HYBRID ROUTING PROTOCOLS FOR AD HOC WIRELESS NETWORKS

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ABSTRACT

An ad hoc wireless network has a dynamic nature that leads to constant changes in its network topology. As a consequence, the routing problem becomes more complex and challengeable, and it probably is the most addressed and studied problem in ad hoc networks. Based on the routing information update mechanism Ad hoc wireless networks routing protocols are classified into Proactive, Reactive and Hybrid Routing Protocols. Out of these, Hybrid Routing Protocol combines the best futures of the first two categories. The Zone Routing Protocol (ZRP) is one of the hybrid routing protocols in which every network node proactively maintaining routing information about its routing zone, while reactively acquiring routes to destinations beyond the routing zone. In this paper, we proposed the Independent Zone Routing Protocol (IZRP) an enhancement of the Zone Routing Protocol which allows adaptive and distributed configuration for the optimal size of each node's routing zone, on per-node basis. We demonstrate the performance of IZRP with various performance metrics. Furthermore, we compared the performance of IZRP and ZRP by considering performance metrics Packet Delivery Fraction, Normalized Routing Overhead and End-to-End Delay.

KEYWORDS

Ad hoc wireless networks, Hybrid routing, Zone Routing Protocol, Independent Zone Routing, Routing Zone, IZRP, End-to-End Delay.

1. INTRODUCTION

A mobile ad hoc network (MANET) is comprised of mobile hosts that can communicate with each other using wireless links. In this environment a route between two hosts may consist of hops through one or more nodes in the MANET. An important problem in a mobile ad hoc network is finding and maintaining routes since host mobility can cause topology changes. [1]

Mobile ad hoc networks have been employed in scenarios where an infrastructure is unavailable, the cost to deploy a wired networking is not worth it, or there is no time to set up a fixed infrastructure. Some scenarios where an ad hoc network can be used are business associates sharing information during a meeting, emergency disaster relief personnel coordinating efforts

DOI : 10.5121/ijasuc.2011.2407

after a natural disaster such as a hurricane, earthquake, or flooding, and military personnel relaying tactical and other types of information in a battlefield. [3]

Algorithms for a MANET must self-configure to adjust to environment and traffic where they run, and goal changes must be posed from the user and application. Ideally, a routing algorithm for an Ad hoc network should not only have the general characteristics of any routing protocol but also consider the specific characteristics of a mobile environment—in particular, bandwidth and energy limitations and mobility [34] [35]. Some of the characteristics are: fast route convergence; scalability; QoS support; power, bandwidth, and computing efficient with minimum overhead; reliability; and security. [2] [3]

Based on the routing information update mechanism, Ad hoc wireless network routing protocols are basically divided into pro-active routing and re-active protocols. The Proactive routing algorithms aim to keep consistent and up-to-date routing information between every pair of nodes in the network by proactively propagating route updates at fixed time intervals. Usually, each node maintains this information in tables; thus, protocols of this class are also called table-driven algorithms. The pro-active routing protocol learns the network topology before a request comes in for forwarding. Since the proactive routing algorithms maintain routing tables for all nodes in the network, a route is found as soon as it is requested. Proactive protocols tend to provide better quality of service than reactive protocols. The advantage of a proactive protocol is its low latency in discovering new routes and minimizes the end-to-end delay. Examples of proactive protocols are Destination-Sequenced Distance Vector (DSDV) [9], Optimized Link-State Routing (OLSR) [7], Cluster-Head Gateway Switch Routing Protocol(CGSR) [11], Wireless Routing Protocol(WRP)[11] and Topology-Based Reverse Path Forwarding (TBRPF) [8] Protocols.

Reactive on-demand routing algorithms establish a route to a given destination only when a node requests it by initiating a route discovery process. Once a route has been established, the node keeps it until the destination is no longer accessible, or the route expires. The re-active routing protocol becomes active only when a node is willing to forward a request. Reactive protocols tend to be more efficient than proactive protocols in terms of control overhead and power consumption because routes are only created when required. Some of the re-active routing protocols are Dynamic Source Routing Protocol (DSR) [6], Ad Hoc On-Demand Distance-Vector Routing Protocol (AODV) [4] [5], Temporally Ordered Routing Algorithm (TORA) [10], Associativity-Based Routing (ABR) and Preferred Link-Based Routing Protocol (PLBR) and some of the pro-active routing protocols are DSDV [9] and [10].

In spite of a reactive protocol gives the low overhead of control messages, it has higher latency in discovering routes as it determine the route using flooding route request packet in the network and builds the route on demand from the responses it receives. On the other hand, proactive protocols need periodic route updates to keep information updated and valid, also many available routes might never be needed all these increases the routing overhead and consume large amounts of bandwidth [3].

