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# On optimising route discovery in absence of previous route information in MANETs

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## Abstract

This paper present a new routing protocol for Ad hoc networks, called On-demand Tree-based Routing Protocol (OTRP). This protocol combines the idea of hop-by-hop routing such as AODV with an efficient route discovery algorithm called Tree-based Optimized Flooding (TOF) to improve scalability of Ad hoc networks when there is no previous knowledge about the destination. To achieve this in OTRP, route discovery overheads are minimized by selectively flooding the network through a limited set of nodes, referred to as branching-nodes. The theoretical analysis and simulation results showed that OTRP outperforms AODV, DYMO, and OLSR and it reduces overheads as number of nodes and traffic increase.



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# On Optimising Route Discovery in Absence of Previous Route Information in MANETs

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## Abstract

*This paper present a new routing protocol for Ad hoc networks, called On-demand Tree-based Routing Protocol (OTRP). This protocol combines the idea of hop-by-hop routing such as AODV with an efficient route discovery algorithm called Tree-based Optimized Flooding (TOF) to improve scalability of Ad hoc networks when there is no previous knowledge about the destination. To achieve this in OTRP, route discovery overheads are minimized by selectively flooding the network through a limited set of nodes, referred to as branching-nodes. The theoretical analysis and simulation results showed that OTRP outperforms AODV, DYMO, and OLSR and it reduces overheads as number of nodes and traffic increase.*

## 1. Introduction

Ad hoc networks consist of a set of de-centralised end-user nodes which perform routing in a distributed manner over the wireless medium. This distinct feature of such networks has created a number of new and challenging research issues in the wireless data networking paradigm. One such issue is routing, which has consequently received significant attention. The scalability issue is one of the main problems researched in routing. This has led to the proposition of various types of routing protocols such as reactive (or on-demand) routing protocols. These routing protocols improve the scalability by reducing the amount of routing overheads introduced through the network by limiting route calculations to occasions when a route is required. Consequently, a significant amount of reduction in routing overhead can be achieved at a cost of extra delays[1][5][6].

This paper presents a new on-demand routing strategy, which aims to increase scalability of Ad hoc networks. Much of the previous work in on-demand routing in Ad hoc networking have tackled this problem by introducing strategies, which improve scalability and routing overheads when a source node has previous knowledge of the required destination [2][5][7]. In reality a significant part of routing involves determining routes to destinations without previous location knowledge. In this paper, we focus on improving the performance of on-demand routing when previous knowledge of the destination is unavailable at the source. To do this, a new routing protocol is proposed which reduces the number of redundant rebroadcasts during route discovery without relying on previous knowledge of the destination.

The rest of this paper is organised as follows. Section II presents a summary of previous literature related to on-demand routing protocols. Section III describes the proposed routing protocol. The simulation parameters and scenarios that are used to investigate the performance of the proposed routing strategy are given in section IV. Then the results of the simulation study are summarised in section V. Section VI concludes the paper.

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## 2 Related Work

On-demand routing protocols have the potential to achieve high levels of scalability in mobile ad hoc networks. However, before this can be realised two major issues need to be resolved. These are high levels of control overhead due to route request packets and also additional delay. The focus of this paper is on reducing the overheads introduced in the networks. Reducing overhead can also reduce the amount of delays introduced into the network. Several approaches have been proposed to reduce the routing overheads of on-demand routing protocols such as stable routing, multi-path routing, load balance routing, and routing based on previous knowledge. The idea behind stable routing in on-demand routing protocols, is to select routes which would stay active for a longer period of time. A number of different strategies have been proposed to determine the stability of routes in [11][12][13] .
Multipath routing provides more than one route which are available for data transmission. This means that a single

route failure may not always require route-recalculation. DSR[6] and SMR [8] are On-demand routing protocols that use this strategy. However, in highly mobile environments such strategy may not show significant levels of performance improvement over single path routing algorithms. Load-balanced on-demand routing protocols attempt to improve route discovery by distributing the network load and hence minimising the creation of traffic bottlenecks on the network like in [1] and [8].
Some on-demand routing protocols use the routing based on previous knowledge approach to fix link failure of an existing path. Therefore, often a source node is required to re-calculate routes to the same destination. To minimise the level of route re-calculation due to route failures, a number of different strategies have been proposed, which attempt to minimise the number of re-broadcasting nodes during route discovery process. In AODV [5], the source nodes uses expanding ring search along with the last hop count to the destination to minimise the scope of Route Request (RREQ) packets propagation. Other on-demand routing protocols limit the RREQ packets propagation to a localised region like LPAR[1], RDMAR[2], LAR[7].

