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An Energy Efficient Routing Protocol using GLOBEE

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ABSTRACT

Wireless Sensor Network is composed of multiple energy-constrained nodes that have limited computing power. Due to heavy traffic and high load in the wireless sensor environment, the network falls short in routing metrics to address the energy-constraints. This paper proposes Global Load Balancing Energy efficient (GLOBEE) Routing Protocol for Wireless Sensor Network that maximises packet delivery ratio, reduces end-to-end delay and minimises the response time by considering available network size and buffer size. Simulation result shows that the proposed protocol outperforms in aforementioned parameters than the existing protocols.

Index Terms: Wireless Sensor Networks, Global Load Balancing Energy efficient, Cluster head

I. INTRODUCTION

IN the WSN environment, the wireless connections all over the gateways are possible to be a congestion of the network. If the routing algorithm prohibits the traffic load because gateways may be overloaded while the others may not. It affects the overall network capacity. This project aims to regain from node failures and manage load balancing through break up the traffic across a set of available node disjoint paths to steadily balance the energy consumption of multiple sensor nodes. WSN is divided into numerous overlapping clusters. Clustering which categorise the nodes into clusters, where some nodes act as Cluster heads and coordinate other nodes in the clusters. A Cluster head takes the responsibility of controlling the traffic load on the wireless connections and checks the energy level in each sensor node for maximising the network life time. The protocol maximises the packet delivery ratio, reduces end-to-end delay, minimises the response time and maximises the network lifetime. It enhances the overall network capacity in the sensor network by providing energy and loads awareness different layers of a protocol stack.

Recent advancement in wireless sensor networks has forced to many new routing protocols specifically, map out for sensor networks[1]. Almost every one of these routing protocols considered energy efficiency as the ultimate objective to maximise the whole network lifetime. However, the addition of video and imaging sensors has created additional challenges. Transmission of video and imaging data requires both energy and QoS aware routing to ensure dynamic usage of the sensors and efficient access to the gathered measurements. However, with the explicit consideration of characteristics of sensor networks such as dynamic topology, high network density, power, bandwidth and large-scale deployments lead to many challenges in the design and development of sensor networks.

In [8], this protocol discovers a low cost, the delay-constrained path for real-time data regarding link cost that captures nodes energy reserve, transmission energy, error rate and other communication parameters. Moreover, the throughput for non-real-time data is maximised by adjusting the service rate for both real-time and non-real-time data at the sensor nodes.

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The energy depletion is a key design criterion for the routing protocols in wireless sensor networks[6]. Some of the conventional single-path routing schemes may not be optimal to maximise the network lifetime and connectivity[6]. This paper proposes a distributed, scalable and localised multipath search protocol to discover multiple node-disjoint paths between the sink and source nodes. This paper compares its proposed scheme with the directed diffusion, directed transmission, N-to-1 multipath routing, and the energy-aware routing protocols.

In [10], it proposes a routing metric known as Weighted Cumulative Expected Transmission Time with Load Balancing (WCETT-LB) for wireless networks. WCETTT-LB enhances the basic Weighted Cumulative Expected Transmission Time (WCETT) to integrate load balancing into the routing metric[10]. Unlike other existing schemes initiates a load balancing for wireless networks, WCETT-LB implements load balancing at mesh routers[10]. WCETT-LB gives a congestion-aware routing and traffic splitting mechanism to attain global load balancing in the network[10].Dynamic Load-Aware Routing (DLAR) protocol has been considered as the primitive route selection technique[10]. A route load is defined as the summation of a load of nodes on the route.A load of a node is defined as the number of packets buffered in the queue of the node[10]. To utilise the most up-to-date load information when selecting routes and to minimise the overlapped routes, which cause congested bottlenecks, DLAR prevents intermediate nodes from replying to route request messages[10].

In [6], routing with load balancing scheme (LBAR), the destination collects as much information as possible to choose the optimal route in terms of minimum nodal activity (i.e. the number of active routes passing through the node) [6]. By gathering the nodes activity degrees for a given route, the total route activity degree is found [6]. LBAR determines a new technique for routing known as the degree of nodal activity to exhibit the load on a node[6]. In LBAR routing information on entire paths is forwarded through setup messages to the destination[6]. Setup messages incorporate nodal activity information of entire nodes on the traversed path[6]. After collecting information on all paths, the destination chooses a path with the optimum cost value and forwards an acknowledgement to the source node. LBAR also contributes efficient path maintenance to compensate the burst links by detouring traffic to the destination[6].

