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Zone Radius Optimization Based On Maximum Node Velocity, Number of Transmitting Nodes and Total Number of Nodes

Amir Aliabadian

Abstract* —ZRP (Zone Routing Protocol) is a hybrid routing Protocol specifying routs within a region of a network, called routing zone. ZRP can be configured for a particular network by adjusting the routing zone radius. Routing zone radius (R) is defined based on the number of hops. So, a routing zone maintains some nodes that their distances to a specified node are at most R hops. In fact, ZRP is designed for optimizing the (Query/reply) mechanism efficiency. ZRP is a combination of proactive and reactive protocols; within the zone, it is in proactive and between zones is reactive. The first one is called IARP and the latter one IERP. In this paper, we intend to evaluate the ZRP Performance in a network. To do this, we change the zone radius and performance is evaluated by measuring the control traffic generated during routing process. In fact, control traffic is viewed as the sum of the IARP routing update packets and the transmission of IERP request/reply/failure packets. Our results determine the optimum zone radius considering the node velocity, the number of transmitting nodes and the total number of nodes.

Keywords: Zone routing protocol, Ad-hoc networks, zone radius, node velocity.

I. INTRODUCTION

A. A brief Overview of Ad-Hoc Network

Wireless Ad-Hoc networks are self-organizing infrastructure less networks composed of mobile nodes [1]. Limitation on power consumption imposed by portable wireless radios results in a node transmission range that is typically small relative to the span of the network. To provide communication throughout the entire network, each node is also designed to serve as a relay. The result is a distributed multi hop network with a time–varying topology.

Each node includes a router and a host that are usually implemented using one computer. As there is no required infrastructure for providing wireless communicative networks, Ad-Hoc networks are used to provide a tight communication rapidly [2-3]. These characteristics make Ad-Hoc networks suitable for tactical communication in military and emergency efforts. In order to provide decentralized and tether less communication, ad-hoc networks need to overcome the limitations of portable wireless communication. The unguided wireless medium and surrounding physical environment significantly attenuate and distort radio transmission signals, resulting in relatively unreliable communication channels.

The potential for large-scale ad-hoc networking applications calls for a special class of ad hoc networks which we refer to as RWN (Reconfigurable Wireless Networks). RWN may span over a wide geographic area and consist of many nods which can exist on a variety of platforms (i.e., pedestrians, tanks, planes, etc.). Routing in Ad-Hoc networks is difficult because of the low bandwidth and permanent topology changes.

B. Routing Protocols

Ad-Hoc routing protocols [4] are divided into two groups: proactive and reactive. Proactive routing protocols usually require maintenance of routing tables and thus, in a dynamically changing network, nodes would need to exchange routing updates periodically. On the other hand, its advantage is that the routing information is ready when needed. So, it has low delay for the price of increased network control traffic. Popular proactive routing protocols for ad-hoc networks include: Destination Sequenced Distance Vector (DSDV) protocol [5], Wireless Routing Protocol [6], and the Source Tree Adapting Routing (STAR) protocol [7]. Reactive protocols evaluate the routes only when it is intended to send a packet and finding a route is needed. Routing is usually performed in query/reply mechanism and through a flooding search [8]. The route request packet spreads through the network until it reaches its destination. So, the information related to the routes that this packet requests, returns to the source for sending the new information. Its advantage is low overhead traffic for the price of some delay before finding a suitable route. Some of on-demand routing protocols use Adaptive On-Demand Distance Vector (AODV) protocol [9], Dynamic Source Routing (DSR) protocol [10] and the Temporally Ordered Routing Algorithm (TORA) [11]. According to the above mentioned points, a pure proactive protocol is not suitable for Ad-Hoc networks. These protocols use a lot of network capacity for maintaining and updating the routing information. However, most of the information that proactive protocols maintain are not usable which results in wasting additional network capacity. Reactive protocols must first determine the route, which may result in considerable delay if the information is not available in caches. The optimum way is to use a hybrid protocols. By partitioning the network nodes into groups, these protocols combine the advantages of proactive and reactive protocols. So, we use the proactive protocol for routing among the nodes inside a group and the reactive one for routing among different groups. ZRP is an example of a hybrid protocol.

