Performance Enhancement of Zone Routing Protocol in MANET for Reliable Packet Delivery

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Abstract—**Mobile Ad-hoc network (MANET) is infrastructure less network in which nodes are mobile, self reconfigurable, limited battery powered. The key challenge of ad hoc networks is the design of dynamic routing protocols that can efficiently establish a route between pair of nodes. As nodes in MANET are limited battery powered, they may get totally discharged during active communication, causing packet drops resulting in low packet delivery ratio. The aim of this paper is to reduce the packet drops due to node failures thereby increasing packet delivery ratio. Our modified protocol named Improved Zone Routing Protocol (IZRP) makes use of energy factor, which is a function of residual energy of the node and it selects the nodes with good battery lifetime to establish a path between source and destination. The goal of this work is to find a solution to address the link failure challenges in improving the reliability of packet-delivery services in MANETs. To analyze relative performance of modified protocol IZRP over ZRP, we performed various trials using QualNet 5.0 simulator. The performance of these routing protocols is analyzed in terms of packet delivery ratio, end to end delay and energy consumption. It is observed that IZRP performs better than existing ZRP in terms of packet delivery ratio, end to end delay, throughput and energy consumption.**

Keywords— MANET, protocols, ZRP, routing zone.

I. INTRODUCTION

Over the last couple of years, importance of wireless communication in our day-to-day life has so much increased that a world without it is no longer imaginable for most of us. In conventional wireless communication, there is a need of base station for communication between two nodes. These base stations lead to more infrastructures and more cost. [1] While an ad hoc network facilitates communication between nodes without any fixed infrastructure or central administration. All nodes (mobile/immobile) of this network can be connected to each other dynamically in an arbitrary manner and act as routers which discover and maintain routes to other nodes in the network. The mobile nodes that are in radio range of each other can directly communicate, whereas others need the help of intermediate nodes to route their packets. The scopes of the ad-hoc network are also associated with dynamic topology changes, bandwidth-constrained, energy constrained operation, limited physical security, mobility-induced packet losses, and limited wireless transmission range, broadcast nature of the wireless medium hidden terminal problem, and packet losses due to transmission errors.

As Mobile hosts are free to move randomly; thus the network's topology may change frequently and unpredictably. Due to this uncontrolled and dynamic nature, ad hoc networks are prone to frequent route breakages that resulting in increased packet loss and delay. This phenomenon can further cause performance degradation, especially for voice over MANET, where delay and Packet Loss Rate (PLR) should be restrained. For example, Voice over Internet Protocol (VoIP) is widely used nowadays for long-distance voice communication due to its competitive cost. The main requirements for voice communication are delay bound and low packet loss rate. Network layer is used for routing of packets from source to destination. The main objective is to design routing protocol in such a way that it delivers all the packets reliably over the network.

The paper is organized as follows. Section II explains different types of routing protocols. Section III discusses the basics of Zone Routing Protocol (ZRP) and study of performance enhancement schemes for hybrid protocols. Section IV discusses the proposed modification in ZRP. Section V represents the simulation details and Quality of Service (QoS) parameters. Section VI discusses results obtained by QualNet simulator. Finally section VII concludes the paper with future work in section VIII.

II. CLASSIFICATION OF ROUTING PROTOCOLS

In MANET, each node acts both as a host (which is capable of sending and receiving) and a router which forwards the data intended for some other node. [2] The routing of data packets from source to destination is controlled by different routing protocols. In general, existing routing protocols can be classified as either proactive, reactive, or a hybrid of the two.

A. Proactive Routing Protocols

In proactive routing, each node maintains correct routing information to all other nodes in the routing tables at all times by propagating updates throughout the network. Because the network routing tables are constantly maintained, routing for a packet is known without additional setup delay. The weakness of this routing scheme is that a large portion of bandwidth is used to keep the routing information up-to-date. Many proactive routing protocols have been proposed, for e.g.

Destination Sequence Distance Vector (DSDV), Optimized Linked State Routing (OLSR), etc.

B. Reactive Routing Protocols

In reactive routing, routing information is collected only when it is needed, and the reactive route discovery is usually based on a query–reply exchange, where the route query is flooded through the network to reach the desired destination. When the destination is reached, route reply will be sent back to the source. The weakness of this routing scheme is excessive setup delay. Several reactive protocols have been proposed such as Ad hoc On-demand Distance Vector (AODV), Dynamic Source Routing protocol (DSR), Dynamic MANET On-demand (DYMO), etc.

