Effect of Varying Node Density and Routing Zone Radius in ZRP: A Simulation Based Approach

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***Abstract*— The Zone Routing Protocol (ZRP) is a hybrid routing protocol for MANET which combines the advantages of the proactive and reactive approaches by maintaining an up-to-date topological map of a zone centered on each node. Routes within a routing zone are usually maintained by a table driven proactive routing approach whereas for destinations outside the routing zone, ZRP employs a Reactive Routing mechanism thus making an attempt to utilize both the features of proactive as well as reactive routing policy. In this work, a simulation based study has been carried out to explore the behavior of Zone Routing Protocol (ZRP) under an environment where the density of the nodes in the network and more importantly the radius of the routing zone vary considerably. This will throw an insight on the operation of the protocol and understand its sensitivity on varying and fast changing network topology which is most common in any form of wireless networks.**

Keywords- Hybrid Routing, Proactive Routing; MANETs; Reactive Routing; ZRP;

I. INTRODUCTION

Ad hoc network is a multi-hop wireless network, which consists of wireless mobile hosts forming a temporary network without the aid of any centralized administration or standard support services regularly available on the wide area network to which the host may normally be connected [1].

Nodes, in the ad-hoc Network are free to move around causing the network topology to frequently change thus resulting in frequent route updates within the network. Further, the limitation imposed on the transmission range of the nodes have lead to the development of routing policy where packets are allowed to traverse through multiple nodes thus making each node act as terminal as well as router [2]. Since the nodes in Ad hoc networks are free to move over a certain area which results into frequent change in the network topology, design of suitable routing protocol is essential to adapt the dynamic behavior of the network. Significant research activity over the last few years has been concentrated on popular proactive and reactive routing protocols (such as DSDV, ADOV, DSR etc). However not enough attention was given on hybrid routing protocols which combines the feature of both proactive and reactive routing mechanism. This literature makes an attempt not only to understand the behavior and operation of Zone Routing Protocol (ZRP) but also makes a sensitivity analysis on the same by varying the node density as well as zone radius.

To summarize, this paper is organized in five sections where Section I deals with an introduction to wireless ad-hoc networks, section II provides a brief overview on Zone Routing Protocols (ZRP), Section III describes the simulation methodology and performance metrics that has been used during simulation, section IV deals with the simulation result and detailed analysis of the result obtained from the experiments and section V concludes the work and also provides the future scope of the work.

II. OVERVIEW OF THE PROTOCOL

Zone routing protocol is a hybrid routing protocol which effectively combines the best features of both proactive and reactive routing protocols. The key concept employed in this protocol is to use a proactive routing scheme within a limited zone in the ρ-hop neighborhood of every node, and use a reactive routing scheme for nodes beyond this zone [2]. ZRP consists of the Intra Zone Routing Protocol (IARP), which is proactive in nature and the Inter Zone Routing Protocol (IERP), which is reactive in nature.

A. IntrAzone Routing Protocol (IARP):

"A node's routing zone is defined as a collection of nodes whose minimum distance in hops from the node in question is no greater than a parameter referred to as zone radius" [6]. In ZRP, a node proactively maintains the route to the destination within its zone radius. Zone is defined in terms of hops and not as a physical distance [4]. All nodes proactively store local routing information and route requests can be more efficiently performed through a special type of multicasting process, known as bordercasting. 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) [4].

The nodes of a zone are divided into interior nodes and peripheral nodes.

Peripheral nodes are those nodes whose minimum distance to the node in question is exactly equal to the zone radius (ρ). The nodes whose minimum distance is less than zone radius (ρ) are known as interior nodes [5, 6].

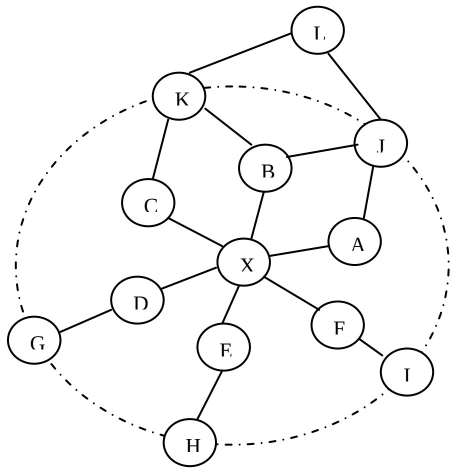


Figure 1: A routing Zone of radius ρ=2

An example of a routing zone for node X of radius ρ =2 hops is shown in figure 1. In the given example nodes A, B, C, D, E and F are interior nodes and G, H, I, J and K are peripheral nodes where L node not in the zone radius and it is outside the zone of node X.

