

# Traffic Analysis of On-Demand Routing Protocols in Ad-hoc Wireless Networks

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**Abstract:** This paper presents a statistical analysis to estimate the traffic volume (data and routing control packets) in ad-hoc wireless networks that use on-demand routing protocols. It provides an analytical framework for estimating the routing overhead due to mobility and link breakage. Detailed analysis is presented for estimating the number of control packets (RREQ, RREP and RERR) as a function of time, number of nodes, node degree, transmission range, mobility of nodes, average hop count and link density. The analysis presented in this paper can be used for selecting a suitable on-demand routing protocol and for designing novel and efficient routing protocols for ad-hoc wireless networks.

## 1. Introduction

Control Traffic in on-demand routing protocols is mainly generated during the route discovery process. Three routing control packets used during route discovery are route request (RREQ), route reply (RREP) and route error (RERR). The ratio of number of control packets to the number of data packets transmitted is defined as normalized routing load [3].

Normalized routing load =

$$\frac{\text{Number of routing control packets generated}}{\text{Number of data packets transmitted}} \quad (1)$$

For on-demand routing protocols this is an excellent performance metric since it evaluates the efficiency of the routing protocol. The number of RREQs ( $N_{RREQ}$ ) generated in a single route discovery in terms of average degree of node  $E[d]$  and mean hop count  $E[h]$  is given in [2] as follows

$$N_{RREQ} = E[d] + E[d]^2 + \dots + E[d]^{E[h]} \quad (2)$$

$E[h]$  represents the mean hop count. It can be approximately given in terms of  $E[d]$  and the number of nodes ( $n$ ) in the network. This paper discusses a detailed analysis of control packets generated during routing in both DSR and AODV.

## 2. Analytical Model

### A. Normalized routing load in AODV

This section derives the rate of routing control packets in AODV. The number of route requests ( $N_{AODV}$

$-RREQ$ ) transmitted in a single route discovery process can be computed from (2). The number of RREQs can be estimated as a function of time ( $N_{AODV-RREQ}(t)$ ) and is given as product of rate of route discovery ( $r_{rd}(t)$ ) and number of route requests ( $N_{AODV-RREQ}$ ) generated in a single route discovery process.

$$N_{AODV-RREQ}(t) = r_{rd}(t) * [N_{AODV-RREQ}]^{\frac{\ln(n)}{\ln(E[d])}} * [(1 - P_{AODV}(i)) * C(t) + [1 - [A_{ij}(t)]^{\frac{\ln(n)}{\ln(E[d])}}] * [n] * [n-1]] * [E[d] + E[d]^2 + \dots + E[d]^{E_{AODV}^{[i]}}] \quad (3)$$

where  $P_{AODV}(i)$  is the probability of route being known by an intermediate node  $i$ ,  $C(t)$  are the number of route discovery sessions initiated in time  $t$ ,  $(1 - P_{AODV}(i)) * C(t)$  gives the number of new route discoveries,  $A_{ij}(t)$  is the link availability between nodes  $i$  and  $j$  at time  $t$  and is defined as the probability that there is an active link between them at time  $t$  [1],  $[1 - [A_{ij}(t)]^{\frac{\ln(n)}{\ln(E[d])}}]$  gives the rate of route validity,  $[n] * [n-1]$  gives the total number of routes in the network.

For each route discovery the number of route replies ( $N_{AODV-RREP}$ ) transmitted will be equal to the number of hops  $E[i]$  between the intermediate node generating RREP and the source. Hence, the number of route replies  $N_{AODV-RREP}(t)$  can be estimated as a function of time as follows

$$N_{AODV-RREP}(t) = r_{rd}(t) * [E[i]] = [(1 - P_{AODV}(i)) * C(t) + [1 - [A_{ij}(t)]^{\frac{\ln(n)}{\ln(E[d])}}] * [n] * [n-1]] * [E[i]] \quad (4)$$

The number of route errors (RERRs) depends on the rate of link failure ( $r_{lf}$ ). The RERR packet is intended to be sent to the source from the node with a link failure. The average distance between any such node and the source can be approximately taken as  $E[i]$ .

$$N_{AODV-RERR}(t) = E[i] * (r_{lf}(t)) = [E[i]] * \left[ \frac{n * E[d]}{2} \right] * [1 - A_{ij}(t)] \quad (5)$$

The total number of control packets is the sum of number of RREQs, RREPs and RERRs. The total data packets sent across the network are computed based on the average number of data packets sent per session ( $D_{average}(t)$ ). Therefore,

$$N_{AODV-control-packets}(t) = N_{AODV-RREQ}(t) + N_{AODV-RREP}(t) + N_{AODV-RERR}(t)$$

$$N_{data}(t) = C(t) * D_{average}(t)$$

$$Normalized\ routing\ load = \frac{N_{AODV\_Control\_Packets}(t)}{N_{data}(t)} \quad (6)$$

### B. Normalized routing load in DSR

AODV and DSR share the on-demand routing functionality and the method of route discovery. In DSR the number of RREQs generated for a single route discovery is same as AODV and can be obtained from (2). The difference in operation lies primarily in the rate at which routes are discovered due to the difference in number of routes cached by each node.