## 3. Description of OTRP

The idea behind OTRP is to reduce the number of redundant rebroadcasts when previous information about destination is not available. This is achieved through a new algorithm called Tree based Optimised Flooding (TOF) which strategically selects forwarding nodes during the route discovery phase. Those selected nodes are called branching-nodes because they form a tree-based structure to scan the network. The root of the tree is the source node with at most four brances and parent nodes have at most three branches. In fact the brances nodes are one hop neighbours of parent nodes which forward RREQ packets. In this paper, branching-nodes are refered to as rebroadcasting nodes. To ensure that most of network nodes have received RREQ packets, branching-nodes are also selected based on their locations. The locations are obtained by using GPS. The transmission area of the parent nodes is called neighbours area. This area is divided into four regions that are Right_Top (RT), Left_Top (LT), Left_Down (LD), and Right_Down (RD) (see Figure 1). Source node is located at $(x, y)$ on network of size $W \times L$. The source node selects a node $(x_j, y_j)$ in each region. Each region will have its own scanning process to rebroadcast RREQ packets. The area of each region and range of $x_j$ and $y_j$ are shown in Figure 1. Transmission range $I$ of source node or parent node is partitioned into three subareas $i_1$, $i_2$, and $i_3$ that are:
$i_1$=$[\frac{T}{2}, \frac{T}{2} + (\frac{T-\frac{T}{2}}{2})]$
$i_2$=$[\frac{T}{2}, T]$
$i_3$=$[0, T]$
These ranges are shown in Figure 2.