2. ZONE ROUTING PROTOCOL (ZRP)

Zone Routing Protocol (ZRP) [12] is a well-known hybrid routing protocol that is most suitable for large-scale networks. The ZRP framework is designed to provide a balance between the contrasting proactive and reactive routing approaches.

Its name is derived from the use of "zones" that define the transmission radius for every participating node. This protocol uses a proactive mechanism of node discovery within a node's immediate neighborhood, while interzone communication is carried out by using reactive approaches. ZRP utilizes the fact that node communication in ad hoc networks is mostly localized, thus the changes in the node topology within the vicinity of a node are of primary importance. ZRP makes use of this characteristic to define a framework for node communication with other existing protocols. Local neighborhoods, called *zones*, are defined for nodes. The routing zone of a given node is a subset of the network, within which all nodes are reachable within less than or equal to *zone radius* hops. The size of a zone is based on ρ factor, which is defined as the number of hops to the perimeter of the zone. There may be various overlapping zones, which helps in route optimization. [13]

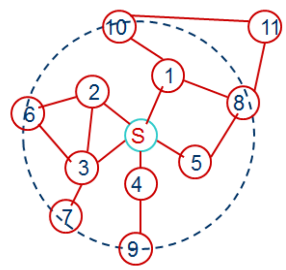

Figure 1: A routing zone with radius ρ = 2 hops

An example of a routing zone for node S of radius 2 is shown in figure 1[14]. The nodes from 1 to 10 belong to the routing zone of S, but not node 11. The nodes 6 to 10 are called peripheral nodes because hop distance from S is equal to radius of the routing zone. The information about neighbors is required to construct a routing zone of a given node. A neighbor is defined as a node with whom *direct* communication can be established. Neighbor discovery is accomplished by either the Intrazone Routing Protocol (IARP) [16] or simple "Hello" packets. Node discovery is achieved with periodic transmission of beacon packets (active discovery) or with promiscuous snooping on the channel to detect the communication activity (passive discovery) [15].

IARP [16] is proactive approach and always maintains up-to-date routing tables. Since the scope of IARP is restricted within a zone, it is also referred to as a "limited scope proactive routing protocol." Route queries outside the zone are propagated by the route requests based on the perimeter of the zone (i.e., those with hop counts equal to ρ), instead of flooding the network. The Interzone Routing Protocol (IERP) [17] uses a reactive approach for communicating with nodes in different zones. Route queries are sent to peripheral nodes using the Bordercast Resolution Protocol (BRP) [18]. Since a node does not resend the query to the node in which it received the query originally, the control overhead is significantly reduced and redundant queries are also minimized.

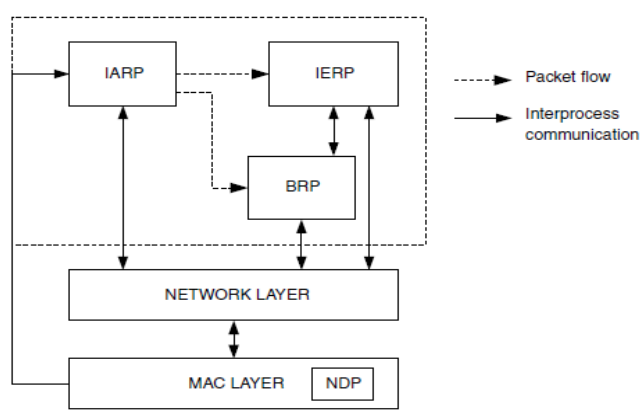

Figure 2: Design diagram of ZRP

ZRP provides a hybrid framework of protocols, which enables the use of any routing strategy according to various situations. It can be optimized to take full advantage of the strengths of any current protocols [12].

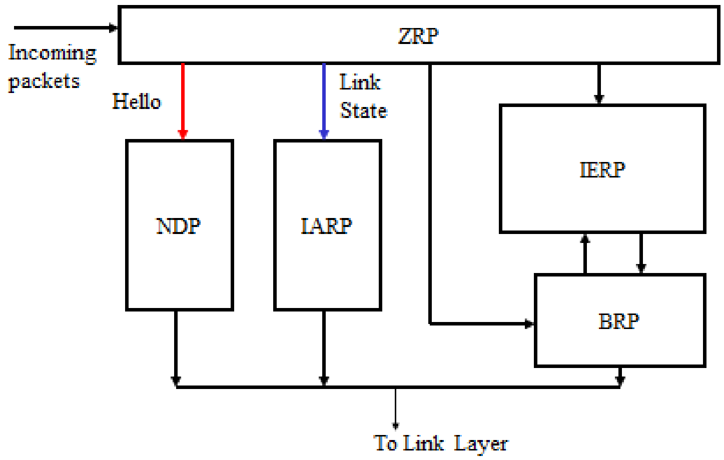

Figure 3: Hello and Link-State Packets

Neighbor discovery information is used as a basis for proactive monitoring of routing zones through the IntrAzone Routing Protocol (IARP) [16]. Since ZRP assumes that local neighbor discovery is implemented on the link-layer and is provided by the Neighbor Discovery Protocol (NDP) [15] [33], the first protocol to be part of ZRP is the IntrAzone Routing Protocol, or IARP [16]. Hence the larger the routing zone, the higher the update control traffic. The paths to the nodes which are outside the routing zone can be achieved by IERP [17].