C. Hybrid Routing Protocols

Hybrid routing protocols are a combination of both proactive and reactive routing, where proactive maintains route in the zone and reactive maintains route between the zones. They attempt to take advantage of the strengths of purely proactive and reactive routing, while minimizing the weaknesses of both forms of routing. Several hybrids routing protocols have been proposed such as Zone Routing Protocol (ZRP), Zone-based Hierarchical Link State (ZHLS), etc.

III. ZRP OVERVIEW AND RELATED WORK

The Zone Routing Protocol, as its name implies, is based on the concept of zones. This protocol relates one of the facts that distant nodes communicate with each other less often than the neighbouring nodes. [3] Therefore, ZRP reduces the proactive scope to a zone centred on each node and reactive approach outside the zone.

A. Routing Zones

A routing zone is defined for each node separately, and the zones of neighbouring nodes overlap. The routing zone has a radius ‘r’ expressed in hops. The zone thus includes the nodes, whose distance from the node in question is at most ‘r’ hops. An example routing zone is shown in fig. 1, where the routing zone of S includes the nodes A–G, but not H. In the illustration, the radius is marked as a circle around the node in question.

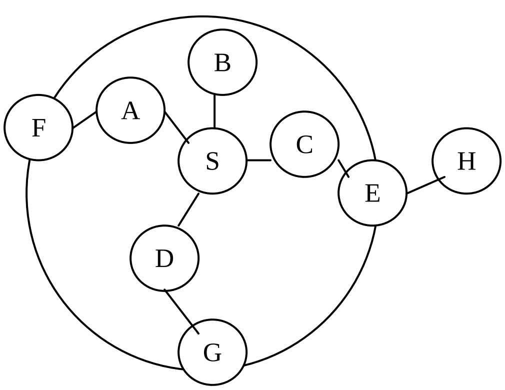

Figure 1. Routing zone of node‘s’ with radius of 2 hops

The nodes of a zone are divided into peripheral nodes and interior nodes. Peripheral nodes are nodes whose minimum distance to the central node is exactly equal to the zone radius r. The nodes whose minimum distance is less than r are interior nodes. In fig. 1, the nodes A–D are interior nodes; the nodes E–G are peripheral nodes and the node H is outside the routing zone.

B. Architecture

ZRP routing is basically performed using two separate routing components: the proactive routing component, IntrAzone Routing Protocol (IARP) and the reactive routing component, IntErzone Routing Protocol (IERP). IARP [4] is a family of proactive link-state routing protocols. It periodically computes the route to all intrazone nodes (nodes that are within the routing zone of a node) and maintains this information in a data structure called IARP routing table. Correspondingly, IERP [5] is a family of reactive routing protocols that offers enhanced route discovery and route maintenance services based on local connectivity monitored by IARP.

Since IARP employees a proactive link state routing protocol for maintaining intrazone routing information, the first thing which becomes necessary for IARP is to know about the neighbours of a node. In order to learn about a node’s direct neighbours and possible link failures, IARP relies on a Neighbour Discovery Protocol (NDP) provided by the MAC layer. NDP transmits “HELLO” beacons at regular intervals. Upon receiving a beacon, the neighbour table is updated. Neighbours, for which no beacon has been received within a specified time, are removed from the table.

For route discovery by IERP, there are two mechanisms: classical flooding i.e. broadcasting and selective bordercasting. The Broadcasting is similar to typical reactive protocols while Bordercasting utilizes the topology information provided by IARP to direct query request to the border of the zone. The bordercast packet delivery service is provided by the Bordercast Resolution Protocol (BRP). By employing query control mechanisms, route requests can be directed away from areas of the network that already have been covered. [6]

C. Routing

A node that has a packet to send first checks whether the destination is within its local zone or not using information provided by IARP routing table. If the destination is within the zone, then the IARP routing table must have a valid route to the destination. So in this case, the packet is routed proactively to the intrazone destination. Reactive routing is used if the destination is outside the zone.

The reactive routing process is divided into two phases: the route request and the route reply. In the route request, the source sends a route request packet to its peripheral nodes using BRP. If the receiver of a route request packet knows the destination, it responds by sending a route reply back to the source. Otherwise, it continues the process by bordercasting the packet. In this way, the route request spreads throughout the network. [6]

The reply is sent by any node that can provide a route to the destination. To be able to send the reply back to the source node, routing information must be accumulated when the request is sent through the network. The information is recorded either in the route request packet (source routing approach), or as next-hop addresses in the nodes along the path similar to AODV. In the first case, the nodes forwarding a route request packet append their address and relevant node/link metrics to the packet. When the packet reaches the destination, the sequence of addresses is reversed and copied to the route reply packet. The sequence is used to forward the reply back to the source. In the second case, the forwarding nodes record routing information as next-hop addresses, which are used when the reply is sent to the source. This approach can save transmission resources, as the request and reply packets are smaller.

