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A Consolidated Analysis of MANET Routing Protocols

Danish Vasan [1], Hameedullah Kazi [2], Arshad Shaikh [3], Ibrahim Channa [4]
[1] Isra university, Hyderabad, Pakistan, danish.vasan@isra.edu.pk,
[2] Isra University, Hyderabad, Pakistan, hkazi@isra.edu.pk,
[3] Isra University, Hyderabad, Pakistan arshad.shaikh@isra.edu.pk,
[4] Quest, University, Nawabshah, Pakistan, ibrahim.channa@quest.edu.pk

ABSTRACT

A mobile ad-hoc network (MANET) is an infrastructure-less network, in which nodes communicate with each other without any central administration. Nodes in an ad-hoc network behave simultaneously as host as well as router agreeing to forward data traffic for other nodes. A routing protocol is needed to establish routes for data transmission. Many routing protocols have been proposed and are being studied as a topic of active research. A significant amount of work has already been done on the performance evaluation of these routing protocols. However, in order to compare the results presented in these individual efforts, a level ground is needed. The work presented in this paper is an effort to provide such a level field for three performance metrics viz. Average throughput, End-to-end delay and Packet delivery ratio by applying some heuristics, normalization and other statistical measures. The techniques presented are then applied to the results of some of the leading research works and conclusions are drawn if there was a trend observed. Particularly, three protocols viz. AODV, DSDV and DSR remained the focus of this work.

Key words: Mobile Ad-Hoc Network, MANET, Routing Protocol, AODV, DSDV, DSR, QoS, Performance Analysis, Average throughput, End-to-end delay and Packet delivery ratio.

1. INTRODUCTION

In a Mobile Ad-Hoc Network [1] nodes are mobile and are connected via wireless link in an arbitrary manner with the neighboring nodes present in their antenna ranges. The overall end to end communication is, therefore, multi-hop Routing protocols are used to discover and maintain routes; however in such an highly dynamic environment, routing is a very challenging task [2][3]. Several routing protocols have been proposed, and have been a topic of active research for more than a decade. Researchers have studied these protocols and calculated their performance metrics by simulating them under varying scenarios (mobility, size, density, load, etc.). However in order to compare the results of these efforts and to make consolidated inferences one need to normalize these results to a common scale.

This paper discuses three performance metrics (viz. Average throughput [4], End-to-end delay [5] and Packet delivery ratio [6]) and presents approaches to normalize each of them in order to establish comparisons between observations made by various researchers.

Rest of the paper is organized as follows: Section 2 presents a brief review of existing routing protocols. Section 3 reviews some of the recent literature whose results are then normalized in section 4 to establish the comparison. Finally, section 5 presents the conclusion and indicates some of the possible future research directions.

2. ROUTING PROTOCOLS

Routing protocols are used to find a path from source to destination. Essentially these protocols have been classified into three categories. Proactive routing protocols, Reactive routing protocols and Hybrid (Proactive + Reactive) routing protocols. Figure 1 shows a classification of these routing protocols.

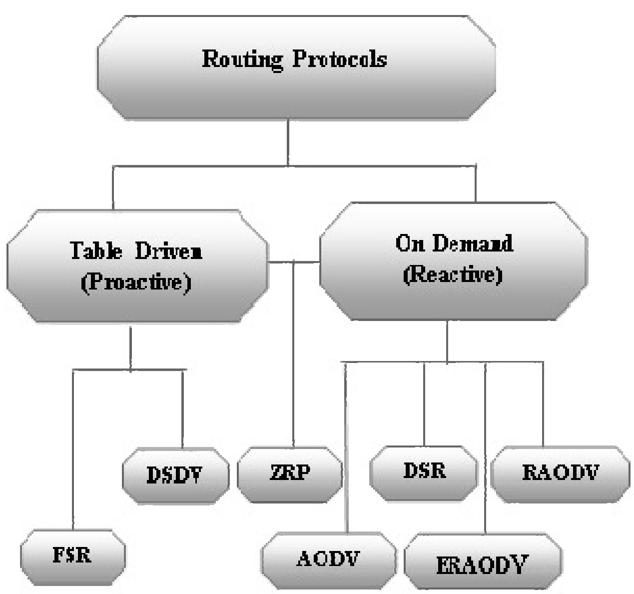

Figure 1: A classification of MANET routing protocol.