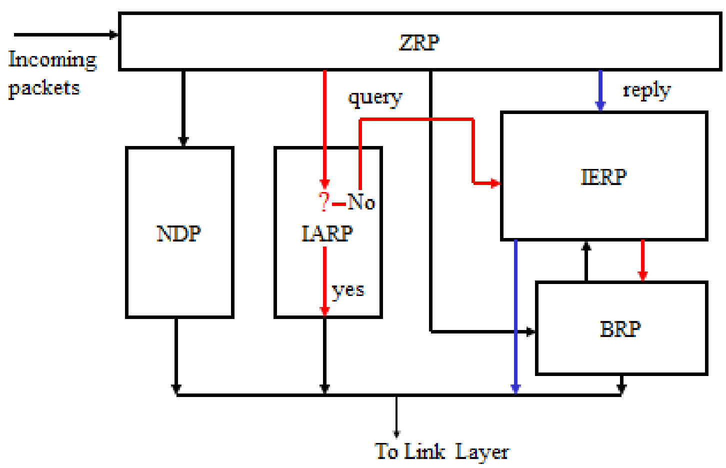

Figure 4: Route Query and Reply

If the destination belongs to its own zone, then it delivers the packet directly. Otherwise, source node bordercasts the *Route Request* to its peripheral nodes. If any peripheral node finds destination node within its *routing zone*, it sends a *Route Reply* back to source node indicating the path; otherwise, the node rebordercasts the *Route Request* packet to the peripheral nodes and this procedure continues until the destination is identified [12].

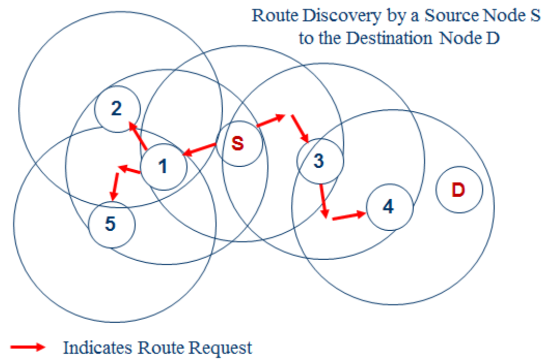

Figure 5: Route Request in ZRP with Zone Radius $K = 2$

In the above figure , S is source and D is destination. If the destination node D is present within the routing zone of the source node S then the routing is completed in the intrazone routing phase. If the destination node D is not present in the routing zone of source node S then the source node dends the packet to its peripheral nodes through bordercasting. After that, using reactive routing protocol route to the destination will be discovered [12].

Source node S sends a route request to peripheral nodes of its zone using bordercasting. There are two methods for bordercasting the route request packet to the peripheral nodes by a source node. In the first method a multicast tree for the peripheral nodes is maintained whose root is the source node S. In the second method source node S maintains a routing table for its zone and routes the packet to the peripheral nodes using information present in this routing table. Each peripheral node performs one of these two methods. Initially each peripheral node searches for destination node D in its routing zone, if the destination node is available then the packet is forwarded to it. If the destination node is not available in peripheral node's zone then the route request packet is forwarded to its peripheral nodes using bordercasting and the procedure is continues until the destination node is found [12].

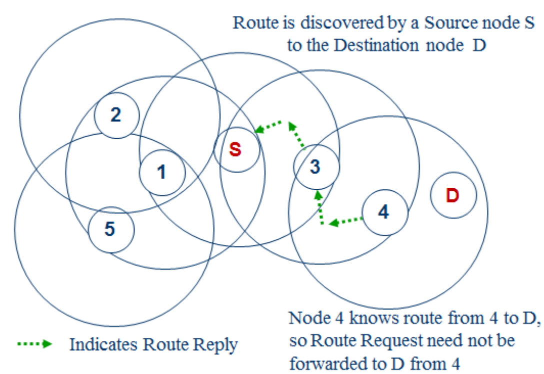

Figure 6: Route Reply in ZRP with Zone Radius $K = 2$

If a node finds the destination node D in its routing zone then it initiates a route reply packet. During the route request phase each node appends its address to the route request packet like route request in Dynamic Source Routing (DSR) [6]. This accumulated address can be used to send the route reply (RREP) back to the source node S. An alternative strategy is to keep forward and backward links at every node's routing table like in the AODV [5] protocol where we can keep the packet size constant.