D. Performance Enhancement Schemes for hybrid protocols

Several adaptive zone radius and efficient routing techniques have been proposed to enhance the throughput of hybrid routing protocols in MANET. Zone-Based Routing (ZBR) protocol, where the network area is divided into fixed none-overlapping square zones is proposed in [7]. There is a zone-head in each zone that acts as a router in the network and maintains information of its member nodes. A Path is a collection of ID numbers, which represent the specific zones the path traverses.

Fisheye Zone Routing Protocol (FZRP) is proposed in [8]. FZRP provides the advantage of a larger zone with only a little increase of the maintenance overhead. Two levels of routing zone are defined in FZRP: the basic zone and the extended zone. Different updating frequencies of changes of link connectivity are associated with the basic zone and extended zone.

Adaptive zone radius protocol (AZRP) is proposed in [9] in which the performance of ZRP can be improved, just using variable zone radius by every single node in the network. During low node mobility and packet traffic periods, small zone radius is selected while during high node mobility and packet traffic, large zone radius is selected. Each node has its own zone radius: faster node keeps a smaller zone radius; while slower node keeps a larger zone radius.

Amit Jaiswal and Pardeep Singh [10] proposed a New Scheme of Adaptive Zone Routing Protocol (NSAZRP). In which, each node is assigned a zone radius depending upon its mobility pattern. Nodes with high mobility are assigned smaller zone radii and stationary nodes are assigned highest radii. Depending upon the calculated speed, they assigned different zone radii to the nodes.

The proposed Zone and Link Expiry based Routing Protocol (ZLERP) [11] an enhancement to existing ZRP that offers better routing services. In ZLERP, stability of link is determined on the basis of signal strength received at periodic time interval by node which is on the periphery of other node's zone. This can be done with the help of NDP in ZRP by introducing additional field "signal strength received" in neighbor table of each node. Depending on the difference between the signals strengths received periodically, we can predict the relative mobility.

IV. PROPOSED IDEA

In this section, the modification steps for ZRP protocol are discussed. The modified protocol is named as IZRP. The ZRP protocol is modified in route discovery process. Basic idea of IZRP is based on the idea that querying can be done more efficiently than flooding to find route for forwarding data. We used the energy factor of the node for selection of energy efficient path.

A. Energy Factor Calculation

Yang Qin et. al. [12] have proposed an energy efficient routing metric called as Energy factor which is defined as:

$$\text{Energy factor} = \frac{\text{Remaining energy of a node}}{\text{Initial energy of a node}} \qquad (1)$$

where, remaining energy in (1) is defined as:

$$\text{Remaining energy } = \text{Initial energy} - \text{Consumed energy} \qquad (2)$$

They have used this metric for multipath concept where the most energy efficient as well as shortest path is selected to deliver the data packets. In our method, we use this metric to select the next hop node while discovering the path to destination. We define this energy-efficient routing metric for selecting the node having sufficient energy to route the packets.

B. Algorithm for IZRP

At source node:

a) Whenever source S wants to send some data to destination D, then S first checks its routing table for path to destination.
b) If path is not readily available then it initiates route discovery process.
c) Using pure flooding, Source node S broadcasts Route Request (RREQ) packets to all its neighbours containing destination address.

At intermediate node:

d) Upon receiving RREQ packet at intermediate node, first it checks its Energy factor.
e) If Energy factor is above the Threshold then it forwards this RREQ packet to the next node in the network otherwise it simply discards the packet.
f) This way, nodes with low energy level is prevented from participating in route acquisition process.
g) This process goes on until the destination node is found.

if (EF of the node ≥ Threshold)
    (Process the packet and forward it to next node)
else
    (Discards the RREQ packet)

At destination node:

h) When the destination node is found, it generates the RREP packet with source as new destination and sends it back to the source and path is established with all intermediate nodes having good battery life preventing the packet losses due to node failures.

V. SIMULATOR DETAILS AND QOS PARAMETERS

We have carried out simulations using the QualNet Simulator 5.0. QualNet provides a comprehensive environment for designing protocols, creating and animating network scenarios, and analyzing their performance. It can be used for applications in wireless, wired, and mixed network platforms. QualNet architecture is divided into three levels, Kernel, Model Libraries and Graphical User Interface (GUI).

