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*Research Article*

# Restrictive Disjoint-Link-Based Bioinspired Routing Protocol for Mobile Ad Hoc Networks

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The design of routing protocols for mobile ad hoc networks (MANETs) is a complex task given the dynamic nature of such networks. Particular types of routing protocols are known as bioinspired. Related to theses, the algorithms based on Ant Colony Optimization (ACO), are particularly relevant. This work presents a new variant of AntOR, a multihop adaptive routing protocol based on AntHocNet which already has two versions: disjoint link routes (AntOR-DLR) and disjoint node (AntOR-DNR). The new protocol, called AntOR-RDLR, differs from AntOR-DLR in the pheromones updating process and the route discovery mechanism. The simulation results indicate that AntOR-RDLR improves their predecessors in all analyzed metrics.

## 1. Introduction

A mobile ad hoc network (MANET) [1] is a collection of mobile devices, which form a communication network without predefined infrastructure. This fact determines the design of routing protocols for this type of network to suppose an arduous task. Particular types of routing protocols are called bioinspired, which take into account the behaviour of some animals (insects, etc.) to obtain their food. A representative protocol of so-called bioinspired is AntOR [2], multihop adaptive routing protocol based on AntHocNet [3]. The specification of this protocol includes two versions: disjoint link routes (AntOR-DLR) and disjoint node (AntOR-DNR). This work presents a variant of the first one. This paper consists of 6 sections, with this being the first of them. The rest of the paper is structured as follows. Section 2 discusses briefly the most representative works in the area of bioinspired algorithms for their application in the design of routing protocols for mobile ad hoc networks. Section 3 presents AntOR, predecessor algorithm and its two versions; also making a comparison between both, whose analysis lays the main keys for AntOR-RDLR. Section 4 introduces AntOR-RDLR, emphasizing the differences with respect to its predecessor. A comparative study between AntOR-RDLR and AntOR-DLR is shown in Section 5. Finally, the conclusions are established in Section 6.

## 2. Related Work

Many bioinspired protocols have been proposed in literature. In ant routing algorithm for mobile ad hoc networks (ARAMAs) [4] discovery and route maintenance overhead is reduced through the control of the number of forward ants. However they do not clarify how to control the generation of ants in a dynamic environment. [5] presents a protocol that has a low delivered data packet ratio in scenarios where mobility is high, but has a high overhead due to broadcast messages sent several times. [6] uses the flood process to update the pheromone tables on all nodes, being the packet transmission reach higher than a simple broadcast, but with one overhead greater. [7] presents a robust protocol that provides better quality of service (QoS), but it has a high latency in the route discovery by being a reactive protocol. HopNet [8] is a highly scalable protocol, but has the disadvantage that when the node number is low, it experiences a greater delay than other protocols because of the continuous movement of peripheral nodes inciting more discovery processes of new routes. However, undoubtedly, the most representative protocol is AntHocNet [3], adaptive and multipath protocol which takes into account the dynamic topology and other characteristics of the MANETs and presents a hybrid operation: reactive because it has agents operating on demand to establish routes to destinations and is proactive because it has other agents which obtain information to discover new alternative routes on prevention by the link failures. A variant of AntHocNet is AntOR, protocol which the present work is based on.

## 3. AntOR

AntOR is a hybrid ACO protocol which for its properties is adapted to the MANETs. It has the following characteristics which distinguishes it from AntHocNet:

(i) disjoint-link and disjoint-node protocol;

(ii) separation between the pheromone values in the diffusion process;

(iii) use distance metric in route proactive exploration.

Disjoint-Link version (AntOR-DLR) is that in which the links are not shared. In the Disjoint-Node version (AntOR-DNR) are nodes that are not shared. Every disjoint-node is also a disjoint-link, but not vice versa. The two types of routes have the following advantages.

(a) When a node fails, it will only affect a route, but not to the whole network.

(b) The load balancing is better with the disjoint property, because routes are not repeated.

Although it has some disadvantages such as the need for more resources by not sharing links or nodes. In [9], we are seeing a comparison whereby we can see how Link-disjoint improved Node-disjoint. Below a more detailed comparison of these two versions is presented. In the comparison we have used the following two metrics.

(i) *Delivered data packet ratio*: relationship between the number of packets sent and the number of packets delivered successfully.

(ii) *Average end-to-end delay*: measure of accumulative effectiveness of experienced delays by the packets going from source to destination.

