Extension algorithms for reactive routing protocols on Ad-Hoc networks

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***Abstract* — In reactive routing algorithms on Ad-Hoc networks, one of the most important challenges is to minimize the number of route discovery processes, due to their high cost in bandwidth. This is achieved through a careful selection of the expiration time, i.e. the time each node keeps active the current route. Most implementations use system-wide random or arbitrary values for this parameter, even though the failure probability of a route depends of its size. Thus the use of a fixed expiration time is not necessarily efficient, and we propose a variable allocation of expiration times for routes, according to their size, introducing the VTOA (Variable Time Out Allocation) method. VTOA can be applied to any Ad-Hoc routing algorithm. In particular, we present an implementation of this method on the AODV algorithm. The results obtained by simulation show VTOA improves the network's performance, both in terms of the routing overhead (8.5% lower) and average end-to-end delay (21.3% lower), when compared to the original AODV, while other indicators, as the packet delivery fraction, remain the same or are slightly better.**

***Index Terms* — Ad-Hoc networks, Ad-Hoc On-Demand Distance Vector, Ad-Hoc routing, Expiration Time Allocation.**

I. INTRODUCTION

Lately, the demand for wireless technologies has experienced a considerable increase. The need for communication at any time and at any place has pushed the development of hybrid networks, that interconnect networks of different topologies and platforms, which is one of the main challenges for the future 4G networks. Particular types of wireless network are the MANETs or Ad-Hoc networks. These are temporary nets, which are conformed in a random and autonomous way. They are composed of a collection of mobile nodes and do not have a fixed topology.

Routing in this type of networks poses great challenges [1]-[5]. Different from other types of wireless networks, these networks face important scalability problems, firstly because of its mobile nature, and secondly due to the impossibility of implementing a hierarchical complex network organization, since they do not have a fixed topology. Also, unlike other wireless technologies (cellular telephony, WLAN, etc.), in these networks the nodes must be able to relay packets through multiple-hop routes.

Our contribution is the VTOA (Variable Time-Out Allocation) method, which consists on a methodology that allocates the route expiration time according to the size of the route, and so ensures a probability of failure that is independent of the number of links in the route. As we show, this probability P_r can be chosen in such a way as to optimize the performance of the network in terms of the desired parameters, including throughput, delay, routing overhead, packet delivery fraction and so on. This methodology, in principle, is applicable to any routing algorithm in networks with mobile nodes. As an example, we develop an implementation of VTOA as an extension of the reactive algorithm AODV (Ad-Hoc On-demand Distance Vector). Through computer simulations, in different scenarios of operation of the algorithm, we show that our extension results on improvements of the routing delay and overhead performance measures of the network, on the order of 21% and 8.5%, respectively, when compared with the original AODV algorithm.

The remainder of the paper is organized as follows: section II describes the methodology used for the determination of the expiration time, which depends on the size of the routes, for a fixed route failure probability. In this section, we also search for an adequate value of the route failure probability P_r. Section III describes the implementation of the VTOA method as an extension of the AODV algorithm, and also details the computer simulations made for measuring its performance. We also discuss and analyze the results obtained in the different simulations. Finally, section IV presents our conclusions.

II. VTOA METHODOLOGY

In reactive routing algorithms, a fixed value is used for the route expiration time. However, the more links a route has, the higher the probability P_r of its failure, since a route will fail when at least one of its links fails. This can be written as $P_r = 1-(1-P_e)^h$, where h is the number of hops, and P_e is the probability of failure of a single link, which depends on the route expiration time t.

For a given route, a value of P_r that is too small will result in very short expiration times for the route, and hence a waste of useful routing information (a large overhead). On the other hand, a very high value of P_r will also have a negative effect on the communication process, because it is very likely that the system will frequently attempt to use routes with broken links, resulting in packet loss. It is reasonable to think that controlling the failure probability P_r will then lead to a better performance of the network. Since an ad-hoc network can have active routes of various different lengths, either simultaneously or at different moments in time, the probabilities of failure of these routes will be very different, and difficult to control.

Our methodology then consists in: a) select a given route failure probability P_r, which optimizes the performance measures of the network; b) calculate the route expiration time t, using P_r; c) apply these values to the given routing algorithm.