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***** Correspondence Author (s)
Amir Aliabadian, Faculty member of Electronic and Computer Engineering Department of Shomal University, Amol, Iran.

II. THE ZONE ROUTING PROTOCOL

A. Architecture

The Zone Routing Protocol, as its name implies, is based on the concept of zones. A routing zone (of radius R) is defined for each central node and includes the nodes whose minimum distance in hop to the central node is at most R hops. An example of a routing zone of radius two hops is shown in fig.1.

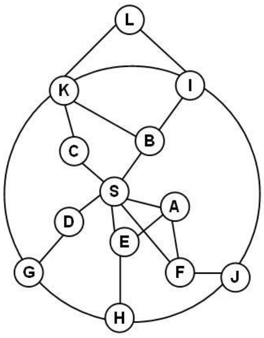

Fig.1. A routing zone of radius two hops for central node S

For the purpose of illustration, we depict zone as a circle around the nodes in question. However, one should keep in mind that the zone is not a description of physical distance, but rather nodal connectivity (hops).

Note that in this example, node A-K are within the routing zone of the central node S. Node L is outside S's routing zone. Peripheral nodes are nodes whose minimum distance to the node in question is exactly equal to the zone radius. The remaining nodes are categorized as interior nodes. Thus, in Fig.1 , nodes A-F are interior while nodes G-K are peripheral nodes. The number of nodes in a routing zone can be regulated through adjustments of each node's transmitting power. Subject to the local propagation conditions and receiver sensitivity, the transmission power determines the set of neighbor nodes, which are in direct communication with the central nodes. To provide adequate network connectivity, it is important that a node be connected to a sufficient number of neighbors. ZRP refers to the locally proactive routing component as the IntrA-zone Routing Protocol (IARP). The globally reactive routing component is named IntEr-zone Routing Protocol (IERP). IERP and IARP are not specific routing protocols. Instead, IARP is a family of limited-depth, proactive link-state routing protocols. IARP maintains routing information for nodes that are within the routing zone of the central node. Correspondingly, IERP is a family of reactive routing protocols that offer enhanced route discovery and route maintenance services based on local connectivity monitored by IARP [17], [18].

B. IntrAzone Routing Protocol (IARP)

Each node is assumed to maintain routing information only to those nodes that are within its routing zone [17]. Because updates are only propagated locally, the amount of update traffic required to maintain a routing zone does not depend on the total number of network nodes (which can be quite large). We assume that a node learns its zone through some sort of a proactive scheme, which we refer to here as the IntrAzone Routing Protocol (IARP). However, any other proactive scheme would do. While the performance of the ZRP depends on the choice of IARP implementation, our experience suggests that the tradeoffs are not strongly affected by the particular choice of the proactive scheme used [16].

C. IntErzone Routing Protocol (IERP)

As the global reactive routing component of the ZRP, the IntErzone Routing Protocol (IERP), takes advantage of the known local topology of a node's zone and using a reactive approach enables communication with nodes in other zones. For RWN, the coverage of a routing zone is relatively small compared to the size of the network. Thus, most destinations lie outside of the node's routing zone, and the desired routing information cannot be provided by the IARP immediately. Route queries within the IERP are issued on demand that is only when a request for a route to a destination beyond the node's routing zone is made. The delay caused by the route discovery (in contrast to IARP, where the route is immediately available) is minimized through the use of border casting [19], an approach in which the node does not submit the query to all local nodes, but only to it's peripheral nodes. Furthermore, a node does not send a query back to the node the request came from.

The IERP is distinguished from the standard flooding-based query/response protocols by exploiting the structure of the routing zone. In order to convert an existing reactive routing protocol for use as the IERP in the ZRP, it is necessary to disable pro-active updates for local routes, since this functionality is provided by the IARP. Furthermore, IERP needs to be able to take advantage of the local routing information provided by the IARP, as well as changing the way route discovery is handled. Instead of flooding a route request to all nodes, it should use the Bordercast Resolution Protocol (BRP) to only initiate route requests with peripheral nodes. This approach prevents non peripheral nodes from accessing the bordercasted messages as they are relayed to the edge of the routing zone. As will be shown later, such access is central to the control of the route query process. As a more suitable implementation, bordercasting indirectly sends messages to peripheral nodes by forwarding them between adjacent nodes. The IntErzone Routing Protocol, including an example implementation (Reactive Source Routing), is described in more detail in [17].

