Impact of ZRP Zone Radius Value on Wireless Network Performance

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Abstract. In this paper, we highlight the impact of the routing load on the performance of ad hoc wireless networks. Specifically, we analyze Zone Routing Protocol (ZRP) routing load and the impact of zone radius value on this protocol performance. First, we show that performance parameters curves such as routing overhead, Packet Delivery Ratio and End-to-End Delay don't evaluate monotonously according to zone radius value. In our test context, we note optimal values for routing overhead and Packet Delivery Ratio (PDR) when $R = 3$. For delay, minimal values are observed when $R = 1$ and $R = 4$. Second, we study this hybrid protocol routing overhead according to network density and compare it to pure on-demand and table-driven routing approaches. Contrary to that is largely presented, in realistic wave propagation model context, taking into account obstacles and their effects such as multi-path one, proactive routing approach performs better than reactive one. In fact, in lossy link context, route request and route error packets broadcasted are significant. In dense network, ZRP, due to its multitude control packets, performs the worst for routing overhead and packet delivery ratio (PDR) parameters.

Keywords: Wireless networks · Routing algorithm · Zone Routing Protocol · Zone radius · Realistic simulation conditions

1 Introduction

Wireless networks are characterized by their mode of communication and limited bandwidth. To transmit data to a destination, source node proceeds by diffusion. This blind broadcast added to multi-paths effect, due to obstacles in the propagation medium, generates a high level of interference. Specifically, signaling mechanisms used to avoid collisions [1] and to update neighbors set, negatively impact on throughput and transmission delay. In this context, routing protocols play an important role. They determine in particular the network overhead, then the proportion of bandwidth consumed by control messages. Most of routing

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protocols used in wireless communications are from the adaptation of those already used in wired networks. These include proactive protocols like Open Shortest Path First protocol (OSPF) and reactive protocols like Routing Information Protocol (RIP).

Proactive protocols, also call table-driven protocols, maintain an updated routing table they exploit when needed communication. For that, the various nodes in the network must periodically exchange topology control messages. To transmit data, a route is immediately available but maintenance of the routing table leads to an important routing overhead.

Considering reactive routing protocols, also call on-demand routing protocols, to transmit data, the source node must, first, initiate a route discovery process and wait a route is found before starting data transmission. This waiting time helps increase communication delay. In an erroneous environment, network topology is unstable, established routes break very fast. Broadcast Route ERROR (RERROR) messages for restoring paths also becomes frequent.

Hybrid routing protocols have been developed to overcome the shortcomings of these two families of protocols. They use the proactive routing approach for establishing and maintaining routes with the nearest neighbors witch are defined by a zone radius parameter. Thus the distribution of topology control message is limited to the area defined by the zone radius value. For communications with remote locations, the on-demand routing approach is used. Route REQuest (RREQ) messages are broadcast for route discovery. Periodic broadcasting of control messages is limited by the zone radius value, but then we are left with a multitude of control messages.

Zone Routing Protocol (ZRP) is one of the most used hybrid protocol. In the literature, very few studies have focused on optimal zone radius determination in realistic transmission conditions. In this article, we conduct a detailed study of the significance and components of this protocol routing load and we present the impact of the neighborhood zone radius value on routing overhead.

The main contributions of this paper are:

- a detailed analyze of ZRP routing load components,
- a comprehensive assessment of the impacts of zone radius value on the protocol performance parameters (routing overhead, Packet Delivery Ratio and delay),
- the optimal value determination of zone radius.

The remainder of this paper is organized as follows: in Sect. 2, we present related work. In Sect. 3, we analyze ZRP protocol routing load. We present our simulation conditions and analyze simulation results in Sect. 4, then we conclude in Sect. 5.

2 Related Work

Routing protocols used in Mobile Ad hoc NETwork (MANET) [2] are mostly derived from an adaptation of those already used in wired networks. Thus Optimized Link State Routing (OLSR) protocol [3] is based on OSPF and Ad hoc

On-demand Distance Vector (AODV) protocol [4] is inspired from RIP. Because of the transmission mode (blind diffusion) in wireless networks, optimization solutions should take into account interference and congestions. OLSR, for example, introduces the Multi-Point Relay (MPR) mechanism [5]. The goal of this mechanism is to limit routing overhead, by selecting a subset of nodes which are the only ones allowed to broadcast topology control (TC) messages. Despite this mechanism, the routing load is always important for this protocol. It is a critical component for achieving good performance in wireless communications. Negative impact of congestion on the performance of wireless networks has been noted in several studies [6–9].