1.2. Gap Analysis

A host of beforehand researched papers were not combined the two traits of the WSN, i.e., about energy constraint and load balancing. The load imbalance across the network will lead to end-to-end delay, packet drop and affects network capacity. The traffic load adversely affects the energy of the sensor nodes due to retransmitting the packets which are undergone packet drop. The sensor nodes have only limited computing power so it’s necessary to save the energy. The existing system needs to cope with energy constraints and global load balance across the network which are challenging.

II. PROPOSED WORK

(A) Review Stage

It is a combination of both energy constraints and global load balancing routing scheme. A routing metrics is introduced to handle the heavy traffic and higher load in the wireless sensor network along with energy constraints. The wireless connections throughout the gateways are likely to be a congestion of the network. If the routing algorithm does not take account of the traffic load, some gateways may be overloaded while the others may not. Energy Efficient Global Load Balancing protocol for wireless sensor network to balance the energy consumption and to divide the heavy traffic load across the different nodes. It satisfies the QoS standard by minimising the one-way delay. An approach named duty cycle is used to reduce the energy consumption of sensor nodes. It maximises the network lifetime, reduces the response time, maximises the packet delivery ratio and increases the throughput.

1) *Wireless Sensor Network*: A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensor devices that collaborate with each other to accomplish a common task (e.g. environment monitoring, object tracking, etc.) and report the collected data through the wireless interface to a centre node (sink node).
2) *Routing:* Routing is the process of moving packets across a network from one host to another.
3) *Quality of Service:* QoS (Quality of Service) refers to a collection of networking standards and techniques. It provides guarantees on the ability of a network to deliver expected results. A chunk of network performance within the scope of QoS repeatedly include bandwidth, delay time, availability, and error rate.
4) *Load Balancing:* Load balancing is a networking methodology to assign workload across different computers or network links, CPU(central processing unit), computer clusters, hard disk drives, or sensor nodes to achieve optimal resource utilisation, increase throughput, decrease response time, and avoid overload.
5) *End-to-End Delay (Latency):* End-to-End Delay is the time the packet travels from source to destination.
6) *Gateway:* A network gateway is an internetworking system able to join two networks that use dissimilar base protocols.

(B) System Architecture

Wireless Sensor Networks is divided into multiple overlapping clusters. Clustering which split the nodes into clusters, where some nodes act as Cluster head(CH) and coordinate other nodes in it. Cluster Head plays a vital role in controlling the traffic load on the Wireless connections and audits the energy level in each sensor node for maximising the life time of the networks. The entire network consists of only one common source kept in the centre of the network. If any of the nodes in the network needs the data, it gets directly from the source.

The routing is based on energy i.e. which node have the highest energy towards the destination is elected as the next intermediate hop, and likewise, the routing is established. If any of the intermediate hops gets overload means their corresponding Cluster head will release the load to the optimum neighbour of the loaded node. Cluster head election and updating energy are repeatedly done in the network.

The Figure2.1 shows the architectural design of wireless sensor network. The cluster head will check the node every 10 seconds to avoid heavy traffic, which affects the overall network performance and leads to packet drop. For every 50 seconds, the Cluster head selection will be carried out according to the energy

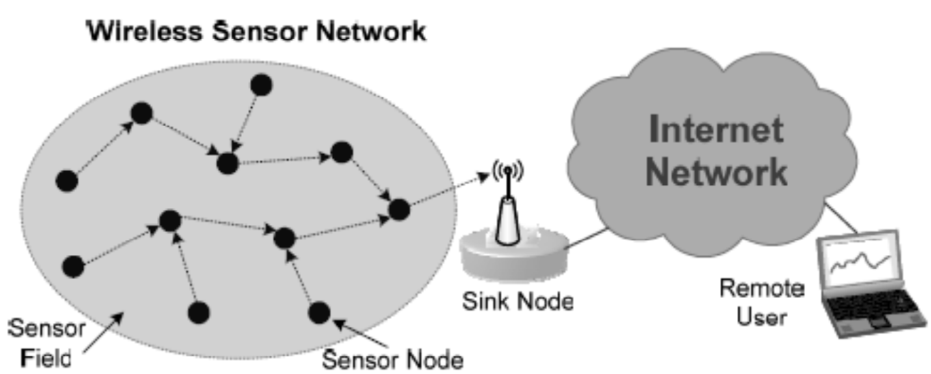

Figure 2.1: Magnetisation as a function of applied field. Note that "Fig." is abbreviated. There is a period after the figure number, followed by two spaces. It is good practice to explain the significance of the figure in the caption

level. The routing path will be changed based on energy to preserve the energy. Duty cycling is performed to reduce the consumption of energy. The nodes didn't take in place routing will goes to SLEEP state.

