# Routing in Wireless Ad Hoc Networks using ZRP

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*Abstract* – A mobile ad hoc network consists of a collection of wireless mobile nodes that are capable of communicating with each other without the use of a network structure or any centralized administration. As such, the topology of the network changes dynamically. The nodes of a mobile ad hoc network operate as end hosts as well as routers. Routing protocols for mobile ad hoc networks have to face the challenge of frequently changing topology, low transmission power and asymmetric links. Both proactive and reactive routing protocols prove to be inefficient under these circumstances. Reconfigurable Wireless Networks (RWNs) are a special class of ad-hoc networks that are characterized by: large geographical coverage, wide range of nodal mobility and large nodal density. Recently, a new routing protocol for this type of networks was proposed and coined the Zone Routing Protocol (ZRP). The main feature of the ZRP protocol is its dynamic behavior – the operation of the scheme is governed by a single parameter, the zone radius, which adjusts the scheme's behavior from purely reactive to proactive routing. We evaluate and measure through simulations different route maintenance strategies of in Ad hoc networks to cope with these issues using ZRP.

*Key-Words*: - ZRP, IARP, IERP, BRP, Ad-hoc networks, Routing

## 1 Introduction

A Reconfigurable Wireless Network (RWN) is a mobile ad-hoc network architecture that is distinguished by its large span and large number of highly mobile nodes, can be rapidly deployed without relying on preexisting fixed network infrastructure. The nodes in a RWN can dynamically join and leave the network, frequently often without warning, and without disruption to other nodes' communication. Finally, the nodes in the network can be highly mobile, thus rapidly changing the nodal constellation and the presence or absence of links.

The currently available routing protocols are inadequate for the RWN. The main problem is that they do not support either fast-changeable network architecture or that they do not scale well with the size of the network (number of nodes). Surprisingly, these shortcomings are present even in some routing protocols that were proposed for ad-hoc networks. [1].

More specifically, the challenge stems from the fact that, on the hand, in-order to route packets in a network, the network topology needs to be known to the traversed nodes.

In the past, routing in multihop packet radio networks was based on shortest-path routing algorithms, such as the distributed Floyd-Warshall (DFW) algorithm [2]. These algorithms suffer from very slow convergence (the "counting-to-infinity" problem). Besides, DFW-like algorithms incur large update message penalties. Protocols that attempted to cure some of the shortcomings of DFW, such as destination sequenced distance vector routing (DSDV) [3], were proposed. However, synchronization and extra processing overhead are common in these protocols.

In wired networks, the problem of routing convergence has been addressed by link-state protocols, particularly the open shortest path first (OSPF) protocol [4]. While link-state protocols converge more rapidly than distance vector protocols, they do so at the expense of significantly more control traffic. For networks like the RWN, which experience frequent changes in network topology, the increase in control traffic overhead can overwhelm the network's resources. The recently proposed optimized link state protocol (OLSR) [5] utilizes a multicast-like mechanism (called ``multipoint relay") to reduce the amount of traffic produced by the periodic topology updates. This has the potential for performing well on smaller ad hoc networks. However, the underlying mechanisms of periodic and global topology updates do not appear to scale up to the larger more dynamic RWN's.

The main problem within a mobile ad hoc networks is its dynamics. The topology is likely to change very frequently. When a mobile node joins an ad hoc network, this mobile node has to notify itself to its neighbors. In case the mobile node leaves the network, due to loss of coverage or de-activation, the network has to be aware that this node is not available anymore. These changes of network topology has to be establishing a connection. The topology information stored in the databases of the network nodes may be updated each time the topology changes, or gathered only when needed.

These two different approaches of gathering topology information can be categorized as *proactive* and *reactive*.

A proactive technique scans the topology periodically to obtain the most actual information for the routing algorithm. The reactive technique scans only if no information is available or is found to be invalid [10].

## 2 Zone Routing Protocol (ZRP)

In general, the existing routing protocols can be classified either as proactive or as reactive. Proactive 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. The family of Distance-Vector protocols is an example of a proactive scheme. Reactive protocols, on the other hand, invoke a route determination procedure on demand only. Thus, when a route is needed, some sort of global search procedure is employed. The family of classical flooding algorithms belong to the reactive group. Some examples of reactive (also called on-demand) ad hoc network routing protocols are [6] and [7].

