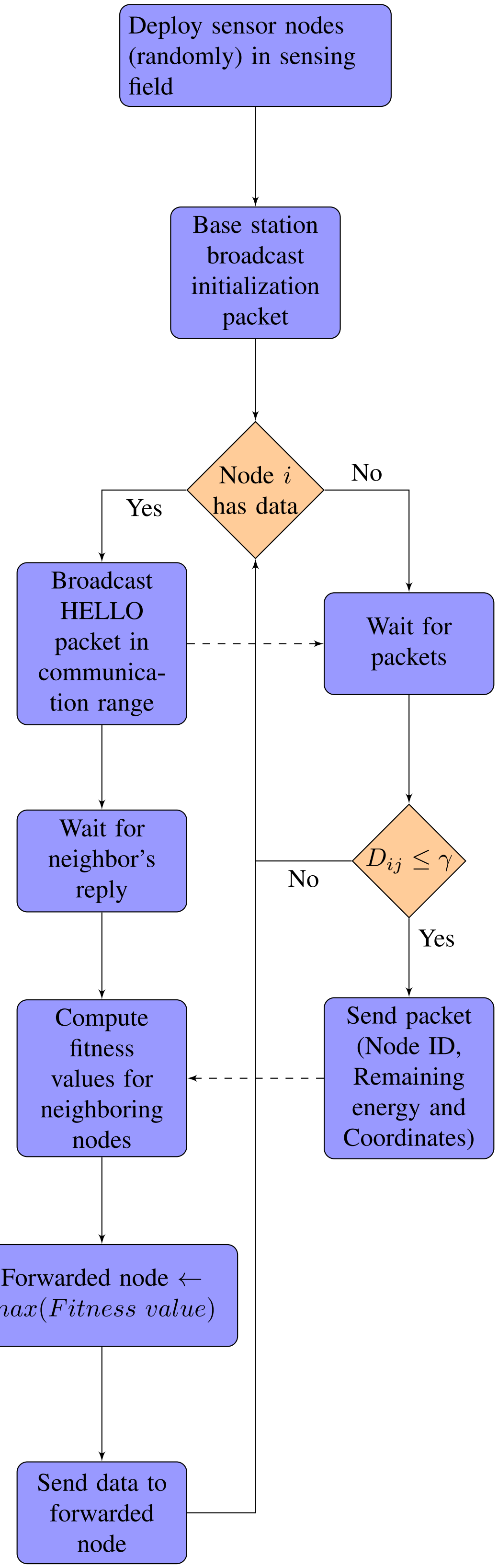
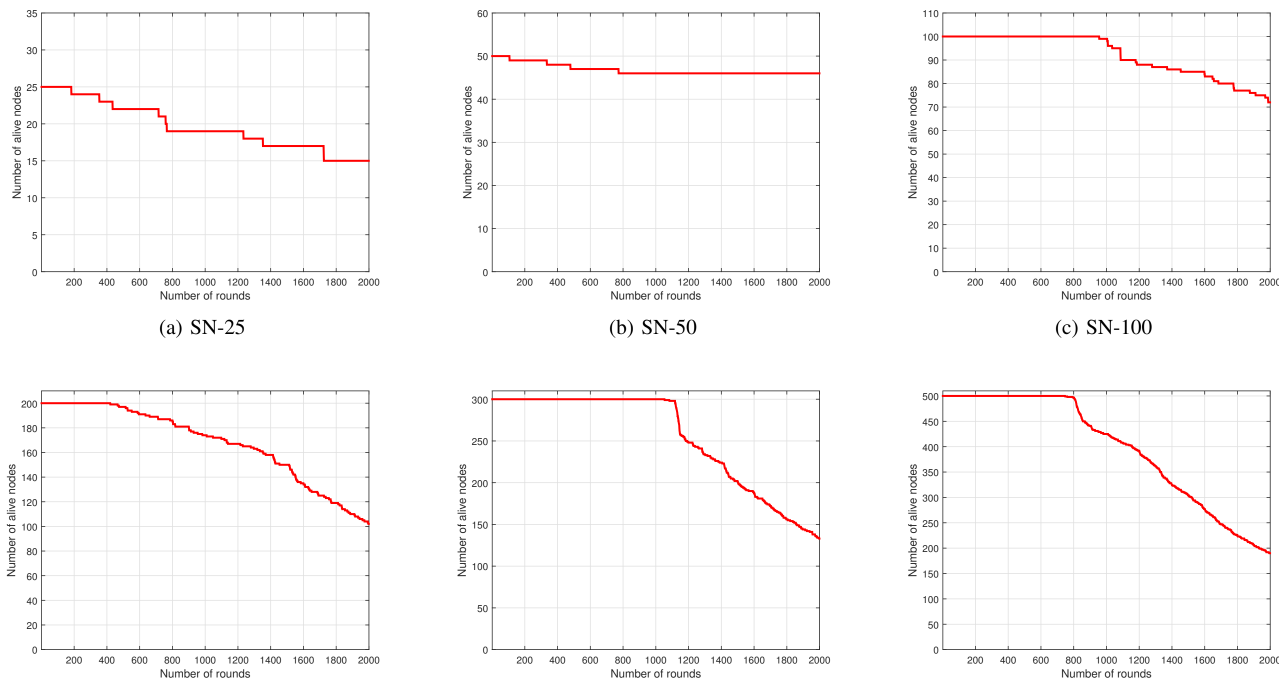


