

A Comparative Study for Reactive and Proactive Routing Protocols in Mobile Ad hoc Networks

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ABSTRACT: Mobile Ad hoc Network (MANET) is a collection of mobile nodes that form a dynamic topology and highly resource constrained network which are the most important characteristics of a MANET come from node mobility and Infrastructureless nature of MANETs. These characteristics essentially lead to adopt a routing protocol that quickly adapts to nodes mobility. Routing protocols in MANETs are classified into three types: proactive (table-driven), reactive (on-demand) and hybrid protocols. A routing protocol also may be considered a single path protocol or multipath protocol based on the routing mechanism. A routing protocol should try to minimize routing overhead such as control traffic and delay time overhead, maximize data packet delivery and throughput. This paper provides a comparative study for the performance of reactive against proactive routing protocols in MANETs. A comparison study has been introduced between proactive-reactive, single path-multipath protocols, and between reactive protocols only in terms of packet delivery fraction, average end-to-end delay, routing overhead and throughput. This evaluation and comparison study have been performed by means of simulation using NS2.

Keywords: Routing comparison, Table-driven, On-demand, Single path, Multipath, Mobility

Received: 19 September 2009, Revised 15 October 2009, Accepted 1 November 2009

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1. Introduction

Mobile Ad hoc Network (MANET) is a sort of infrastructureless wireless networks [1]. It can be defined as a collection of mobile nodes that form a dynamic topology and highly resource constrained network [2, 3]. Unlike Wireless LAN (WLAN) which is infrastructure based and single hop network, MANET is considered a multi-hop network.

Since there is no infrastructure, mobile nodes communicate directly and cooperatively with each other in a multi-hop manner. That means there are no access points or routers, no coordination or configuration prior to setup of a MANET [4]. Thus, it is difficult to apply any kind of central administration on MANETs such as the case in routing, authentication, or congestion control. Also, due to high mobility, resource constrains (power, storage, and bandwidth) in MANET environment [5], and nodes operating in a dynamic topology, more challenges are encountered in routing, security, and quality of service [6]. Routing is still a big challenge for MANETs. Finding a route between nodes inside a MANET is still a major problem especially in high mobility scenarios. So far, routing protocol can be considered suitable for all situations [7].

This paper provides an analytical study that compares the performance of reactive against proactive routing protocols in MANETs. A simulation study has been performed using NS2 and the comparison study has been conducted between three typical reactive routing protocols namely Dynamic Source Routing (DSR) [8], Ad hoc On-Demand Distance Vector Routing

(AODV) [9], and Temporally Ordered Routing Algorithm (TORA) [10] and then, between these reactive protocols and a typical proactive protocol namely Destination Sequenced Distance Vector (DSDV) [11]. Finally, a comparison has been performed between single path protocols (DSDV and AODV) and multipath protocols (DSR and TORA).

2. Overview of MANETS Routing Protocols

Routing management can be defined as detecting and maintaining the optimal route that is used to send data packets between source and destination via intermediate node(s) [3, 12]. This section emphasizes on routing protocols classification and a brief description for each of the four protocols, DSDV, DSR, AODV, and TORA.

2.1 Proactive, Reactive and Hybrid Protocols

Routing protocols in MANETs are classified into three types, proactive protocols (table-driven), reactive protocols (On-demand), and hybrid protocols [3, 12, 13, 14].

Proactive protocols update periodically routing information to various nodes in the network, so that a source node can find the route to the destination whenever needed. As the route is always known, forwarding packets is faster in proactive protocols. The main disadvantage of such protocols is the large overheads of route discovery process which is launched periodically. Also, more bandwidth and power are consumed for updating process in proactive protocols [12]. DSDV and Wireless Routing Protocol (WRP) are examples of such protocols [14].

In reactive protocols, the optimal route should be discovered on-demand and selected among multiple routes detected. As the route detected when needed and no updating overhead occurs, reactive protocols have smaller overheads of route discovery process than proactive protocols. Less bandwidth and power are consumed in such protocols. More delay time may be spent to receive Route Replies RREPs of route discovery process. DSR, AODV and TORA are examples of such protocols [3, 2, 4].

Hybrid protocols are a sort of combination between both proactive and reactive. An Example of such protocols is Zone Routing Protocol (ZRP) [15]. In this paper, routing protocols of flat structure have been compared while protocols of hierarchal structure are out of scope of this paper.