Hybrid protocols have been proposed to overcome full control messages dissemination of proactive routing protocols.

ZRP is a well-known hybrid routing protocol [10]. It is characterized by its zone radius R which determines the scope of topology control messages broadcasting. For communications to close neighbors (to less than R range), table-driven routing approach is used. For communications with more remote nodes, on-demand routing approach is used. Thus, ZRP implementation has tree components: IntrAzone Routing Protocol (IARP), Interzone Routing Protocol (IERP) and Bordercast Resolution Protocol (BRP). IARP is a limited-scope proactive routing protocol [11]. Since each node monitors changes in its surrounding R-hop neighborhood (routing zone), global route discovery processes to local destinations can be avoided.

IERP is the reactive routing component of ZRP [12]. It adapts existing reactive routing protocol implementations to take advantage of the known topology of each node (surrounding R-hop neighborhood). The availability of routing zone routes allows IERP to pass over route queries for local destinations. A BRP allows a node to send a route request packet to each of its peripheral nodes by unicast or multicast system [13]. By employing query control mechanisms, route requests can be directed away from areas of the network that already have been covered [10,14].

Duc et al. present congestion as a dominant cause of packet loss in Mobile Ad hoc NETworks (MANET). They propose a Congestion adaptive Routing Protocol (CRP) [15]. A key in CRP design is the bypass concept. A bypass is a sub-path connecting a node and the next non-congested node. If a node is aware of a potential congestion ahead, it finds a bypass that will be used in case the congestion actually occurs or is about to. Part of the incoming traffic will be sent on the bypass, making the traffic coming to the potentially congested node less.

In [16], it is proposed a Dynamic Probabilistic Route Discovery (DPR) scheme based on neighbor coverage. In this approach, each node determines the forwarding probability according to the number of its neighbors and the set of neighbors which are covered by the previous broadcast. This scheme only considers the coverage ratio by the previous node, and it does not consider the neighbors receiving the duplicate RREQ packet. Rajeeve et al. [17] propose a rebroadcast technique for reducing routing overhead in wireless network. In their approach, they enhance route request packet with two parameters: rebroadcast delay and rebroadcast probability to define the neighbor coverage knowledge in the network. RREQ message also plays the role of Hello message to detect neighbors.

Authors in [18–20] analysed zone radius impact in ZRP performance. They concluded that the zone radius should be configured to as low as 2 hops in case of low traffic and mobility scenarios, but as the traffic increases so must the zone radius. But, as performance parameter, they are mainly limited to estimating the network load. For us, parameters such as transmission end-to-end delay and packet delivery ratio (PDR) are more decisive. Their simulation environment also has not been sufficiently presented.

Authors in [21] conduct a study on the impact zone radius on the performance of ZRP. The results explanations do not stick to the obtained curves. These results contradict some widely recognized facts. For example, the delay and jitter are recognized the best for table-driven protocols because paths are immediately available for data transmissions and are more stable. They have not been detailed. In [22] it is reminded that the accuracy of the optimal zone radius computation would still be limited by the quality of the network model used.

3 Analyze

For communication with close neighborhood, ZRP uses the table-driven approach thanks to IARP. For remote destinations, it use the on-demand approach thanks to IERP. The radius area determines the close neighborhood (limited to neighbors at most R hops). This zone radius value R is an important parameter for this protocol. The larger it is, more the protocol behaves as pure table-driven protocol like OLSR protocol. The less it is, its route search process is simular to pure on-demand routing protocol like AODV protocol. It determines the scope of control messages dissemination and then routing load. It is expected for ZRP, a better control of the routing load compared to OLSR one (control packet dissemination is limited) and a better transmission delay compared to AODV. However, due to its multitude control messages, the routing overhead can be important. It includes topology control messages broadcasted periodically for the local networking, route search queries: route request, route reply an route error packets. On the other hand if the topology is too unstable, it creates consistency for the membership or not of a node to the neighboring and hence the existence of a pre-established route.