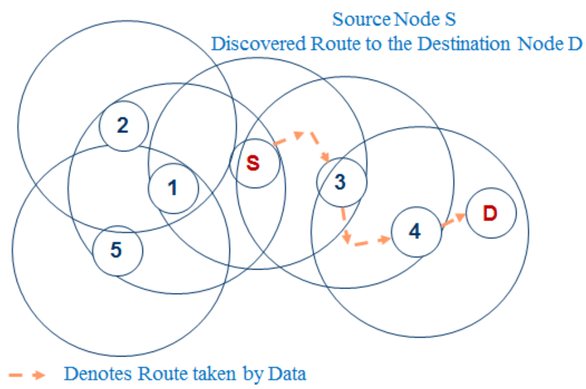

Figure 7: Data Forwarding in ZRP with Zone Radius $K = 2$

Once the Route Reply packet is received by the source node S, it starts sending the data as shown in the figure 7 [36].

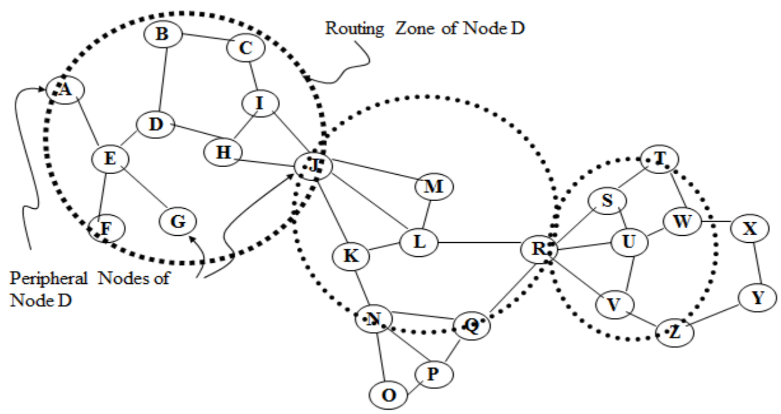

Figure 8: Working of an IARP with Zone Radius 2.

In the above example, D maintains Routes for nodes in zone using IARP and it knows route to G. If node not found, resort to Inter zone search.

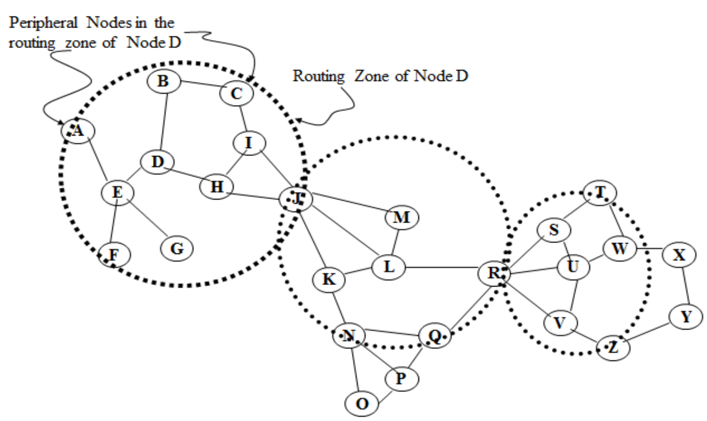

Figure 9: Working of the IERP

In the figure 9, Y is the destination and using IERP, D bordercasts query to its border nodes. J is a border node which bordercasts again to its border nodes N and R. R bordercasts to its border nodes W, T and Z. Y is found [17].

A Route Request (RREQ) usually results in more than one RREP and ZRP keeps track of more than one path between S and D. An alternative path is chosen in case one path is broken. A local path repair procedure is initiated if there is a broken link along an active path between source S and destination D which is always within the routing zone of some node [21] [22].

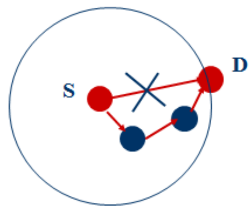

Figure 10: Route Maintenance

The repair is done by the starting node of the link (node A in the Figure 10) by sending a route repair message to node B within its routing zone. This is like a RREQ message from A with B as the destination [21].

The path-finding process may result in multiple *Route Reply* packets reaching the source, in which case the source node can choose the best path among them which may be the shortest path, least delay path, etc [24].

3. QUERY CONTROL MECHANISMS

In ZRP, due to the large overlapping of node's routing zones there is higher control overhead. The main aim of Query control mechanisms is to avoid redundant or duplicate route request that are forwarded. ZRP has three schemes for query control. These note that redundant querying occurs when a route request packet arrives in a previously queried zone. In this section, we introduce a collection of query control mechanisms so called Query Detection (QD), Early Termination (ET) and Selective Bordercasting (SB) which meet the basic design objectives [19] [20].

