



PERFORMANCE ANALYSIS OF REACTIVE AND PROACTIVE ROUTING PROTOCOLS IN MANET

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ABSTRACT

In the artificial disaster field, Mobile Ad-hoc Network (MANET) routing is considered a challenging task because of the unpredictable changes in the network topology due to the absence of any centralized control. This routing has led to the development of several different routing protocols for MANET. Thus, it is hard to decide which of these protocols act better than the others. The objectives of this study are of two folds. First, this study provides a performance comparison of MANET routing protocols in terms of delay, packet lost, throughput, jitter, packet delivery ratio (PDR), and normalized routing load (NRL). Second, this study identifies whether MANET routing protocol has an impact on the artificial disaster and suggests which protocols may perform better. For experimental purposes, Network Simulator 2 (NS-2) was used. High density nodes were created in a 1000×1000m location area, and each node was assigned a CBR traffic load. Random Waypoint Mobility mode was used to be implemented with varying pause time and the number of connections. The simulation results show that Destination Sequence Distance Vector (DSDV) protocol provides better throughput and PDR with less jitter, delay and NRL for low or high-traffic load and mobility. However, DSDV still has performance limitations with packet loss parameter. Additionally, the results obtained show that DSDV gives a great improvement for using network resources, especially when the number of connections is high with low mobility. Hence, DSDV is considered as a better routing protocol that is used in the artificial disaster and emergency recovery application.

Keywords: MANET, routing protocol, artificial disaster, network simulation 2.

INTRODUCTION

Mobile Ad-hoc Network (MANET) is a group of devices or nodes which communicate with each other with no need to the availability of fixed pre-installed physical infrastructure or a service providing organization. The nodes in MANET are responsible for keeping the end-to-end communication link alive by dynamically discovering the nearby nodes. Additionally, it is self-configured to achieve this target by depending on wireless links. The result of this scenario is an arbitrary topology which may change rapidly, and unpredictably the nodes are free to move randomly inside and outside the network (Habbal & Hassan, 2012; Aarti & Tyagi, 2013).



Figure-1. Mobile Ad-hoc networking.

MANET's main benefit and advantage allow devices and people to seamlessly internetwork in places without pre-existing communication infrastructure. Therefore, this idea is deployed in various applications, such as disaster recovery, games, and groupware. Also, many applications interested in providing video materials like video on demand and real-time video streaming, which also depend on MANET (Yoon, 2014).

A disaster area can be defined as the malfunction of a community or a system which results in a heavy effect on people. Two types of catastrophic disasters are existed: natural disasters like a volcano, flood, earthquake, and artificial disasters, such as terrorism and war (Bhimarao & Uma, 2014). This study focuses mainly on the sudden artificial disasters like a terrorist attack, where different response actions in reacting to such an event and varied information will be stored according to the period of time elapsed since the beginning of the disaster.

In such catastrophic situations, communication will be an important key factor for an effective management and successful disaster recovery. Hence, all resources and recovery personnel should be able to exchange and share information with each other to successfully achieve their assigned tasks (Mahapatra et al., 2010). MANET can be greatly used to establish a disaster-recovery network for collecting essential and significant information about the affected citizens and properties (Bhimarao & Uma, 2014). Due to the critical nature of such networks, it is important to choose the right routing protocol that can create the required rigid network, on which authorities and organizations can depend to protect people (Habbal & Hassan, 2011).



Generally, routing can be considered as a main networking issue for sending data from one node to another. In MANET and other networks, which are built to provide the needed communications, are limited or no networking infrastructures are available by depending on mobile devices to create a dynamic and temporary network. In this case, routing has additional problems and issues. MANET has received much attention because many civilians use them and due to potential military applications (Aarti & Tyagi, 2013). Currently, MANET has classified different routing protocols categories, such as reactive, proactive, and hybrid. Each category has its own list of protocols developed to meet specific applications, mainly reactive, proactive and hybrid protocols which derive their significance from depending on algorithms and their application support.

The main target of this paper is studying and analyzing four traditional routing protocols of MANET with low or high traffic and mobility, respectively in order to confirm, which is the most suitable protocol that saves the network resource consumption (e.g. Bandwidth) in the artificial disaster field.