2.1 Proactive Routing Protocols

In proactive (table-driven) [7] [8] protocols all nodes periodically exchange the information about currently known shortest routes with their neighbors. Each node, then, analyzes this information to compute new shortest routes to each possible destination in the network. These types of protocols are not difficult to implement however due to the its resource hungry nature, limited energy of the nodes and slow propagation of routing information it becomes infeasible to be used in larger MANETs. DSDV (Destination Sequenced Distance-Vector), FSR (Fisheye State Routing Protocol), and CGSR (Cluster Head Gateway Switch Routing Protocol) are some examples of proactive routing protocols.

2.2 Reactive Routing Protocols

In reactive (on-demand) [9] [10] protocols, nodes do not continuously exchange routing information with their neighbors; instead a route is constructed only when it is needed. When a source node needs a route to a destination node it starts a node discovery process, in which route request messages are flooded across the network. The destination node responds to this request hence establishing a route. The Route is maintained until destination become unreachable, or source is no longer interested in destination. AODV (Ad-Hoc on Demand Distance Vector Routing Protocol) [7], DSR (Dynamic Source Routing Protocol) [8], TORA protocol (Temporary-Ordered Routing Algorithm), CBRP (Cluster Based Routing Protocol) are examples of reactive routing protocols.

2.3 Hybrid Routing Protocols

Hybrid (proactive + reactive) [11] [12] protocols are simply the combination of two protocols stated above. ZRP (Zone Routing Protocol) being a typical example in which the whole topology is divided into a hierarchy of zones. Proactive routing is used locally within each zone, while reactive routing is used to create routes between the zones.

3. LITERATURE REVIEW

Following four papers have been carefully selected after a handful of literature review. Observations and results of many papers were unusable because of the insufficient availability of scenario parameters such as number of connections or data rate. Also some papers were dropped from consideration due to the inconsistencies between their input and output parameters.

3.1 Comparison of DSDV, AODV and DSR by Asma Tuteja et al., [13]

This paper compares DSDV, AODV and DSR routing protocols using network simulator NS2.34. In particular the effects of changing packet size, pause time and mobility on the Throughput, PDR (Packet Delivery Ratio), End to End Delay, and Routing overhead were studied. The scenario consisted of 25 nodes with a single source (node 0) and a single destination (node 2). The simulation time was 10 seconds with Packet sizes were 1000, 500 and 100 bytes. Packet sending interval was set to 0.015, 0.15 and 1.5 seconds in different scenarios.

The paper made the following observations: In AODV and DSR, the number of packets received at destination was found decreasing with the increase in packet sending interval. DSDV was found independent of varying packet sizes. In AODV and DSR Protocols both throughput and packet delivery ratio (PDR) were observed to be decreasing with increase in packet size. Overall, the performance of DSDV protocol was not good compared to AODV and DSR protocols. In some situations AODV performed better than DSR, however in general DSR performed slightly better than AODV. Performance of all three protocols was found decreasing with increase in node mobility.

3.2 Comparison of DSDV, AODV, DSR and OLSR by Deepank Modi et al., [14]

In this paper DSDV, AODV, DSR and OLSR routing protocols are compared using network simulator NS2. It studies the effects of changing network density (number of nodes in unit area) and traffic load (number of connections) on the Throughput, PDR (Packet Delivery Ratio), End to End Delay, and Normalized Routing Load. The scenarios consisted of 30 to 150 nodes in a 1 km x 1 km area. The traffic load in one set of scenarios was 15 connections while it was 25 connections in the other.

The paper concluded that AODV protocol produced best results in all network scenarios and traffic conditions with respect to throughput and packet delivery ratio. However the proactive protocol DSDV guarantees lowest values of delay and shows best performance in terms of end-to-end delay.
DSR was observed to be having the worst performance in congested networks.