A. Simulation Models

A simulation model mainly consists of Energy Model, Battery Model, Traffic Model and Mobility Model. User specified energy model is used which is shown in table 1.

TABLE I. ENERGY MODEL PARAMETERS

Parameters	Value
Transmission current load (mA)	280
Reception Load (mA)	204
Idle current load (mA)	178
Sleep current load (mA)	14
Supply voltage of interface (v)	3

In all simulations, mobile nodes move around a square region of size 1000 m × 1000 m according to Random waypoint mobility model. We used Linear Battery Model for the experimentation and Constant bit-rate (CBR) traffic sources are used. The source-destination pairs are spread randomly over the network.

B. Quality of Service (QoS) Parameters

- Packet Delivery Ratio (PDR)

Ratio of number of packets successfully received by destination nodes to number of packets sent by source nodes.PDR describes information about packet loss rate [13]. Higher value of PDR for network indicates the better reliability of protocol.

- Average End to End Delay

End-to-end delay indicates how long it took for a packet to travel from the CBR source to the application layer of the destination [13]. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times.

- Throughput

The throughput is defined as the total amount of data (in bits) received at the destination node divided by the total time taken to receive all the packets. The throughput is measured in bits per second (bit/s or bps).

- Energy Consumed

Total energy consumed required to transmit all data packets to destination node. To achieve better energy efficiency, energy consumed should be as low as possible. The less energy consumption by nodes extends the network lifetime i.e. nodes in the network can communicate for longer period.

VI. SIMULATION RESULTS AND ANALYSIS

Pause time and speed are considered to be important aspects of MANET. Here we have compared different QoS parameters with respect to changes in pause time and speed independently.

TABLE II. PARAMETERS FOR FINDING THE EFFECT OF PAUSE TIME AND SPEED

Parameters	Pause time	Speed
Number of mobile nodes	50	50
Network size (m*m)	1000*1000	1000*1000
Simulation duration (s)	300	300
Packet size (bytes)	512	512
Pause time (s)	30,60,90,120,150	30
Speed (m/s)	10	1,5,10,15,20,25
Data packet rate (packets/s)	1	1

A. Impact of Variation of Pause time

In this section, we will discuss the effects of variation in pause time on performance parameters.

From fig. 2, it can be seen that IZRP outperforms the other two in delivering packets to the destination. Here, PDR of IZRP is successfully increased to 60% even in high mobile network which is well suited for real time video communication applications. The delay for IZRP, from fig.3 shows little increment (approx. 2-4 ms) which is negligible as per the ITU standard G.114 which states that of one-way, end-to- end delay ensures users' satisfaction for telephony applications. From fig.4, throughput increases as pause time increases. IZRP shows better value of throughput for all cases over ZRP. Fig.5 depicts that energy consumption decreases as pause time increases and energy consumed by IZRP is more or less same as ZRP.

B. Impact of Variation of Node Speed

In this section, node speed is varied to study the impact of node mobility on network parameters.

As shown in fig.6, PDR for IZRP is consistently better than ZRP when the speed is varied. Fig.7 shows that delay decreases with increase in speed of nodes. IZRP takes less time than ZRP to deliver more number of packets to the destination as speed increases. From fig.8, it is clear that IZRP shows improvement in throughput as compared to ZRP. From fig. 9, energy consumed for IZRP and ZRP is almost same. So we can say that IZRP performs better than other two in terms of all three QoS parameters.

