# Comparison of MANET Routing Protocols in Different Traffic and Mobility Models

Sabina Baraković, Suad Kasapović, and Jasmina Baraković

*Abstract* — **Routing protocol election in MANET (Mobile Ad Hoc Network) is a great challenge, because of its frequent topology changes and routing overhead. This paper compares performances of three routing protocols: Destination Sequenced Distance Vector (DSDV), Ad Hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR), based on results analysis obtained using simulations with different load and mobility scenarios performed with Network Simulator version 2 (NS-2). In low load and low mobility scenarios routing protocols perform in a similar manner. However, with mobility and load increasing DSR outperforms AODV and DSDV protocols.**

*Keywords* — **AODV, DSDV, DSR, MANET.**

## I. Introduction

THE need for Internet access trough mobile devices, anywhere and anytime, has caused the development of model which is different in comparison to access based on a previously set fixed infrastructure over which wireless devices connect to the Internet nowadays.

The new model is called Mobile Ad Hoc Network (MANET). MANET is a collection of wireless mobile nodes that communicate with each other using multi-hop wireless links without any existing network infrastructure or centralized administration [1]. Each node in the network behaves as a router and forwards packets for other nodes.

Routing, as an act of moving information from a source to a destination trough intermediate nodes, is a fundamental issue for networks. Numerous widely used routing algorithms are proposed for wired networks. Routing is mainly classified into static and dynamic routing. Static routing refers to routing strategies set in the router, manually or statistically. Dynamic routing refers to routing strategies learned by an interior or exterior routing protocol [2]. Two most popular dynamic routing algorithms in wired networks are distance vector and link state protocols.

When using distance vector protocol, which is based on Bellman – Ford routing algorithm, each router periodically exchanges information about distances to all available destinations with its neighbors, thereby maintaining and updating routing table. In case of multiple paths to a destination, this protocol provides the shortest path. Its main disadvantages are no routing loops prevention and slow convergence which leads to "count to infinity" problem.

When using link state protocol, each router periodically informs all routers in the network about current state of its links, thereby providing a partial picture of the whole network. When a link state change occurs, individual reports will reach every router in the network by flooding. All routers, upon receiving the report, re-calculate their paths according to fresh topology information, thereby updating their routing table. The shortest path is calculated using the Dijkstra algorithm.

Previously described traditional routing protocols perform well in wired networks, because of their predictable network properties, such as static link quality and network topology. However, when applied in MANETs, these protocols don't perform well. This is partly a consequence of frequent topology changes in MANETs, which have asymmetric, no explicit links and all communication is done by broadcasting. Also, dynamic topology increases routing overhead, which can take the already limited bandwidth. In addition, these algorithms cause routing loops and inconsistency of routing information. Thus, we can conclude that routing in MANETs is significantly different from routing in wired networks.

Many routing protocols have been proposed for MANETs, but none of them has good performances in all scenarios with different network sizes, traffic loads, and node mobility patterns [3]. Each of the proposed protocols is based on different principles and has different characteristics, so their classification is necessary. Usually, classification is made based on characteristics related to the information which is exploited for routing and roles which nodes may take in the routing process. The most popular classification method is based on how routing information is acquired and maintained by mobile nodes. According to this method, we can divide MANET routing protocols into proactive and reactive routing protocols.

When using proactive routing protocols, also called "table driven" protocols, mobile nodes continuously evaluate routes to all reachable nodes and attempt to maintain consistent and up-to-date routing information, regardless of whether data traffic exists or not. The advantages of this type of protocols are discovery of the shortest path through network and availability of routes at the time of need, which reduces delays. The lack of

Sabina Baraković, Ministry of security of Bosnia and Herzegovina, Trg BiH 1, 71000 Sarajevo, B&H (e-mail: barakovic.sabina@gmail.com).

Suad Kasapović, Faculty of Electrical Engineering, University of Tuzla, Franjevačka 2, 75000 Tuzla, B&H (e-mail: suad.kasapovic@untz.ba).

Jasmina Baraković, BH Telecom d.d Sarajevo, Obala Kulina bana 8, 71000 Sarajevo, B&H (e-mail: jasmina.barakovic@bhtelecom.ba).

proactive routing protocols is providing a resistance to network topology changes [4].