Most monitoring applications depends on a simultaneous idealogy where readings are carried out with a sampling frequency. In such a case two major approaches can be weighed to minimise the energy consumed by a sensor, i.e., Duty Cycling and adaptive sensing.It wake up the sensor when it needs.

In a network, each sensor node initially broadcast message to its neighbouring nodes to gather information about its neighbour nodes. The network will be divided into multiple overlapping clusters. The Cluster head selection will be based on the energy; the node within the cluster which has high unused power will be elected as a Cluster head. The Cluster head will group the nodes and discover the path to a route. It checks the energy level of all nodes and analyses the shortest path then sends the packet to destination node or sink node.

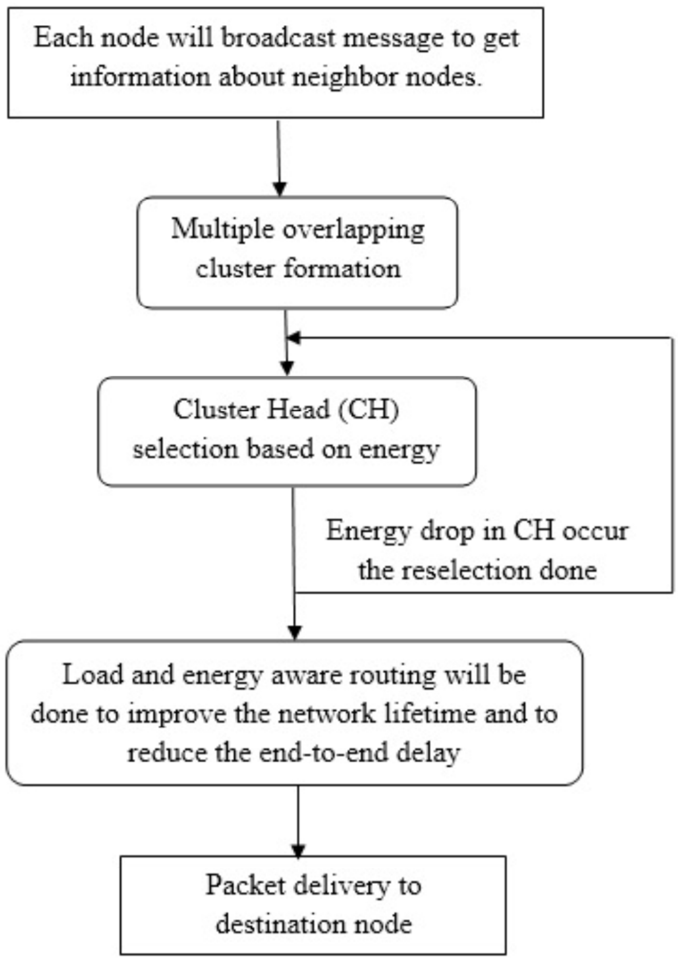

Figure 2.2: Flowchart of proposed methodology

It periodically checks the traffic load on the network to preserve the network capacity. If load disproportion occurs, then it divides the traffic across the node. Periodically the Cluster head selection will be performed as to save energy.

III. IMPLEMENTATION

(A) Network Formation

Let assume N identical nodes are distributed randomly in the network. All nodes have the equal transmission range, enough battery power to carry their sensing, computing, and communication activities. The network is completely connected and data can be sent from one node to another in multi-hop basis. Each node in the network is allocated with a unique ID and all nodes are ready to participate in communication process by forwarding data. Furthermore, let's assume that the nodes are stationery for their lifetime. Additionally, at any time, let's assume that each node can compute its unconsumed energy (the remaining energy level), and its available buffer size (remaining memory space to cache). It assumed that all nodes are coactive and trusted.

At network initialization, each node which is going to participate in the network will be in active mode, and the nodes which are available, but not going to participate in data transmission will go to sleep state to save their battery power.

Each node should be aware of the nodes which are within in its transmission range. They are identified by the nodes which are reachable by the current nodes.

NH (i) = i ≠ i' where distance (i, i') ≤ range

Calculate the mobility and battery power of each node. The nodes mobility causes changes in the network topology. Each mobile node broadcast a HELLO message to its neighbouring nodes to have enough information about its neighbours can deliver it with the highest quality data. Each mobile node maintains and updates its neighbour information using its adjacent table during this phase. The adjacent table contains information about the list of an adjacent host of the network node. Fig 2.4.1 illustrates the structure of the HELLO message.