Each node is assumed to maintain the routing information to all nodes within its routing zone and those only. So, even a network can be quite large, the updates are locally propagated. The node learns the topology of its routing zone through a localized proactive scheme which is known as IntrAzone Routing Protocol (IARP). IARP is a family of limited-depth proactive link state routing protocol.

B. IntErzone Routing Protocol (IERP):

In ZRP, the globally reactive routing is named as Interzone Routing Protocol (IERP). Using IERP, ZRP reactively discover routes to destination beyond a node's routing zone. Knowledge of local routing zone topology can be exploited to efficiently relay a query through the network. This is achieved through a packet delivery service, called bordercasting, which directs message from one node out to its peripheral nodes [7].

One approach is for a node to compute its bordercast (multicast) tree and append the corresponding packet forwarding instructions to the bordercast packet. Alternatively, each node may reconstruct the bordercast tree of its interior routing zone by proactively maintaining the topology of an extended zone. If IARP maintains an extended zone of radius 2ρ-1, bordercast messages can be relayed without the need for explicit directions from the bordercast source [8].

C. Bordercast Resolution Protocol (BRP):

The Bordercast Resolution Protocol (BRP) provides the bordercasting packet delivery service. The BRP uses a map of an extended routing zone, provided by the local proactive Intrazone Routing Protocol (IARP), to construct Bordercast (multicast) trees along which query packets are directed. (Within the context of the hybrid ZRP, the BRP used to guide the route requests of the global reactive Interzone Routing Protocol (IERP)). The BRP uses special query control mechanisms to steer route requests away from areas of the network that have already covered by the query. The combination of multicasting and zone based query control makes Bordercasting an efficient and tunable service that is more suitable than flood searching for network probing applications like route discovery.

The Bordercast Resolution Protocol (BRP) is a packet delivery service, not a full featured routing protocol. Bordercasting enabled by local proactive Intrazone Routing Protocol (IARP) and supports global reactive Interzone Routing Protocol (IERP) [9].

Route Discovery Process:

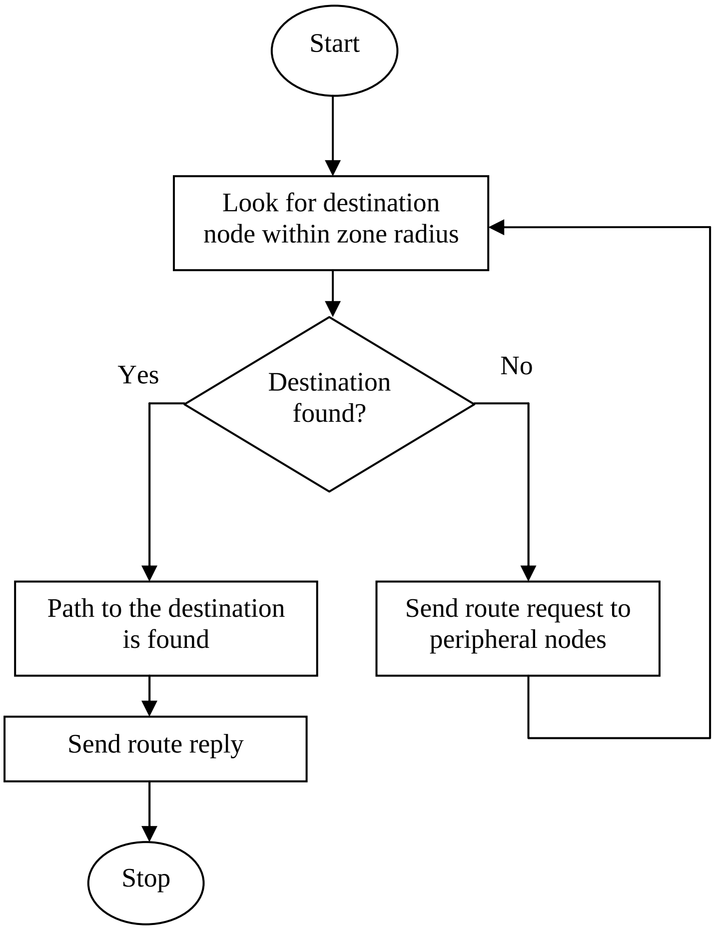
The route discovery process of ZRP operates as follows [5, 10]:

(i) The source node first checks whether the destination is within its zone. If so, the path to the destination node is known and no further route discovery is required.