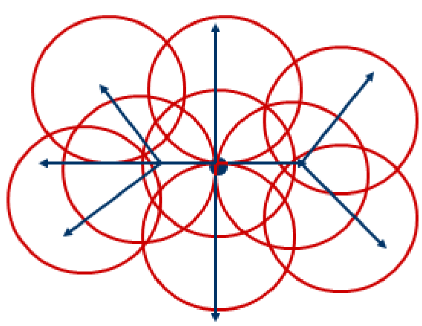

Figure 11: Guiding the Search in InterZone Routing

When a node receives a route request message, it records the message in its list of route request messages that it has received. If this node receives the same route request message once again, then it does not forward that route request packet [20].

3.1 Query Detection (QD1/QD2)

Redundant querying occurs when a query message reappears in the routing zone of a node that has already bordercast the query. Clearly, a bordercasting node is aware that its own zone has been queried. If the query message were relayed from a bordercasting node to its peripheral nodes via IP, the query would travel through the routing zone, undetected by ZRP. Here, Bordercast Routing Protocol (BRP) [18] is performing query detection in two levels.

The first level of query detection would allow nodes to detect queries as they relay them to the edge of the routing zone. (QD1). Thus, these nodes will maintain some info with regards to the query and discard duplicate queries if seen. The second level of query detection allows nodes to overhear queries as they are propagated (e.g. node 5 in figure 12). Node make note of overheard queries and thus, discard duplicate queries if they are received. This extended query detection capability (QD2) can be implemented by means of IP and MAC layer broadcasts. Other query control mechanisms may require QD to record additional information contained in the route query packet. Of particular importance is the ID of the node that most recently bordercast the query. As we will see in the next section, this information provides valuable insight into the local coverage of the query, which can be used to terminate or prevent redundant queries [20].

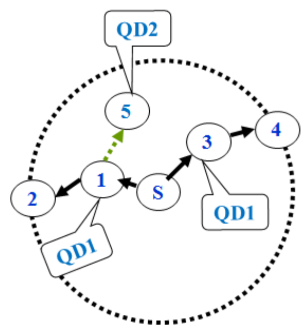

Figure 12: Advanced Query Detection (QD1 and QD2)

3.2 Early Termination (ET)

In the promiscuous mode of operation according to IEEE 802.11 standards, a node can overhear passing traffic. If a given node is already covered by the query packet, the protocol drops the query packets which come again using Early Termination.

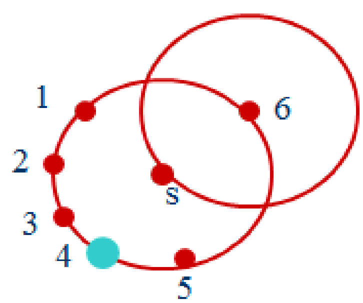

Figure 13: Early Termination of Unnecessary RREQs

In the figure 13, a node ‘s‘ has a list of nodes 1, 2, 3, 4,5 such that the RREQ message has already arrived in the routing zones of the nodes 1, 2, 3, 4, 5. Now ‘s‘ receives a request to forward a

RREQ message from another node 6. This may happen when‘s‘ is a peripheral node for the routing zone of node 6. ‘s‘ receives a RREQ from node 6 since ’s‘ is a peripheral node for the routing zone of node 6. ‘s‘ does not bordercast the RREQ to 1, 2, 3, 4, 5 but only to 4 which is not in its list.

Through advanced query detection and knowledge of the local topology, each node is able to identify surrounding regions that have already been covered by the query. Nodes can steer queries away from those areas by early termination of stray messages, encouraging the search to proceed outward. In some cases, delaying the early termination processing for a random period of time provides a valuable opportunity to detect recent additions in query coverage.

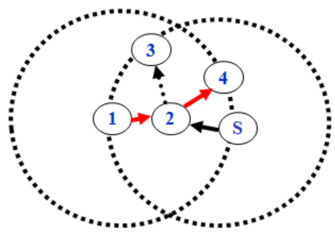

Figure 14: Early Termination (ET)

In the figure 14, Node 2 has seen a bordercast packet from 1(Sent to 4). Now, later on, it gets a packet from S to be bordercast to node 3. Node 2 would note that node 3 belongs to the previously queried zone (of node 1) and will withhold transmission. It would need to know that node 3 was in node 1’s bordercast tree. The absence of hierarchies eliminates definitive points of congestion.

A node will not relay a query packet to a bordercast recipient either if that recipient lies inside the routing zone of a previously bordercast node or if it has already relayed the query to a recipient. This scheme is called Early Termination. To identify a node that lies inside the routing zone of a previously bordercast recipient, an extended routing zone has to be maintained.