Source ID	Hop Count	Residual Energy	Buffer Size

Figure 3.1: Hello Message Structure

Hop count gives the distance in hops for the message from its originator. Residual energy will give the current nodes energy level, and buffer size indicates the nodes buffer's available size. Initially, it will be same for all nodes.

(B) Cluster Head (CH) Selection

The entire network is partitioned into Cluster with one node in the cluster will act as a Cluster head (CH). Energy is a critical source in Wireless Sensor Networks. A cluster head is elected for its relatively high energy capacity and its low mobility because frequent link break is one of the constraints in WSN, which happens due to the mobility of the nodes. When the mobility increases, automatically the network-load imposed by the increased cluster-head update also increases. A cluster head consumes an enormous amount of energy than the usual node since it has other functionalities: coordination among the members, cluster maintenance and load balancing. Mobility plays an important role for cluster head election. If Cluster head has high mobility, then CH election has to conduct again. Because of the additional functionalities for which the Cluster head is designed, its energy is likely to be shattered.

A minimum threshold of energy is defined for each cluster head. If it is reached, the cluster heads election procedure is started immediately. If at some specific time a node is separated from its current cluster and attached to another cluster, the corresponding cluster heads will update their members' in the routing table. If a node leaves its cluster and doesn't find any other cluster to append itself, the cluster heads election procedure is invoked. The cluster formation is implemented within the following steps:

- The Cluster Head is selected based on the weighted sum W = w1D1 + w2D2 + w3D3

Where D1 is the power level, D2 is the connectivity factor, and D3 refers to stability index and W1, W2 and W3 are the weighting factors.

- Cluster head will be chosen for the node which has the maximum W value.
- A head cluster stores the information concerning its members (ID, status, load & energy).
- It can detect if any other cluster head is entered in its cluster. In these cases, one of the cluster head is to give up its role. In our case, it is the one which has less energy. Once CH is selected it will be informed to all its members.
- If a node receives a message from CH over one time, then it is assumed that the node is identified to be a gateway or in the reachable range of over cluster head.
- Every unconsidered node undergoes the election method. After the choice of thought about nodes, the election algorithm will be terminated.
- The number of nodes per cluster is limited to avoid the cluster head congestion and for better resources utilisation.

(C) Energy Calculation at each node

After initialization phase, each node has complete information to measure the cost function for its neighbouring nodes. Then, the sink node locally computes its next node using the cost function and sends out an RREQ message to its most preferred node.

The purpose is to find the shortest path with the largest minimum residual energy to ensure real-time data transmission quality. A proper shortest path with largest average residual energy has to be obtained to reduce the probability of route collapse due to power exhaustion.

Energy cost function is used by the node to select the next hop during the path discovery phase. Each node needs some power to receive and transmit a packet. The energy cost function is calculated as the sum of node’s available energy, a threshold value of a node (minimum energy needed by a node to survive) and the power spent on overhearing. Let LN be the set of active neighbour nodes of node j. Each node has to spend some energy for overhearing from its neighbours.

$$Enew(j) = (Etrm(j) - Erec(j)) + Ethreshold + Eoverheard(j) * LN$$

In this cost function, we only consider the residual energy of node j but not i. Because node j consumes energy for data reception and transmission if it is selected as the next hop for node i. We do not consider node i, because whatever node j is, node j still needs to spend the same amount of energy on data transmission.

(D) Global Load Balancing Algorithm

A principal role of a cluster head is the maintenance of load balancing of each node in its cluster. It is the Principal Coordinator(PC) of its cluster; it periodically collects information about each member node’s energy and load values in its cluster. These data are stored in the members table. When a node reaches a low energy state, a warning message will be sent to its cluster head. Later, it consults with the member’s table and chooses the one which has the smallest load and the highest energy capacity. Then it sends a response message to the respective node. Whenever a new node joins a cluster, or an existing node exits it, the members table is updated.

The global load balancing algorithm works as follows:

- Cluster head nodes maintain their member’s tables to control their member’s loads. Periodically, each node in a cluster sends a HELLO message and communicates its energy and load values to the cluster head which updates its table.

- Two thresholds are defined for each node: the maximum load and the minimum energy. When this is reached, the node knows that it is going to disappear soon, so it decides to transfer its load to another node.
- Each node checks its load as well as energy and compares them with the two thresholds.

Two cases are considered:

Case 1: if nothing happens (two thresholds are not reached), the load balancing algorithm is not invoked.

