# Defining an Optimal Active Route Timeout for the AODV Routing Protocol

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***Abstract*— Reactive ad hoc network routing protocols attempt to minimize the route discovery overhead by caching the route information for some period of time after a connection expires. How long each node should keep this route information is set a priori, and usually arbitrarily. In this extended abstract, we focus on the Ad-hoc On-demand Distance Vector (AODV) protocol, and see that there is an optimal value to the length of time each node should keep the route information. Further, we derive a new taxonomy of route errors, which allows us to identify the optimal value efficiently. We are conducting extensive simulations to better characterize the optimal value.**

## I. Introduction

Routing protocols in ad-hoc networks are typically divided in two categories: proactive and reactive protocols. Proactive protocols, such as OLSR [1] attempt to monitor the topology of the network in order to have route information between any source and destination available at all time. On the other hand, reactive protocols such as AODV [2] or [3], find a route only when it is needed, upon the start of a connection. While the former approach performs well in low mobility environment, the latter is better suited to networks of more mobile nodes.

However, since networks are never exclusively static, or highly mobile, even reactive protocols keep some route state information for some period of time, in order to avoid the overhead of route establishment. Once a route has been successfully established between two end points, it is remembered in case it should be used again in the near future. This raises the question: how long should the route state be kept? If the state is kept a short time only, then the route might still be valid in the network, but not available for the next connection. If it is kept too long, the underlying topology might have changed, and packets might get lost before a new route is found.

We attempt to answer this question, while focusing specifically on the AODV routing protocol.

The AODV routing protocol builds and maintains route state based on two main processes. First the route discovery process allows to the source and destination nodes to establish a route. In this process, the source floods a route request (RREQ) over the network, and the destination unicasts a route reply (RREP) to the source, allowing the intermediate nodes to store a route state between the endpoints. Each node keep this state for a length of time given by the Active Route Time-Out (ART) value. Every time the route is used, the timer is reset to back to the ART.

Secondly, AODV offers the possibility to invalidate a route if, due to link layer or mobility events, the route breaks before the ART expires. When link failure happens, AODV initiates a route error (RERR) process, which notifies the source with the invalid route.

The ART is a static parameter that defines how long a route is kept in the routing table after the last transmission of a packet on this route. This parameter is arbitrarily set to 3 seconds. For comparison, DSR keeps a similar time-out parameter, denoted RouteCacheTimeout, but with value set at 300 seconds. Neither of these values has been particularly well justified.

Either way, this static value does not take into account either the actual lifetime of the path nor the scale of the time correlation between two successive connections between the same end-points. Finding an optimal value requires a balance between choosing a short ART that causes a new route discovery even if a valid route is still available, and choosing a long ART and risking to send packets on an invalid route. In the first case, the cost is the initiation of a new route discovery that could be avoided, and in the second case it is the loss of one or more packets and the initiation of a RERR process instead of a new route discovery without losing any packet.

In this document, we highlight the above trade-off and define a taxonomy of the route errors, which allow us to characterize the optimal ART value. The preliminary results described here are obtained by NS-2 simulations.

## II. Method

### A. Performance Metrics

The packet delivery ratio (PDR) is the usual metric to illustrate the performance of ad-hoc networks protocols. However, it is not the most appropriate to assess the value of the ART: some packet errors are unavoidable under any value of the ART, for instance those that occur when a route breaks during a live connection. This illustrates the need for a better way to describe the packet errors.

Packet errors in AODV generate RERR messages, and as such, the PDR is correlated to the number of RERRs. We introduce here a novel taxonomy of the RERRs which allow us to identify the ones that are relevant to the value of the ART.

Packet errors are detected using the Link Layer Feedback (LLF) mechanism, rather than the HELLO messages, in order to detect a broken link with less latency (i.e., sooner).

### *B. RERRs classification*

In the AODV standard, there are three ways to invalidate a route, and remove it from the route table: (1) when the route becomes stale and expires, (2) when the route breaks, and a LLF is received for an attempted transmission on this route, (3) when a RERR is received from another node, which contains an invalidation for a route in the route table.