D. Routing

A node, that has a packet to send, first checks to see whether the destination is within its local zone using the information provided by IARP; in that case, the packet can be routed proactively. Reactive routing is used if the destination is outside the zone [20]. The reactive routing process is divided into two phases: route request and 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. An example of this Route Discovery procedure is demonstrated in figures 2.a and 2.b.

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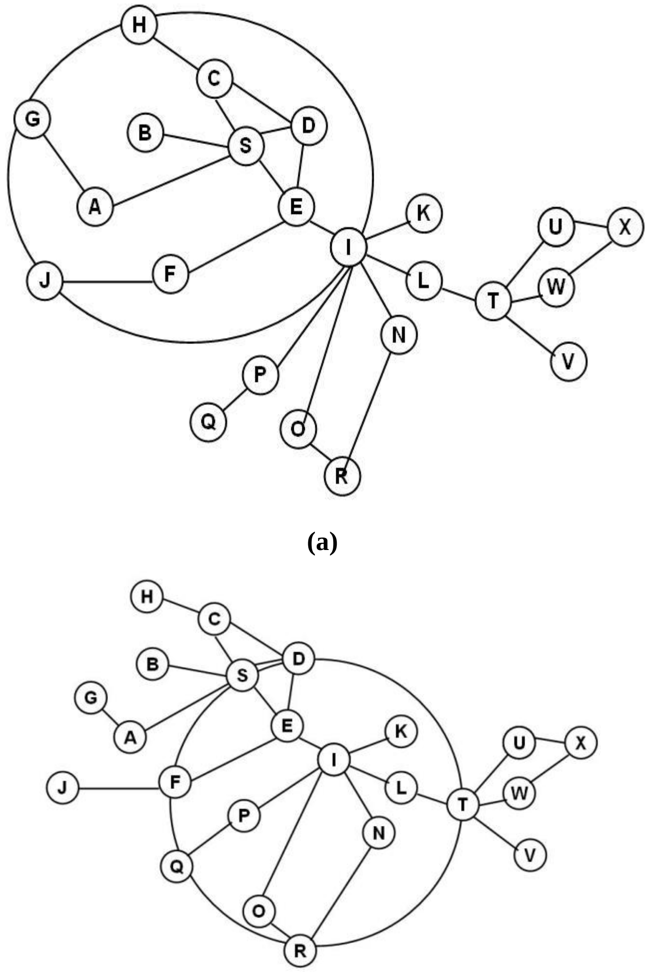

(a)

(b)

Fig.2. IERP routing between zones

Source node S needs to send a packet to the destination L. To find a route within the network, S first checks to see whether D is within its routing zone. If so, S knows the route to D. Otherwise, S bordercasts a query to its peripheral nodes; that is, S sends a query to nodes G, H, I and J. Now, after verifying that D is not in its routing zone, each one of these nodes forwards the query by bordercasting it to its peripheral nodes. In particular, I sends a query to S which recognizes D as being in its routing zone and responds to the query, indicating the forwarding path: S-E-I-L. In this way, the route request spreads throughout the network. If a node receives several copies of the same route request, these are considered as redundant and are discarded [18], [20]. Any node that can provide a route to the destination sends the reply. To be able to send the reply back to the source node, routing information must be recorded either in the route request packet, or as next-hop addresses in the nodes along the path. 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 [18], [21]. The source can then receive the complete source rout to the destination.