In particular, routing protocol, challenges, and related works in MANET are presented in the next following sections. In the next section, outlines the simulation setup and performance metrics. The further section presents the results and discussions. Finally, the conclusion is presented in the next section.

ROUTING PROTOCOLS IN MANET

Challenges in routing protocols

Jain, Fatima, Gupta, and Bandhopadhyay (2009) highlighted the challenges which usually arise in the development of MANET routing protocols. Among the most important challenges are scalability, quality of service, energy consumption, and security.

Scalability can be defined as the network's ability to give an acceptable service quality in the presence of the large number of nodes. It can be considered an important issue accompanying ad-hoc networks due to the dynamic nature of these networks when nodes are free to join or leave. Regarding the ad-hoc routing protocols, they can also be considered as one of the factors that limits the scalability of the ad-hoc networks.

Quality of Service (QoS) can be defined as a term in which a network confirms its capability to provide a specific performance in terms of the quantities of delay, bandwidth, packet loss, and jitter. QoS of a wireless network is not guaranteed and still considered as an open issue due to the difference in the link's quality and stability used by the routers which are usually asymmetrical links. Apparently, QoS routing policies, algorithms and protocols with preemptive priorities still need to be researched in the future. Because of the nature of the ad-hoc networks, it is not possible to guarantee the QoS for a long period due to the variations in the wireless link.

Energy consumption is another factor that needs to be considered in ad-hoc networks. Mobile nodes have

limited power resource and each node act as end host, as well as intermediate node. Because each node in the network needs to route on any traffic to the other nodes. The energy-efficiency issue become an important factor that has a negative impact on the network performance. In general, protocols are designed to work on a specific layer (i.e., Layer 3), but it still connects with the physical and the MAC layers from a power perspective that creates a cross layer issue and needs to have more attention to improve the performance.

Security is also a critical issue of the ad-hoc networks because networks are wireless and operate in open shared radio medium. Therefore, in unsecured conditions, they will be good targets for malicious attacks which could results in actions, such as the Denial of Service (DoS). However, many peculiar features of the ad-hoc network increase the security risks, and the most serious security problem is the possibility that one of the nodes could be captured and the node is considered as a part of the entire network. The problem already has access to the network traffic information which will help the attacker to use these data to send false routing information that may cause the entire network to be completely shut down very quickly.

In addition to the abovementioned factors, ad-hoc network also have many other challenging factors, such as node cooperation, aggregation, multicast, as well as routing protocol limitations from a theoretical perspective.

Classification of routing protocols in MANET

MANET routing protocols have to adapt fast to the frequent changes in topology that is also unpredictable. It has to be effective in properly utilizing the network resources. The protocols are classified into three: proactive (table-driven), reactive (on-demand) and hybrid. Figure-2 shows the classification of MANET routing protocols. Every group has various routing strategies that employ a hierarchical or flat structure of the routing.

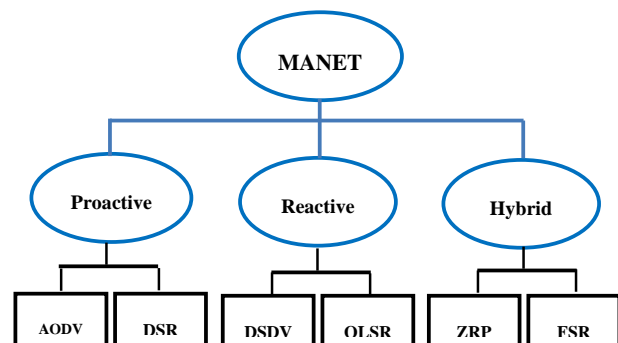


Figure-2. Routing protocols of MANET.

Reactive routing protocols

Reactive routing protocols (Garg, Aswal & Dobhal, 2012) provide a route for on demand flow of information. Hence, routes are decided and maintained for nodes that need to send data to a specific destination.



However, the node could remain idle or active for participating in the process of forwarding for serving other source nodes. Reactive protocols consume less resources while the nodes remain idle for discovering a route (as they do not have any information regarding topology).

The following sections outline the two different reactive routing protocols which are Ad-hoc On-demand Distance Vector (Perkins & Royer, 1999) and Dynamic Source Routing (Johnson, Hu & Maltz, 2007). A comparison between their performances is done as well. Table-1 depicts the summary of the theoretical performance, as well as the characteristics of each protocol.