(ii) If the destination node is not within the source routing zone, the source node bordercast a ‘route request’ to its peripheral nodes.

(iii) The peripheral nodes perform the step as indicated in (i) to check whether the destination node is within their zone or not. If so, a ‘route reply’ is sent back to the source indicating the route to the destination.

(iv) If the destination node is not available in the zones of the peripheral nodes, route requests are forwarded to their peripheral nodes.



This procedure executed till the destination node is found.

Figure 2: Flowchart of route discovery process

An example of route discovery procedure is shown in figure 3, where S is the source node and D is the destination node.

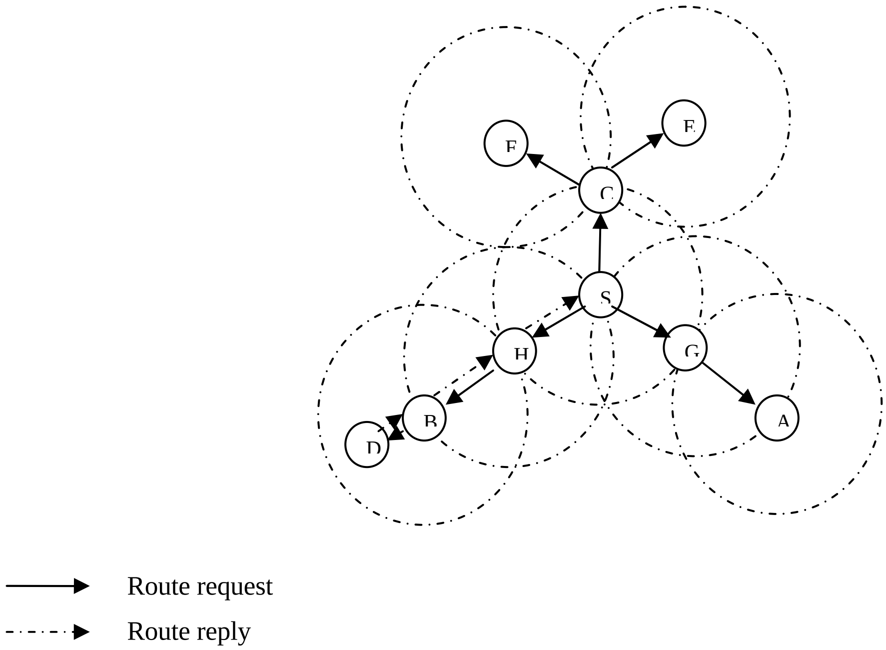


Figure 3: Example of IERP operation

To find a route from node S to node D in the network S first check whether D is within its routing zone or not.

As node D does not lie within S’s routing zone, S bordercast a route request to all its peripheral nodes, i.e. to nodes C, G and H.

Nodes C, G and H then determine whether D is in their routing zone or not and therefore bordercast the route request to their peripheral nodes.

One of H’s peripheral nodes, node B, recognizes D as being in its routing zone and respond to the route request, indicating the forwarding path S->h->B->D.

To complete the route discovery process, a route reply is sent back to the route query source. It is the responsibility of the route accumulation procedure to acquire sufficient information during route request phase, so that route reply can be routed back to the source. Given sufficient storage space, nodes may remove the routing information accumulated in the route request packet and store it in a temporary route query cache. This has the benefit of reducing the length of the request packet, and so the query-response time decreases.

A good advantage of distributed route discovery process, that, a single route query can return multiple route replies. The best route can be selected on the basis of relative quality (a route with smallest hop count or shortest accumulated delay) [5].

III. SIMULATION METHODOLOGY

Simulation based study using Network Simulator NS-2 [11] has been used to analyze the performance of Zone Routing Protocol under varying node density and varying zone radius. It is assumed that the size of network, pause time, maximum speed of nodes and transmission rate are constant while the density of nodes in the network and the zone radius of each node vary considerably. Tables I and Table II summarize the parameters used in the communication and movement models for simulation.