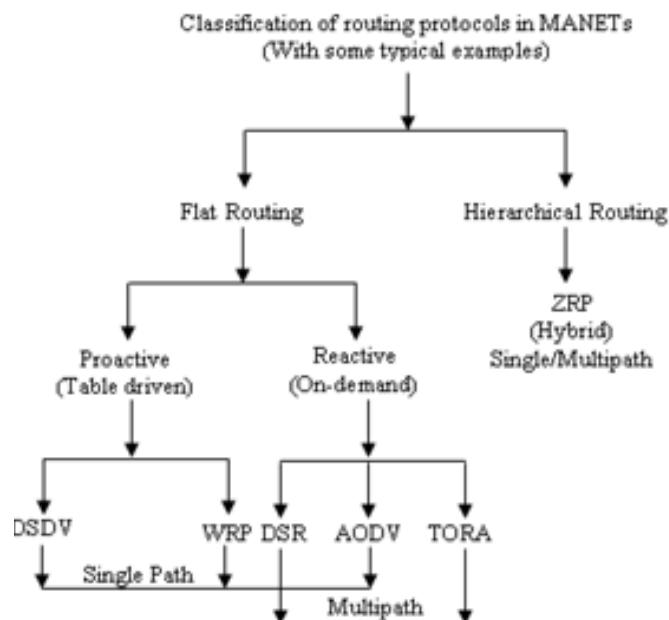


Figure 1. Classification of routing protocols in MANETs with some examples

Figure 1 shows a 4-level classification of routing protocols in MANETs with some examples of proactive, reactive, hybrid, single path and multipath protocols while Table I shows the most important differences between the four typical routing protocols in MANETs.

2.2 Single Path Vs. Multipath Protocols

Single path abstraction in routing protocols means that multiple routes could be detected due to routing discovery process and one route of them (the optimal) should be maintained in a source node routing table. DSDV and AODV are examples of single path routing protocols. In multipath routing protocols, multiple routes could be detected due to routing discovery process and all of these routes should be maintained in a source node routing table. All of these routes could be used for data transmission between source and destination nodes. DSR and TORA are examples of multipath routing protocols.

Many multipath extensions of AODV have been developed to improve the performance of AODV protocol especially in high mobility scenarios where link failures increase so that launching a route discovery process frequently causes more routing overhead and more consuming of bandwidth and power. In such situations, there is a need for backup routes by applying a sort of route maintenance. Examples of such extensions are Ad hoc On-demand Multipath Distance Vector (AOMDV) [18], AODV Backup Routing (AODV-BR) [24], Multiple Next Hops (MNH) [26] and Multiple Route AODV (MRAODV) [23]. Criteria that have been used in this paper for comparing single-path routing and multi-path routing in MANETs are the average routing discovery overhead (ROH) and the average throughput (the average number of received data packets [27]).

Comparison Aspect	DSDV	AODV	DSR	TORA
Routing Form(Flat/hierarchal)	Flat	Flat	Flat	Flat
Routing Mechanism	Tabledriven	Ondemand	Ondemand	Ondemand
Loop Free Routes	Yes	Yes	Yes	Yes
Multipath Abstraction	No	No	Yes	Yes
Distributed	Yes	Yes	Yes	Yes
Route MaintenanceSupport	No	No	Yes	Yes
Unidirectional LinkSupport	No	No	Yes	Yes
QoS Support	No	No	No	No
Capability ofApplying SecurityTechniques	No	No	No	Possible
Route cache strategy	No	No	Yes	No
Power-aware	No	No	No	No
Routing Metric(s)	Greater sequence number, and less hop count	Mostrecent andshortestpath	shortestpath	shortestpath

Table 1. Comparison of some ad hoc proactive and reactive routing protocols

2.3 DSDV Protocol

DSDV [11] is flat (non hierarchal) and proactive routing protocol which means that routes to all destinations are readily available at every node at all times. It is considered a distributed routing protocol because it is an enhanced version of the distributed Bellman-Ford algorithm [3]. In DSDV, every node maintains a routing table that contains next-hop entry and the number of hops needed for all reachable destinations. DSDV uses the abstraction of single path and bidirectional links, and thus DSDV does not support a unidirectional link. It also provides loop-free routes. In DSDV, nodes broadcast a periodical

route advertisement frequently to maintain routing information within a network. Routing table entries are involved in the route advertisements. On receiving a route advertisement, a node's routing table is updated. Sequence numbers are used for optimal route selection so that the optimal route is the route that has greater sequence number. Hop count is the next criteria of optimality. A route with lower hop count is chosen if the sequence numbers are equal.