Table-1. Characteristics of AODV and DSR routing protocols.

	AODV	DSR
Protocol Type	On-Demand /Reactive	On-Demand /Reactive
Routing Structure	Flat	Flat
Hello Message	Yes	No
Multiple Route	No	Yes
Route Maintained in	Route table	Route cache
Communication Complexity	For Route Discovery is $O(2^{\text{Number of nodes in the network}})$ for Route Maintenance is $O(2^{\text{Number of nodes in the network}})$	For Route Discovery is $O(2^{\text{Number of nodes in the network}})$ for Route Maintenance is $O(2^{\text{Number of nodes in the network}})$
Time Complexity	For Route Discovery is $O(2^{\text{Diameter of the network}})$ For Route Maintenance is $O(2^{\text{Diameter of the network}})$	For Route Discovery is $O(2^{\text{Diameter of the network}})$ For Route Maintenance is $O(2^{\text{Diameter of the network}})$
Characteristic	Erase route then source notification or local route repair	Erase route the source
Advantage	Adaptable to highly dynamic topology, Less overhead when successful	Multiple routes, Promiscuous overhearing,
Disadvantage	Scalability problems, large delays if route not found immediately, Hello message	Scalability problems due to source routing and flooding, large delay

- Ad-hoc On-demand distance vector (AODV)

AODV is a reactive routing protocol that establishes a route when a node needs to send data packets. AODV is capable of multicast, as well as unicast routing (Palaniammal & Lalli, 2014). It does not maintain routes from all nodes to all other nodes in the network. It performs route discovery by control message Route Request (RREQ) and Route Reply (RREP).

Routes in AODV are set up by flooding the network with packets of RREQ, which however does not collect the traversed hops' list. Instead, as a RREQ traverses through the network, the traverses mobile nodes keep the information regarding the source, destination and the mobile node from which they accepted the RREQ. Later information is used for setting up the reverse path back to the source. When a mobile node is reached by RREQ, it knows a destination route or the destination itself; the mobile node gives a response to the source with a data packet (RREP), which is routed via the reverse path and set up by RREQ. This sets the route forward from source to destination.

For avoiding overburdening the mobiles with route information, which is not used thereafter, the nodes discard the information after a particular timeout. When one of the destinations or intermediate moves, a route error (RERR) is sent to the affected source nodes. When the error is received by the source node, route discovery can be reinitiated by it if the route is still required. The information regarding neighborhood is gained by periodic broadcast of Hello Packets (Perkins & Royer, 1999). For route maintenance, two methods can be used. One is ACK messages in the layer of MAC, and the second is HELLO messages in the layer of network (Aggarwal, Gandhi & Chaubey, 2011).

- Dynamic source routing (DSR)

DSR is quite simple, as well as efficient reactive routing protocol that is designed to be used in MANET. It is used for delivering to the target node by using route cache that can be updated periodically for enabling new route detect node to get updated. When a packet reaches the target node, a sender got to input information inside the packet header for following the direction with the purpose of reaching the target node and for identifying hops addresses by the next node, and even to forward to the needed destination.

DSR protocol uses two algorithms that work combined for the discovery and maintenance of source route. First, Route Discovery (RD) is the mechanism through which a source node that tries to send a packet to a destination node gathers a source route to the destination. This is utilized just as the source node tries to send a packet to a different node and does not have the knowledge of the route. Second, Route Maintenance (RM) is the mechanism through which the source node is capable of detecting the failure of the source route to the destination because the network topology changes (Garg et al., 2012).



While RM shows that a source route is not existing, source node can try to utilize other routes that source node distinguishes to the destination or can invoke the RD mechanism again for finding a new route. RD and RM of DSR are both used on demand. When a source node needs to send a packet of data, its route cache is the first thing that source node checks. If the needed route is available in the cache, the routing information is included in the data packet header prior to sending it. Alternatively, the source node initiates a mechanism for route discovery by flooding route request packets (Almarimi, Abdelaziz & Almerhag, 2014).

Proactive routing protocols

In proactive routing protocols (Garg et al., 2012), every node maintains information regarding routing to other nodes in the network. Routing information is kept on various tables. These tables get updated periodically or when the topology changes. Difference among them exists in the way in which the routing information gets updated, and detects the kind of information maintained in the routing tables. Additionally, every routing protocol may maintain various numbers of tables.