When a node bordercasts a query, all nodes within its routing zone are effectively covered by the query. Any further query messages directed into this region are redundant and represent a potential inefficiency of bordercasting. In general, it is not possible to guide the query perfectly outward into uncovered regions of the network. Fortunately, information obtained through advanced query detection (QD1/QD2), combined with knowledge of the local topology, can support Early Termination (ET) of many query messages that otherwise would stray inward.

When a node relays a query along a bordercast tree, it can safely prune any downstream branches leading to peripheral nodes *inside* covered regions of the network. The relaying node can use the known topology of its extended routing zone (or standard routing zone plus cached bordercast trees, in the case of root directed bordercast) *interior* routing zone members of each previously bordercast node in the Detected Queries Table. Relaying the same query message to a peripheral node for a second time would not add to the overall query coverage.

3.3 Random Query Processing Delay (RQPD)

When a node initiates a bordercast to its peripheral nodes, the node’s routing zone is instantly covered by the query. However, it takes some finite amount of time for the query to make its way along the bordercast tree, and be detected through the QD mechanisms. The routing zone may vulnerable to query overlap from the nearby bordercasts during the bordercast propagation.

Although this bordercast propagation of vulnerability is not very large, it can be a real problem when nearby nodes initiate bordercasts at roughly the same time. In single-channel networks the above problem is common when neighboring peripheral nodes receive a query message and simultaneously re-bordercast the message farther out into the network [20].

This problem of “simultaneous” bordercasts can be addressed by spreading out the bordercasts with a Random Query Processing Delay (RQPD). Specifically, each bordercasting node schedules a random delay prior to bordercast tree construction and ET. During this time, the waiting node benefits from the opportunity to detect the added query coverage from earlier bordercasting nodes. This, in turn, promotes a more thorough pruning of the bordercast tree (through ET) when it is time for the waiting node to bordercast. Increasing the average RQPD can significantly improve performance, up to a point. Once the bordercast times are sufficiently spread out, further increases in delay have a negligible impact on query efficiency [20].

4. INDEPENDENT ZONE ROUTING PROTOCOL (IZRP)

IZRP [25] refers to the locally proactive routing component as the Adaptive IntrA-zone Routing Protocol (AIARP) [26] and the globally reactive routing component is named Adaptive IntEr-zone Routing Protocol (AIERP) [26] [27]. The topology of the Intrazone of each node is used to reduce traffic in global route discovery [29].

In IZRP [25], Border casting utilizes the topology information provided by AIARP [27] to direct query request to the border of the zone using the Border cast Resolution Protocol (BRP) [18]. BRP [18] constructs bordercast trees for the query packets using extended routing zone (2ρ-1) information. Like in ZRP, here *query control* mechanisms which are explained in the previous section are used to direct the route requests away from areas of the network that already have been covered [20].

4.1 Adaptive IARP (AIARP)

Each node has its own zone radius depends on the mobility values. Faster node keeps a smaller zone radius; while slower node keeps a larger zone radius [23].

When a node’s zone radius is ‘1’, it does not send any proactive packets, neither HELLO packets nor IARP [16] packets; does not receive any proactive packet from other nodes, either. This zone radius is used for very high mobility nodes, e.g., 30 – 40 m/s and no pause times. When a node’s zone radius is a non-zero value, say ‘n’, it sends HELLO packets periodically and maintains ‘n’ hops routing zone around it. When it receives a HELLO packet from one of its neighbors, it adds the neighbor into its neighbor list if and only if the neighbor’s zone radius is higher than or equal to its zone radius. This means that a node keeps in its neighbor list only those nodes that have equal or less mobility. When it hears an IARP [27] packet, the node receives it if and only if the sender’s zone radius is equal to its zone radius. That is, the exchange of IARP [16] packets is limited to nodes of identical mobility [30] [31].

4.2 Adaptive IERP (AIERP)

A node which needs a route first check its routing table and its routing zone, if a route exists in the routing table or the destination node is in its routing zone, there is no need to do a route query. Otherwise, the node will initiate a route query by using its IERP [17] and BRP [18] enabled with the query control mechanism. This phase is different from the original ZRP [28] [32].

5. ZRP vs IZRP

In ZRP the same value of zone radius is maintained for all nodes in the network. When a node initiates a route query, all nodes will participate in the query process irrespective of their mobility's and can be part of the final route. In this routing the nodes with higher mobility and nodes with lower mobility get same opportunity in constructing a route. This causes fragile and unreliable routes because link breakage may occur frequently due to the movement of the fast intermediate nodes.

