

# A Selective Border-casting Zone Routing Protocol for Ad-hoc Networks

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## Abstract

*One of well-known routing protocol for ad-hoc networks is Zone Routing Protocol (ZRP). The performance of ZRP is better than other protocols. However, many useless control packets are used resulting in the increase of network load and decrease of network performance. In this paper, we propose a Selective Border-casting Zone Routing Protocol (SBZRP) to reduce the network load by limiting the number of control packets when the protocol searches for a new route. The performance evaluation via simulations shows that the SBZRP has better performance than ZRP.*

## 1. Introduction

With the development of computer industry, the computer size is getting smaller but with rich functionality. New types of computers such as note Personal Computer (PC), Personal Digital Assistant (PDA), the increase of network speed and decrease of transmission cost have increased the number of users and computers resulting in very fast growing of Internet. But now the users want to connect to the network at any place and any time. The wireless mobile networks and devices are becoming increasingly popular to provide users the access anytime and anywhere. In order to connect mobile terminals to the network generally are used wireless LANs [1]. But, in wireless LAN, the communication between mobile terminals is done using access points and thus the movement of mobile terminals is limited. Presently, to deal with this problem ad-hoc networks are proposed. The Mobile Ad Hoc Networks (MANETs) [2] do not use any fixed infrastructure. The nodes of MANET intercommunicate through single-hop and multi-hop paths in a peer-to-peer fashion. Intermediate nodes between two pairs of communication nodes act as routers. Thus the nodes operate both as hosts and routers. The nodes are mobile, so the topology of the network may change rapidly and unexpectedly.

Much work has been done on routing in MANETs [3,4,5]. Many protocols and algorithms such as Destination-Sequenced Distance-Vector (DSDV) protocol, cluster-based routing algorithms, Dynamic Source Routing (DSR) protocol, Ad hoc On-demand Distance-Vector (AODV) protocol, Zone Routing Protocol (ZRP), Temporally Ordered Routing Algorithm (TORA), and Associative Bit Routing (ABR) have been proposed. Among these protocols, the ZRP has a wide application [6]. However, when the protocol searches for a new route, it sends many useless control packets, which increase the network load and decrease the network performance.

In this paper, we propose a Selective Border-casting Zone Routing Protocol (SBZRP) to reduce the network load by limiting the number of control packets when the protocol searches for a new route. The performance evaluation via simulations shows that the SBZRP has a good behavior and better performance than ZRP.

This paper is organized as follows. In Section 2, we introduce ad-hoc network routing protocols. In Section 3, we explain ZRP. In Section 4, we present the proposed SBZRP. In Section 5, we discuss the performance evaluation. Finally, some conclusions and future work are given in Section 6.

## 2. Ad-hoc network routing protocols

The effectiveness of a routing protocol in ad-hoc increases as network topology information becomes more detailed and up-dated. Also, the topology may change quite often, requiring large and frequent exchanges of data among network nodes.

Existing ad-hoc routing protocols can be classified into two groups: proactive and reactive routing protocols.

Proactive routing protocols attempt to continuously evaluate the routes within the network, so that when a packet needs to be forwarded, the route is already known and can be immediately used. Proactive protocols can be divided in Distance Vector (DV) protocols (e.g. DSDV) and Link State (LS) protocols (e.g. Optimized Link State Routing (OLSR)).

The LS protocols converge faster than DV protocols, but at the expense of significantly more control traffic. Motivation to both improve protocol convergence and to reduce control traffic has led to the development of proactive path finding algorithms by combining the DV and LS protocols. Path finding algorithms like Wireless Routing Protocol (WRP) [7] are able to eliminate the “counting-to-infinity” problem and reduce the occurrence of temporary loops.

Reactive protocols invoke a route determination procedure on an on-demand basis. 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. The on-demand discovery of routes can result in much less traffic than DV or LS protocols. However, the reliance on flooding may still lead to considerable control traffic in the highly versatile ad-hoc networking environment.

The advantage of proactive schemes is that route information is available when needed, resulting in little delay prior to data transmission. In contrast, reactive schemes may produce significant delay in order to determine a route when route information is needed, but not available.