2.4 DSR Protocol

DSR [8] is flat and fully reactive routing protocol which means the route is detected when needed and no updating overhead occurs. It is considered a distributed and multipath routing protocol. DSR is a source routing protocol which means that an ordered list of all routes used by a packet sent between a source and any intermediate node (or the destination itself) are maintained in the packet header. Each node in the network maintains a route cache in which all routes used frequently to any given node are stored. Since it is a reactive protocol, DSR uses on-demand route discovery mechanism by flooding route request (RREQ) packets through the network nodes. Each intermediate node looks for the required route in its route cache and if the route is found, the node replies a Route Reply (RREP) packet back to the source node using the source route maintained in the RREQ packet. If the required route is not found, the intermediate node forwards the RREQ to all neighbors and so on until it reaches the destination node.

The destination node replies back to the source node a RREP packet for each RREQ packet received. Each RREP is replied using the source route maintained in the corresponding RREQ packet. Each RREP received by the source represents an independent path to the destination. All these multiple routes are maintained in the routing table of the source node and thus DSR is considered a multipath protocol. Finally, DSR uses route maintenance mechanism in case of link failures.

2.5 AODV Protocol

AODV [9] is a reactive, flat, single path and distributed routing protocol designed for MANETs. Unlike proactive protocols, which maintain updated information about all routes related to each node in its routing table, AODV builds routes between a source and a destination only on-demand of source nodes. It does not require mobile nodes to maintain routes to destinations that are not communicating [25].

Unlike DSR, AODV is not a source routing protocol meaning that a packet does not maintain a list of all routes to the source node. Instead, AODV deals only with neighbors from the first class for forwarding a RREQ or replying a RREP. In AODV, routing table stores information about the next hop to the destination and a sequence number to guarantee loop-free routes [31].

Based on AODV mechanism, one route entry (the optimal route) is maintained in the routing table of each node for each destination that the node is communicating with in the network. This feature is called single route abstraction in AODV [28]. When a source wants to send a data packet to a destination, supposed that no valid entry for that destination is in its routing table, it floods a Route Request packet (RREQ) to all first hop neighbors in the network. A RREQ packet contains source identifier, destination identifier, source sequence number, destination sequence number, broadcast identifier, time to live field, and a hop count. A RREQ is flooded by forwarding it to the whole network until it reaches the destination from different routes. The destination node keeps track of all detected routes and then sends back a Route Reply (RREP) in a backward process until it reaches the source node using all routes established in the forward process. On receiving the packet by an intermediate node, hop count is incremented and the routing table entry is updated [5, 13].

AODV uses error messages for route maintenance. When a node detects a broken link to the next hop, it generates a route error message that contains a list of unreachable destinations and sends it to related nodes. The source node should reestablish a new route discovery process to detect an alternative route to the same destination [21].

2.6 TORA Protocol

TORA [10] is a reactive, flat, multipath, distributed and highly adaptive loop-free routing protocol designed for MANETs. It is designed to operate in a high mobility environment of a network. It belongs to a family of algorithm called link reversal algorithm [5]. The idea behind TORA is taking into account the status of the communication links between nodes which is a function of nodes positions or in other words, the variability in mobility and network topology.

Based on this idea, TORA is designed to resist the variability of network topology due to many considerations such as mobility and power considerations. The key design concept of TORA is to use control messages in a small set of nodes near

the potential change of topology. Each node in the ser maintains routing information about the first class neighbors [29]. TORA utilizes a sort of route maintenance process to repair link failures that may be occurred in the network.

3. Related Work

MANET routing protocols have been tested and evaluated in so many literatures especially in relation to the comparison of their performance from different perspectives. In this section, we provide brief review of such literatures.

Larsson and Hedman [16] have made a simulation for AODV and DSR. Results of [16] have shown that DSR is better than AODV in general. However, when the network size increases, AODV becomes better because DSR is a source routing protocol. They have concluded that a combination between AODV and DSR could be a solution with better performance than the original AODV and DSR.

Boukerche [22] has made a comparison between different ad hoc routing protocols including DSR and AODV. In [22], source routing protocols such as DSR had very high throughputs while the distance vector protocols such as AODV exhibit a very short end-to-end delay of data packets. Both [16] and [22] have emphasized more on reactive protocols and both did not introduce a framework for a sort of combining between DSR and AODV features.