RERRs are sent in three cases: (i) if a LLF is received, (ii) if a packet must be relayed by an intermediate node which does not have a valid route table entry for the destination, or (iii) if a received RERR contains unreachable destinations that match one or more routing table entries.

This allows us to classify RERRs as follows:

1) Timeout RERRs. A packet must be sent, but the ART for the route has previously expired, and so the route is no longer valid and cannot be used.
2) Link layer RERRs. A LLF is received and routes going through the invalid path are invalidated.
3) Forwarded RERRs. A received RERR is forwarded. The corresponding routes are invalidated at the other nodes.
4) Latency RERRs. A packet must be sent on a previously invalidated route, as the packet sender has not received the RERR notification yet.

The timeout and the link layer RERRs are the ones most pertinent to finding the optimal value of the ART. The latency RERRs stem from the unavoidable delay between the sender and the nodes downstream towards the receiver.

### *C. How to find the optimal ART?*

Since we are not interested in the latency RERRs, which only add noise to our RERR observation, and to better focus on the relationship between mobility and the value of the ART, we consider here traffic composed of very short single packet bursts and longer exponentially distributed idle times.

We show that for such a traffic, the PDR reaches a maximum before decreasing when the lifetime of the route table entries becomes too long and detrimental. A traffic with longer packet streams will have a different PDR, but the packets lost will be due to the other types of RERR, namely latency RERRs. More packets are delivered during a burst, and more are lost because of an invalidated route. This affect the PDR, but not the optimal value of the ART.

## III. Preliminary results

Ad hoc networks of many nodes are very complex systems, and the length of time a route is valid is a quantity that is (so far) difficult to evaluate analytically. Previous attempts (for instance [4], [5]) focus on special cases or simplified models. Because direct analysis is difficult, we are conducting a simulation study.

We simulated a network in a square area of $1400 \times 1400\, m^2$. We placed 100 nodes moving according to the Modified Random Waypoint Model [6]. Traffic is composed of 15 simultaneous unicast connections between 15 random node pairs. We used two types of traffic. One is the single packet burst with exponentially distributed idle time we describe above. We call this traffic pattern the *reference traffic*. We benchmark the results we obtain with this traffic against a traffic with the same idle time distribution, but longer bursts. This we denote by *bursty traffic*. During burst time, 4 packet of 512 bytes are sent every second on a 2 Mbps 802.11 MAC layer protocol. The idle time is normalized to 10s, and the burst time in the *bursty traffic* is 50s.

These results are only preliminary results, and more simulation runs as well as more diversified simulations scenario will be available for the final report.

### *A. Reference traffic*

Figure 1 presents the results for a maximum speed of 10 m/s using the reference traffic. It highlights the important influence of the choice of ART on the PDR. This tends to show that an optimal ART value exists according to the maximum PDR. By our design choice, the latency RERRs are non-existent. One can see the two conflicting mechanisms: the decrease of the number of the timeout RERRs, but the increase of the link-layer and forwarded RERRs, due to more links breaking with an active route, and due to more nodes requiring the RERR to be forwarded to them.

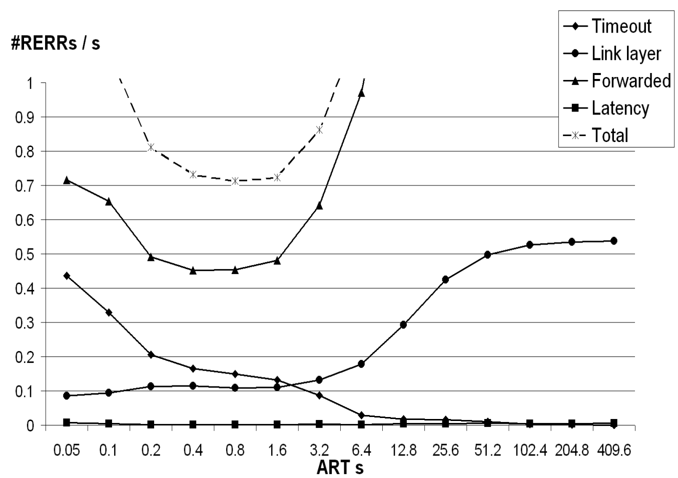


Fig. 1. Number of RERR/second as a function of the ART, for each RERR type

Figure 2 shows the PDR for an average node velocity of 0, 10 and 20 m/s. One can see that, as expected, the PDR decreases as the velocity increases. When there is no mobility, routes never expire, and the longer the ART the better. However, AODV is designed with mobile ad hoc networks in mind. As the velocity increases, one sees the appearance of an optimal ART value, which seems to be about 10s in this set-up. This value is natural, as 10s is also the average time between successive connections in the simulations.