Routing schemes, whether proactive or reactive, require some exchange of control traffic. This overload can be quite large in ad-hoc networks, where the topology frequently changes. Reactive protocols produce a large amount of traffic by effectively flooding the entire network with route queries. Therefore, they can not be used for real-time communication applications. Pure proactive schemes are likewise not appropriate for ad-hoc networks, as they continuously use a large portion of the network capacity to keep the routing information current.

Proactive protocols tend to distribute topology changes widely in the network, even though the creation/destruction of a new link at one end of the network may not be a significant piece of information at the other end of the network. Also, since ad-hoc network nodes may move quite fast, and as the changes may be more frequent than the routes requests, most of this maintained routing information is never used. This results in further waste of the network capacity.

### 3. ZRP

The comparison of proactive and reactive schemes shows that what is needed is a protocol that initiates the route-destination procedure on-demand, but at limited search cost. The ZRP is a hybrid reactive/proactive scheme. On one hand, it limits the scope of the proactive procedure only to the node’s local neighborhood. On the other hand, the search throughout the network, although global, can be performed efficiently by querying selected nodes in the network, as opposed to querying all network nodes.

In ZRP, a node proactively maintains routes destinations within a local neighborhood, which is considered as a routing zone. A node routing zone is defined as a collection of nodes whose minimum distance hop from the node is no greater than a parameter referred to as the zone radius. Each node maintains its own routing zone, but the routing zones of neighborhood nodes overlap. For construction of a routing zone the information of neighbor nodes is needed. A

neighbor node is defined another node that a direct communication can be established and is one hop away. In ZRP, the IntrAzone Routing Protocol (IARP) is used for routing within a zone and IntErzone Routing Protocol (IERP) for routing beyond the routing zone.

The neighbor discovery information is used for proactive monitoring of routing zones through IARP. The IARP is a simple timer-based LS routing protocol. To track the topology of “*i*” hop routing zone, each node periodically broadcast its link state for a depth of “*i*” hops, which is controlled by a Time-To-Live (TTL) field in the update messages. The nodes after receiving the IARP packets transmit them to the neighbor nodes until the Hop Counter (HC) number becomes the same as zone radius. However, if the HC in the IARP packet is bigger than the HC recorded in a node routing table, it is considered that packets are coming from the routing loops. This procedure is carried out periodically for all nodes and the routing tables are updated. When a request comes from nodes inside the zone radius, the routing table is checked and the packets are sent immediately to the destination node.

The IERP is responsible for routes located beyond the routing zone. IERP uses a query-response mechanism to discover routes on demand. The IERP is distinguished from standard flooding algorithms by exploiting the structure of the routing zone, through a process known as *border-casting*. Border-casting is a packet delivery service that allows a node to efficiently send a message to its peripheral nodes. The ZRP provides this service through a component called Border-cast Resolution Protocol (BRP).

An IERP route query is triggered at the network layer, when a data packet is destined for a node that does not lie within its routing zone. The source generates a route query packet, which is uniquely identified by a combination of the source node’s ID and request number. The query is then border-casted to all the source’s peripheral nodes. Upon receipt of a route query packet, a node adds its ID to the query. The sequence of recorded node ID’s specifies an accumulated route from the source to the current routing zone. If the destination does not appear in the node’s routing zone, the node border-casts the query to its peripheral nodes. If the destination is a member of the routing zone, a route reply is sent back to the source, along the path specified reversing the accumulated route. As with standard flooding algorithms, a node will discard any replicated route query that it has previously encountered.

### 4. Proposed Protocol

The proposed SBZRP uses for intra-zone routing the IARP the same as ZRP, but uses a new IERP for inter-zone routing.

To explain IARP let consider Fig.1. The node S generates the IARP packet (S is Source Node (SN) and the HC is 1) and sends it to all neighbor nodes (nodes A, B and C). The node after receiving IARP packet updates its own routing table using IARP packet information. The neighbor nodes of node S (A, B and C) send the received IARP packet to their neighbor nodes (see Fig. 2). The nodes are moving so the route information may be inappropriate after a period of time. For this reason, TTL parameter is used as shown in Table 1.