III. RELATED WORKS

Previously, routing in multi-hop packet radio networks was based on shortest-path routing algorithm [12], such as Distributed Bellman-Ford (DBF). These algorithms suffer from very slow convergence (the “counting to infinity” problem). Besides, DBF-like algorithms incur large update message penalty. Protocols that attempted to cure some of the shortcoming of DFB, such as Destination-Sequenced Distance-Vector Routing (DSDV) [5], were proposed and studied. Nevertheless, synchronization problems and extra processing overhead are common in these protocols. Other protocols that rely on the information from the predecessor of the shortest path solve the slow convergence problem of DBF. However, the processing requirements of these protocols may be quit high, because of the way they process the update messages. Use of dynamic source routing protocol, which utilizes flooding to discover a route to a destination, is described in [10]. A number of optimization techniques, such as rout caching are also presented that reduce route determination/maintenance overhead. In a highly dynamic environment, such as RWN, this type of protocols lead to a large delay and the techniques to reduce overhead may not perform well. A query-reply based routing protocol has been introduced recently in [13]. Practical implementation of this protocol in the RWN-s requires complicated hardware equipments. A new distance-vector routing protocol for packet radio networks (WRP) is presented in [14]. Upon a change in the network topology, WRP relies on communicating this change to its neighbors, which effectively propagates throughout the network. The salient advantage of WRP for the RWN is in the fact that routing nodes constantly maintain full routing information in each network node, which was obtained at relatively high cost in wireless resources. In [15], routing is based on temporary addresses assigned to nodes. These addresses are concatenation of the nodes addresses on a physical and a locations, producing a long path for communication between two close-by nodes.

In [16], the optimum zone radius is evaluated based on the network configuration and node behavior such as the virtual network. However, routing requires full connectivity among all the physical network nodes.total number of nodes (N), node density (δ) and the perceived Furthermore, routing may not be optimal, as it is based on addresses, which may not be related to the geographical by the ZRP, has been expressed in terms of the rate of new neighbor acquisition rather than the physical measure of velocity. But, in our simulation, we directly use velocity as a parameter in random waypoint model of mobility.

IV. EVALUATION OF THE ZRP

We use the NS-2 network simulator to evaluate the performance of the ZRP over a variety of RWN. We consider k as the number of transmitting nodes, N as the number of total nodes and V as a node movement velocity.

Table 1 shows the parameters for simulation.

Simulator	Ns-2
Simulation duration	100 seconds
Simulation area	3000*4000m
Number of mobile hosts	100
Transmission range	250 m
Mobility model	Random waypoint
Maximum speed	5-20m/s
Traffic type	CBR (UDP)
Zone radius (R)	1-5

Table (A). Simulation parameters

We intend to evaluate the ZRP performance in a network by changing routing radius from the reactive routing (R=1) to proactive routing ($R \rightarrow \infty$). Its performance is estimated by measuring the control traffic generated by ZRP. In fact, control traffic is viewed as the sum of the IARP route update packets and the transmission of IERP request/reply/ failure packets. The IARP routes get update when there is a connection change with neighbor. One IERP traffic is considered as traffic generated in any query and is multiplied in a rate that the query is done. A simple approach to estimate the optimal zone radius is to periodically adjust the zone radius until a radius is found that appears to minimize the amount of ZRP traffic.When the estimation process begins, the routing zone radius can either be incremented or decremented by one hop. The choice to initially increment or decrement can be arbitrary or can be based on additional information provided by triggering mechanism. During the kth estimation interval, the amount of ZRP traffic $Z(R(k))$ is measured. If the current amount of ZRP traffic is less than the previous one, $(Z(R(k)) < Z(R(k-1)))$, it is assumed that the ZRP traffic can be further reduced by continuing to increment/decrement the zone radius. Otherwise, the direction of radius change is reversed $(\Delta R = -\Delta R)$, and the zone radius is altered accordingly. The process continues until a minimum is detected, based on the following condition:

$$(Z(R) < Z(R-1) and Z(R) < Z(R+1)).$$

Our results demonstrate the optimum zone routing radius and node behavior dependency (the radius dependency to N, K and V).

A. IARP and IERP Control traffic

Route fashioning process means it would bring the changes in the region topology and routing table to the nodes inside the routing region. This is a function of the node number within the zone. Both of these are functions of Nzone, where Nzone is the zone Population. So, we expect that there is a relation between the amount of IARP traffic and routing zone radius (R^2) .