Case 2: if one of the two thresholds is reached (or both of them), the node sends a message (Discharge Request) to its Cluster head. Cluster head chooses the one which has the smallest load and the highest energy capacity.

If one node is found, the CH sends a positive response (message) to the requesting node. If several nodes are found, it chooses one arbitrarily. If no node is found, the cluster head diffuses a solicitation message to its different neighbour's cluster heads. If it is positive, a receiving node is designated, and a quantity of work is transferred to it. If a response is negative, the node is constrained to execute the work locally.

Route discovery

If a source node needs a path towards the destination and no one is stored in a cache, it transmits an RREQ packet to all its neighbours with Residual Energy and PML field initialized to 0.

Source Addr	Request ID	Source Seq No.	DestAddr	DestSeq No.	Hop Count	Residual Energy	PML

Figure 3.2: New Structure of RREQ

When the intermediate node receives an RREQ packet, it checks if it is the first time or not. If it is the first time, the node adds a routing entry in its routing table, and its current average load and its remaining energy value in Residual Energy and PML field then propagates the RREQ packet.

Otherwise, any intermediate node compares its remaining energy to the value of Residual Energy field in the RREQ; if the value is low, it changes the value of Residual Energy by its proper value. The node also compares its routing table load with the RREQ. If the RREQ load is higher than the current nodes, load it drops the RREQ. Else add its current average load to the value of PML filed of the RREQ packet. Then, the intermediate node appends its identifier to the RREQ packet and rebroadcasts it to its neighbours. This process will be continued until the RREQ packet arrives at the destination.

Structure of routing table entries

Each entry in the routing table consists of following fields: Source: identifier of source node

Sequence number: consists of RREQ sequence number.

Route: contains the path traversed by RREQ packet.

Residual Energy: maintains the minimal residual energy of nodes

Destination
Sequence_number
Hop count
Route list { (nexthop1, hop count1, Res. Energy1, PML1), (nexthop2, hopcount2, Res. Energy2, PML2), … }
Timeout

Figure 3.3: Structure of routing table

Route selection

After the first RREQ packet, the destination node waits for a certain period "Wait_time" before starting route selection procedure. When this period expires, destination node selects as a primary route.

After the selection of the primary route, destination node sends an immediate reply to the source node.

RREP

If a node has a valid route to the destination, it sends a Route Reply Message (RREP) back to the source.

Message format:

Source Addr	Des Add	DestSeq No.	Hop count	Life Time	Residual Energy	PML

Figure 3.4: Structure of RREP

Route maintenance

If an intermediate node identifies a link failure, it transmits an RERR message to the upstream direction of the route. Every node receives the RERR message, removes each entry in its route cache that uses the broken link, and forwards RERR message to the next node towards the source node. If the source node has no route, then it starts a new route discovery phase.

When the destination node receives the RREQ packet, it sends an RREP packet to the reverse route created by the intermediate nodes.

GLOBAL_AODV Algorithm Pseudo-Code

- RREQ: Route Request Packet
- RREP: Route Reply Packet
- AVG_L: Average load of a node
- PML: Load value of nodes in the RREQ packet
- RTL: Routing Table LOAD
- ML_THRESHOLD: Max. Accepted average load for a node

```
// in the source node
Initialize Residual Energy and PML to 0;
Broadcast the RREQ;
   IF (message type=RREQ) THEN
      IF (the node is the source) THEN
         Drop RREQ
   END
   END
   (When a node receives a routing message)
   IF (message type = RREQ)
   {
    IF (RREQ has been heard before) THEN
   // Original AODV would drop the RREQ message
   IF (RTL > PML) THEN
   (RTL = PML)
   ELSE
   {Drop RREQ
   END
   ELSE // if this is first RREQ then update RREQ ->MAC_LOAD
   {PML = PML + CURR_MAC_LOAD
   Forward        RREQ}
   END
   }
   IF (message type = RREP)
   {
```

```
IF (RREP has been heard before) THEN
IF (RTL > PML) THEN
(RTL = PML)
ELSE
Drop RREP
END
ELSE
{// Original AODV would forward RREP
IF (CURR_MAC_LOAD < ML_THRESHOLD) THEN
PML = PML + CURR_MAC_LOAD
(Forward RREP)
ELSE
(drop RREP) }
END
    END
}
// in the destination node
On receiving an RREQ:
Compute average residual energy of the received path (ui)
Eavg = 1/n Σ_(i=1)^n'%(E(ui))
IF this is the first RREQ from some source THEN
Save average residual energy, PML and hop count in the route table;
Reply with an RREP to the source node;
ELSE IF RREQ received previously THEN
    //subsequent RREQ from other nodes
IF (Hop count of this route<= hop count in RT) AND
(PML <= RTL) OR (Residual Energy <= RT residual energy) THEN
Replace average residual energy, PML and hop count in the route table with that of this route;
Reply with a RREP to let the source node use this new route;
    ELSE
       Drop this RREQ;
    END
END
```

IV. PUBLICATION PRINCIPLES

(A) Performance Evaluation

The performance and validate the effectiveness of this enhancement are evaluated and compared to AODV through simulation. The simulation is done regarding Delivery Ratio, Throughput, Average Energy and Packet Drop.