When the HC in the IARP packet is bigger than the HC in the routing table, the packets are discarded (see solid line arrows in Fig.2).

Let explain IERP by using Fig.3. Let consider that SN S received a request to find a route to Destination Node (DN) J. If there is not routing information in the routing table, an IERP packet is generated. The IERP packet has this information: SN = S, DN = J and the Border-cast Hop Number (BHN) = 1. The format of IERP packet is shown in Fig.6(a). The generated IERP packet is sent to all nodes which are in the zone border (see Fig.4), which have the same HC with zone radius. Therefore, there are many nodes within the zone radius. The IERP request format after node S has sent the request is shown in Fig.6 (b).

The nodes in the zone boundary which receive the ReQuest Packet (RQP) increase the BHN by 1. Then, the node checks its routing table to find a route to the DN. If the node does not find the DN in its table, the border-cast procedure continues (see solid line arrows in Fig.4). However, the IERP RQ packet is not sent to the SN (see dotted line arrows in Fig.4). In the case when a node find a DN or is itself the DN, the node sends back to the SN (S) the IERP packet (see Fig.5). This packet is called Reply Packet (RP). In this example, in the routing table of node G is recorded the information of node J, because node J is a member of routing zone G. Therefore, node G sends back the IERP RP to S by reversing the accumulated route.

The reply route format in this case is shown in Fig.6 (c). After receiving the IERP RP, the SN knows the route to send the data packets. The data packet format is shown in Fig.7. When a SN finds a route to the DN, in ZRP for inter-zone routing, the IERP RQPs are border-casted to all zone nodes. But, when a route if found, for a short period of time may be this route is still a good one and can be used for routing without searching a new route. In SBZRP, when a new search is carried out for the same node, the number of IERP packet sending directions is limited. The IERP RQPs are saved for awhile in a buffer and if there are requests for routing in the same DN, the IERP RQP are sent only to the nodes of the previous search as shown in Fig.8.

When a node moves but is inside the zone as shown in Fig.9, the intermediate nodes of the previous recorded path are C and G. In SBZRP, when the IERP RQP arrives at node C, node J is inside node C zone, thus node C sends the IERP RP to SN S. When a node moves outside a zone, but the period of time from the last search is short, it can be considered that node is not too far from the route recorded in the IERP. Therefore, a node in the IERP can search to find a new route to node J. In Fig. 10, when a RP arrives in node G, but it has not found a route to node J, a new search is started from node G. Thus, the number of the border-cast nodes and IERP packets can be decreased resulting in the increase of the throughput and the decrease of packet mean delay.

## 5. Performance Evaluation

We consider the following scenarios for simulations. In Scenario I, the number of nodes is 10, the field size is 500 m x 500 m, the transmission distance is 100 m, and the nodes are not moving (network topology is not changed).

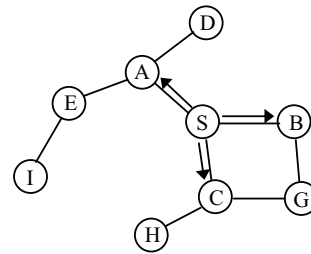


Fig. 1. IARP packet broadcasting.

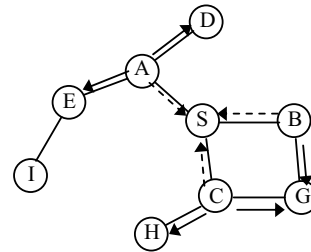


Fig. 2. IARP packet forwarding.

Table 1. Routing table of node H in Fig. 2.

DN	HC	SN	TTL (ms)
S	2	C	1500
C	1	C	2000

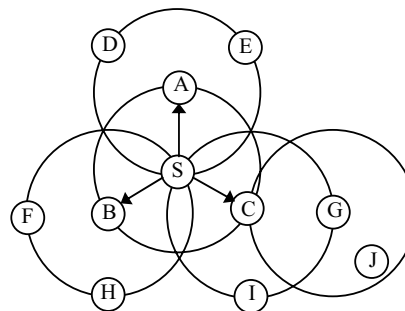


Fig. 3. IERP border-cast.