Sesay, Yang, Qi and He [30] have introduced a comparison of the four typical ad hoc routing protocols namely DSDV, TORA, DSR and AODV. The comparison in [30] has been achieved in more dynamic environment than [22] and [30]. This means that it takes the mobility parameter into consideration. However, the comparison does not concern the comparison of single path and multipath which make a difference in the protocol performance especially in overall throughput.

Misra and Mandal [19] have conducted a comparative study between DSR and AODV which are both on-demand protocols. Although, it is more recent than the previous study, unfortunately, DSDV and TORA are not involved in this comparative study.

Layuan, Chunlin and Peiyan [17] have performed one of the most recent comparison study of routing protocols in MANETs. Performance evaluation and a comparison study of four typical routing protocols of MANETs, namely DSDV, DSR, AODV, and TORA, have been discussed from the perspective of varying network size. In [17], jitter and connectivity have been used as computer metrics. However, the parameter of mobility is neglected in the simulation, which can be considered a main drawback of this comparison.

In this paper, we introduce a performance evaluation using a simulation study for four MANET routing protocols, DSDV, DSR, AODV, and TORA. The advantage of this study is that TORA is involved in the evaluation. The evaluation in this comparative study is mobility-aware so that the protocols are evaluated in three mobility scenarios: high, medium and low mobility in terms of packet delivery, average end-to-end delay and routing overhead. Thus, mobility is used as a main input parameter in the simulation process of this comparative study.

Furthermore, an advantage of this comparative study may be that it concerns the comparison between the four typical protocols from the perspective of single path and multipath abstractions. An evaluation has been conducted for single path and multipath protocols in terms of route discovery overhead and the average throughput.

4. Simulation-Based Evaluation

To execute the simulations, the same movement models have been used for all simulations using NS2 for the four typical routing protocols, DSDV, DSR, AODV and TORA. In this section, we describe the mobility and traffic scenarios, input parameters and performance metrics used in the simulation process.

4.1 Mobility and Traffic Scenarios

The mobility model used was the random waypoint model [20] in a rectangular area. Coverage area used for the simulation is 500m x 500m with 50 nodes scattered randomly. Based on random waypoint model, each node moves from a random location to a random destination with a speed chosen randomly (the maximum speed of the nodes was set to 20m/s), node pauses for a while and then removes to another random location within the specified area.

For packet transmission, a packet starts traveling from a source chosen randomly with a speed chosen randomly (often uniformly distributed between 0 and 20m/s). Once the packet reaches destination, another random destination is targeted after a pause. Simulations are run for 100 seconds and the pause time have been varied as 0s, 10s, 20s, 40s and 100s and 250s. Protocols are simulated using different mobility and traffic scenarios for more accurate results. However, number of traffic sources was fixed at 20. Regarding buffering, packets are dropped if they wait in the node buffer for more than 30s. Interface queue is used to maintain packets (both data and routing) sent by the routing layer. When MAC layer is ready, it transmits these packets and then releases the interface queue.

The maximum size of interface queue used for our simulation is 50 packets using a priority queue. A higher priority is assigned to routing packets and a lower for data packets. Continuous Bit Rate (CBR) traffic sources have been used with a packet size of 512B and IEEE 802.11 with speed of 2Mbps has been used for MAC sub-layer. Protocols maintain a send buffer of 64 packets.

Mobility is considered here the most important input parameter affects the behavior of routing protocols. Pause time is used to measure the degree of mobility. Small pause time value indicates to a high mobility so, if pause time = 0, this means nodes continue moving and do not stop. Large pause time value indicates to a low mobility so, if pause time = 250, this means nodes stop for long time (250s) before start moving again. In this paper we have used mobility as an input parameter for the simulation process.

4.2 Performance Metrics

The performance metrics used to evaluate our simulation results can be summarized as follows:

- Packet delivery fraction (PDF) the ratio of the data packets delivered to the destinations.
- Average end-to-end delay of data packets (End-to-End Delay) delays caused by buffering, queuing, retransmission delay propagation time and transfer time.
- Normalized routing load number of routing packets transmitted per data packet (RPO) delivered at the destination.
- Average route discovery overhead (ROH), which is the same as RPO but with the average value.
- Throughput which can be represented by the average number of received data packets.

The first two metrics mentioned above are the most important for evaluation while the third metric evaluates routing efficiency. The last two metrics have been used for the comparison between single path and multipath routing.

5. Results and Performance Evaluation

In this section, a result study will be introduced for reactive protocols against proactive and then between the three reactive protocols themselves. Evaluation will be applied for all protocols under the same circumstances according to our performance metrics.