The advantage of the proactive schemes is that, once a route is needed, there is little delay until the route is determined. In reactive protocols, because route information may not be available at the time a datagram is received, the delay to determine a route can be quite significant. Furthermore, the global search procedure of the reactive protocols requires significant control traffic. Because of this long delay and excessive control traffic, pure reactive routing protocols may not be applicable to real-time communication. However, pure proactive schemes are likewise not appropriate for the ad hoc networking environment, as they continuously use a large portion of the network capacity to keep the routing information current. Since nodes in ad hoc networks move quite fast, and as the changes may be more frequent than the route requests, most of this routing information is never even used! This results again in an excessive waste of the wireless network capacity. What is needed is a protocol that, on one hand, initiates the route-determination procedure on-demand, but at limited search cost. The presented here protocol, termed the "Zone Routing Protocol (ZRP)," is an example of a hybrid reactive / proactive routing protocol.

The ZRP, on one hand, 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 in nature, is done by efficiently querying selected nodes in the network, as opposed to querying all the network nodes.

A related issue is that of updates in the network topology. For a routing protocol to be efficient, changes in the network topology have to have local effect only. In other words, creation of a new link at one end of the network is an important local event but, most probably, not a significant piece of information at the other end of the network. Proactive protocols tend to distribute such topological changes widely in the network, incurring large costs. The ZRP limits propagation of such information to the neighborhood of the change only, thus limiting the cost of topological updates.

The ZRP is based on two procedures: the IntrAzone Routing Protocol (IARP) and the IntErzone Routing Protocol (IERP). Through the use of the IARP, each node learns the identity of and the (minimal) distance to all the nodes in its routing zone. The actual IARP is not specified and can include any number of protocols, such as the derivatives of Distance Vector Protocol (e.g., Ad Hoc On-Demand Distance Vector [AODV], Shortest Path First (e.g., OSPF [4]), [8]). In fact, different portions of an ad hoc network may choose to operate based on different choice of the IARP protocol. Whatever the choice of IARP is, the protocol needs to be modifying to ensure that the scope of this operation is restricted to the zone of the node in question [9].

Note that as each node needs to learn the distances to the nodes within its zone only, the nodes are updated about topological changes only within their routing zone. Consequently, in spite of the fact that a network can be quite large, the updates are only locally propagated.

Although the IARP can be implemented through various proactive protocols, we present here an example of an implementation based on a modified version of the Distance Vector algorithm that restricts the of the algorithm's operation to the range of the routing zone radius.

While IARP finds routes within a zone, IERP is responsible for finding routes between nodes located at distances larger than the zone radius. IERP relies on bordercasting. Bordercasting is possible as any node knows the identity and the distance to all the nodes in its routing zone by the virtue of the IARP protocol.

The higher layer interface of the BRP is designed to be compatible with any IP based application. However, it is assumed that the routing zone hierarchy is visible only to the ZRP entities, making bordercasting services only of use to the IERP.

## 3 Route Maintenance

Conventional routing protocols integrate route discovery with route maintenance by continuously sending periodic routing updates. If the status of a link or router changes, the periodic updates will eventually reflect the changes to all other routers, presumably resulting in the computation of new routes.

Route maintenance can also be performed using end-to-end rather than the hop-by-hop acknowledgements, if the particular wireless network interfaces or the environment in which they are used are such that wireless transmissions between two hosts do not network equally well in both directions. As long as some route exists by which the two end hosts can communicate (perhaps different routes in each direction), route maintenance is possible [10].

So when neighboring nodes in a route move out of direct contact radio, the resulting link failure interrupts data flow across the route. For a purely reactive routing protocol, any routes that include the broken link immediately fail. To maintain end-to-end connectivity, a new route discovery / repair would have to be initiated. Until a replacement route or route segment is discovered, incoming data packets are either delayed or dropped, degrading application performance [10].