1) Packet Drop: It gives the ratio of the packets delivered to the destination, which reflects the degree of reliability of the routing protocol Fig 4.1 gives the Packet Drop in our work. There is no packet drop since the load and Energy are monitored, and whenever there is an overload at any node, then the Cluster Head is informed immediately. The neighbour nodes which can direct the packets are given route information and packets are redirected to that node. So no or very less chance of Packet Drop compared with AODV.

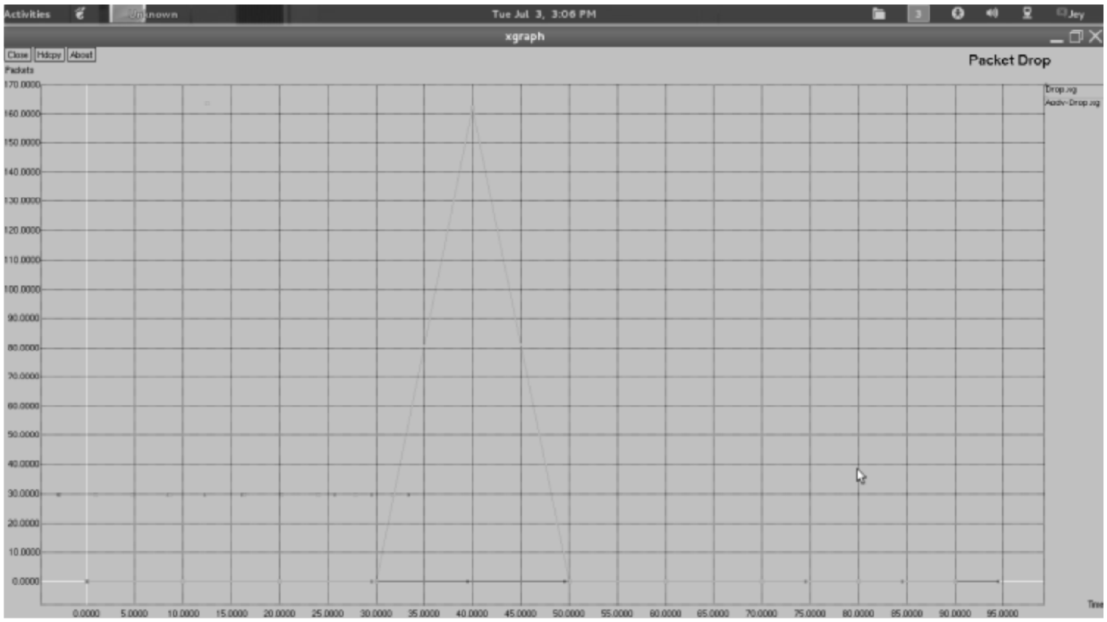

Figure 4.1: Packet Drop

2) Packet Delivery Ratio: It gives the ratio of the packets delivered to the destination which generated by the sources, which reflects the degree of reliability of the routing protocol. The results also show that the packet delivery fraction reduces with increase in load in the network.

From Fig 4.2, it can be seen that, under low load conditions, the performance of the three protocols is identical, as very few packets are dropped even if a protocol makes a poor decision.