A. Communication Model

The simulator assumes constant bit rate (CBR) traffic with a transmission rate of 8 packets per second. The number of nodes varies from 25 to 200 in the denomination of 25, 50, 75,100 and 200.

TABLE I. PARAMETERS OF COMMUNICATION MODEL

Parameter	Value
Traffic type	*CBR*
Number of nodes	*25, 50, 75, 100, 200*
Transmission rate	*8 packets/second*

B. Movement Model

In line with the realistic mobility pattern of the mobile nodes, the simulation assumes a Random Waypoint Model, where a node is allowed to move in any direction arbitrarily [12]. The nodes select any random destination in the 500 X 500 space and moves to that destination at a speed distributed uniformly between 1 and nodes maximum speed (assumed to be 20 meter per second). Upon reaching the destination, the node pauses for fixed time, selects another destination, and proceeds there as discussed above. This behavior repeats throughout the duration of the simulation (500 seconds). Meanwhile, number of nodes has been varied to compare the performance of the protocols for low as well as high density environment. Table II lists the movement parameters of the simulations.

TABLE II. PARAMETERS OF MOVEMENT MODEL

Parameter	Value
Simulator	*NS-2*
Simulation time	*500 seconds*
Area of the network	*500 m x 500 m*
Number of nodes	*25, 50, 100, 200*
Pause time	*20 seconds*
Maximum speed of nodes	*20 meters per second*
Mobility Model	*Random waypoint*

C. Performance Metrics

Three performance metrics have been measured for the protocols:

(i) Throughput: Throughput is the number of packet that is passing through the channel in a particular unit of time [8]. This performance metric shows the total number of packets that have been successfully delivered from source node to destination node. Factors that affect throughput include frequent topology changes, unreliable communication, limited bandwidth and limited energy.

$$Throughput = \frac{Received\_Packet\_Size}{Time\_to\_Send} \quad (1)$$

(ii) Average End-to-End Delay: A specific packet is transmitting from source to destination node and calculates the difference between send times and received times. This metric describes the packet delivery time. Delays due to route discovery, queuing, propagation and transfer time are included metric [9].

$$Avg\_End\text{-}to\text{-}End\_Delay = \frac{\sum_{i}^{n}(CBRSentTime - CBRRecvTime)}{\sum_{i}^{n}(CBRRecv)} \quad (2)$$

(iii) Normalized Routing Load: Normalized Routing Load is the ratio of total number of routing packet received and total number of data packets received [10].

$$Routing\ Load = \frac{Number\_of\_Routing\_Pkts\_Recvd}{Number\_of\_Data\_Pkts\_Recvd} \quad (3)$$

IV. SIMULATION RESULT AND ANALYSIS

A. Varying Node Density Model:

Figure 4, 5 and 6 shows the result obtained from the simulation based study on Zone Routing Protocol considering that the density of nodes are varying from 25 to 200 in an area of 500m X 500m and the zone radius for each node is 2(constant). This is in order to understand the response of ZRP when the number of nodes in the network is varying. Further, this study has also enabled to identify the maximum number of nodes that ZRP can handle for successfully performing the routing operation under the given scenario (as indicated in Table – I and II). The results obtained in this model will give an insight for performing another simulation based study where the zone radius is considered to be variable and the same is discussed in the following subsection.

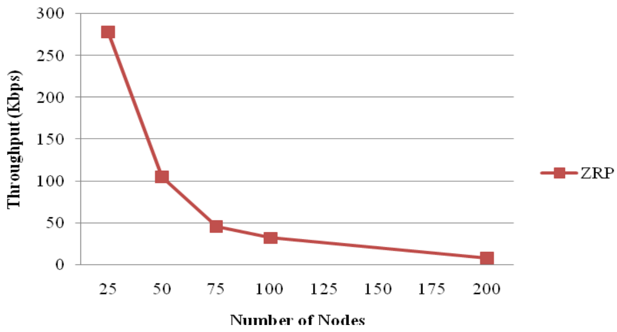


Figure 4: Throughput Analysis

Figure 4 depicts that there is a declination in throughput with an increase in node density. It is also worth mentioning that the throughput is almost negligible whenever the node density exceeds 100 nodes. The possible reason behind this is that fact that a small change in the network topology causes frequent table update of every intermediate node for its zone through IARP. IARP develops more number of control packets that consumes more bandwidth and decreases the performance of the network in terms of throughput.