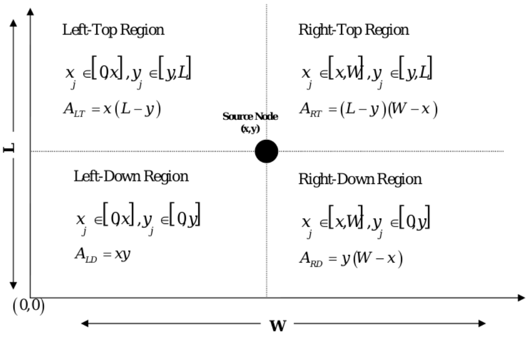



Figure 1: Neighbours area of source node with OTRP

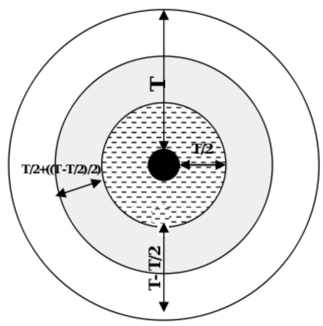



Figure 2: Division of transmission range of source node in OTRP

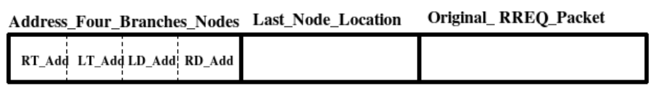



Figure 3: The formate of RREQ packet with OTRP

The broadcasting node will append to RREQ packet its own location and addresses of four branching-nodes that will rebroadcast RREQ packet in four regions. The formate of RREQ packet with OTRP is shown in Figure 3. In TOF algorithm, if no route reply is received after two retries of using this algorithm then normal broadcasting will be carried. TOF algorithm starts where received node checks whether it is one of the branching-nodes that are indicated in the RREQ packet. If it is then it will process the packet, otherwise the packet is ignored. Processing received RREQ packet includes finding branching-nodes, updating the RREQ packet and then rebroadcasting it. In the process of finding branching-nodes, the rebroadcast nodes are selected in each region through at most three iterations according to the transmission range of source node or parent node and the locations of its neighbour nodes. The parent node searches its routing table to find the location of its one-hop neighbours with active links. In this process, assume the distance between source node and its neighbour is $D$ where $D < T$. The parent node will firstly search for branching-nodes that their $D$ are in range $i_1$. This range is considered to be the first area to search for nodes because the node may cover more different nodes than parent node does and simultaneously the link between the node and its parent may be more reliable. If no node is found in $i_1$, the search range will be extended to $i_2$. Lastly, parent node will choose any neighbour nodes within its transmission range T. At the end of finding branching-nodes process, the addresses of branching-nodes are found. After this process, the RREQ is updated by replacing the value of the node location, and updating the addresses of four branching-nodes that will rebroadcast RREQ packet in four regions. Since each selected node doesn't broadcast RREQ packets back to the region where the packet comes from, therefore it chooses only three branching-nodes to rebroadcast. However, the source node of RREQ packet selects four nodes as first time for broadcasting the packet. The parent node address is assigned to node address of Address_Four_Branches_Nodes in RREQ packet if its region is excluded from broadcasting or there is no node has been found in that region. If there are unreachable nodes or no route was found through above procedure, then all nodes will rebroadcast RREQ. The process of maintaining route is the same as default one that on-demand routing protocol uses. The location of one-hop neighbours of parent node are valid as the link is active between two nodes. As node mobility affects the stored information about node location, the locations of neighbours are updated using control packets (i.e. RREQ, RREP, and RERR) that include location of last node that has been visited. When a nodes receives any control packet, it copies the location of the its neighbour ,that forwarded the packet, to its routing table. Then it replaces the location values in the control packet with its own location information.

### 3.1. Theoretical Analysis of OTRP

We theoretically compare the performance of OTRP with AODV in reducing overheads. Suppose the nodes have been distributed in grid form as in Figure 4. Assume that the transmission range of all nodes is $T$ and each node has four neighbours (branching-nodes) that are located on top, left, right and down. The distance between each pair of nodes is $\frac{T}{2}$.
Let the source node be located at $(x, y)$ of network size $W \times L$ with total number of nodes $N$. Hence,
$N = (\frac{W}{T/2} \cdot \frac{L}{T/2}) \ldots (1)$
where there is a node in each $T/2$.

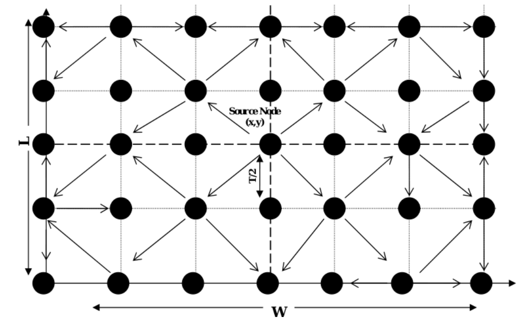



Figure 4: OTRP with grid distribution of nodes

The source node will start route discovery process by selecting for four branching-nodes in each region. Figure 4 shows this distribution and path of RREQs packets through branching-nodes. By using Figure 1 and 4, lets consider nodes in Top Right region. The distribution of nodes will form a rectangular area that is equal to

$$A_{RT} = (L - y)(W - x)$$

Let $N_{RT}$ be the total number of nodes in this region where $N_{RT}$ is an integer value and there is a node on each $\frac{T}{2}$ of source node:

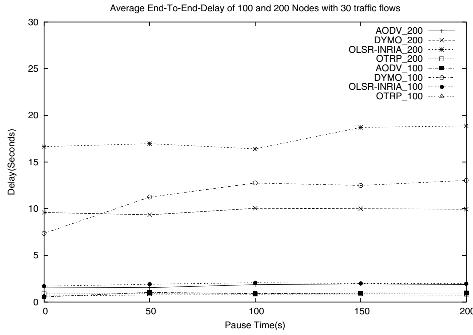
$$N_{RT} = ((W - x)/(\tfrac{T}{2}))((L - y)/(\tfrac{T}{2})) \ldots (2)$$