The following sections outline the two different proactive routing protocols which are Destination Sequence Distance Vector (Perkins & Bhagwat, 1994) and Optimized Link State Routing (Sidhu et al., 1993). A performance comparison is also done, which is shown in Table-2.

Table-2. Characteristics of DSDV and OLSR routing protocols.

	DSDV	OLSR
Protocol Type	Table Driven/Proactive	Table Driven/Proactive
Routing Structure	Flat	Flat
Hello Message	Yes	Yes
Number of Table	2	3
Frequency of Update	Periodic and as required	Periodic
Memory Overhead	$O(\text{Number of nodes})$	$O(\text{Number of nodes}^2)$
Control Overhead	$O(\text{Number of nodes})$	$O(\text{Number of nodes}^2)$
Time Complexity	$O(\text{Diameter of the network} * \text{Average update interval})$	$O(\text{Diameter of the network} * \text{Average update interval})$
Characteristic	Loop free, Simple, and low latency	Low control overhead and Hierarchical structure
Advantage	Loop free, No latency caused by route discovery	Reduced control overhead and connection,
Disadvantage	No sleeping nodes, High traffic overhead	2-hop neighbor knowledge required

Destination sequence distance vector (DSDV)

DSDV is a proactive unicast MANET routing protocol (Garg et al., 2012). DSDV is based on conventional algorithm of 'Bellman-Ford' (BF). Table driven DSDV protocol is an advanced version of 'Distributed Bellman-Ford' (DBF) algorithm that has been successfully utilized in various dynamic packets switched networks (Manickam, Guru Baskar, Girija & Manimegalai, 2011). The BF method offers a way for calculating the minimal paths from source node to a destination node if the metrics to every link is known. DSDV makes use of this idea and overcomes the tendency of DBF for creating routing loops by including a parameter known as the destination-sequence number.

In DSDV, each node is needed to transmit a sequence number that is periodically increased by two and transmitted along with other messages of routing updates to every nearby node. On receiving the updated messages, the nearby nodes use the algorithm below for deciding whether to ignore this update or to make the essential changes to the routing table:

First step: Reception of updated message,

Second step: Updating the routing table if any of the below conditions satisfies:

- i) $S_n > S_p$
 - ii) $S_n = S_p$
- Hop count is less. Else, ignore the update message.

S_n and S_p denote sequence numbers of new messages and the existing message. When a path gets invalid because of node movements, the source is to be informed by the node that detected the broken link. This simply erases the previous path and searches for a new path for data transmission. The benefit is latency because route discovery is low, and loop-free path is guaranteed. One disadvantage of the protocol is the large volume of control messages (Manickam et al., 2011).

Optimized link state routing (OLSR)

OLSR is considered as one of the proactive routing protocols. Each node has a route table containing information regarding routing of all nodes in the network. As such, the routes are ready to use right away all the time as required. OLSR is one of the optimized versions of link-state protocol. Therefore, the topological alteration results in the inundation of information regarding the topology to every attainable node in the network.

OLSR protocol uses Multi-Point Relays (MPR) for reducing potential network overheads. The whole idea of MPR is to decrease inundation of broadcasts via the reduction of the same broadcast in certain parts of the network and for providing the minimal path. OLSR utilizes such control messages as Topology Control (TC) and Hello. TC messages are utilized to broadcast information regarding own promoted neighbors. This contain at least the MPR selector list. On the other hand, Hello messages are utilized for coming upon the information regarding the connection status and the neighbor nodes. Reactivity may be optimized by OLSR for



topological alterations by Maximum Time Interval (MTI) reduction for periodical control message sending.

OLSR also has Multiple Interface Design (MID) for allowing the nodes to have multiple OLSR interface addresses and for providing external routing information, enabling the routing possibility for external addresses. Based on this information, the ad-hoc network nodes act as gateways for other possible networks (Kaur & Kumar, 2012).

Related works

Aggarwal et al. (2011) conducted a performance analysis study of the AODV, DSR and DSDV in MANET in the case of high mobility and under low, medium and high density cases with nodes ranging from 25 of low density to 200 of high density. Results of the simulation verify that AODV yields better performance compared with the other two.