On the other hand, when mobile nodes use reactive routing protocols, also called “on-demand” protocols, route discovery operation is performed only when a routing path is needed, and it is terminated when a route or no route has been found. A very important operation in reactive routing is route maintenance. The advantages of this type of protocols are efficiency, reliability and less control overhead. However, a major lack is a long delay caused by a route discovery operation in order to transmit data packets [4].

This paper presents a performance comparison of three prominent routing protocols in MANET based on results analysis obtained by running simulations with different scenarios in Network Simulator version 2 (NS-2) [5]. Scenarios differ in the number of sources in the network, duration of pause times, maximum movement speed and sending rate. Parameters based on which the comparison is performed are Packet Delivery Ratio (PDR), Normalized Routing Load (NRL) and average end to end delay.

A description of considered routing protocols is given in Section II. Scenarios and simulation parameters are described in Section III. Simulation results and analysis are presented in Section IV. Section V concludes this paper.

## II. Routing Protocols

The following three routing protocols are considered in this paper:

### A. *Destination Sequenced Distance Vector (DSDV)*

The DSDV [6] routing protocol is a proactive routing protocol, described in detail in this paper. It is based on the Bellman-Ford routing algorithm. Each node in the network maintains a routing table which contains all available destinations with associated next hop towards destination, metric and destination sequence number. Sequence number presents improvement of DSDV routing protocol compared to distance vector routing, and it is used to distinguish stale routes from fresh ones and avoid formation of route loops.

Routing tables are updated by exchanging the information between mobile nodes. Each node periodically broadcasts its routing table to its neighbors. Broadcasting of the information is done in Network Protocol Data Units (NPDU) in two ways: a full dump and an incremental dump. A full dump requires multiple NPDUs, while the incremental requires only one NPDU to fit in all the information. A receiving node updates its table if it has received a better or a new route. When an information packet is received from another node, node compares the sequence number with the available sequence number for that entry. If the sequence number is larger, entry will be updated with the routing information with the new sequence number, whereas if the information arrives with the same sequence number, metric entry will be required. If the number of hops is smaller than the previous entry, new information will be updated. Update is performed periodically or when a significant change in the routing table is detected since the last update. If network topology frequently changes, a full dump will be carried out, since an incremental dump will cause less traffic in a stable network topology.

Route selection is performed according to the metric and sequence number criteria. The sequence number is also the time indication that destination node sends, allowing routing table update. If we have two identical routes, the route with a larger sequence number will be saved and used, and the other will be destroyed.

### B. *Ad Hoc On-demand Distance Vector (AODV)*

The AODV [7] routing protocol is an “on demand” routing protocol, which means that routes are established when they are required. This routing protocol is based on transmitting Route Reply (RREP) packets back to the source node and routing data packets to their destination. Used algorithm consists of two steps: route discovery and route maintenance.

Route discovery process begins when one of the nodes wants to send packets. That node sends Route Request (RREQ) packets to its neighbors. Neighbors return RREP packets if they have a corresponding route to destination. However, if they don’t have a corresponding route, they forward RREQ packets to their neighbors, except the origin node. Also, they use these packets to build reverse paths to the source node. This process occurs until a route has been found.

Routing tables which only have information about the next hop and destination are used for routing information maintenance. When a route link disconnects, for example, a mobile node is out of range, neighbor nodes will notice the absence of this link. If so, neighbor nodes will check whether there is any route in their routing tables which uses a broken link. If it exists, all sources that send traffic over the broken link will be informed with Route Error (RRER) packet. A source node will generate a new RREQ packet, if there is still a need for packet transmission.

### C. *Dynamic Source Routing (DSR)*

Routing protocol DSR [8] uses explicit source routing, which means that each time a data packet is sent, it contains the list of nodes it will use to be forwarded. In other words, a sent packet contains the route it will use. Routes are stored in memory, and data packets contain the source route in packet header. Mechanism allows nodes on route to cache new routes, and also, allows source to specify the route that will be used, depending on criteria. This mechanism, also, avoids routing loops.