5.1 Packet Delivery Fraction (PDF)

On-demand protocols, DSR, AODV, and TORA performed particularly well, delivering over 85% of the data packets regardless of mobility rate. As shown by Figure 2, the highest rate of PDF was in AODV protocol and then in TORA and after it came DSR and the least of them all was for DSDV.

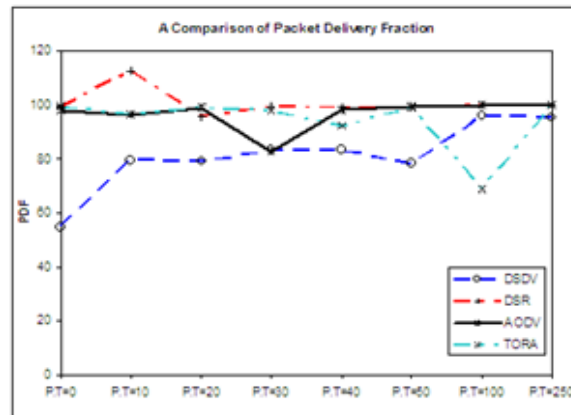


Figure 2. Comparison of packet delivery fraction

5.2 Average end-to-end Delay (AVGD)

As shown by Figure 3, the average end-to-end delay of packet delivery was higher in DSDV as compared to DSR, AODV, and TORA. In summary, all on-demand routing protocols, AODV, DSR and TORA outperformed the DSDV.

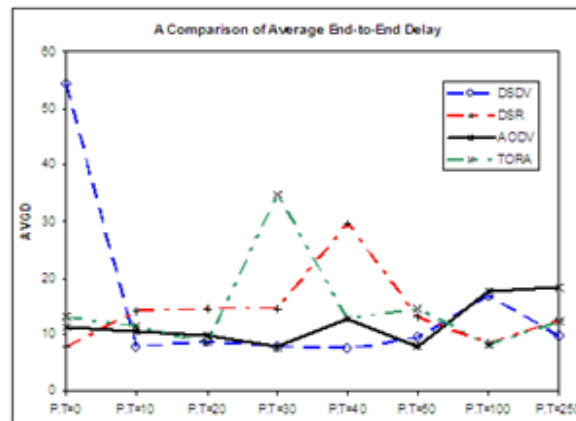


Figure 3. Average end-to-end delay of the four protocols

5.3 Routing Packet Overhead (RPO)

Regarding the routing packet overhead (RPO) metric, it is clear that TORA outperforms all other protocols in all mobility scenarios. However, there is no big difference between the performance of TORA and DSR (both of them use multipath routing) in term of RPO in all mobility scenarios. The conclusion here is not related to the perspective of proactive and reactive, it is related to single path and multipath perspective. It is clear that multipath protocols outperform single path protocols. A comparison between the four protocols from the perspective of single path and multipath will be conducted in the next subsection.

As shown by Figure 4, TORA is considered the best candidate between all the others compared by routing packet overhead, and DSR demonstrates significantly lower routing load than AODV. All reactive protocols, DSR, AODV, and TORA perform very well when mobility is high. DSR outperforms AODV and TORA slightly in high mobility scenarios in term of data packet delivery while AODV outperforms DSR and TORA slightly in term of average end-to-end delay in low mobility scenarios. TORA outperforms both DSR and AODV in term of routing overhead in all scenarios.

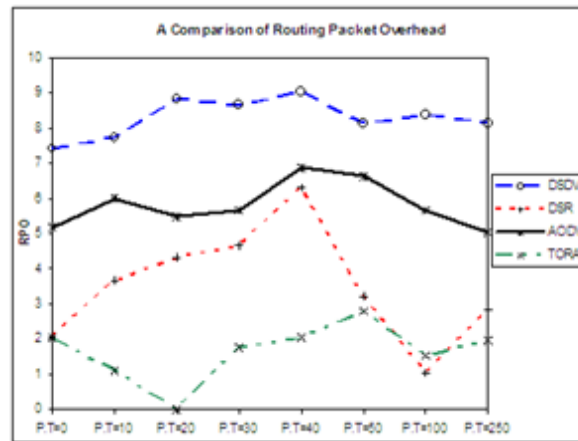


Figure 4. Routing packet overhead of the four protocols

5.4 Evaluation of Low and Medium Mobility Scenarios

In medium and low mobility scenarios, AODV slightly outperforms all other protocols in term of PDF. DSDV performance improves in term of PDF 200% in medium and low mobility scenarios than that in high mobility scenarios. However, this still proves that reactive protocols outperform proactive protocols in term of packet delivery fraction in all mobility scenarios.