Network Simulator NS-3 has been used (specifically version 8) [10]. Simulation parameters are as follows: we have utilized 100 nodes configured according to the Standard IEEE 802.11b, moving in a random scenario dimensions 1000 m × 1000 m according to the pattern of mobility *Random WayPoint* (RWP). The application of data traffic is *Constant Bit Rate* (CBR) with a packet sending rate of 2048 bps (4 packets of 64 bytes per second). We apply 5 random data session, where mobility is variable from 0 m/s up to a maximum of 10 m/s. Total simulation time is 120 s and pause time at intervals of 30 seconds from 0 s to a maximum of 120 s has been varied. In Figures 1 and 2, you can observe how AntOR-DLR improves AntOR-DNR according to the performance metrics of delivered data packet ratio and average end-to-end delay. More specifically, in Figure 1 we appreciate how the delivery of data packets is better in link-disjoint version than in node version, being significantly higher in simulations where the pause time is scored in 30 and 60 s.

In addition, in Figure 2 we see how the delay is clearly lower, but as it increases the pause time delays are approaching, but fail to match.

These two figures give us information on how the link-disjoint routes have better performance by the failures of link/node. This is due to the fact that the failure of the node-disjoint route is more frequent (as link-disjoint routes serve themselves from independent links that use other nodes).

## 4. AntOR Disjoint-Link Restrictive (AntOR-RDLR)

This restrictive version, AntOR-RDLR (restrictive disjoint-link route version) covers two characteristics that differentiate it from its predecessor. Firstly, it is the pheromone update process, and on the other hand, the so-called link-Disjoint restrictive property. Thus, in AntOR [2] same route cannot have regular and virtual pheromone simultaneously. In AntOR the updating is in the following way, knowing that the regular pheromone takes precedence over the virtual.

(a) If the node A, which has a route to the destination D, already has regular pheromone, and it reaches virtual pheromone in pheromone diffusion process, then the virtual value is not updated on node A. Therefore, the value of final virtual pheromone is zero, as is shown in

$$\begin{aligned}\text{Regular}_{\text{final}} &= \text{Regular}_{\text{old}}\\ \text{Virtual}_{\text{final}} &= 0.\end{aligned} \tag{1}$$

(b) If the node A, which has aroute to the destination D, already has virtual pheromone, and it gets regular pheromone in the route discovery process, then the value of virtual pheromone is replaced by the value of regular pheromone that arrives. Therefore, the new value of virtual pheromone is 0, as it picks up from

$$\begin{aligned}\text{Regular}_{\text{final}} &= F(\text{Regular}_{\text{new}}, \text{time})\\ \text{Virtual}_{\text{final}} &= 0.\end{aligned} \tag{2}$$

In the new protocol, AntOR-RDLR, the updating process is as follows.

(a) If the node A, which has a route to the destination D, already has regular pheromone, and it reaches virtual pheromone in pheromone diffusion process, then

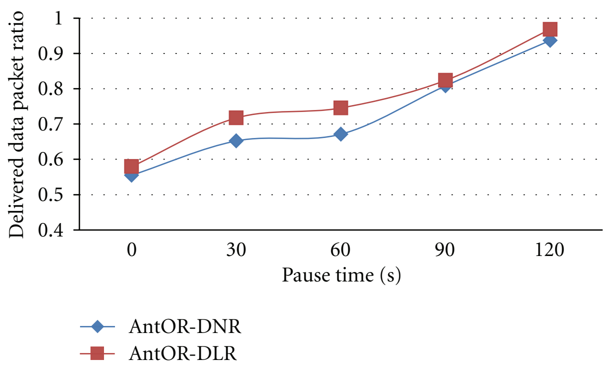


Figure 1: Pause time against delivered data packet ratio.

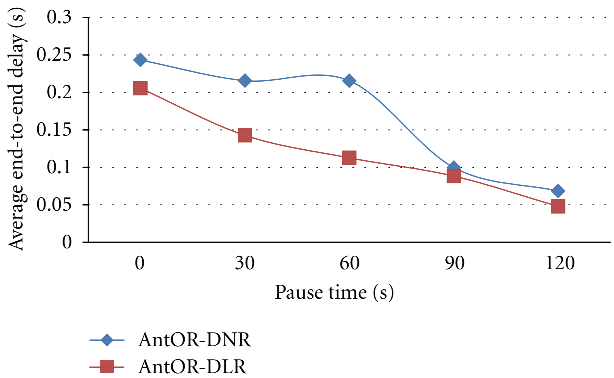


Figure 2: Pause time against average end-to-end delay.