Which value to assign to this zone radius for better performance ? Very few studies have addressed the question.

To demonstrate such effects in a simulation requires the use of a realistic physical layer and a realistic propagation model. Therefore, in our tests, we enhanced Network Simulator (NS2) with CRT simulator [23]. CRT software implementes a realistic model of wave propagation taking into account environment characteristics.

In the next section, we analyse and evaluate ZRP routing overhead components and the impact of zone radius on the protocol performances in realistic simulation conditions.

4 Performance Evaluation

4.1 Experimental Setup

The global parameters for the simulations are given in Table 1.

Table 1. Simulation parameters.

Parameter	Value
Network simulator	ns-2
Simulation time	66 s
ZRP zone radius	2–6
Simulation area	1000 m * 1000 m
Transmission power	100 mw
Data type	CBR
Data packet size	512 bytes
MAC/physical layer	802.11a
Mac rate	24 Mbps

We have also used a realistic model of the Munich town (urban outdoor environment, see Fig. 1.), obstacles (building, etc) are printed red. Points represent nodes.

In this paper, we focused only on fixed nodes scenario. This fixed-nodes scenario facilitates the study and analyse of node route choice during routing process. Ten simultaneous unicast data transmissions occurred during 66 s. Beyond, time has no significant impact on the evolution of trends.

We analyze ZRP Routing Overhead (RO) and its impact on transmission End-to-End Delay and Packet Delivery Ratio (PDR). Then, we study the impact of ZRP zone radius value (R) on network performance. PDR is the ratio of the number of successfully delivered data packets over the number of sent data packets. End-to-End Delay concerns only successfully delivered packets. This includes delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at MAC layer, and propagation and transfer times. Routing Overhead (RO) is the number of routing protocol control packets. It permits to evaluate the effective use of the wireless medium by data traffic.

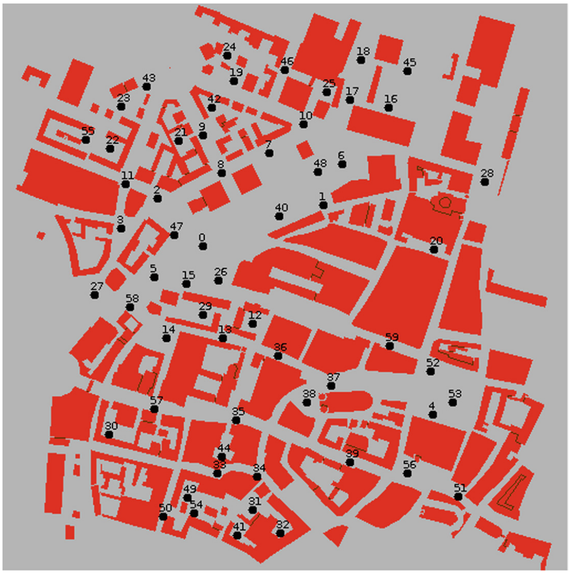

Fig. 1. Simulation environment with number of nodes = 60. Obstacles are printed red. (Color figure online)

4.2 Simulation Results

For these tests, number of nodes is fixed to 60. The average node density is 3.1. The ten simultaneous communications are selected so that source-destination distance vary from 2 to 6 hops. We observe ZRP performance when zone radius value varies from 1 to 6.

We see in Fig. 2 that, contrary to that is presented in the among of related work, routing overhead curve evolution according to zone radius is not monotonous. RO decreases with R until R = 3, then it is growing beyond. The optimal value of R is 3. Simulation trace files analysis shows that most of the routing load concerned Route REQuest (RREQ) and Route ERROR (RERROR) messages (on-demand routing approach of ZRP). We bear in mind that the routing load has essentially two components: control messages related to the reactive routing approach (RREQ, RERROR and route reply packets of IERP) and control messages related to the table-driven routing approach (IARP). When the radius R increases, naturally, the number of topology control (TC) messages increases. The solicitation of the proactive approach (IARP) and the scope of TC messages diffusion increase. For very high values of R (6 for example), the routing load due to these TC messages is very important. It nears the purely proactive approach as OLSR. This is not enough to justify the current values of number of control messages (see Fig. 2). The analysis of trace files shows that the number of route request and route error messages also increases. The dissemination of these messages is due to the non-existent paths between source-destination, therefore not included in the routing tables. For requests of transmission from a source to an unreachable destination, the purely proactive routing like OLSR reports the failure of communication while the reactive approach tried unsuccessfully a path establishment. This is the case for ZRP. With on-demand routing approach, route breaking causes a RERROR messages broadcasting to notify and apply for routing tables purification while the proactive approach initiates a local repapration the broken route.