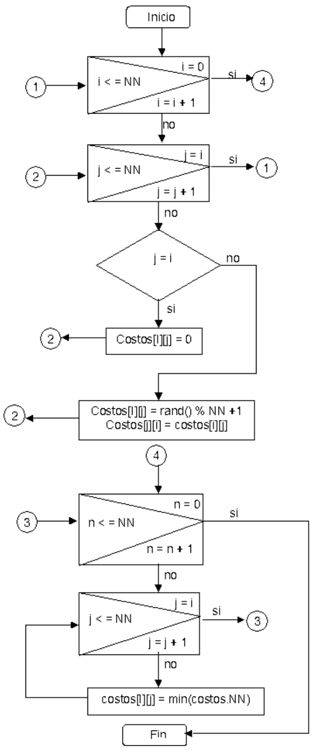


**Figure 1.** Flow Chart of Maintenance Process.

After a route is acquired, knowledge of the local topology can be used to bypass link failures and sub-optimal route segments. The resulting increase in route lifetime and reduction in route length translates in to a more stable, lower latency and higher throughput in network application [11].

**Table 1.** Fixed Simulation Parameters for scenarios.

| Parameter | Symbol | Value |
|---|---|---|
| Number of Nodes | *N, n* | 20 |
| Network Coverage Area | $X_{MAX}$ and $Y_{MAX}$ | 100 m. x 100 m. |
| Size of package | $TAM_{PACK}$ | 32000 bits |
| Transmission Radius | $DX_{MIT}$ | 10 meters |
| Beacon Period | Tbeacon | 0.6 and 5 seconds |
| Transmission Rate | $RX_{MIT}$ | 1.0 Mbps |
| Arrival Rate | $\lambda$ | 10 and 20 mgs/sec |
| Mobility | $VEL_{MAX}$ | 2 and 5 m/s |
| Utilization Factor | $\rho$ | 0.7, 0.85 and 1 |

The simulated Reconfigurable Wireless Network (RWN) consists of 20 mobile nodes, whose initial positions are chosen and they uniformly distributed over an area of 100 m. by 100 m. Each node ***j***, moves at a constant speed, ***v***, and a new direction in random way with uniform distribution in a rank of $[0,2\pi]$ [10].

### 3.1 Routing Zone Based Querying

We illustrate the basic operation of routing zone based in route discovery through a simple (but as we will see, inefficient) IERP implementation. The source node, in need of a route to a destination node, first checks whether the destination lies within its routing zone. (This is possible since every node knows the content of its routing zone). If a path to the destination is known, no further route discovery processing is required. On the other hand, if the destination is not within the source's routing zone, the source bordercast a route query to all of its peripheral nodes. Upon receipt of the route query, each peripheral nodes executes the same algorithm. If the destination lies within its routing zone, a route reply is sent back to the source, indicating the route to the destination. Else where, this node forwards the query to its peripheral nodes. This process continues until the query has spread throughout the network.

## 4 Numerical Results

In this section a mathematical analysis will provide for an overview on how the parameters of the different routing protocols influence each other in multihop ad hoc LAN's.

There are two cases which have to be distinguished:

1. Low topology dynamics and many connection requests.
2. High topology dynamics and few connection requests

By comparing these two cases for the different routing strategies it will be shown which platform will be most capable to adapt to the network's behavior.

*A. Network Parameters*

First of all, the network parameter for the calculation has to be defined

### Average distance between two nodes

$$\bar{d} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} d_{ij}}{N(N-1)} \qquad \textbf{(1)}$$

$d_{ij}$ is the distance between node $i$ and $j$ $(i \neq j)$ and $N$ is the number of the nodes in the network.

### Connectivity factor

$$cf = \frac{\sum_{i=1}^{N} M_i}{N * (N-1)} \qquad \textbf{(2)}$$

$M_i$ is the number of neighbors of node $i$ in a network

### Density of nodes per area

$$\rho = cf * (N-1) \left[area^{-1}\right] \qquad \textbf{(3)}$$

where *area* is defined as the area covered by a nodes receive range $r_s$. This area is set to 10.