Fig. 3: Flowchart of Proposed Mechanism: LBIN



(a) SN-25 (b) SN-50 (c) SN-100

(d) SN-200 (e) SN-300 (f) SN-500

Fig. 4: Simulation results for the total number of sensor nodes in the network.

lifetime of network is increases with sensor node because total energy of network increases. Increase in sensor nodes also increases the load balancing in network resultant network stability period and lifetime increase. It is also observed that the packet delivery is almost constant that shows the network reliability. Figure 4e indicate that the three hundred nodes in this deployment scenario is sufficient. It has been observed for figures that the stability period of LBIN protocol is depend on the network topology.

B. Energy of Sensor Nodes

To evaluate the effect of energy level on lifetime and data dissemination number of simulation are performed. We take five level of energy for sensor node. The number of events is taken as 100, total hundred sensor nodes are deployed in $250 \times 250m^2$ area of sensing field with 50 meters communication range. The other parameters taken for simulation are shown below in Table I. It has been observed from figure 5 that the nodes energy exhausted in equal proportion. It is inferred that on increasing initial energy, a lifetime of the network is also increases. It has been observed that proposed protocol significantly balance the network energy consumption for each node.

C. Number of Events

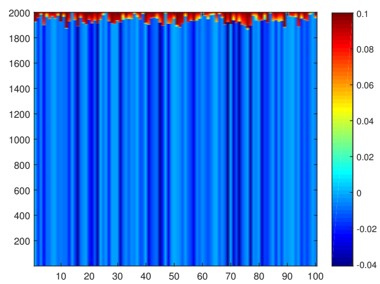
The effect of a different number of events on network lifetime and data dissemination is analyzed. We take five values for events. The hundred sensor nodes with 0.5 J initial energy are deployed in $250 \times 250m^2$ area of sensing field. The base station positioned at the corner of the sensing field. The other parameters taken for simulation are shown below in Table I. Figure 6 shows that the increase the number of events sharply decreases the stability period of network. It happens because increase in number of events increases the number of transmission which cause loss of energy in sensor node. Stability of network is significantly low due to large number of events in sensing field. An increase in number of events deplete nodes energy in sensing and communication. It also observed that data delivery decreases with time.

D. Performance Comparison

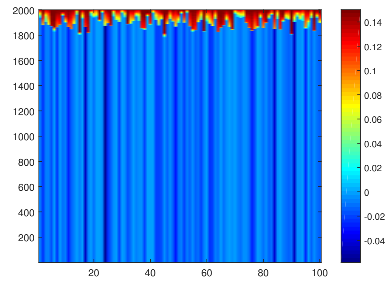
In this section the performance of RTLD [25], GTEB [24] and LBIN are compared using the same network scenario. In this, nodes are randomly deployed in $100times100m^2$ area. Each node installed with $3.3J$ energy and transmit data in 128-byte sized packets.

Fig. 7 illustrates the performance of RTLD, GTEB, and LBIN with an increasing packet generation rate in a fixed network size. This figure shows that the LBIN protocol performs better than the other existing RTLD, GTEB protocols. This shows that the LBIN achieve better load balancing the existing protocols.

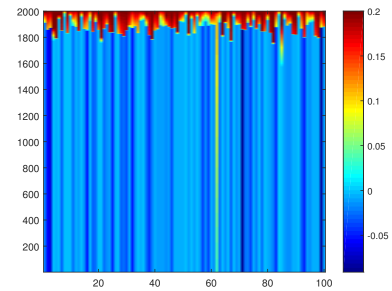
The performance of protocols is also compared for varying number of sensor nodes for fixed sensing field. It has been observed that the increasing the number of nodes increases the lifetime of the network in both protocols. However, the LBIN significantly enhance network lifetime than GTEB as shown in fig. 8.