By increasing radius, the number of nodes within the zone increases. Therefore, the IARP route update packets increase. On the other hand, the number of peripheral nodes decreases. So, the numbers of IERP request/reply packets decreases. The reason is that when the radius increases, the surrounding nodes that are under test in on-demand way decrease (Recall that a node will only propagate a query the first time that it is detected). Total traffic is the sum of IARP and IERP traffic. We have shown in figure 3 the IARP, IERP and the total traffic as function of radius.

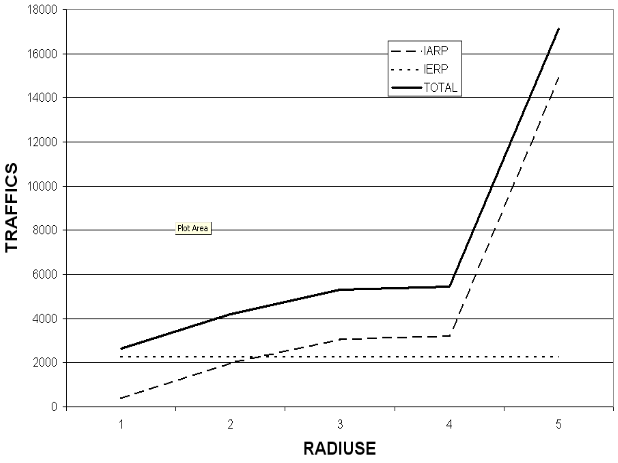

Fig.3. Relation between IERP, IARP and total traffic with R (K=2, Vmax=5 m/s, N=100)

According to figures 4 and 5, the IERP and IARP traffic both increase by velocity.

By increasing N, IARP and IERP traffic increase as shown in figure 6 and 7.

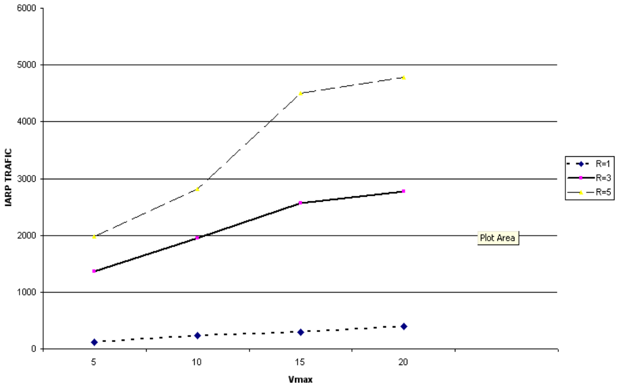

Fig.4. IARP traffic versus maximum velocity (N=100, K=44)

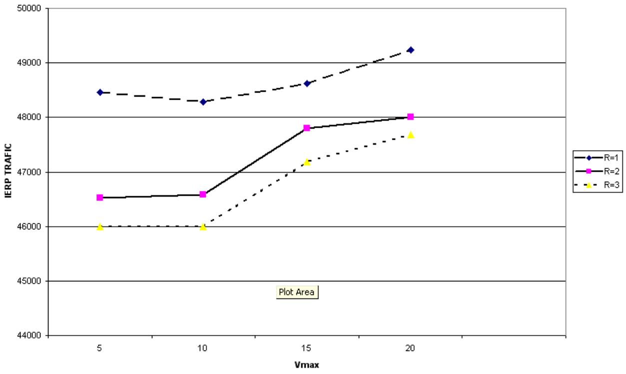

Fig.5. IERP traffic versus maximum velocity (N=100, K=44)

R	1	2	3	4	5
IERP	48159	47257	46520	46457	45997
IARP	0	813	1361	1612	1976
Total	48267	48070	47881	48069	47973

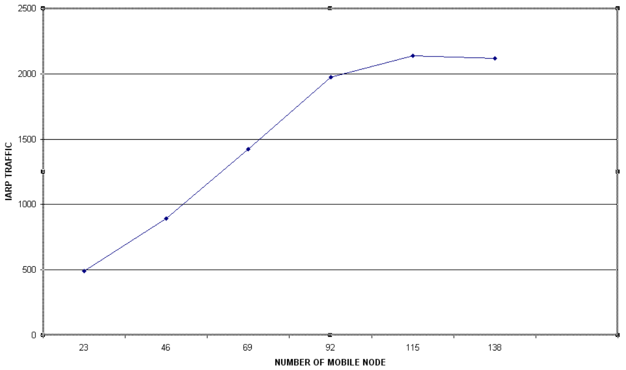

Fig.6. IARP traffic versus number of node (K=44, Vmax=5m/s, R=5)