Node mobility is considered here by choosing nodes which are located at T/2 from parent node to to improve link reliability. In case of pure flooding in AODV, all these nodes in equation 1 will rebroadcast RREQs. Therefore, the number of node that will rebroadcast in Top Right region using AODV is $B_{RT-AODV}$ where $B_{RT-AODV} = N_{RT}$.
If we apply OTRP, the number of nodes that rebroadcast in Top Right region is
$B_{RT-OTRP} = \frac{1}{2}((W - x)/(\frac{T}{2}))((L - y)/(\frac{T}{2})) \ldots (3)$
where each selected node will chose 4 nodes only in each direction of distance T/2. By comparing equations 2 and 3 we will get :
$B_{RT-OTRP} = \frac{1}{2} B_{RT-AODV} \ldots (4)$
This means that OTRP reduces the number of rebroadcast nodes by $\frac{1}{2}$. We can find the number of rebroadcasting nodes with OTRP in each region as we did above using Figures 1 and 4. By summing the number of rebroadcast nodes in each region we get the total number of rebroadcasting with OTRP:
$= \frac{1}{2}(\frac{W}{T/2} \cdot \frac{L}{T/2})$
$= \frac{N}{2}$ , using equation $(1) \ldots (5)$ We can do the same thing to find number of rebroadcast nodes with AODV.The total number of rebroadcasting with AODV:
$= (\frac{W}{T/2} \cdot \frac{L}{T/2})$

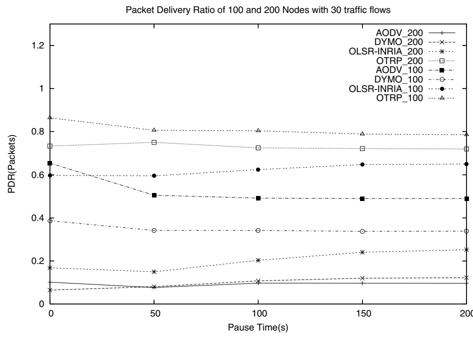
$= N$ , using equation $(1) \ldots (6)$
By comparing equation 5 and 6 we will get the same result as in 4 where
$B_{OTRP} = B_{AODV}/2 \ldots (7)$
This means that OTRP reduces number of rebroadcasting nodes by $\frac{1}{2}$ in this case. Generally, overheads of AODV in worse case:
$OH_{AODV} = N^2 \ldots (8)$
Hence, $OH_{OTRP} = \frac{1}{\lambda} \cdot OH_{AODV} \ldots (9)$
where $\frac{1}{\lambda}$ is a factor that eliminate overheads with OTRP. This factor depends on the distribution of nodes and neighbours density. In case of grid distribution, $\lambda$ equals to 2 as equation (7). From equations 8 and 9, we can notice that the density of nodes can directly effect the overheads. If traffic load is fixed and number of nodes increases constantly where there is a node in each T/4 then number of broadcasting nodes will be constant as parent node will select a node that located at T/2 in each region. In this case the OTRP overheads will be less than 1/8 overheads of AODV. At same time, traffic has also a role in increasing overheads. With AODV, all nodes are participating in rebroadcasting RREQ packets in route discovery process as illustrated in equation 6. Therefore, increasing traffic loads means increasing the loads on all nodes in the network. Consequently, this will increase overheads significantly. However, with OTRP only rebroadcasting nodes will be affected. In other words, the affect of increasing load traffic on the overheads of OTRP will be much less than with AODV. We can illustrate the factor of traffic that affect the overheads as below:
$OH_{AODV} = \alpha \cdot N^2 \ldots (10)$
$OH_{OTRP} = \frac{\beta}{\lambda} \cdot OH_{AODV} \ldots (11)$
where $\alpha \geq 1$, $\beta \geq 1$ and $\alpha > \beta$ with same traffic loads.