A. Determination of route failure probability P_r

Since the value of the expiration time can be tuned to obtain a fixed probability of failure of a route, P_r, the question remains about what value of P_r is the best. To determine the adequate value range of P_r, we made simulations using the ns-2 software, in a similar way as the one used in [6]. The simulations were made using a space of 1000 x 1000 meters, with a network of 100 mobile nodes and a maximum of 40 constant bit rate connections. We made 10 simulations for each scenario, with traffic and movement patterns randomly generated. The metrics used to evaluate the performance of the network are the overhead, the average delay and the network's throughput.

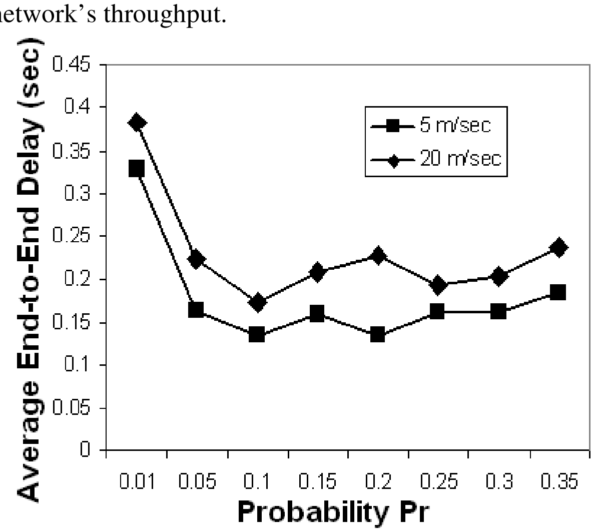

Fig. 1. Average End-to-end Delay vs. P_r in AODV-VTOA

Figure 1 shows the network performance, in terms of the End-to-End Delay, according to a given failure probability P_r. For each scenario, we made simulations at maximum speeds of 5 and 20 m/s. The simulation results show that the performance gets worse when the probability is lower than $P_r = 0.05$. Above that value, there is a range with little performance variations, from P_r = 0.05 to 0.25, and that there is a slow negative tendency for values of $P_r > 0.25$. The best value seems to be close to P_r = 0.1, which is the value we use for evaluating the performance of the VTOA extension. Note that when designing a network, similar simulations can be utilized to determine the best value or range of values of the failure probability, for the specific conditions of the network being designed.

B. Determination of expiration time for fixed P_r

Using fixed expiration times for the routes leads to a variable failure probability P_r, which depends on the size of the route. Conversely, we use variable expiration times for the acquired routes, so that P_r remains within a small range of a fixed target value. To obtain the expiration time required for a fixed value of the probability P_r, we must find t in the equation $P_r = 1-(1-P_e(\Delta t))^h$, where h is the number of hops of the route, R is the coverage radius and [7]

$$P_e(\Delta t) = \begin{cases} \frac{2}{\pi}\arcsin\left(\frac{V_{\max}\Delta t}{2R}\right) - \frac{4}{3\pi}\tan\left[\frac{1}{2}\arcsin\left(\frac{V_{\max}\Delta t}{2R}\right)\right] + \\ \frac{1}{3\pi}\sin\left[2\arcsin\left(\frac{V_{\max}\Delta t}{2R}\right)\right], \text{ for } 0 \le \Delta t \le \frac{2R}{V_{\max}} \\ 1-\frac{8R}{3\pi V_{\max}\Delta t}, \text{ for } \Delta t \ge \frac{2R}{V_{\max}} \end{cases}$$

Figure 2 shows the expiration time curves versus the number of hops, obtained for networks with V_{max} = 10 (m/s), with different values of P_r.

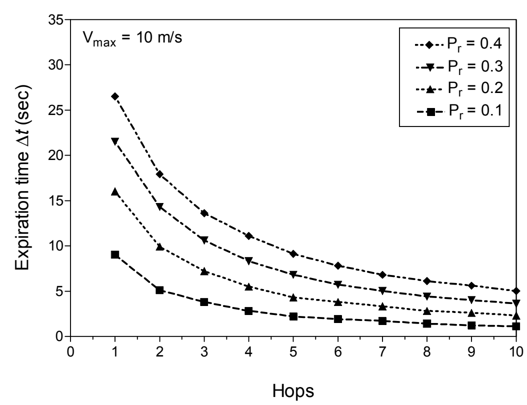

Fig. 2. Expiration time vs. number of hops for V_{max} = 10 m/s

III. VTOA Implementation and Results

VTOA implementation basically consists in the allocation of route expiration times depending on the size of the obtained routes, used the time values experimentally obtained before. The simulation to evaluate the performance of VTOA method was carried out with the ns-2 software. The goal was to evaluate and compare the performances of both the original AODV and AODV with the VTOA extension.