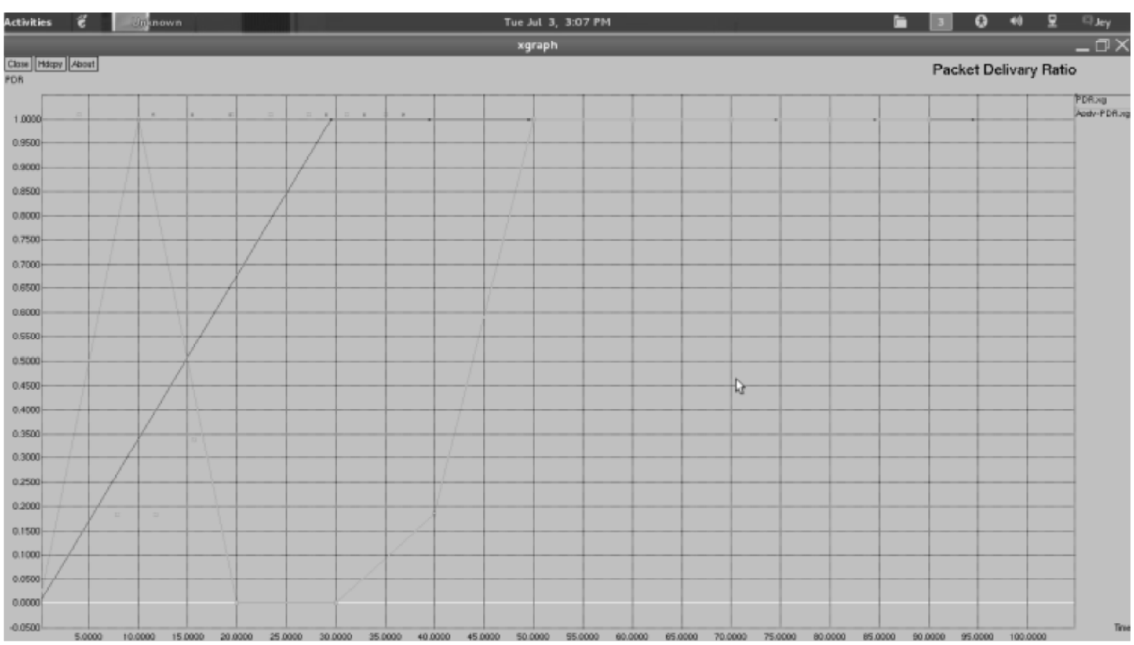

Figure 4.2: Packet Delivery Ratio

3) Throughput: Throughput is the amount of a successful message delivered over a physical or logical link, or pass through a certain network node. It can be measured in bits per second (bps), and sometimes in data packets per second.

Paths generated by the ad-hoc routing protocols can deviate far from the shortest path. Due to the mobility of the nodes in ad hoc networks, the formation of routing paths may change significantly while the connectivity is intact. Most of the previously proposed on-demand routing schemes do not initiate a new path discovery process until there is a link failure (a node fails or moves out of range). This leads to the reduction in throughput and increases End to End Delay as shown in Fig 4.3.

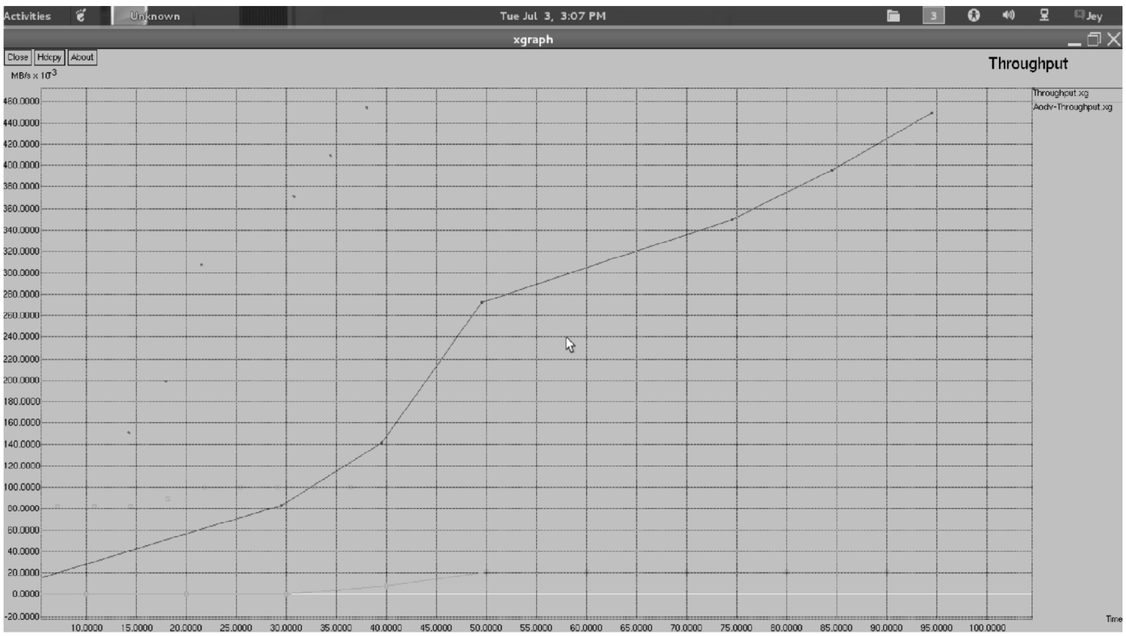

Figure 4.3: Throughput

4) Average Energy: It measures the energy consumed per delivered data packet. It is expressed as

$$\frac{\sum EnergyExpenedByEachNode}{TotalNumberofDataPackectsDelivered}$$

Energy Consumption Route discovery in AODV is energy intensive. The data packet carries pointers to the full route in itself, which incurs additional energy overheads during routing compared to data packets of routing protocols that carry only neighbourhood information. The additional energy consumed is proportional to network size.