If a node has to send a packet to another one, and it has no route, it initiates a route discovery process. This process is similar to AODV route discovery process. In other words, the network is being flooded with RREQ packets. Each node that receives a RREQ packet, broadcasts it, except for destination node or nodes that have a route to destination node in their memory. A route trough network is built by RREQ packet, and RREP packet is being routed backward to the source. A route that returns RREP packet is cached on the source node for further use. There can be multiple RREP packets on one RREQ packet.

In DSR, when a broken link is detected, a RRER packet is sent backward to the source node. After receiving a RRER packet, a source node initiates another route discovery operation. Additionally, all routes containing the broken link should be removed from the route caches. This protocol aggressively uses source routing and route caches.

## III. Simulation parameters

### A. Traffic model

Traffic model uses Continuous Bit Rate (CBR) traffic sources. This type of traffic is predictable, but unreliable and undirected. Traffic scenarios differ in the number of pairs, which varies in order to change a network load. Those source-destination pairs are spread randomly over the network. In this paper we considered scenarios with 10, 20 and 30 sources.

Also, in order to examine the behavior of considered routing protocols, in one set of scenarios we varied the sending rate, while keeping the value of pause time and maximum movement speed fixed. Values of sending rate range from 20 to 200 kbps, pause time is 0 simulation seconds, and maximum movement speed is 20 m/s.

### B. Mobility model

Mobility model uses a random waypoint model in a rectangular field. Node mobility scenario is created for 50 nodes, topology boundary of 500m×500m and simulation time of 100 simulation seconds. Each packet starts traveling from a random location to a random destination with a randomly chosen speed. After a node reaches a destination, it moves to another randomly chosen destination after a pause. Identical movement and traffic scenarios are used across protocols.

In one set of scenarios, the duration of pause time, which affects the relative speeds of mobile nodes, is varied, while the value of maximum movement speed and sending rate is kept fixed. Values of pause time are 0, 10, 20, 40 and 100 simulation seconds, movement speed is 20 m/s, and sending rate is 20 kbps.

Also, in order to examine the impact of movement speed on performances of routing protocols, we varied the maximum movement speed, while value of pause time and sending rate was kept unchanged. In that case, values of maximum movement speed range from 10 to 50 m/s, while pause time duration is 0 simulation seconds, and sending rate is 100 kbps.

### C. Performance metrics [4], [9]

1) *Packet Delivery Ratio* (PDR): PDR shows how successful a protocol is in delivering packets from source to destination. Equation for PDR is:

$$PDR[\%] = \frac{\sum_{i}^{n} CBR\_received}{\sum_{1}^{m} CBR\_sent} \times 100, \qquad (1)$$

where $n$ is number of received packets, and $m$ is number of sent packets.

2) *Average End to End delay*: This is the average end to end delay of all successfully transmitted data packets from source to destination. Equation for average end to end delay is:

$$AvrEtEDelay = \frac{\sum_{1}^{n} (CBR\_sent\_time - CBR\_receive\_time)}{\sum_{1}^{n} CBR\_received}, \qquad (2)$$

where $n$ is number of received packets.

3) *Normalized Routing Load* (NRL): NRL is the number of routing packets transmitted per data packet delivered at the destination. Equation for NRL is:

$$NRL = \frac{\sum_{1}^{k} Routing\_packets}{\sum_{1}^{n} CBR\_received}, \qquad (3)$$

where $n$ is number of received packets, and $k$ is number of routing packets.

## IV. Results and Analysis

Obtained results show characteristic differences in performance between considered routing protocols, which are the consequence of various mechanisms on which protocols are based. Although we carried out simulations with 10, 20 and 30 sources, only results with 20 sources are presented in this paper.

As in [1], "on-demand" routing protocols, AODV and DSR, achieve high values of PDR, which means they are efficient protocols from the point of delivering packets to their destination (Fig. 1). For AODV and DSR protocols, PDR is independent of mobility and number of sources, while DSDV has approximately the same PDR under low mobility. As shown in Table 1 and Table 2, AODV and DSR protocols deliver over 90% of packets for all considered values of pause time and maximum movement speed. Since DSDV protocol uses a "table driven" approach of maintaining routing information, it isn't adaptive to the route changes that occur under high mobility as AODV and DSR protocols are. That is why it delivers less data packets, which is also shown in Table 1 and Table 2. Therefore, DSDV protocol is not suitable for MANETs, because it is slow.