In DSR intermediate nodes cache all the nodes listed in the RREQ packet in contrast to the AODV's procedure of caching only the next hop. The expression for the number of routes cached ( $R_{DSR}(E[h])$ ) by all the intermediate nodes due to a single route discovery session in DSR can be given by

$$R_{DSR}(E[h]) = \frac{E[h] + E[d] + 2E[d]^2 + \dots + E[h]E[d]^{E[h]}}{E[h] + E[d] + 2E[d]^2 + \dots + E[h]E[d]^{E[h]}} \quad (7)$$

The factor  $2E[d]^2$  shows that all the intermediate nodes also install the route inserted into the route request packet. The route expiry time in DSR is higher than that of AODV, the routes cached by nodes will remain in their routing table for longer period. Therefore, a new route discovery is not required every time a session is initiated. The rate of RREQ generation ( $N_{DSR-RREQ}(t)$ ) can be estimated as,

$$N_{DSR-RREQ}(t) = (N_{RREQ}) * (r_{rd})$$

$$= (N_{RREQ}) * [(1 - P_{DSR}(i)) * C(t)] + [1 - A_{i,j}(t)] \frac{\ln(n)}{\ln(E[d])}$$

$$* [n] * [n - 1]$$

The rate at which route replies are generated is given by

$$N_{DSR-RREP}(t) = [r_{rd}(t)] * [N_{DSR-RREP}]$$

$$= [(1 - P_{DSR}(i)) * C(t) + [1 - [A_{i,j}(t)] \frac{\ln(n)}{\ln(E[d])}]] * [E_{DSR}[i]$$

$$* P_{DSR}(i) * n] \quad (8)$$

The rate at which RERRs are generated is given by

$$N_{DSR-RERR}(t) = N_{DSR-RERR} * (r_{lf}(t))$$

$$= \left[ \frac{n * E[d]}{2} \right] * [1 - A_{i,j}(t)] * E_{DSR}[i] * P_{DSR}(i) * n \quad (9)$$

The expression for number of control packets for DSR is same as that for AODV, therefore equation (6) holds good for both AODV and DSR.

### 3. Quantitative Analysis and Simulation Results

In this section, the analytical model presented is evaluated by assuming realistic values for each of the parameters explained in the previous section. The model presented in section II is used for estimating the rate of control packets for AODV and DSR. Such comparison

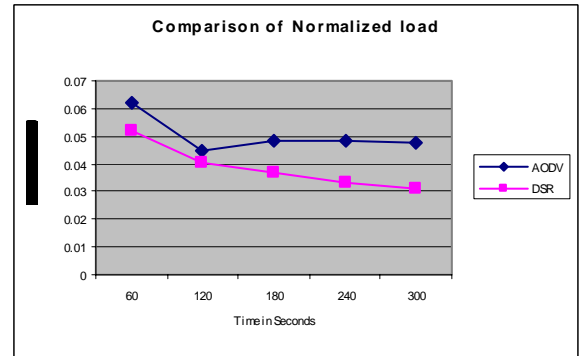
has previously been done experimentally in [3]. Therefore this comparison is used to validate the proposed model. The values of parameters chosen are  $n=20$ ,  $E[d]=3$ ,  $C(t)=10/\text{min}$ ,  $R_{eq}=500\text{m}$ ,  $1/\lambda=30\text{sec}$ ,  $\mu=10\text{kph}$ . The normalized load, which is the number of routing control packets transmitted per data packets delivered at the source is computed based on average data packets transmitted per session,  $D_{average} = 1200$  packets.

Estimate of	AODV	DSR
Number of routes cached per route discovery	34.5	77.71
Probability of finding a route to destination	0.36	0.81
Average distance of intermediate node in hops	4.1	3.8

TABLE I

#### QUANTITATIVE RESULTS.

In order to validate and strengthen the quantitative analysis discussed above, detailed simulations were done using GloMoSim network simulator.



### 4. Simulation Results

The quantitative analysis presented here gives an insight into the proposed analytical model. The simulation results show a striking similarity in the trend of generation of these control packets and closely follow the dependence on time. The analysis presented in this paper will be used to develop routing protocols in ad-hoc networks that minimize the control traffic such as the protocol described in [4].

### 5. References

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