Although AODV is the best protocol in term of the total average of average end-to-end delay (AVGD) especially in high mobility scenarios, it is clear that DSDV outperforms all other protocols in medium and low mobility scenarios in term of AVGD. DSDV performance improves in term of AVGD 500% in medium and low mobility scenarios than that in high mobility scenarios. This proves that proactive protocols outperform reactive protocols in term of average end-to-end delay in all low and medium mobility scenarios and vice versa in high mobility scenarios.

Regarding the routing packet overhead (RPO) metric, it is clear that TORA outperforms all other protocols in all mobility scenarios. However, there is no big difference between the performance of TORA and DSR (both of them use multipath routing) in term of RPO in all mobility scenarios. The conclusion here is not related to the perspective of proactive and reactive, it is related to single path and multipath perspective. It is clear that multipath protocols outperform single path protocols. A comparison between the four protocols from the perspective of single path and multipath will be conducted in the next subsection.

5.5 Comparing Single Path and Multipath Routing

As shown in Figure 5, the average overhead of route discovery in multipath routing (DSR and TORA) is much more than that of single path routing (DSDV and AODV). On the other hand, the rate of route discovery is much less in a network which uses multi-path routing, since the system can still operate even if one or a few of the multiple paths between a source and a destination fail.

Figure 6 shows a comparison of the average throughput between multipath and single path protocols, it is clear that using multipath routing (DSR and TORA) results in a higher throughput than that in single path routing (DSDV and AODV). The reason is that all nodes are assumed to have (and limited) capacity (bandwidth and processing power). Since multi-path routing distributes the load better, the overall throughput would be higher.

6. Conclusion

This paper evaluates a proactive protocol (DSDV) against three reactive protocols (DSR, AODV, and TORA). A comparison study has been introduced between reactive and proactive protocols then, between the three reactive protocols themselves and finally, between the four protocols from the perspective of single path and multipath abstractions. This evaluation and comparison study have been done by means of simulation using NS2. The simulations have shown that generally reactive

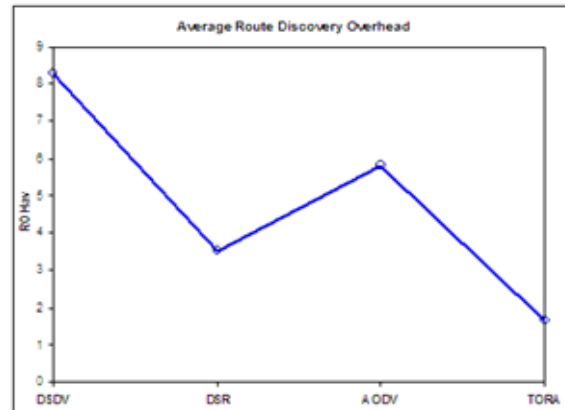


Figure 5. Comparison of the average overhead of route discovery between multipath and single path protocols

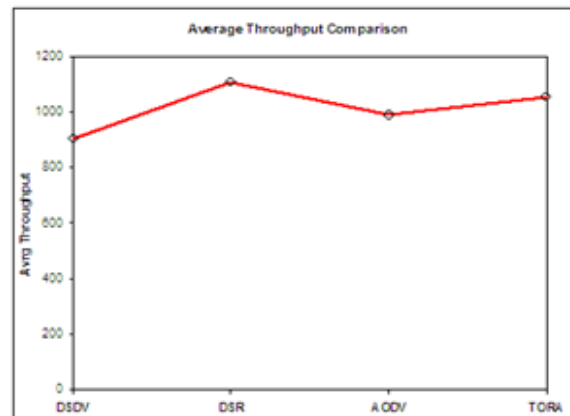


Figure 6. Comparison of the average throughput between multipath and single path protocols

routing protocols outperform proactive protocols in most situations in terms of the three performance metrics used in the simulation, packet delivery fraction, average end-to-end delay of data packets and routing packet overhead. Regarding reactive routing protocols themselves, some of them outperform in high mobility scenarios while the others outperform in low mobility scenarios. DSDV performance increases dramatically in high mobility scenarios. In case of high mobility and high traffic load, AODV is more desirable than the other protocols.

As a future work, it is worthy to evaluate multipath extensions of some reactive protocol as they are well-tested in this paper and lead to good performance over proactive protocols may be in AODV extensions as AODV is more desirable candidate.

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