Results obtained by running simulations with a changeable sending rate confirm the previous conclusion, but also show that all three routing protocols don't perform well when network load increases. As shown in Table 3, when the network load is the largest routing protocols deliver barely 50% of packets.

However, in all considered cases, regardless of mobility, source number or network load, DSR protocol generates significantly less routing load than AODV and DSDV protocols as Fig. 2 shows. In high network load cases, nodes using considered routing protocols send more packets, thereby sending a larger number of routing packets. On the other hand, in high mobility cases, link failures happen very often. Link failures initiate route

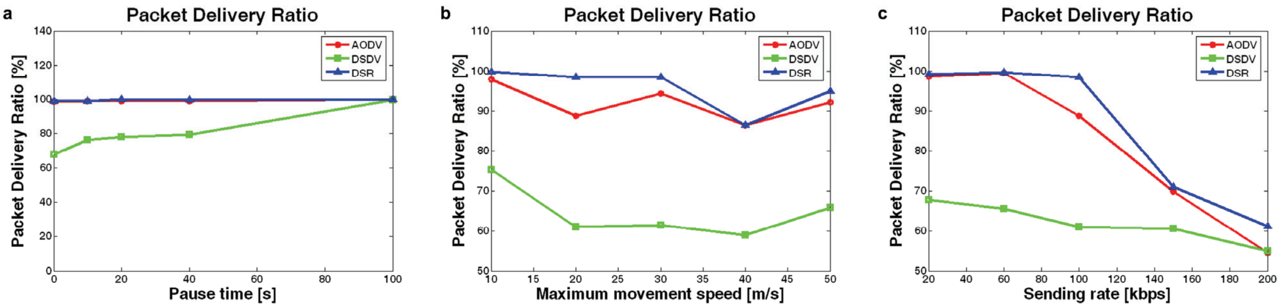


Fig. 1. Packet Delivery Ratio for: a. Pause time; b. Maximum movement speed; c. Sending rate.
Legend: AODV (Ad Hoc On-demand Distance Vector); DSDV (Destination Sequenced Distance Vector); DSR (Dynamic Source Routing).

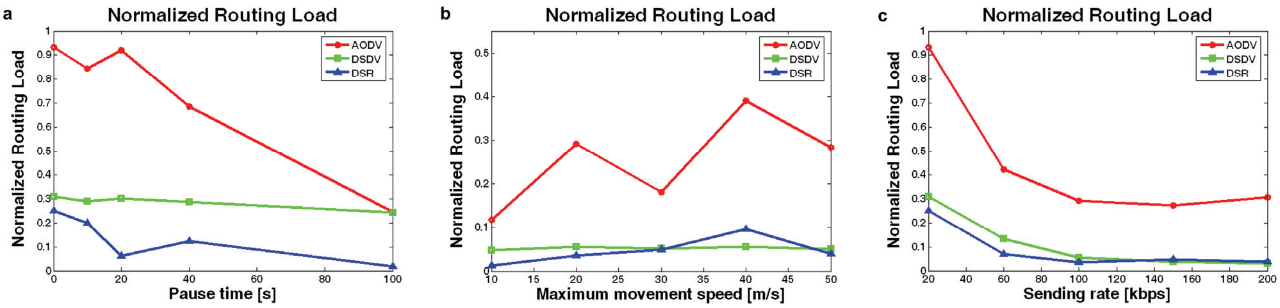


Fig. 2. Normalized Routing Load for: a. Pause time; b. Maximum movement speed; c. Sending rate.
Legend: AODV (Ad Hoc On-demand Distance Vector); DSDV (Destination Sequenced Distance Vector); DSR (Dynamic Source Routing).