In addition, when links are very unstable (in lossy link context), the bordercasting mechanism [13, 24] is ineffective. It produces a lot control packets to keep up to date neighborhood nodes defined by R. Remind that this process support ZRP IERP process [24]. Thank to query control mechanisms of ZRP BRP, route requests can be directed away from areas of the network that already have been covered [14].

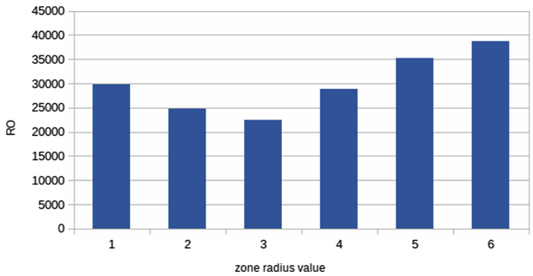

Fig. 2. Routing overhead evolution according to zone radius value

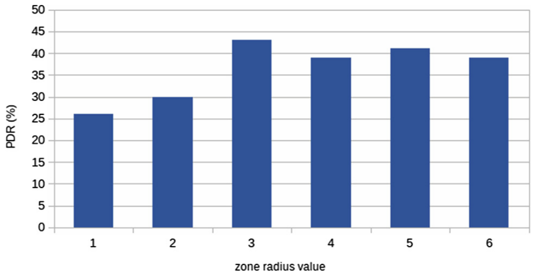

Fig. 3. PDR evolution according to zone radius value

The RO curve is consistent with the PDR one (see Fig. 3). The two curves are inversely proportional. A significant data packet loss due to lack of route, means that ZRP has used IERP process, so to multitudes RREQ and ERROR messages broadcast.

The same curve trend is observed for PDR (Fig. 3) and delay (Fig. 4). The optimal value is observed for PDR at R = 3. For delay, the best value is observed when R = 1. At the moment ZRP behaves as OLSR, established links are more reliable.

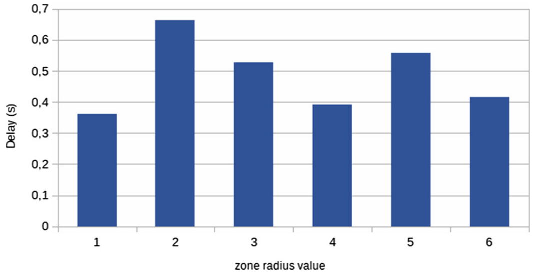

Fig. 4. Average delay evolution according to zone radius value

With these results, we can say that we must challenge the notion of optimal value of the ZRP. It must be determined for each desired performance parameter.

5 Conclusion

Congestion is one of the main cause of ad hoc wireless network cons-performance. This congestion is mainly due to the blind broadcast of routing control messages. By considering a realistic wave propagation environment, we conducted a comprehensive study on ZRP routing load and impact of zone radius value on the performance of this hybrid routing protocol. Thus, we highlight that when we take into account the lossy nature of wireless links, the on-demand routing approach generates more routing overhead than proactive approach.

We show that, in realistic conditions, the curve of routing overhead is not monotonically increasing with the neighborhood area defined by the zone radius value R. The optimal value is observed when $R = 3$. For packet delivery ratio parameter, the optimal value is 3. For delay there are 1 (equivalent at this time to OLSR) and 4. When the obstacles in the propagation medium are taken into account, the radius zone has not mean the same as the physical distance as seen in the free-space model.

These poor results of ZRP are also due to an inconsistency in the routing. Indeed, IARP can be acted to manage the routing while the concerned destination is no longer in the vicinity of the source node.

As prospects, we plan to study the impact of mobility on the optimal value of ZRP.

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