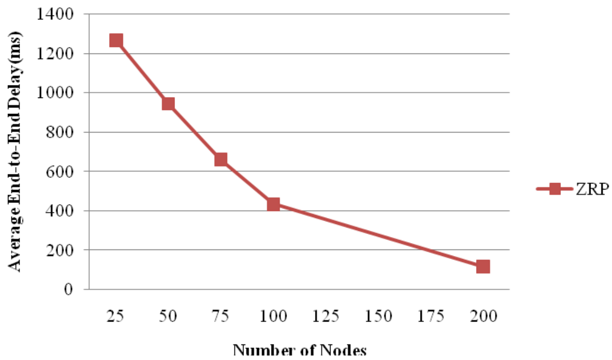


Figure 5: Average End-to-End Delay Analysis

Based on the simulation result depicted in figure 5, it is evident that the average end-to-end delay decreases with the increase of node density. Since ZRP uses proactive routing (within the routing zone) and reactive routing mechanism (outside the routing zone) to find the shortest route between source and destination, high node density network will create more number of zones which will be overlapped thus encouraging proactive routing thereby leading to decrease in average end-to-end delay.

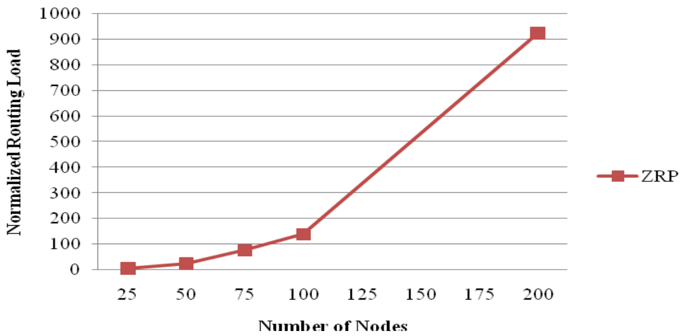


Figure 6: Normalized Routing Load Analysis

Result shown in figure 6 depicts that there is a rise in normalized routing load whenever there is an increase in node density. It is also observed that there is a stiff inclination of normalized routing load after the density of nodes has exceeded 100 numbers. The possible reason behind the rise of normalized routing load is due to the fact that more number of control packets will be generated whenever there is a slight topological change of the network. This effect is more prominent in denser network than a sparsely dense network, thus tending to increase the normalized routing load. The effect of increased normalized routing load can be interpreted as loss of packets in the network. Therefore it is imperative to state from the above result that the successful delivery of packets is nearly negligible whenever the density exceeds 100 nodes in a 500m X 500m network area.

B. Varying Zone Radius Model:

Results obtained from above model shows that the performance of ZRP degrades significantly with there is an increase in node density. The performance is almost negligible when the density of the network exceeds 100 nodes. Therefore, it may be assumed that a maximum of 100 numbers of nodes can be handled for the scenario as indicated in Table – I and II for successful packet delivery in the network. Further, it may be noted that high normalized routing load indicates more number of packet losses. For these reasons, 100 nodes is considered as the maximum number of nodes for current scenario and to find optimal zone radius for current network scenario, simulation has been done for 100 nodes in varying zone radius model.

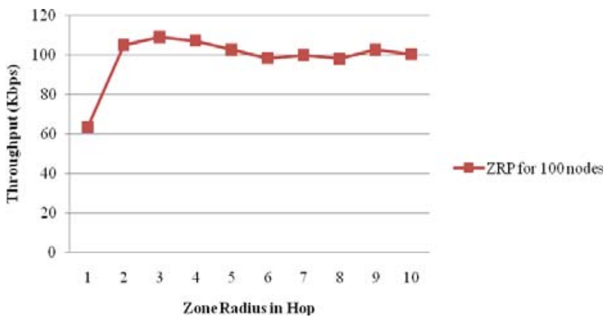


Figure 7: Throughput Analysis

Figure 7 depicts the simulation result in terms of throughput for varying zone radius. The working mechanism of ZRP for zone radius of 1 hop is purely reactive in nature, so it is not able to exploit the advantage of proactive routing mechanism for local routing table maintenance. For smaller zone radius (2 hops, 3 hops and 4 hops) the hybrid nature of ZRP exploits the advantages of both proactive and reactive routing mechanism and results better throughput. As the zone radius increases, ZRP tends to proactive nature. Proactive routing mechanism (IARP) causes greater number of control packets and as the zone radius increases, throughput of the network decreases.