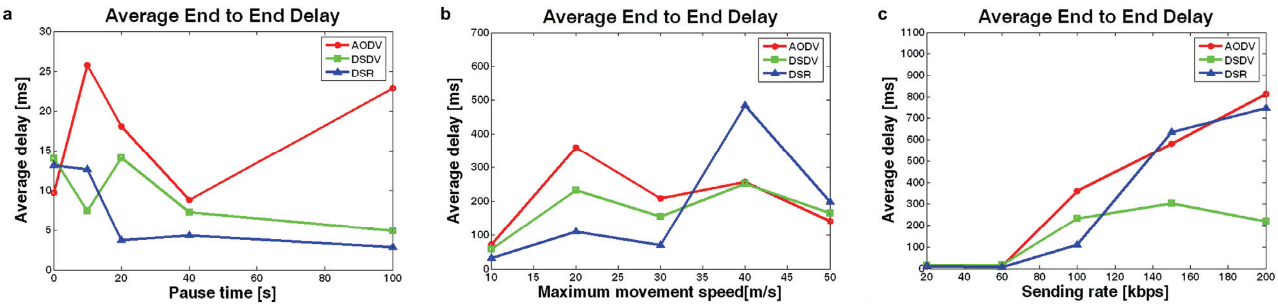


Fig. 3. Average End to End Delay for: a. Pause time; b. Maximum movement speed; c. Sending rate.
Legend: AODV (Ad Hoc On-demand Distance Vector); DSDV (Destination Sequenced Distance Vector); DSR (Dynamic Source Routing).

TABLE 1: NUMBER OF SENT PACKETS, ROUTING PACKETS AND LOST PACKETS FOR CHANGEABLE PAUSE TIME.

| ***Pause time [s]*** | ***Routing protocol*** | ***Sent packets*** | ***Routing packets*** | ***Lost packets*** |
|---|---|---|---|---|
| 0 | **AODV** | 3421 | 3149 | 46 |
| | **DSDV** | 3398 | 715 | 1099 |
| | **DSR** | 3433 | 859 | 29 |
| 10 | **AODV** | 3424 | 2866 | 31 |
| | **DSDV** | 3401 | 757 | 800 |
| | **DSR** | 3411 | 671 | 36 |
| 20 | **AODV** | 3420 | 2566 | 30 |
| | **DSDV** | 3395 | 804 | 741 |
| | **DSR** | 3410 | 216 | 5 |
| 40 | **AODV** | 3422 | 2360 | 30 |
| | **DSDV** | 3433 | 786 | 703 |
| | **DSR** | 3402 | 432 | 8 |
| 100 | **AODV** | 3396 | 837 | 1 |
| | **DSDV** | 3433 | 833 | 12 |
| | **DSR** | 3407 | 61 | 0 |

LEGEND: AODV (AD HOC ON-DEMAND ROUTING PROTOCOL), DSDV (DESTINATION SEQUENCED DISTANCE VECTOR), DSR (DYNAMIC SOURCE ROUTING).

discoveries in AODV, since nodes have only one route per destination in their routing table. Thus, the frequency of route discovery in AODV is directly proportional to the number of link failures. That is the reason why a major contribution to AODV's routing overhead comes from RREQ packets. On the other hand, reaction of DSR to link failures in comparison is mild and causes route discoveries less often. The reason is plenty of cached routes at each node and prolongation of route discovery until all cached routes fail. That is the reason why RREQ packets don't contribute so much to DSR's routing overhead. A large contribution in DSR comes from RREP packets.

Analyzing average end to end delay, we come to the conclusion that DSR routing protocol outperforms AODV and DSDV protocols (Fig. 3), unlike the results obtained in [1], where AODV protocol has the best performances. As said previously, for any network topology change, nodes that use AODV protocol have to send RREQ packets. In other words, a route discovery process has to be activated, because AODV is a routing protocol that has no available route when needed. Because of inefficient route maintenance, average end to end delay is the largest for AODV. On the other hand, DSDV protocol proactively holds routes to all destinations in its table, regardless of topology changes. However, DSR protocol has the best

TABLE 2: NUMBER OF SENT PACKETS, ROUTING PACKETS AND LOST PACKETS FOR CHANGEABLE MAXIMUM MOVEMENT SPEED.

