Performance Comparison of Two On-Demand Routing Protocols for Mobile Ad hoc Networks

Matulya Bansal and Gautam Barua
Department of Computer Science and Engineering
Indian Institute of Technology, Guwahati - 781039
{gb@iitg.ernet.in}

Abstract

AODV and DSR are two of the most important routing protocols for ad hoc networks. In this article, we make a comparison of these routing protocols in context of the services offered by them to the transport layer. We first study the interactions between the Transport and MAC layer and then, based on observations, propose metrics to measure the effectiveness of the two routing protocols. Detailed simulations are then performed to compare the performance of AODV and DSR under varying load, mobility and network size and connectivity. Our work makes clear the need for routing protocols to consider network load as an important factor in addition to path length while computing routes. In addition, we find that a suitable caching mechanism is necessary for scalability of a routing protocol and that its effectiveness increases with increasing connection density and decreasing mobility.

Introduction

A central challenge in the design of ad hoc networks is the development of a dynamic routing protocol that can efficiently compute routes between two communicating nodes as and when needed. Among the several routing protocols that have been proposed for these dynamic environments, it is AODV and DSR that have emerged as the prominent schemes. Though several performance evaluations of the routing protocols have been done in the recent past, these evaluations have primarily focussed on measuring the performance for best effort CBR Traffic alone. However, reliable data transfer forms the backbone of several applications that are being used and are likely to be used in such environments. Hence the service provided by these routing protocols to TCP, the de facto standard for reliable data transfer on the Internet, is an issue of major significance. In this paper, we first identify the factors that affect the performance of TCP in ad hoc networks. Following this, we perform an evaluation of TCP over AODV and DSR and on the basis of these experiments, make a comparison of these two routing protocols, suggesting guidelines that shall lead to the design of more efficient and robust routing protocols for these dynamic environments.

A Comparison of AODV and DSR

AODV and DSR are both on-demand routing protocols. However, they differ in several important respects.

DSR is a source routing protocol. It maintains multiple routes to a destimation and uses promiscuous mode listening. AODV, in absence of these mechanisms, resorts to RREQ floods more often for route discovery.

The current specification for DSR does not contain any mechanism for route entry invalidation or route-prioritization when faced with a choice of multiple routes. This leads to stale cache entries, particularly at high mobilities. AODV, on the other hand, follows a more conservative approach. It makes use of timers to expire cache entries and uses sequence numbers to prefer fresher routes when faced with a choice amongst multiple routes. Moreover, AODV uses a a more rigorous route-error notification mechanism and therefore has access to more accurate routing information.

The goal of our simulations is to, through extensive simulations, analyse and quantify the relative merits of these approaches of AODV and DSR.

Related Work

Both AODV and DSR have received a lot of attention in recent times. Das et. al. [5] compared the performance of AODV and DSR using the ns-2 [8] simulator. Broch et.al. [6], the original authors of the simulation model, evaluated the performance of DSDV, TORA, AODV and DSR. However, they used only 50-node scenarios with low traffic loads (4 packet/s, 10-30 sources, 64 byte packets). However, an earlier version of AODV without query control optimization was used leading to superior routing load performance by DSR. A more recent work is by Johansson et. al. [7], who extend the previous work by introducing new *mobility models.* The mod Again only 50 nodes were used and the offered load was relatively limited. However, in all the cases, only CBR sources was used for generating traffic.

TCP and IEEE 802.11

Since most of the earlier work on performance evaluation of routing protocols has focussed around CBR traffic, through these simulations we tried to identify the main factors that affect TCP performance over 802.11 based networks. The experiments show that TCP traffic is inherently different from CBR traffic and therefore the need to evaluate routing protocol performance for TCP traffic.

Number of hops

The purpose of this experiment was to observe the variation in the performance of a single TCP transfer with increasing hop count. A linear chain of nodes was formed and simulations were performed for different path lengths. Here, we observe that TCP throughput initially decreases rapidly as the hop count of the connection increases but then almost stabilizes after three-four hops.

Number of connections sharing a link

In this experiment, the affect of several parallel TCP connections sharing a link in a static ad hoc network chain was observed. It was observed that inspite of increasing the number of simultaneous connections, the combined throughput of all the connections put together remained almost constant. Similar results were obtained for experiments in which a number of connections shared a common node.