the virtual value is not updated on node A. Therefore, the value of final virtual pheromone is zero, as it is shown in

$$\begin{aligned} \text{Regular}_{\text{final}} &= \text{Regular}_{\text{old}} \\ \text{Virtual}_{\text{final}} &= 0. \end{aligned} \tag{3}$$

(b) If node A has a route to the destination D, it already has virtual pheromone, and it gets regular pheromone in the route discovery process, then the value of regular pheromone replaces the virtual pheromone by the maximum of the value of regular pheromone that arrives and the average between the value of regular pheromone that arrives and the old virtual old, setting the value of virtual pheromone equal to 0, as it picks up from

$$\begin{aligned} \text{Regular}_{\text{last}} &= F(\text{Regular}_{\text{new}}, \text{time}) \\ \text{Regular}_{\text{final}} &= \max(\text{Regular}_{\text{last}}, \text{mean}(\text{Regular}_{\text{new}}, \text{Virtual}_{\text{old}})) \\ \text{Virtual}_{\text{final}} &= 0. \end{aligned} \tag{4}$$

With regard to the restrictive property about link-disjoint routes in AntOR-DLR (disjoint-link route) a same route to a destination cannot share links as shown in next Algorithm 1.

Proactive agents (ants) go by ways which are not link-disjoint.

It is allowed AntOR-RDLR to choose disjoint links for the data retransmission up to a maximum of attempts MAX_HOP_RETRY according to following Algorithm 2.

For example, whether in the proactive retransmission process a disjoint-link route has been selected, in theory, it would not be a candidate to be forwarded, according to the original version of AntOR, but this new version can forward up to a maximum of attempts MAX_HOP_RETRY by the route.

## 5. AntOR-RDLR versus AntOR-DLR

We then present a comparison of these protocols. In this we have taken into account the following metrics.

(i) *Delivered data packet ratio*: relationship between number of packets sent and the number of packets delivered successfully.

(ii) *Throughput*: volume of work or information flowing through a system. It is calculated by dividing the total number of bits delivered to the destination by the packet delivery time.

(iii) *Overhead in number of bytes*: relationship between the total number of transmitted control bytes and delivered data bytes.

For this comparison the network simulator NS-3 (specifically version 8) [10] has also been used. Simulations parameters are as follows: we have used 100 nodes configured according to the Standard IEEE 802.11b, moving in a random scenario with dimensions of 1000 m × 1000 m according to the mobility pattern *Random WayPoint* (RWP). The application of data traffic is *Constant Bit Rate* (CBR) with a rate of sending packages 2048 bps (4 packets of 64 bytes per second). We apply 5 random data sessions, where mobility is variable from 0 m/s up to a maximum of 10 m/s. Total simulation time is 120 s and pause time has been changed at intervals of 30 seconds from 0 s to a maximum of 120 s. We have done two kinds of experiments. Firstly, an initial experiment in which we wanted to compare the link-disjoint version and its restrictive version. For this comparison we have established MAX_HOP_RETRY at a constant value of 5 attempts. According to the Figures 3 and 4 the restrictive version wins the original version, link-disjoint route, according to metrics of the delivered packet ratio and throughput.

This makes us see that this restrictive version, AntOR-RDLR, behaves more efficiently, providing a better service because fewer packets are lost. This is especially due to AntOR-RDLR has the restrictive property of Link-disjoint routes, already mentioned previously, which makes it possible to create more alternative routes, providing more security by the link/node failures. The second experiment claimed to analyze the evolution of the restrictive version. To perform this comparison MAX_HOP_RETRY from 2 attempts up to a maximum of 10 has been varied, with a pause time of a constant value of 30 s (25% of the total simulation time).

```
While Proactive Process do
    if Link ≠ Session Source then
        Send Control Packet;
    else
end
```

Algorithm 1: Proactive process in AntOR-DLR.

```
HOP_NUM = 0;
While Proactive Process do
    if Link ≠ Session Source then
        Send Control Packet;
    else
        if HOP_NUM≤MAX_HOP_RETRY then
            HOP_NUM = HOP_NUM + 1;
            Send Control Packet;
        end
    end
end
```

Algorithm 2: Proactive process in AntOR-RDLR.