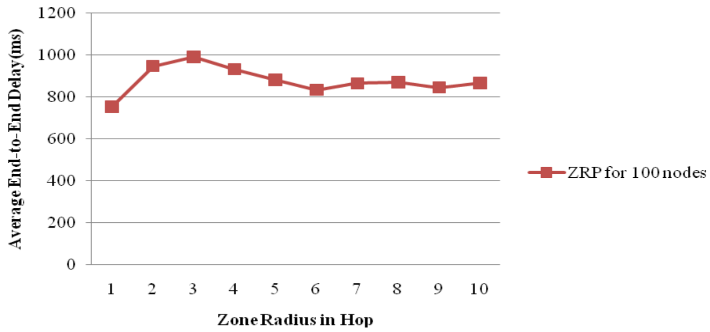


Figure 8: Average End-to-End Delay Analysis

For zone radius of 1 hop, ZRP acts as purely proactively. From figure 8, is has been observed that the increase of zone radius, there are decrease of average end-to-end delay. Larger zone radius increases the scope of proactive routing mechanism, i.e. IARP. In case of proactive routing, once the routing table is updated for every node, the time to send a packet is low. For this reason, as the zone radius increases, average end-to-end delay decreases.

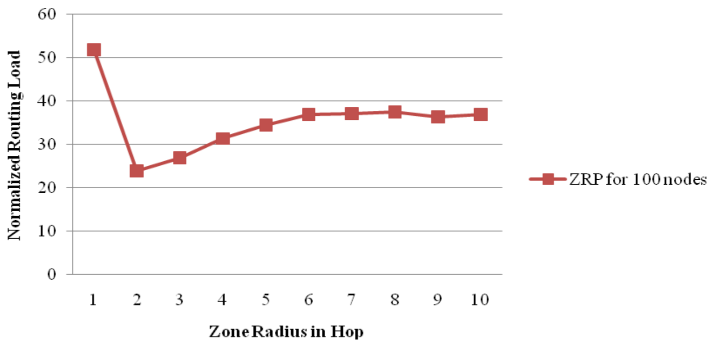


Figure 9: Normalized Routing Load Analysis

For 1 hop zone radius, ZRP acts as a proactive routing protocol. For this reason, for 1 hop zone radius, number of routing packet is much higher than number of data packets and that cause higher routing load. From figure 9, the simulation result shows that as the zone radius increases, normalized routing load is also increases. In higher zone radius, a small change in the network topology tends to high chance to break the link/route between source and destination nodes. The cause behind is that, every intermediate node between source and destination, have to rebuild their own zone routing table through IARP. So the packet loss as well as routing load increases.

V. CONCLUSION AND FUTURE WORKS

The performance of Zone Routing Protocol has been evaluated with respect to metrics viz. throughput, average end-to-end delay and normalized routing load under varying node density and varying zone radius within a fixed simulation area. The results from figure 3, 4 and 5 (under varying node density), it has been observed that the performance of ZRP decreases significantly in terms of throughput and normalized routing load. The reason of performance degradation is due to the fact that an increase in number of nodes in the network causes more number of control packets to flow in the network for establishing the route between a pair of source and destination thus affecting the performance metrics. On other hand, as there is more number of zone overlapping in high dense network, the average end-to-end delay decreases with the increase of node density.

From simulation results of figure 6, 7 and 8, it has been observed that low zone radius (2, 3 and 4 hops) provides better result in terms of throughput and normalized routing loads, where as higher zone radius provides less end-to-end delay. It also has been observed that, with the change of zone radius for higher zone radius, the performance of routing in terms of end-to-end delay is not significant.

In Current work, only three performance metrics have been considered to analyze the performance of ZRP. Inclusion of other performance metrics will provide indepth analysis of this protocol, which may provide an insight on the realistic behavior of the protocols under more challenging environment. The current work has been limited with constant pause time and fixed simulation area (500x500m) with CBR traffic. Varying pause time and simulation area with different traffic will provide indepth performance analysis of these two protocols.

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