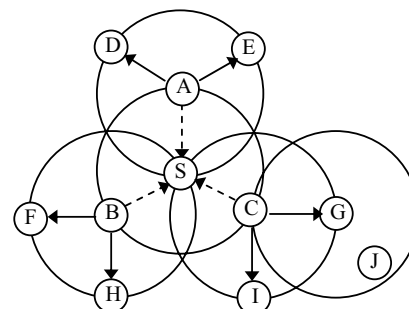


Fig. 4. IERP packet transmission.

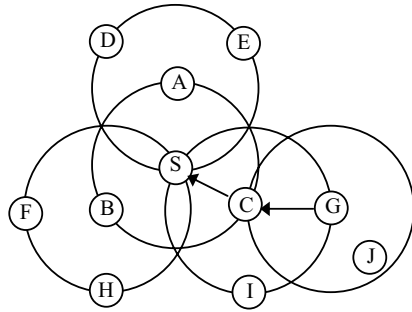


Fig. 5. IERP RP transmission.

DN	SN	Intermediate BN	Packet Type	BHN

(a) IERP packet format.

DN	SN	Intermediate BN	Packet Type	BHN
J	S	Null	RQP	1

(b) IERP request packet format of Fig. 3.

DN	SN	Intermediate BN	Packet Type	BHN
J	S	C, G	RP	2

(c) IERP reply packet format of Fig. 5.

Fig. 6. IERP packet format.

DN	SN	Intermediate BN	Packet Type	Data
J	S	C, G	Data	Data

Fig. 7. Data packet format after Fig. 5 operation.

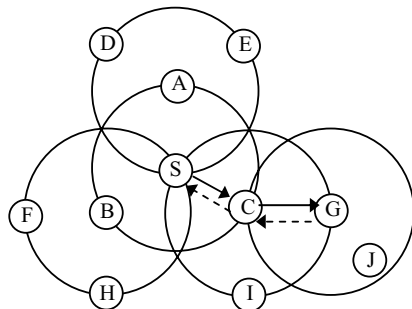


Fig. 8. Route search of SBZRP.

In Scenario II, the number of nodes and the field size is the same as Scenario I, but the generation rate is considered 30 ms (fix generation rate) and the nodes are moving. As moving model for Scenario II, we consider Random Waypoint Model (RWM) and the moving speed is 10 m/s. Until the network becomes stable is needed a period of time.

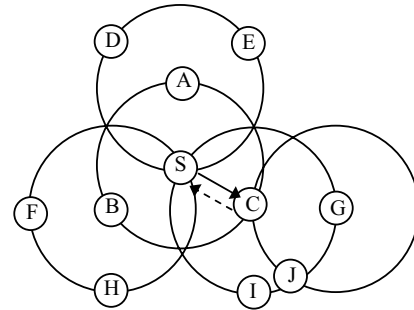


Fig. 9. A case when DN moves inside the zone.

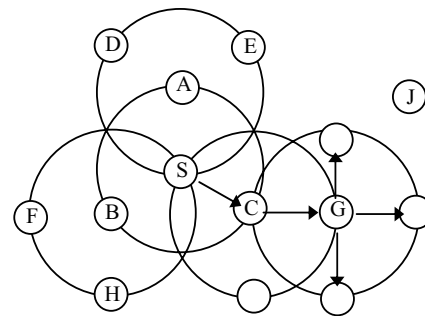


Fig. 10. A case when DN moves outside the zone.

For this reason, first 10 seconds are not considered for simulation calculation. The simulation continues until the number of generated packets reaches 1000. We compare the performance of the proposed SBZRP with ZRP for the performance of the number of packets sent to the DN without loss, the throughput, packet mean delay, and link usability.

In Fig. 11 is shown the characteristic of packet arrival rate versus the generation rate for Scenario I. The results show that when the data generation time is small (the network load is high), the SBZRP has better performance than ZRP. This is because when the network load is high many packets collide and the network performance degrades.

In Fig. 12 is shown the characteristics of throughput versus packet generation rate for Scenario I. In this figure, the same as in Fig.11, when the network load is high, the SBZRP has better behavior than ZRP. When the network load is low, the throughput is decreased for both protocols. This is because the number of generated packets is low which results in low throughputs. Also, when the network load is high, the throughput is decreased. The reason is that the number of collided packets is increased, which results in decrease of network throughput.