While in IZRP [25], different zone radii values are maintained for different nodes in the network depends on their mobility's. Nodes from different zone radius groups have different views of the network topology. This causes the network nodes to establish more reliable, effective and efficient routes. In IZRP [25] when a node initiates a route query, it sets multiple zone radius values in the route request packet before bordercasting the request to its peripheral nodes. Its neighbors eavesdrop the query by using QD2, and according to the zone radius values set in the route request packet, the neighbors decide whether to join the query phase or not. Thus, the query is injected into different zone radius groups and exchanged in each group. Multiple zone radius values are set in the route request packet, so as to

i) Allow specific zone radius groups to join the query, thereby controlling the type of nodes that can be the intermediate nodes.

ii) Limit the number of zone radius groups that can join the request, thereby controlling the amount of the routing traffics.

5.1 Performance Metrics

We have considered the performance metrics as follows:

Packet Delivery Fraction: It is the ratio of successfully delivered data packets to packets generated by CBR sources. It describes how successfully protocol delivers packet from source to destination.

Packet Delivery Fraction (PDF) = (∑ CBR Packet received / ∑ CBR Packet Sent) *100

Normalized Routing Overhead: It the ratio of total number of routing packets "transmitted" during the simulation to the number of "delivered" data packets. For routing packets sent over multiple hops, each transmission of the routing packet (each hop) is counted as one transmission.

End-to-End Delay: It includes factors causing delay in network, such as, queuing delay, buffering during routes discovery, latency and retransmission delay.

6. SIMULATION RESULTS & ANALYSIS

6.1 Simulation Model

The ZRP and IZRP were simulated in NS2 simulator and then performance of the protocols was compared.

In ZRP implementation, IARP is implemented with the link state routing protocol and IERP is implemented with AODV Protocol. Distributed bordercast approach is used for bordercasting.
In our work, we implemented query-control mechanisms which include Query Detection and Early Termination. HELLO message is used to detect neighbor existence if the zone radius is

greater than ‘0’. The distributed coordination function (DCF) mode of IEEE 802.11 standard is used as the MAC layer which uses CSMA/CA, and RTS/CTS/data/ACK dialogue.

In all simulations, mobile nodes move around a square region of size 300 m × 300 m according to Random waypoint mobility model [23]. The sources used here produce Constant bit-rate (CBR) traffic. The load in the network is changed by varying the number of source-destination pairs and the packet sending rate of each pair. The simulation parameters are shown in the table below.

Table 1. Simulation Parameters

Network Size	300 × 300 (m2)
Transmission Radius	250 m
Transmission Rate	2 Mbps
Node Speed	0 – 10 m/s (slow nodes) 10 –20 m/s (medium nodes) 20 – 30 m/s (fast nodes)
Number of Nodes	5/10/20/30 Variable (fast nodes, slow nodes and medium nodes)
Data Packet Size	512 bytes
Sessions	Variable
Data Generating Rate	Variable
Simulation time	300 seconds

Table 2. Simulation Parameters for IZRP

HELLO Message Interval	1.0 s
Allow HELLO Loss Packets	3 packets
Link State Message Interval	3.0 s
Zone Radius	Variable

6.2 Packet Delivery Fraction

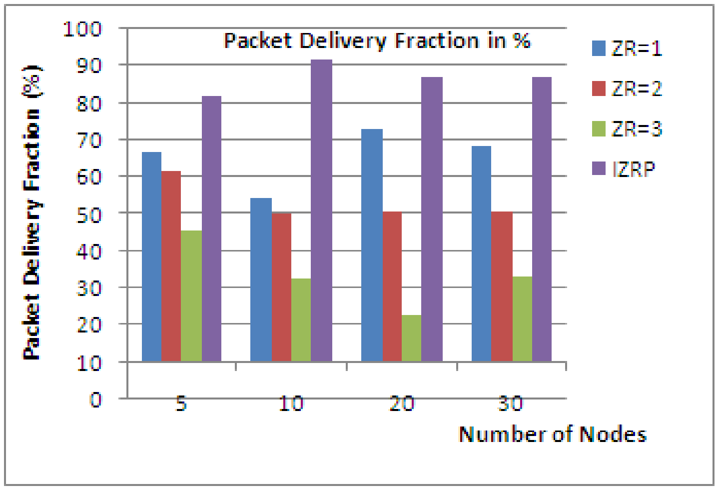

Figure 15: Packet Delivery Fraction for ZRP and IZRP

From the Figure 15, the Packet Delivery Fraction has a downtrend with the zone radius increase in ZRP protocol. A different speed of nodes in the network and a different radius for ZRP protocol will cause great difference of Packet Delivery Ratio.