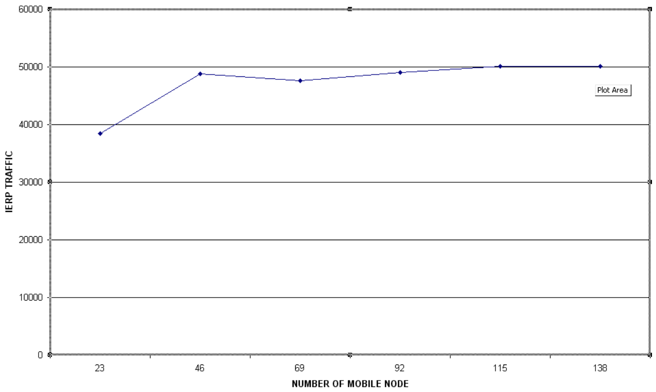

Fig.7. IERP traffic versus number of node (K=44, Vmax=5m/s, R=1)

IERP traffic has a direct proportion to the number of transmitting nodes; but in IARP, for a given zone radius, we observe that the amount of received traffic/query increase with the transmitted packets. As the number of transmitted packets increase, demand for routing increases.

B. Evaluating of ZRP:

As we can sea, when routing zone radius increases IARP traffic increases and IERP traffic decreases. We want to compare these two features and evaluate the total traffic and the optimum radius. An increase (decrease) in the amount of reactive IERP traffic or decrease (increase) in amount of proactive IARP traffic can indicates that the optimal zone radius may change. Regarding table (B), we can sea that for low number of transmitting nodes, reducing the IERP traffic is not compatible with IARP traffic increasing.

R	1	2	3	4	5
IERP	10365	10283	10085	10063	10054
IARP	0	808	1251	1505	1951
Total	10365	10935	11336	11568	12005

TABLE (B) IERP, IARP and total traffics versus radius (Vmax = 5m/s, K=10, N=100

According to table (B), the optimum radius is one, because the number of transmitting nodes is low and IERP reduction is very low compared with IARP increasing. So, the total traffic rises with radius increase. But According to table (C), when the number of transmitting nodes is high, the IERP reduction is noticeable compared to IARP increase.

TABLE (C) IERP, IARP and total traffics versus radius (Vmax=5m/s, K=44, N=100)

As we can see, the IARP increase isn't noticeable compared to the IERP reduction from the radius R=1→R=2, In R=2 → R=3 it is So. But in R=3 → R=4, IARP increasing is more than IERP reduction. It means the traffic increases, so in this example R=3 is optimum. By comparing table (B) with table (C), when the number of transmitting nodes increases, the optimum radius increases. That is because in table 3 by increasing radius, the IARP traffic increases and IERP traffic decreases; but, reduction in IERP is noticeable. The following 2 results are obtained from these two tables.

Reault1: With low number of transmitted packets, the total traffic tends to IARP. Because IERP traffic in respect to IARP is very low, except for radius 1 (and may be radius 2), the total traffic tends to IERP.

Result2: In smallest radius the total traffic tends to IERP and in largest radius the total traffic tends to IARP. Because with increase in radius, IARP traffic increases but IERP traffic decreases.

By increasing velocity, joining and losing new neighbors increases, so IARP traffic increases with the rise in velocity.

The surrounding nodes and communicative nodes change rapidly, so the IERP traffic also increases. This increase in IARP is more than IERP. Both traffics increase with rate raising, so the total traffic increases with it too. We can see this in table 4 and table (E).