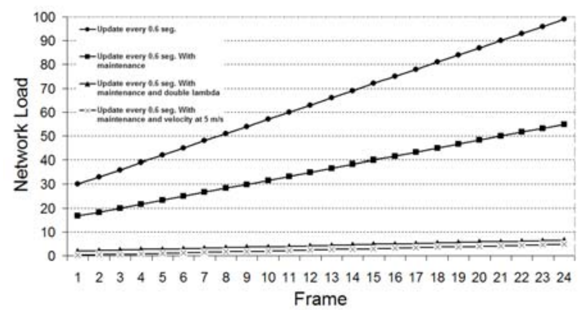


**Figure 2.** Traffic Load for various Beacon Period.

The network set-up overhead is at the same time the maximum traffic load that has to be expected within the entire network.

As seen in Figure 2 all network nodes start to transmit at system activation time. The number of the frames that are used for the complete network decrease with each scenario.

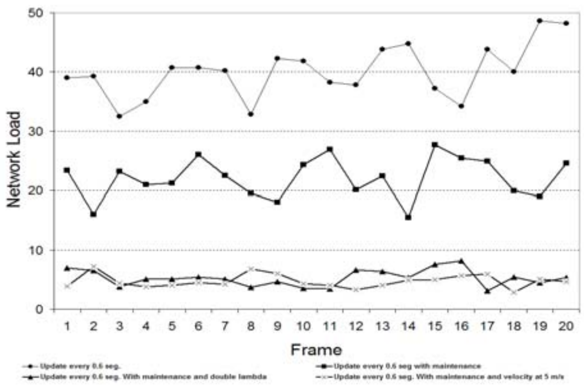


**Figure 3.** Lost node: Traffic Load for various Beacon Period.

Again, the traffic load per frame is computed, see Figure 3. the maximum load reaches 48%.

This results from the simulation behavior, which distributes not only messages on the even of an lost node, but also indicates by additional messages that other nodes, have to be flooded.

B. *ZRP overhead estimation*

Topology events can only affect the area covered by the zone surrounding the event's location. Again, it is assumed that each node within this zone will have to broadcast one message for each $N_{zone} = \rho * h^2$. For requesting a connection the overhead is different for IntrAzone and IntErzone connections. For IntrAzone connections the overhead is the average distance within the zone $\bar{d}$ , for the IntErzone connections all nodes are involved in the worst case $(N_{total})$. The ratio between IntrAzone and IntErzone connections is given by the ratio of the number of nodes within the zone $(N_{zone})$ and outside the zone $(N_{total} - N_{zone})$.

Thus the total overhead for ZRP is given by:

$$\overline{O_{ZRP}} = T * N_{zone} + C * \left( \frac{N_{zone}}{N_{total}} * \bar{d} + N_{total} - N_{zone} \right) \quad \textbf{(4)}$$

When $T$ and $C$ for the appropriate event - either *topology changes or connection request*, and $O$ is the average signaling overhead per event and will be indexed by *ZRP*.

## 5 Conclusions

The Zone Routing Protocol (ZRP) provides a flexible solution to the challenge of discovering and maintaining routes in the Reconfigurable Wireless Network communication environment. The ZRP combines two radically different methods of routing into one protocol.

Intrazone routing uses a proactive protocol to maintain up-to-date routing information to all nodes within its routing zone. In contrast, interzone route discovery is based on a reactive route request/route reply scheme.

With ZRP is reduced the traffic amount compared to pure proactive or reactive routing, and it is able to identify multiple routes to a destination, which provides increased reliability and performance. In addition, ZRP ensures that the routes are free from loops and reduces congestion and overhead usually related to hierarchical protocols. Based on the evaluations studied in this paper, we can conclude that ZRP performs better than any single proactive or reactive protocol. This is especially true if we take into account that almost any pure proactive and reactive protocol can be adapted as an IARP or IERP component of ZRP.

However, the cost of ZRP is increasing complexity, and in the cases where ZRP performs only slightly better than the pure protocol components, one can speculate whether the cost of added complexity outweigh the performance improvement. Furthermore, new protocols that are neither proactive nor reactive, as well as protocols utilizing geographical information may out perform the ZRP.

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