3.3 Comparison of DSDV, AODV and DSR by G. Lakshmikanth et al., [15]

This paper compares DSDV, AODV and DSR routing protocols using network simulator NS2 and studies the effects of changing network density, pause time and mobility on the PDR (Packet Delivery Ratio), End to End Delay, and Normalized routing load. A total of 123 simulations are presented (41 scenarios for each of the 3 protocols). The scenarios consisted of 10 to 100 nodes, with a maximum pause time of 0 to 900 seconds and mobility speeds varying from 0 to 100 m/s. The simulation time was 15 minutes.

The paper made the following observations: At 40 sources, the network was unable to handle all of the traffic generated by the routing protocol and a significant fraction of data packets were dropped. The performance of DSR was very good at all mobility rates and movement speeds, although its use of source routing increases the number of routing overhead bytes required by the protocol. AODV performs almost as well as DSR at all mobility rates and movement speeds and accomplishes its goal of eliminating source routing overhead, but it still requires the transmission of many routing overhead packets and at high rates of node mobility is actually more expensive than DSR. Finally, AODV and DSR performance is better than DSDV when transmission power is increased. At higher transmission powers AODV routing load is increased.

3.4 Comparison of DSDV, AODV and DSR by Julia Rahman et al., [16]

This paper analyses the comparative performance of AODV, DSDV and DSR routing protocols in scenarios with varying network density and mobility by observing the Packet Delivery Ratio, Throughput, End to End Delay, and Normalized Routing Load using NS2 simulator. The scenario consisted of a varying number (10 to 120) of nodes in an area of 1 sq. km and a varying pause time of 0 to 200 seconds and node speed of 20 m/s. The traffic type was CBR 2 Kbytes/sec and simulation time was 200 seconds.

Simulation results show that different routing protocol performs well in different scenarios and good for specific performance metrics. For example, DSDV perform better in the high density networks or the network with strict requirement on time whereas DSR performs well in smaller network. AODV is more adaptable in the networks with high throughputs and preferable for low loss rate environment.

4. NORMALIZATION OF QoS PARAMETERS.

Typically, quality of service (QoS) parameters [17] are used to define the required performance of a connection or a network as described by QoS routing, QoS MAC and resource reservation [18]. However the same parameters may be used as performance metrics to study the effectiveness of a protocol. Following three QoS parameters are analyzed in this study:

4.1 Throughput:

Throughput is defined as the amount of data delivered in a unit of time by the network [19]. It is measured in bits/sec (or sometimes in bytes/sec). Some authors confuse this quantity with average-throughput which is a different parameter.

To compare the throughputs obtained by various studies presented in previous section, and to establish a unifiable pattern, it is very much needed to normalize the throughput values.

Define required-throughput to be the amount of data needed to be transferred in a unit of time and is computed as follows:

Required Throughput = N x R x S

where, N = No of connections

R = Packet rate (in packets/sec)

and S = Packet size (in bits)

Now the throughput values can be normalized by dividing them by the corresponding required throughput. This will help one judge the relative merit or de-merit of a protocol over the other. Table-1 shows the application of this normalization approach on the throughput values observed by Asma Tuteja et al.

Table-1

THROUGHPUT (K bits / sec)		Asma Tuteja et. al.,			
		Scnr-1	Scnr-2	Scnr-3	Scnr-4
Observed	AODV	163.52	33.6	27.28	178.64
	DSDV	65.76	8	6.56	65.76
	DSR	140.4	27.52	24.8	194.64
Required		480	48	48	240
Normalized	AODV	34%	70%	57%	74%
	DSDV	14%	17%	14%	27%
	DSR	29%	57%	52%	81%

Table-2 shows the average of these normalized values for various studies presented in the previous section.

Table-2

	Asma Tuteja et. al.,	Deepank Modi et. al.,	Julia Rahman et. al.,	**Average**
AODV	59%	42%	54%	**52%**
DSDV	18%	24%	46%	**30%**
DSR	55%	32%	34%	**40%**

From the comparison presented in Table-2, it is deducible that AODV gives 40 to 60% of the required throughput while both DSR and DSDV lag AODV on this.