The existence of an optimal ART value strongly suggests to make the ART parameter a dynamic parameter function of

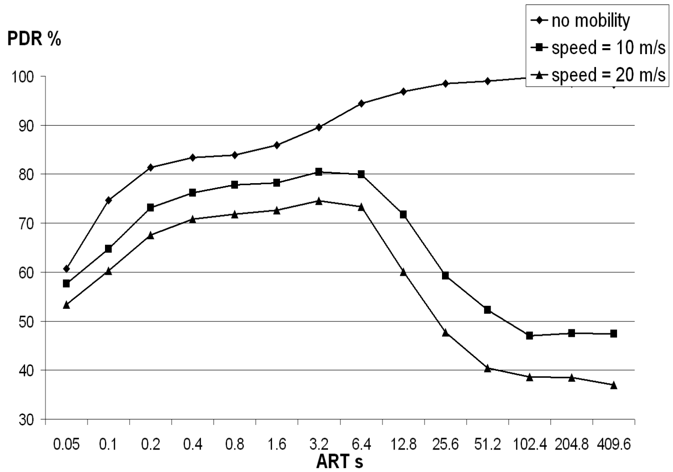


Fig. 2. Packet Delivery ratio as a function of the ART, for average node speed of $0, 10, 20m/s$, reference traffic

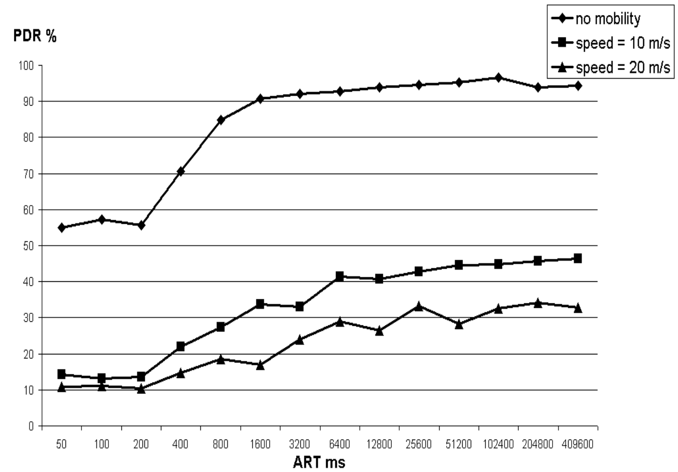


Fig. 3. Packet Delivery ratio as a function of the ART, for average node speed of $0, 10, 20m/s$, bursty traffic

the node mobility.

## B. Bursty traffic

One of the reasons an optimal value for ART has not been identified prior to this work, is that the typical traffic models add a lot of noise which makes it hard to identify. Bursty traffic adds many outstanding packets which are lost when using a broken route with a valid ART; it also increases the packet delivery ratio once a valid route has been found. The internal on-off patterns of the traffic become preponderant.

As an example, Figure 3 shows that, for our bursty traffic model, the PDR increases up until the optimal ART value, then flattens. We expect a behavior either in the form of Figure 3 or 2 to appear for any generic traffic pattern.

Not shown here is the dependence of packet latency on ART. As the value of ART increases, the broken routes are used more often by nodes that are originating traffic. When this happens, the application must wait not only for a new route to be discovered, but also for the previous route to be invalidated. While this often appears to be a very small effect statistically, the users of the applications on the affected nodes will see a relatively large disruption whenever it occurs. This initial delay is likely to be amortized over all packets including the ones originated after a valid route is discovered, so unless care is taken the initial delays will be invisible within the statistics for the later packets of the data stream. We intend to take careful measurements of the initial delays also, and show how the choice of ART affects the measurements.

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