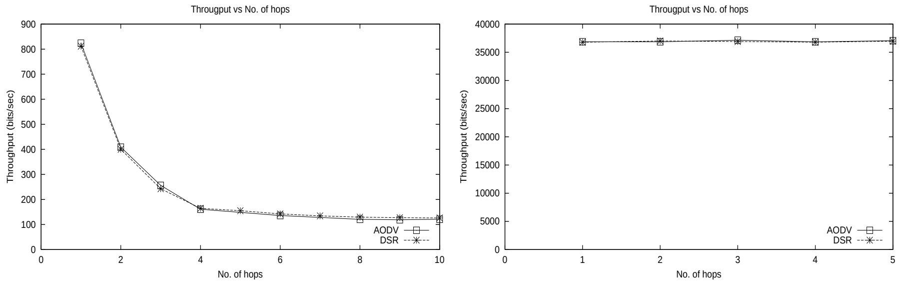
Proposed Metrics

In addition to the standard metrics like *Packet Delivery Fraction, Throughput, Goodput, End-to-end delay of data packets* and *Normalized Routing Load* we also measured *Average Queue Length* (calculated by monitoring the queue length at each node whenever a packet was enqueued), *Average Hop Length* (the average weighted length of paths from the source[s] to the destination[s] where weights were the lifetime of a path with a particular hop-count) and *Average maximum no. of connections sharing a node in the path* (the average weighted maximum number of connections that shared the node in the path from the source[s] to the destination[s] with this connection).

Packet Delivery Fraction, *Goodput*, *Throughput* and *End-to-end Delay* are important for best-effort traffic. A Low *Routing Overhead* is important for scalability. *Average Queue Length* is important where buffer space is a limitation. *Average Path Length,* as observed earlier, is important for TCP traffic. *Average Maximum Node* and *Link Overlap* reflect load awareness and as seen, are important for TCP Traffic.

Simulations

For our simulations, we used the ns-2 network simulator [8] with extensions from CMU [9]. The simulation parameters, the traffic and the monbility models are the same as the ones used in [4, 6]. To



(a) (b)

Figure 1: Throughput vs Number of Hops (TCP, CBR)

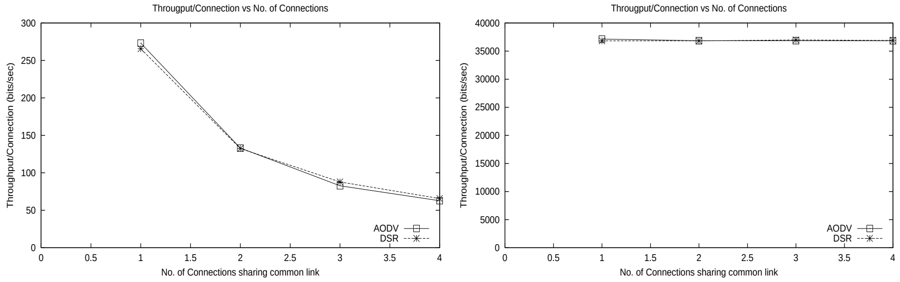


Figure 2: Throughput vs Number of Connections sharing a Link

evaluate the performance of the Routing Protocols, three set of experiments were performed : the first set had only CBR sources (10, 20, 40) while the second set had both CBR (10, 20, 40) as well as TCP(1, 2, 10) sources. Table 1 shows the results for 100 node scenarios with 40 CBR sources respectively. Table 2 shows the result for a 50 node scenario with 10 TCP and 40 CBR connections. Results for the other cases were similar and are not presented here due to space contraints.

Results and Discussion

From these experiments, we observe that under conditions of high mobility, AODV performs better than DSR . However, DSR's performance increases with increased pause-times and it outperforms AODV under conditions of low mobility. The delays experienced by AODV are unaffected by the number of connections, while the performance of DSR improves as the connection density in the network increases. AODV has a higher routing overheads than DSR and while AODV's overheads are dominated by RREQs, RERRs and RREPs dominate DSR's overhead. moreover, DSR's overhead increases with mobility.