## 4. Simulation Models

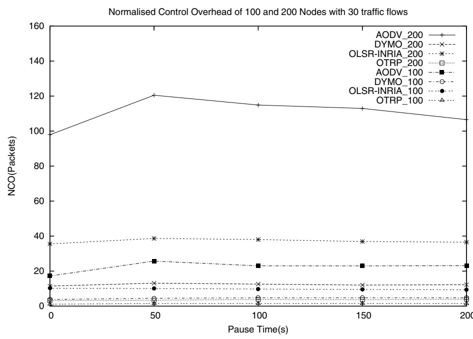
The performance of OTRP is compared to AODV[5], DYMO[3] and OLSR-INRIA [4]. Although OLSR-INRIA is a proactive routing protocol, it uses Multi-Point Relaying technique (MPR) to reduce overheads. Consequently, two strategies (OTRP and MPR) are compared here. Those protocols have been simulated using the QualNet4.5[10] package. The simulations ran for 200s with different values of seeds. Nodes density of 100 and 200 were randomly distributed on 1000 x 1000 grids. Random way point was used as mobility model with four different values of pause times that were 0s, 50s, 100s, and 200s. Speeds of the nodes were varied from 0 to 20 m/s. The simulated protocols have been evaluated with 30 data traffic flows. Constant Bite Rate (CBR) was used to generate data traffic at 4 packets per second. Each packet was 512 bytes . IEEE 802.11b was used as MAC protocol with constant transmission bandwidth of 2Mbps. The transmission power was 15dbm for all nodes. Packet Delivery Ratio (PDR), End-to-End Delay, and Normalized Control Overhead (NCO) were used as performance metrics of each protocol.



(a) Delay



(b) PDR



(c) NCO

Figure 5: Compare OTRP to AODV, DYMO, and OLSR-INRIA with 100 and 200 nodes and 30 traffic flows.

## 5. Results

In this section, we present the simulation results for OTRP, AODV, DYMO and OLSR-INRIA with different number of nodes and 30 data traffic flows. Figure 5 presents the result for 100 and 200 node network scenarios. Generally, as pause time and nodes density increase the End-to-End Delay and NCO increase and PDR decreases. In Figure 5, OTRP outperforms all other protocols. OTRP has the lowest End-to-End Delay and NCO, and the highest PDR which nearly are constant with 100 and 200 nodes compared to other protocols. This is can be refereed to that OTRP strategy depends on finding branching-nodes that reduce number of broadcasting nodes. Hence, as number of nodes increases, the probability of finding branching-nodes also increases. In addition, as traffic loads increases, the demand to discover routes to destinations increases. Consequently, this speeds up the process of scanning networking with less number of rebroadcasting nodes in OTPR. With high node density and fixed traffic load, number of branching-nodes is constant as the number of nodes increases because of the availability of branching-nodes. This explains the constant value of the performance metric of OTRP in Figure 5. In dense networks with high traffic load, OLSR and OTRP outperform AODV where AODV has the highest COH and the lowest PDR as shown in Figure 5. Both protocol minimise the flooding by selectively choosing groups of nodes to rebroadcast control packets while in AODV all nodes are rebroadcasting. This explains why AODV achieves the lowest PDR as it drops more than 50% and 90% of data packets with 100 and 200 nodes respectively as in fig5(b) and with the highest COH as in fig5(c) . In addition, in fig5(c), OTRP eliminate control overheads of AODV which supports the equation 11 in last section. In DYMO, complex functions of AODV, such as local repair and hello messages are eliminated [9]. Hence, DYMO has lower overheads than AODV as shown in fig5(b). On other hands, DYMO has higher delay than AODV because it shows some fragility with respect to timers. Although OLSR and OTRP reduce overheads by selecting which nodes can forward control packets, OTRP outperforms OLSR in high traffic load and dense network. Note although OLSR uses MPR forwarding, it still does one-hop hello packets floods which introduce more overheads. As you can see in fig5(b), OTRP can deliver approximately 80% of data packets with 100 and 200 nodes while PDR of OLSR is not more than 60% with 100 nodes and less than 30% with 200 nodes. Additionally, the ratio of normalized control overhead of OTRP is no more than 5 with different number of nodes while it increases from 10 with 100 nodes to nearly 40 with 200 nodes with OLSR. This is because in dense network, OTRP selects constant number of branching-nodes regardless of node density. However, number of MPR with OLSR can increase as number of nodes increases. This increases overheads with high traffic loads, besides the proactive nature of OLSR.

## 6. Conclusion

In this paper, a new routing algorithm (OTRP) has been proposed to reduce routing overheads of on demand routing protocols where previous knowledge of destination is not available. Particular nodes (branching-nodes) are selected to forward RREQ packets. The performance of OTRP, AODV, DYMO, and OLSR were compared on variety of network conditions like mobility and node density. Simulation results show that OTRP significantly reduces routing overheads and achieves higher levels of data delivery than the other protocols. In the future, we plan to further investigate the performance of OTRP over high level of mobility and network heterogeneity.

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