Radius	1	2	3	4	5
IARP	123	873	1342	1622	1985
IERP	54933	53979	53245	53.44	52760
total	55056	54852	54587	54666	54745

TABLE (D) IERP, IARP and total traffics versus radius (k=50, Vmax =5m/s)

Radius	1	2	3	4	5
IARP	229	1233	1956	2198	2927
IERP	54142	46867	53256	53223	53.82
total	54371	48100	55212	55421	56009

TABLE (E) IERP, IARP and total traffics versus radius (k=50, Vmax =10m/s)

As we can see in table 4 and table (E), by increasing in velocity the optimum radius decreases. Because by increasing velocity, both IARP and IERP traffic increases, but increase in IARP traffic is more than IERP. Therefore, when velocity is high, the less traffic is in lowest radius.

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By increasing total number of nodes (N), for one radius, the number of zones increases, so IARP traffic increases with N rising. By increasing zones the surrounding nodes increase, so IERP traffic also increases with N rising.

TABLE (F) IERP, IARP and total traffics versus radius (vmax=5m/s, k=33, N=92)

Increases, with reduction in radius, the total control traffic may be reduced. So the optimum radius is less. By increasing the number of node, both IARP and IERP traffics increase. But this increase in IARP traffic is more than IERP. Therefore, with high number of N, the less traffic may occur in lower radiuses. By increasing the number of transmitting nodes, the IERP traffic increases but IARP is nearly constant. Therefore, when the number of transmitting nodes increases, with increase in radius (increase in radius cause IERP traffic reduction) the total control traffic may be reduced. So, the optimum radius increases. Finally, by increasing the number of transmitting nodes, the optimum radius increases; but, by increasing the maximum velocity of nodes and the number of nodes, the optimum radius decreases. So, optimum radius can be defined as a function of the number of transmitting nodes, maximum velocity and the

Radius	1	2	3	4	5
IARP	0	921	1517	1896	2318
IERP	50238	49332	49095	49024	48901
Total	50238	50253	50612	50920	51219

TABLE (G) IERP, IARP and total traffics versus radius (vmax = 5m/s, k=44, N=115)

By comparing TABLE 6 with TALE G, we can see by increasing the number of nodes, the optimum radius decreases because both IARP and IERP traffic increases. But increase in IARP traffic is more than IERP. Therefore, when N is high the less traffic is in lowest radius.

C. Searching total traffic for optimum radius

In this section, to study for obtaining optimum R, only the total traffic is drawn while the total number of nodes is considered constant (N=100).

Figures 8 to 10 show total traffic as a function of radius for different maximum velocity and different numbers of transmitting packets. By investigating figures 8 and 10 in Vmax=5, we can see that increasing the number of transmitting nodes, results in higher optimum radius. Because by increasing the number of transmitting nodes, the IERP traffic increases but not the IARP traffic. Therefore, maybe we have less traffic in high radiuses because of IERP traffic reduction.

By studying figure 9, for Vmax=5m/s and Vmax=15m/s, we can see with rate raising, optimum radius reduces because by increasing rate, IARP traffic increases more than IERP. Therefore, in lower radiuses, we might have less traffic because of IARP traffic reduction.

By studding figures 9 and 11, with Vmax=5m/s, we can understand that by increasing the number of nodes, the optimum radius decreases.

By increasing total number of nodes IARP traffic increases more than IERP. Therefore, in lower radiuses, we might have less traffic because of IARP traffic reduction.

Finally, by increasing the number of transmitting nodes (K), the optimum radius increases. By increasing the maximum velocity of nodes (Vmax) and the number of nodes (N) the optimum radius decreases.radius decreases.

Radius	1	2	3	4	5
IARP	0	723	1215	1407	1732
IERP	47790	46990	46487	46514	46459
Total	47790	47713	47702	47921	48191

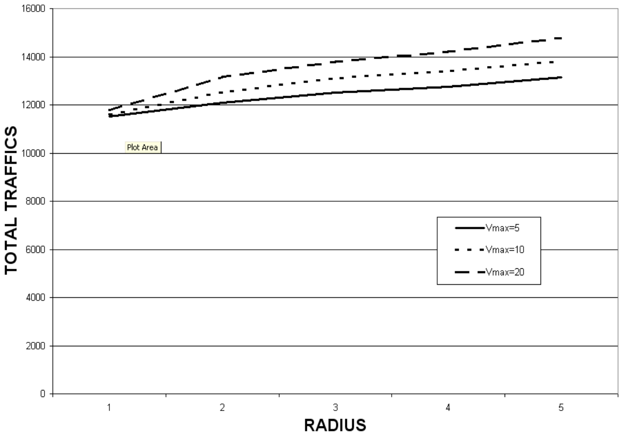

Fig.8. total traffic versus radius (N=100, K=10)