4.2 Packet Delivery Ratio:

Packet delivery ratio is calculated by dividing the number of packets received at the destination by the number of packets originated at the source [20]. For the best performance packet delivery ratio of routing protocol should be as high as possible. A ratio of 1 is the best delivery ratio a protocol can ever achieve. To establish a unified result for this parameter and to provide a level playing field, it is suggested to pivot the PDR of one protocol at some standard point and observe the corresponding value of PDR for the other protocols.

Specifically, pinpoint AODV around 30% and 70% and observe the corresponding values of other protocols. Table-3 presents the results obtained after applying this approach on the papers presented in the previous section and Figure 2 depicts the same on a graph.

Table-3

	Julia Rahman et. al.,	Asma Tuteja et. al.,	Guntupalli Lakshmikanth et. al.,	AVG 70
AODV	70%	63%	70%	68%
DSDV	42%	15%	65%	41%
DSR	72%	52%	75%	66%

	Julia Rahman et. al.,	Asma Tuteja et. al.,	Guntupalli Lakshmikanth et. al.	AVG 30
AODV	30%	34%	33%	32%
DSDV	38%	36%	36%	37%
DSR	20%	12%	39%	24%

From this graph it can be concluded that the PDR of DSR protocol remains comparable to the AODV protocol. In scenarios where AODV has a low PDR (30%), DSR also has a low PDR and in scenarios where AODV has a high PDR (70%), DSR also has a high PDR. However, the PDR of DSR remains slightly lower than AODV. The PDR of DSDV protocols maintains its value around 40% for all types of scenarios.

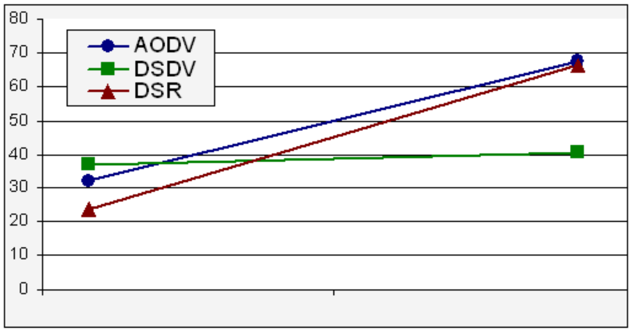

Figure 2: Comparison of Packet Delivery Ratios.

4.3 Average End-To-End Delay:

Average end-to-end delay is defined as the mean time a data packet takes to reach destination from source [5]. Any retransmission delays at the Media Access Control (MAC) layer are also included. It is measured in the units of time (ms). To establish a uniform comparison between the values of end-to-end delay observed in various papers presented in section 3, the end-to-end delay values for DSR and DSDV protocols were divided by the corresponding value for AODV protocol. Multiple values from each paper are then averaged. Table-4 summarizes the end-to-end delay values after this normalization:

Table-4

	Julia Rahman et. al.,	Asma Tuteja et. al.,	Guntupalli Lakshmikanth et. al.	Yin Tan et. al.
AODV	1	1	1	1
DSDV	0.6	0.75	0.85	
DSR	2.1	0.9	0.7	2

From these results it can be concluded that the average end-to-end delay in DSDV protocol remains 60 to 85% of the AODV value in the same scenario. The Average end-to-end delay of DSR is fluctuating above and below AODV value in some scenarios it was observed more than 200% of the AODV end-to-end delay value while sometimes it was found around 70% of the AODV value.

5. CONCLUSION

A novel approach to consolidate the results of various studies available in the literature is presented. Methods were defined to compare the throughput, packet delivery ratio and end to end delay from various scenarios and simulations. After applying the approach on the observations of some selected papers, it was concluded that AODV performance remains better than DSDV and DSR protocols with respect to throughput and packet delivery ratio while DSDV performance was found better with respect to the end to end delay. In the future we would like to extend this work to include other available MANET routing protocols and more performance metrics.

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