The size of the simulation space was defined so to guarantee an adequate node average density for a good performance of the protocol. The used metric to measure the network's density is the number of neighbors per node. Generated scenarios had on average 16.5 neighbors per node. The coverage ratio of each node is 250 meters and the simulation's duration is 100 seconds. For each scenario, 10 simulations were made and the performance values shown correspond to the average of the resulting values of each simulation.

Figure 3 shows the network's throughput performance in terms of the speed. The throughput was calculated as the proportion of bytes of received data with respect to total bytes transmitted. As it can be expected, the throughput decreases when the average speed increases. This is because at a greater speed, routes have a shorter duration, thus increasing the packet loss, because of routes failures and an increase in the number of discovery processes. Since AODV-VTOA has variable and optimal expiration times for each route size the number of packets lost due to routes failures decreases. Figure 3 shows how the throughput is on the average 1.5% higher in AODV-VTOA than in the original AODV.

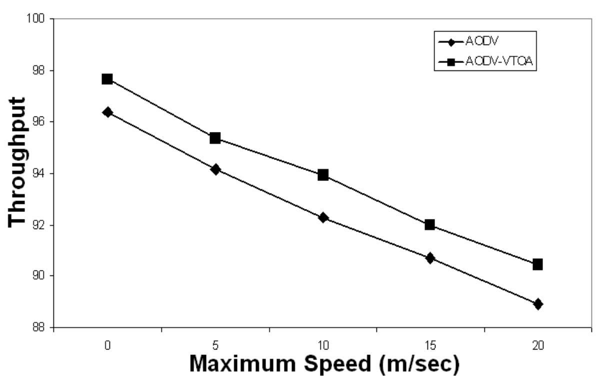

Fig. 3. Throughput *versus* $V_{\max}$ in AODV and AODV-VTOA

The routing overhead was calculated as the proportion of transmitted control messages bytes to total transmitted bytes, including all sent and retransmitted control packets. In AODV the control messages might be RREQ, RREP y RRER. RREQ messages come from the network's flooding process. RREP messages are the replies to RREQ packets and are sent as unicast. RRER packets are sent before failures of links that belong to active routes or before the expiration of active routes. These last types of messages have a variable size that depends on the number of unreachable destinations, produced by the broken link. If the expiration time is too short, the number of sent RRER packets will increase. However, in both simulations, optimal values were chosen for the expiration times. For this reason, most of the control messages come from RREQ packets. Studies show, experimentally, that the RREQ packets represent more than 90% of the total of control messages [15]. The VTOA extension allocates variable expiration times, depending on different sizes of the routes, striving to decrease the number of search processes and, in this way, decreasing the overhead in control messages. Figure 4 shows the routing overhead in terms of the speed. The VTOA extension presents an average decrease of 8.5% on the overhead, compared to the original AODV.