6.3 Normalized routing overhead

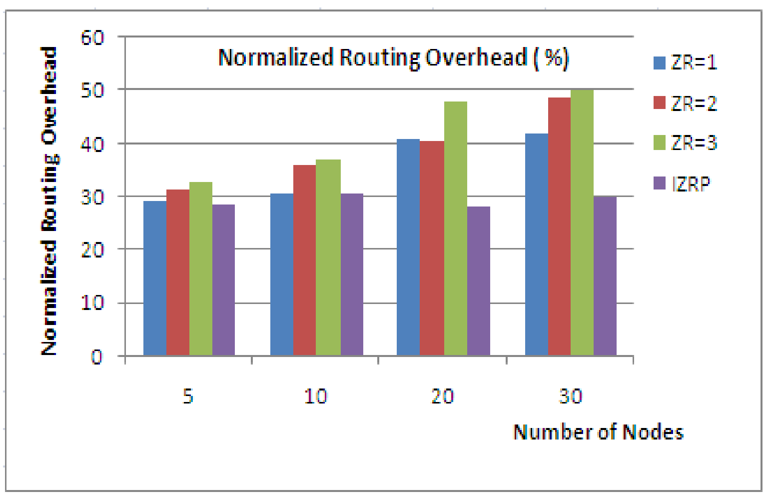

Figure 16: Normalized routing overhead for ZRP and IZRP

6.4 Route Discovery Delay

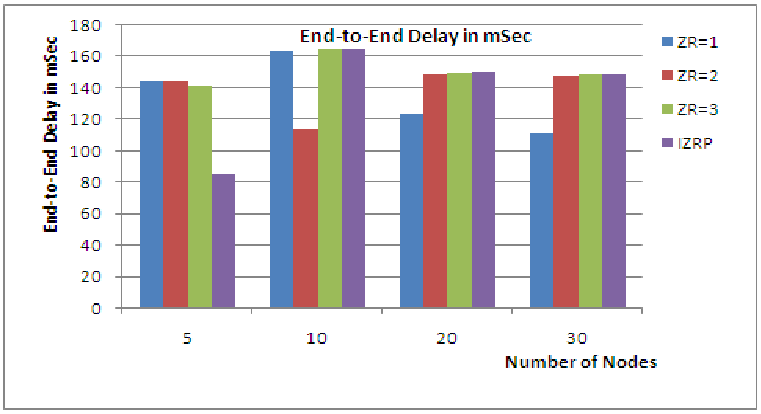

Figure 17: End-to-End Delay for ZRP and IZRP

7. PROTOCOL PERFORMANCES

The performance comparisons between ZRP and IZRP are done for 5, 10, 20 and 30 nodes and the obtained values show the better performance for IZRP. GAWK script is used to analyze the Trace files, which are generated during simulations.

Table 3. Packet Delivery Fraction for ZRP and IZRP

Zone Radius	Packet Delivery Fraction in %			
	5 nodes	10 nodes	20 nodes	30 nodes
ZR=1	66.83	54.17	72.86	68.55
ZR=2	61.57	50.11	50.84	50.84
ZR=3	45.44	32.89	23.04	33.36
IZRP (ZR=VARIABLE)	81.78	91.85	86.80	86.81

Table 4. Normalized Routing Overhead for ZRP and IZRP

Zone Radius	Normalized Routing Overhead			
	5 nodes	10 nodes	20 nodes	30 nodes
ZR=1	29.14	30.68	40.79	42.04
ZR=2	31.13	35.82	40.43	48.76
ZR=3	32.75	36.79	47.83	49.98
IZRP (ZR=VARIABLE)	28.36	30.5	28.17	29.66

Table5. End –to- End Delay for ZRP and IZRP

Zone Radius	End - End – Delay			
	5 nodes	10 nodes	20 nodes	30 nodes
ZR=1	143.80	164.08	123.95	110.79
ZR=2	143.77	113.76	148.99	147.62
ZR=3	141.92	164.62	149.59	148.25
IZRP (ZR=VARIABLE)	85.02	164.55	150.05	148.45

8. CONCLUSIONS AND FUTURE SCOPE

In this paper we proposed IZRP which is modified ZRP with independent zones and its performance is evaluated.

Like ZRP, IZRP also combines reactive and proactive protocols into one protocol. Within the routing zone, the proactive component AIARP maintains up-to-date routing tables. Routes outside the routing zone are discovered with the reactive component AIERP using route requests and replies. The amount of route query traffic is reduced by introducing features like border casting, query detection and early termination. We can also extend our research work to the actual implementation of AIARP and AIERP so that the overall performance will be improved.

IZRP makes an extension for ZRP protocol that can adapt well to the complicated network with nodes moving non-uniformly. IZRP utilizes the excellent performance of the hybrid-driven manner of ZRP and simultaneously overcomes the bad adaptability of ZRP which assumes each node move uniformly and presets the same zone radius. Simulation results show that IZRP performs better than ZRP when nodes move with different velocity. IZRP doesn't fluctuate obviously and has a trend to converge. This is not true for ZRP. When the new algorithm is used, the packet delivery fraction increases while the system routing overhead and the route discovery delay are reduced. For the mobility of nodes is variable in the practical networks, our future work may focus on the change of the zone radius aroused by the mobility change of nodes.

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