The experiments reveal that at smaller pause times, paths chosen by AODV were invariably longer than the ones chosen by DSR. Moreover, they had a larger degree of node and link overlap. This former is along the expected lines. DSR always uses the shortest discovered path from the source to the destination while AODV uses the first path that is discovered. As pause time increases, the cache hit ratio of DSR increases. This results in choosing paths, which are longer than would have been chosen otherwise. This is corroborated by the fact that path lengths gradually increase with increased pause times. The latter observation, however, is a

Table 1: Simulation Results for 100 node experiment with 40 CBR connections

Metrics/Pausetimes	0	125	250	375	500
CBR PDF (AODV)	.353	.613	.669	.638	.689
(DSR)	.278	.415	.609	.689	.770
End to End Delay(AODV)	1.822	1.363	2.240	3.337	2.825
(DSR)	2.847	1.610	1.402	2.142	2.113
Routing Overhead(AODV)	.045	.062	.070	.063	.062
(DSR)	.029	.037	.055	.061	.067
Path Length(AODV)	5.280	5.449	5.162	6.168	6.065
(DSR)	3.689	3.935	3.936	4.438	6.655
Node Overlap(AODV)	4.104	3.865	5.906	5.360	6.756
(DSR)	4.166	4.166	4.589	4.819	4.819
Queue Length(AODV)	10.030	4.727	5.861	7.586	7.354
(DSR)	10.596	8.739	6.516	6.630	6.509

bit surprising. Since AODV chooses the first route reply for forwarding data packets, it should have also implied that AODV chooses the less loaded paths. However, on the contrary, AODV chooses the paths that are more loaded. This happens because of two reasons. Firstly, routing packets are given priority over data packets, nullifying to a large extent the effect of network load upon choice of paths. Secondly, in case of AODV, replies from intermediate nodes which may already be using the route, may reach first to the source resulting in a greater degree of route sharing.

An important consequence of DSR having larger paths at low mobility is its inablity to outperform AODV with respect to TCP throughput since TCP throughput in ad hoc networks varies inversely as the pathlength. However, DSR performs better than AODV when connection density in the network is high and as connection density increases, DSR begins to outdo AODV at higher mobility rates as well.

DSR builds up larger queues than AODV. However, as network load increases, the queue length for DSR becomes less than that of AODV. This is because of the fact that with larger number of connections, DSR finds caching more advantageous and data packets have to spend less time waiting for a route. Moreover, as the number of connections increase, DSR's routing overhead comparatively becomes much lesser than that of AODV, resulting in smaller queues for DSR.

Conclusion

We have compared the performance of AODV and DSR, two prominent protocols for mobile ad hoc networks. Our evaluation of the routing protocols, unlike previous works of similar nature, brings out the effect of routing protocols on the TCP performance. Through experiments, we first outlined the essential differences between TCP and CBR traffic and therefore the need to consider TCP traffic for routing protocol performance evaluation . Based on these experiments, we proposed several metrics for quantifying the performance of a routing protocol. This was followed by extensive simulations for the two protocols under varying conditions of traffic type, traffic load, node mobility and network size.

Based on our observations and analysis, we feel routing protocols for ad hoc networks would in general benefit if the issues of caching and network load are also addressed. Caching is necessary for scalability. It helps limit the RREQ floods and improves network throughput. However, stale routes cause problems and a suitable cache invalidation scheme is also required. Network load is important as it significantly affects TCP performance. Both AODV and DSR and most of the proposed routing protocols for ad hoc networks do not take these into account. The incorporation of these suggestions in the design of routing protocols shall, we believe, lead to more robust, scalable and efficient routing solutions for ad hoc networks.

Table 2 : Simulation Results for Experiment with 50 nodes, 10 TCP connections and 40 CBR Connections

Metrics/Pausetimes	0	250	500	750	1000
TCP Throughput (AODV)	213.076	93.022	192.038	196.731	216.147
(DSR)	111.320	141.240	218.108	69.88	458.288
CBR PDF (AODV)	.451	.674	.687	.768	.559
(DSR)	.421	.486	.554	.714	.564
Path Length (AODV)	4.473	4.019	4.013	3.142	3.521
(DSR)	2.811	3.617	3.011	3.507	4.047
Node Overlap (AODV)	5.749	5,682	6.540	8.472	6.856
(DSR)	4.109	5.699	6.159	6.052	6.465
TCP Goodput (AODV)	.986	.975	.982	.969	.994
(DSR)	.985	.986	.993	.982	.998
Routing Overhead (AODV)	.086	.090	.095	.103	.090
(DSR)	.055	.062	.073	.084	.082
Queue Length (AODV)	12.132	10.551	12.174	10.018	15.189
(DSR)	14.692	12.285	12.738	12.663	16.097
TCP Delay (AODV)	.190	.404	.574	.913	.499
(DSR)	.282	.346	.515	.933	.347
CBR Delay (AODV)	1.970	2.459	3.374	2.463	4.850
(DSR)	3.041	1.930	2.580	2.282	3.832

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