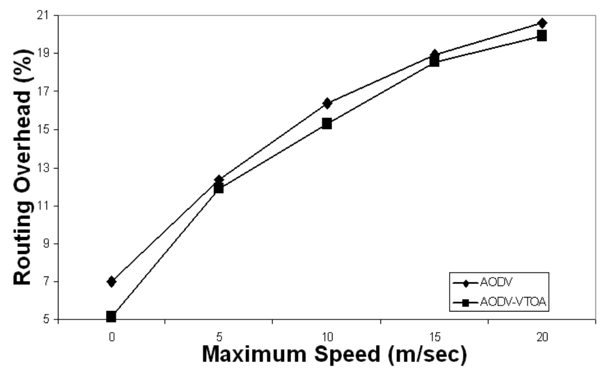

Fig. 4. Routing Overhead *versus* $V_{\max}$ in AODV and AODV-VTOA

The number of search processes also has a negative effect on the average communication delay. This happens because, if any of the route links has a failure, then the node which has detected it sends an RRER message to the source. Once the source receives this message, it saves the generated packets in a buffer and starts a search process. In the LR (Local Repair) extension, the search is started by the node that detected the broken link, if it is closer to the destination than to the source. In both cases, these additional search processes interrupt the communication and increase the average delay of the network. Furthermore, an increase of node speed produces a higher rate of failure in links, which causes an increase on the number of flooding processes. Figure 5 shows the delay as a function of the speed in both algorithms. In average, in AODV-VTOA the delay decreases a 21.3%, as compared to AODV. This is because the number of search processes, both due to route expiration and route failure, decreases. Note that this improvement is achieved without any extra burden on the overhead; furthermore, the overhead decreases.

Another indicator, frequently used to measure the performance of Ad-Hoc routing algorithms, is the fraction of received packets or PDF (Packet Delivery Fraction). The PDF was calculated as the proportion of received control and data packets, to the total number of transmitted packets. Lost packets have a negative influence on this performance indicator. Lost control packets generally are RREP packets, because only these packets are sent to specific addresses (RREQ packets are sent by flooding to the whole network and the RRER packets are sent by flooding with TTL = 1). The number of lost control packets depends on the mobility and is the same in both algorithms. The number of lost data packets can vary in both algorithms; it depends on the failure of links in active routes. Figure 6 shows PDF in terms of the speed. The results show a small average increase of 0.7% on PDF when using AODV-VTOA. Although this increase is not significant, the fact is, this indicator does not deteriorate, while the remaining indicators do improve.

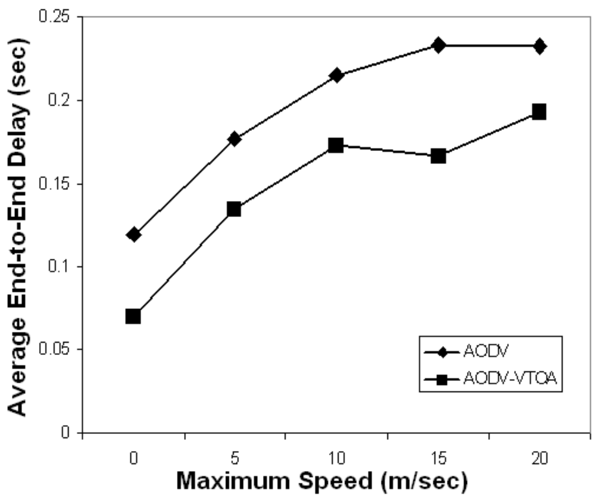

Fig. 5. End-to-end Delay *versus* $V_{\max}$ in AODV and AODV-VTOA

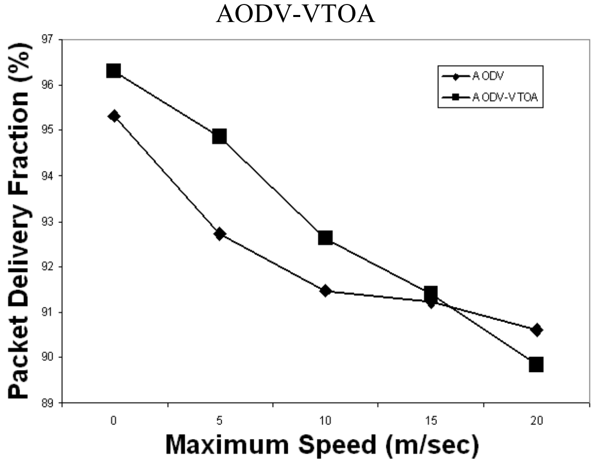

Fig. 6. PDF *versus* $V_{\max}$ in AODV and AODV-VTOA

IV. Conclusions

We analyze the use of variable expiration times for active routes in Ad-Hoc routing algorithms, with the purpose of decreasing the number of discovery processes, because those processes highly reduce the efficiency in the use of bandwidth. We propose the VTOA extension method for the variable determination of expiration times, which guarantees a fixed P_r error probability. We studied the computation and allocation of this expiration time to routes according to their size. To evaluate the performance of the method, we carried out a large number of simulations in mobile node environments at different speeds. The performance of the AODV algorithm with the VTOA extension shows improvements over the original AODV, including a decrease of 8.5% on the overhead and a drop of 21.3% on the average delay.

Acknowledgements

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