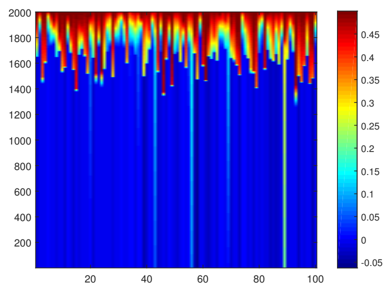
(a) Energy-0.1 J



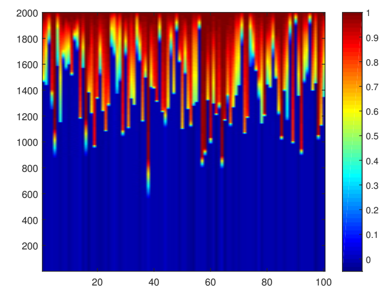
(b) Energy-0.15 J



(c) Energy-0.2 J

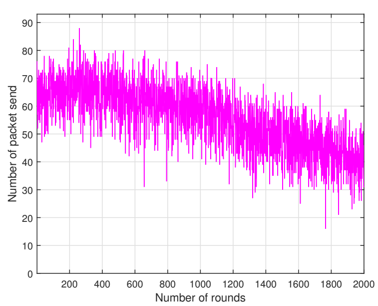


(d) Energy-0.5 J

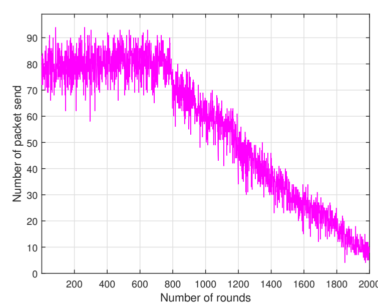


(e) Energy-1 J

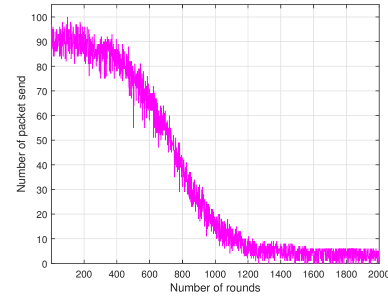
Fig. 5: Simulation results for the initial energy of node.



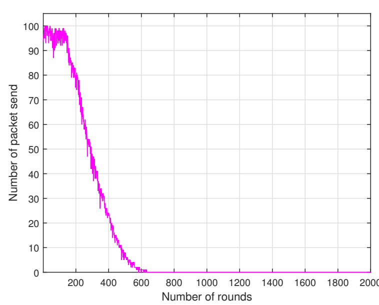
(a) Events-12



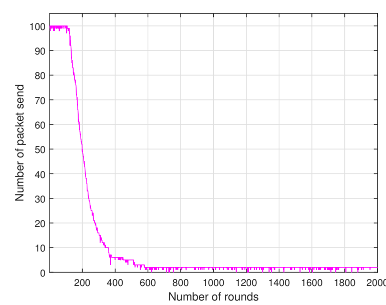
(b) Events-24



(c) Events-48



(d) Events-100



(e) Events-200

Fig. 6: Simulation results for number of events in network.

V. CONCLUSION

In this paper, we proposed a load balancing algorithms with respect to energy requirements which balance load in data forwarding. In wireless sensor network, energy is the most valuable resource. The proposed protocol is designed for real-time multi-hop WSN. In this, each node forward data to the base station using multi-hop communication. The LBIN successfully achieve its objective by balancing energy

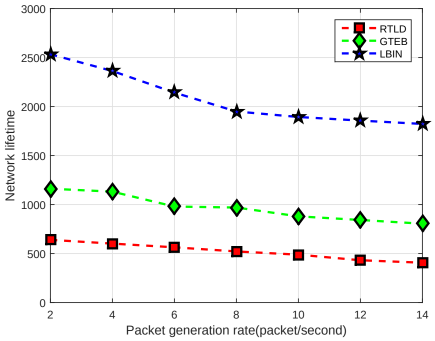


Fig. 7: Performance comparison for packet generation.

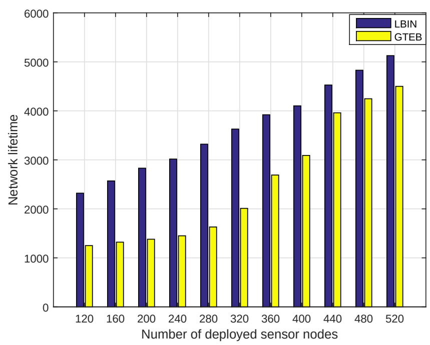


Fig. 8: Performance comparison for total number of sensor nodes.

in intermediate nodes. This resultant a longer lifetime of the network with good considerable reliability. It has been observed that the LBIN is capable of enhancing the network lifetime of the network in a harsh environment for different parameters. It is also observed that LBIN extend network lifetime significantly larger than existing protocols.

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Tanuj Kumar Mishra is a post graduate student in computer science of engineering department of Vedica Institute of Technology Bhopal, India. He received his bachelor in computer science and engineering from the RGTU Bhopal, India in 2011. His research interests include localization in wireless sensor networks.

Raj Kumar Paul is working as Assistant Professor in CSE department at Vedica Institute of Technology, RKDF University, Bhopal, India. His areas of research interest include localization, data aggregation in wireless sensor networks.