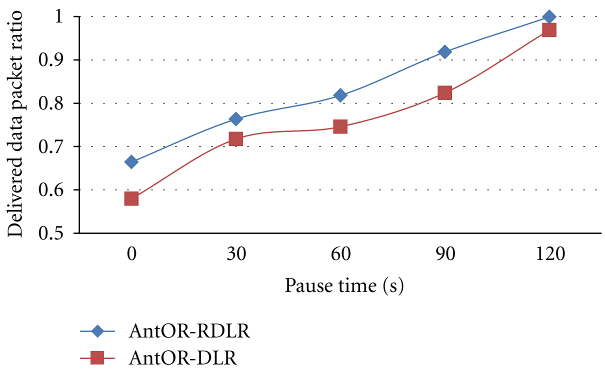


Figure 3: Pause time against delivered data packet ratio.

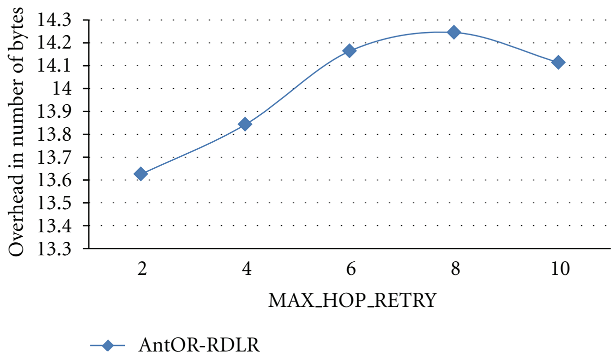


Figure 5: MAX_HOP_RETRY against overhead.

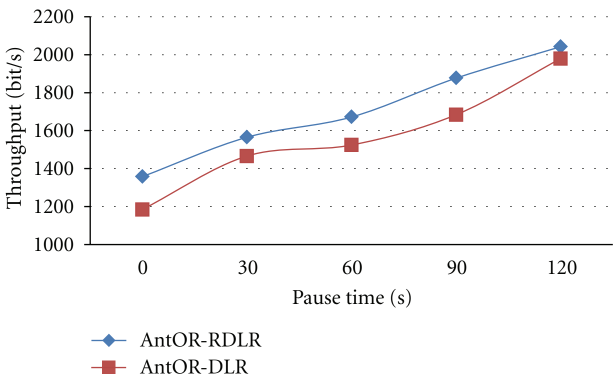


Figure 4: Pause time against throughput.

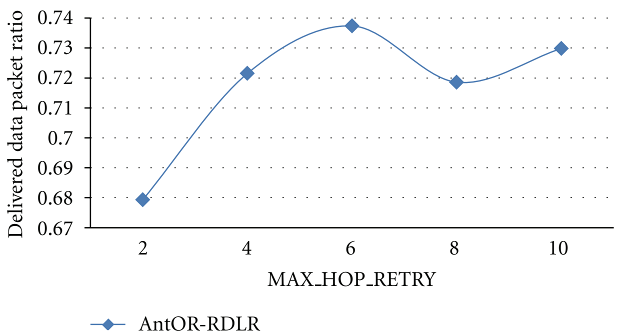


Figure 6: MAX_HOP_RETRY against throughput.

In Figure 5, we observe how the overhead in bytes increases as the number of attempts decreases, but it decreases after 8 attempts. This makes us see that from a given value MAX_HOP_RETRY, we do not improve the performance of the algorithm.

In Figure 6, we have delivered packet ratio. In this graph we can see how the ratio increases according to the number of attempts until reaching a value of 6. From this value, the ratio shows irregular behaviour.

## 6. Conclusions

In this work a family of bioinspired routing protocols for mobile ad hoc networks has been presented. The base protocol, called AntOR, has two versions, the so-called link-disjoint (AntOR-DLR) and node-disjoint (AntOR-DNR). A comparison between these versions have been presented observing how Link-disjoint version (AntOR-DLR) improves to node-disjoint version (AntOR-DNR), because the link-disjoint routes have better performance by the link/node failures or, in others words, a node failure occurs more frequently than link failures since link-disjoint routes serves themselves of independent links which use other nodes. Also, a new version of AntOR, which improves the previous ones, has been presented. This new protocol, called AntOR-RDLR, differs from its predecessor, AntOR-DLR in the pheromone updating process and the route discovery mechanism. It has been shown how AntOR-RDLR improves AntOR-DLR in service performance and how to vary the number of attempts MAX_HOP_RETRY is a very important decision in the functioning of the algorithm, because we allow to generate more alternative routes than in AntOR-DLR version.

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