| *Max. movement speed [m/s]* | *Routing protocol* | *Sent packets* | *Routing packets* | *Lost packets* |
|---|---|---|---|---|
| 10 | **AODV** | 21321 | 2461 | 458 |
| | **DSDV** | 21309 | 759 | 5267 |
| | **DSR** | 21309 | 280 | 46 |
| 20 | **AODV** | 21245 | 5508 | 2380 |
| | **DSDV** | 21288 | 731 | 8314 |
| | **DSR** | 21323 | 742 | 310 |
| 30 | **AODV** | 21312 | 3641 | 1184 |
| | **DSDV** | 21321 | 679 | 8234 |
| | **DSR** | 21260 | 1019 | 313 |
| 40 | **AODV** | 21270 | 7182 | 2882 |
| | **DSDV** | 21285 | 702 | 8743 |
| | **DSR** | 21254 | 1763 | 2888 |
| 50 | **AODV** | 21254 | 5542 | 1669 |
| | **DSDV** | 21217 | 700 | 7242 |
| | **DSR** | 21225 | 789 | 1079 |

LEGEND: AODV (AD HOC ON-DEMAND ROUTING PROTOCOL), DSDV (DESTINATION SEQUENCED DISTANCE VECTOR), DSR (DYNAMIC SOURCE ROUTING).

TABLE 3: NUMBER OF SENT PACKETS, ROUTING PACKETS AND LOST PACKETS FOR CHANGEABLE SENDING RATE.

| *Sending Rate [kbps]* | *Routing protocol* | *Sent packets* | *Routing packets* | *Lost packets* |
|---|---|---|---|---|
| 20 | **AODV** | 3421 | 3149 | 46 |
| | **DSDV** | 3398 | 715 | 1099 |
| | **DSR** | 3433 | 859 | 29 |
| 60 | **AODV** | 8485 | 3577 | 45 |
| | **DSDV** | 8488 | 741 | 1927 |
| | **DSR** | 8514 | 599 | 37 |
| 100 | **AODV** | 21245 | 5508 | 2380 |
| | **DSDV** | 21288 | 731 | 8314 |
| | **DSR** | 21323 | 742 | 310 |
| 150 | **AODV** | 34134 | 6490 | 10224 |
| | **DSDV** | 33958 | 806 | 13387 |
| | **DSR** | 33998 | 1136 | 9873 |
| 200 | **AODV** | 42525 | 7118 | 19329 |
| | **DSDV** | 42467 | 709 | 19151 |
| | **DSR** | 42543 | 1036 | 16107 |

LEGEND: AODV (AD HOC ON-DEMAND ROUTING PROTOCOL), DSDV (DESTINATION SEQUENCED DISTANCE VECTOR), DSR (DYNAMIC SOURCE ROUTING).

performances, because it doesn't depend on periodical activities, and it uses source routing and route caching, but also maintains multiple routes per destination. It excels especially in low mobility scenarios, which means that in cases when network topology is stable, routes are not stale and that results in the best performances under consideration.

When a network contains a small number of sources or node's sending rate is low, AODV and DSDV protocols have a similar average end to end delay as DSR, especially when node mobility is low. In that case, the network is less loaded. However, with source number or sending rate increasing, network load is increasing, and average end to end delay for all three protocols, especially AODV and DSDV, becomes larger.

## V. CONCLUSION

Routing protocol DSDV uses proactive "table driven" routing, while AODV and DSR use reactive "on-demand" routing. Protocol DSDV periodically updates its routing tables, even in cases when network topology doesn't change. AODV protocol has inefficient route maintenance, because it has to initiate a route discovery process every time network topology changes. Both protocols, AODV and DSR, use route discovery process, but with different routing mechanisms. In particular, AODV uses routing tables, one route per destination, and destination sequence numbers as a mechanism for determining freshness of routes and route loops prevention. On the other hand, DSR uses source routing and route caching, and doesn't depend on any periodic or time-based operations.

Generally, we can conclude that in low mobility and low load scenarios, all three protocols react in a similar way, while with mobility or load increasing DSR outperforms AODV and DSDV routing protocols. Poor performances of DSR routing protocol, when mobility or load are increased, are the consequence of aggressive use of caching and lack of any mechanism to expire stale routes or determine the freshness of routes when multiple choices are available.

However, there are many other challenges to be faced in routing protocols design. A central challenge is the development of the dynamic routing protocol that can efficiently find routes between two communication nodes. Also, in order to analyze and improve existing or new MANET routing protocols, it is desirable to examine other metrics like power consumption, fault tolerance, number of hops, jitter, etc. in various mobility and traffic models.

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