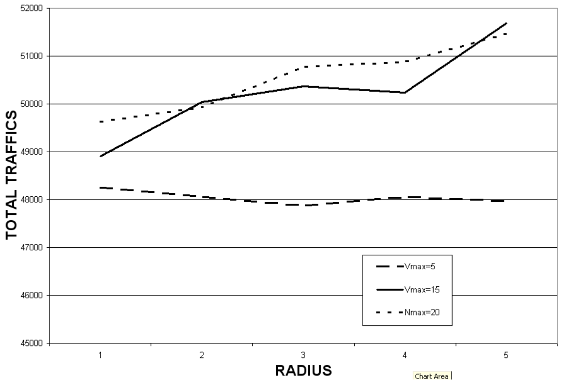

Fig.9. total traffic versus radius (N=100, K=44)

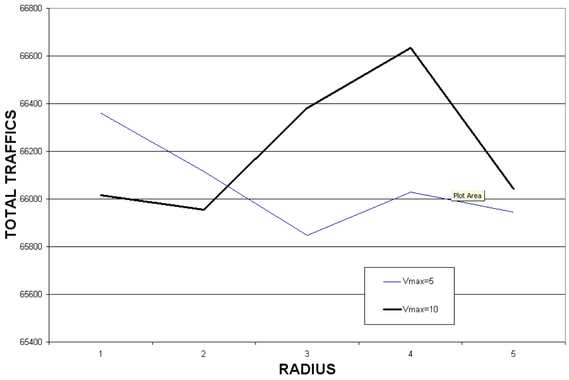

Fig.10. total traffic versus radius (N=100, K=60)

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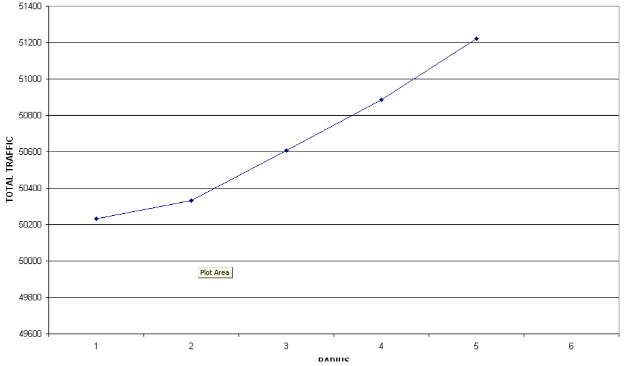

Fig.11. total traffic versus radius (N=138, Vmax=5, K=44)

V. CONCLUSION

The ZRP, by zoning the network, combines the advantages of reactive and proactive protocols. In smaller zones ZRP is more similar to a reactive protocol and in largest zones is more similar to a proactive protocol. In this paper, optimum radius for the minimum control traffic has been obtained. In simulations, the number of transmitting nodes (K), the number of nodes (N) and maximum velocity of nodes (Vmax) has been changed for investigation on control traffic in different radiuses. By increasing in maximum velocity, both IARP and IERP traffics are increased but IARP traffic increases much more than IERP. Therefore, when the maximum velocity number of nodes. That has a direct relation with the number of transmitting nodes, but reversely proportional to node velocity and number of nodes.

Therefore:

$$Rop=f(Vmax, N,K)$$

In our simulations, the transmit power of nodes is considered constant and also, links are considered bidirectional. These limitations can be removed in future works.

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Amir Aliabadian was born in Babol, Iran, in 1982.He received his B.Sc.degree in Electrical Engineering from the Mazandaran University and his M.Sc.degree in telecommunication system in Emam Hossein University, Iran, in 2004 and 2007, respectively. Now, He is Faculty member of Electronic and Computer Engineering Department of Shomal University, Amol, Iran. Research Interesting: Encryption, Communication, Image Processing.