With an operating environment that is plagued with dynamically occurring link disruptions and node failures, it may be very difficult to establish a full route from source to the destination at a given point in time. The source node keeps on sending the packet but will not receive a definite route response from the destination.

There is a significant reduction of the power consumption after load balancing. In this case, the nodes can survive for long periods of time; this involves a good maintenance of the network stability as shown in Fig 4.4.

V. CONCLUSION

This paper presented some schemes for load and energy balancing in wireless sensor networks. Energy-constrained routing and load-balance routing are mutually related and by employing one, the other is

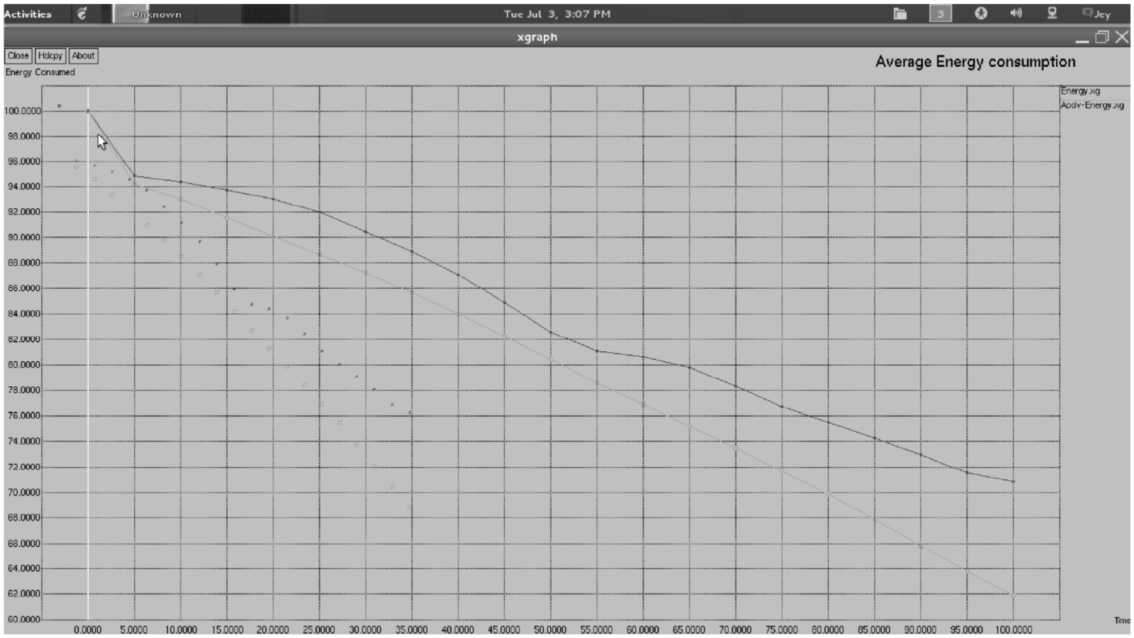

Figure 4.4: Average Energy

improved. However, when both of these metrics are taken into account, more significant results concerning network lifetime can be achieved. In the proposed strategy a load balanced routing path is selected among all feasible paths from weight value calculated for each path. In a feasible path, the higher the weight value, the higher is its suitability for effective traffic distribution. The performance of the proposed work is evaluated with NS-2 simulation environment. The parameters taken into consideration are Packet Drop, Packet Delivery Ratio, Throughput and Average Energy Consumption.

VI. FUTURE WORK

In future, the backup route can be intended to improve the routing metrics. The purpose of a backup route is if the most preferred route fails, the next best route (according to administrative distance) succeeds on the next attempt. If the route installed in the routing table fails for some reason, the routing table maintenance process called each routing protocol process that has registered a backup route and asked them to reinstall the route in the routing table.

The aware interference routing can be implemented to find paths that are better regarding reduced inter-flow and intra-flow interference. The WSN security can be introduced to block the attackers and to provide authentication and data integrity

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