The mean delay versus packet generation rate characteristic for Scenario I is shown in Fig.13. When the network load is high, the mean delay of ZRP is higher than SBZRP. This is because when the ZRP searches for a new route, the number of IERP RQP is increased, thus the node buffer is congested, which results in the increase of mean delay.

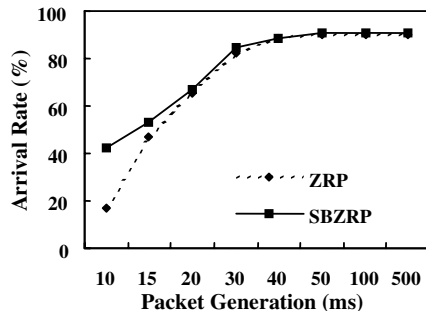


Fig. 11. Packet arrival rate vs packet generation.

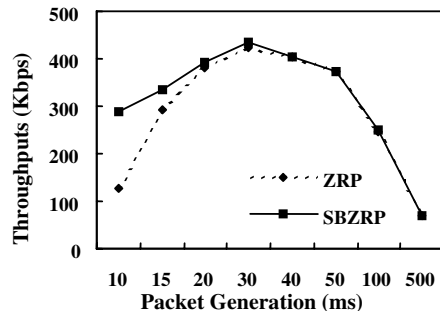


Fig. 12. Throughput vs packet generation.

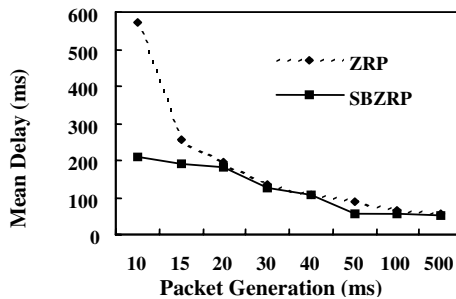


Fig. 13. Mean delay vs packet generation.

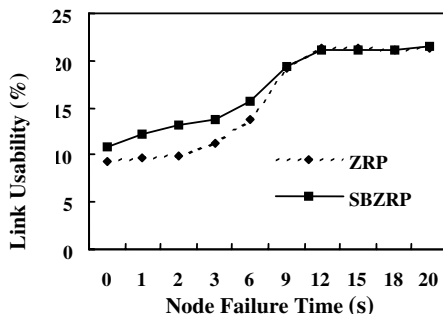


Fig. 14. Link usability vs node stop time.

The link usability versus node stop time for Scenario II is shown in Fig. 14. By using RWP, a node is moving for a period of time then stops for a moment of time. This pattern is repeated in a random way. When the node stops for a short

period of time, that means the moving degree is high, the SBZRP has higher link usability than ZRP. When node moving degree is high, the route search failure becomes high. For the SBZRP, if the route search fails, a new route search starts from the failed node. Thus, the new route search time is shorter than ZRP and the number of data sent to the DN becomes high.

From the simulation results, we conclude that when the network load and node moving degree is high, the performance of SBZRP is better than ZRP.

## 6. Conclusions

In this paper we proposed a new zone routing protocol for ad-hoc networks called SBZRP. The performance of the proposed protocol was evaluated by computer simulations using two Scenarios: Scenario I (nodes were not moving) and Scenario II (nodes were moving). From the simulation results, we conclude as follow. In Scenario I, when the network load is high, the number of arrived packets to DN without loss of SBZRP is higher than ZRP, resulting in better throughput of SBZRP. Also, the mean delay of SBZRP is lower than ZRP. For Scenario II, when the node moving degree is high, the SBZRP has high link usability than ZRP.

In this research, we used a two way transmission link. However, in real wireless environments also exists one way transmission links. Therefore, we would like to consider in the future also this kind of environment. The SBZRP is implemented in Java and embedded in mobile cellular terminals. But during simulations, we had some problems with terminal memory. For this reason, we would like to implement the protocol in C language to deal with this problem. We would like to carry out extensive simulations for different number of nodes and node moving degrees.

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