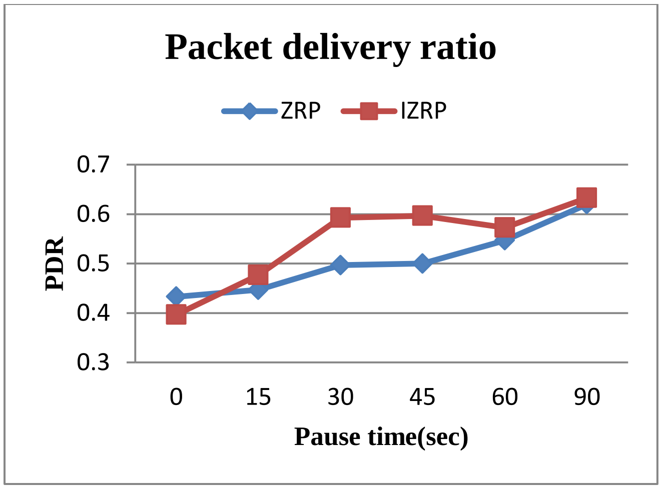

Figure 2. PDR vs. Pause time

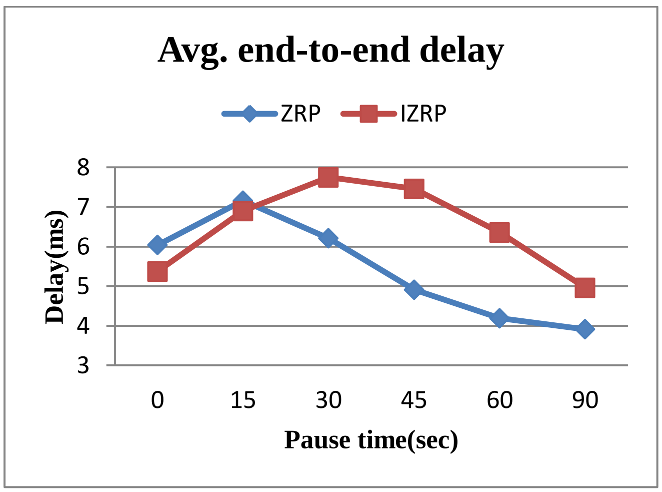

Figure 3. Avg. End-to-End Delay vs. Pause time

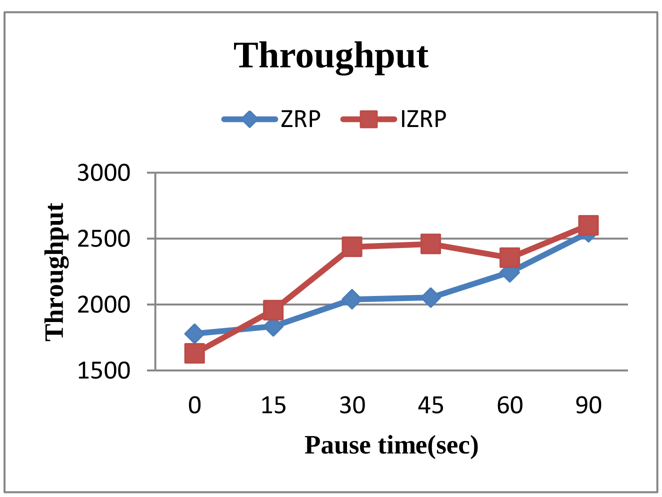

Figure 4. Throughput vs. Pause time

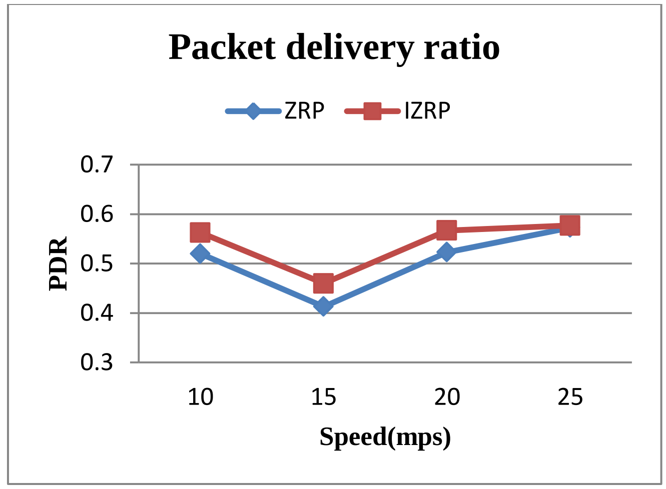

Figure 6. PDR vs. Speed

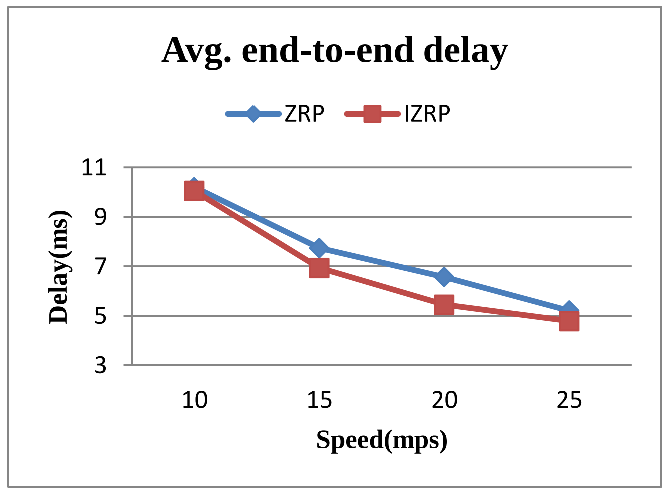

Figure 7. Avg. End-to-End Delay vs. Speed

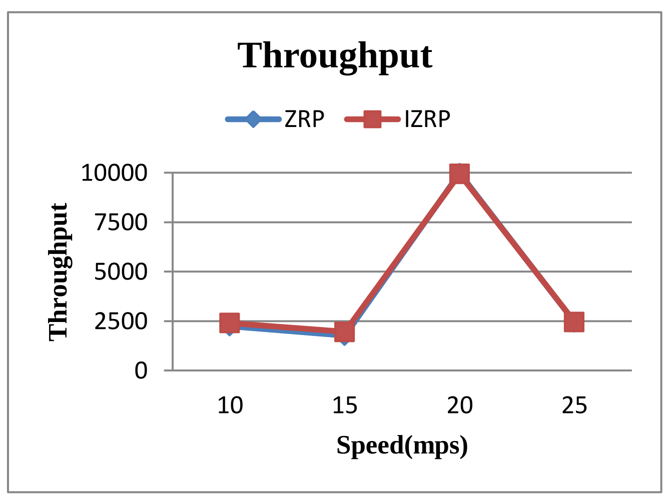

Figure 8. Throughput vs. Speed

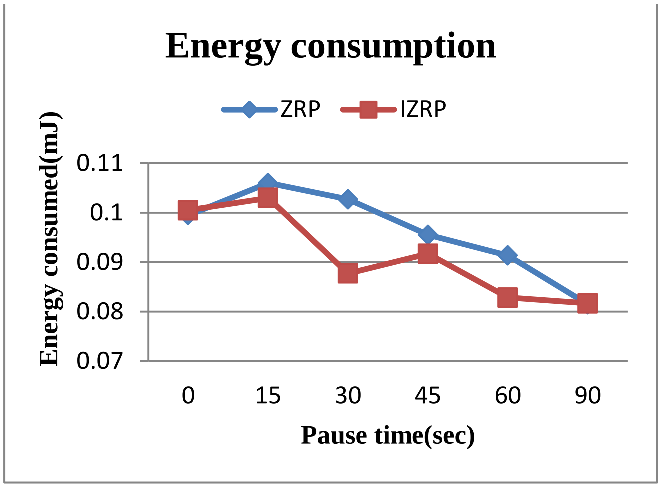

Figure 5. Energy consumption vs. Pause time

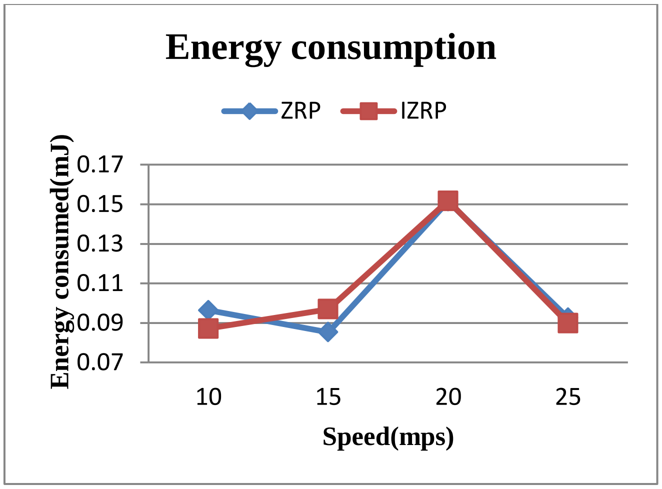

Figure 9. Energy consumption vs. Speed

VII. CONCLUSION

We compared IZRP and ZRP protocols considering the performance metrics such as packet delivery ratio, end to end delay, throughput and average energy consumption. Simulations have been performed under different network conditions to analyze the performance of modified protocol. The analysis of results showed that there is remarkable change in PDR and throughput whereas slight change in delay and energy consumption. IZRP performs better in terms of PDR, throughput and energy consumption over ZRP in moderate network with high mobility and delay increases for IZRP at larger pause times because of path selection with the nodes having good battery lifetime. IZRP improves PDR by up to 10% while consuming equal or less energy as ZRP, thus improving both, packet delivery and network lifetime.

VIII. FUTURE WORK

This work can be extended to analyze the performance of IZRP for different performance metrics such control overheads and jitter. Also the performance of IZRP can be compared for higher packet rate.

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