Mahdipour, Aminian, Torabi, and Zare (2009) evaluated the performance of DSDV and AODV routing protocols in MANETs under the CBR traffic with NS-2. Comprehensive simulation results and analysis demonstrate that the CBR of AODV has a better performance than that of DSDV, and it has a more stable performance at lower mobility speeds in comparison with higher mobility speeds.

Talooki & Ziarati (2006) presented an in-depth simulation of DSDV, AODV, DSR and TORA. Their simulation contained forty wireless nodes, which formed an ad-hoc network. The conclusion is that TORA and DSDV have good performance in the network with lower mobility, whereas DSR and AODV have quite good performance in all the mobility conditions.

Comparison of the performance of DSR and AODV in a situation with constraints is done (Misra & Mandal, 2005). Researchers cite evidence that DSR outperforms AODV in an usual situation. At the same time, in constrained situation, AODV has outperformed DSR. In this case, the degradation is severe as much as 30% compared to AODV, whereas DSR degradation is 10%, marginally. Although both use on demand route discovery, the routing mechanism is different.

SIMULATION SETUP AND PERFORMANCE METRICS

Network Simulator 2 (Fall & Varadhan, 2007) was used for this simulation. This is quite common in the ad-hoc network community. Continuous Bit Rate (CBR) is the traffic source used, and the size of the packet data was 512B. The rate at which data were sent is 4 packet data per second. The source destination pairs were spread randomly in the network in a 1000m x 1000m rectangular file. The simulation time was 200 seconds and the maximum speed of a node was 10 m/s. Various network scenarios with different pause times of 10 to 50sec were applied. From 20 to 100 maximum connections with 200 nodes (high density) were generated. Table-3 shows the summary of the model parameters that was used for the simulation experiment.

Table-3. Simulation parameters.

Parameters	Value
Network Simulator	NS-2.34
Channel Type	Channel/Wireless Channel
Propagation Model	Propagation/Two Ray Ground
Net Interface Type	Phy /Wireless Phy
MAC Type	Mac/802.11
Interface Queue Type	Queue/DropTail/PriQueue/C MUP
Link Layer Type	LL
Antenna Model	Antenna/OmmniAntenna
Max Packet in IFQ	50
Transport Protocol	CBR
Simulation Time	200
Packet Size	512 bytes
Simulation Area	1000m * 1000m
Mobility Model	Random Way Point
Routing Protocol	AODV, DSR, DSDV, and OLSR
Max. Number of Connection	20, 40, 60, 80, and 100
Pause Time	10,20,30,40, and 50
Number of Nodes	200

In this study, we describe various quantitative metrics which can be used for evaluating the performance of a routing protocol for wireless mobile ad-hoc networks.

A. End-to-end delay (E2E)

It is defined as the average delay in time for the packets of data from source node to reach the destination node (Gupta et al., 2010). The performance is good when the packet E2E delay is low.

B. Packet Lost (PL)

It is defined as the ratio of the number of packet data lost while getting transmitted from the source (Bhatia & Kumar, 2014). The performance is good when the PL is low.

C. Throughput

It is defined as the total data amount which gets to the receiver from the sender, and the time it takes for the receiver to receive the final data packet (Kaur & Kumar, 2012; Bhatia & Kumar, 2014). The performance is good when the throughput is high.



D. Delay-variation (Jitter)

It is defined as the variation in the delay of the data packets received (Kaur & Kumar, 2012). The performance is good when the jitter is low.

E. Packet delivery ratio (PDR)

It is defined as the ratio between the number of packets created through the application layer sources, and the number of packets received by the sinks at the end destination (Bindra et al., 2010; Kaur & Kumar, 2012). The performance is good when the PDR is high.

F. Normalized routing load (NRL)

It is defined as the number of routing packets transmitted per data packet delivered at the destination (Bindra et al., 2010; Kaur & Kumar, 2012). The performance is good when the NRL is low.

RESULTS AND DISCUSSIONS

In comparing the performance of all four protocols, two scenarios have been considered:

First scenario: Effect of traffic load

To analyze the traffic load effect, the maximum number of connections was varied as 20, 40, 60, 80, and 100 connections. The network was simulated for a pause time 20 sec. Figures-3-8 show the traffic load effect for AODV, DSR, DSDV, and OLSR protocols regarding the various performance metrics.

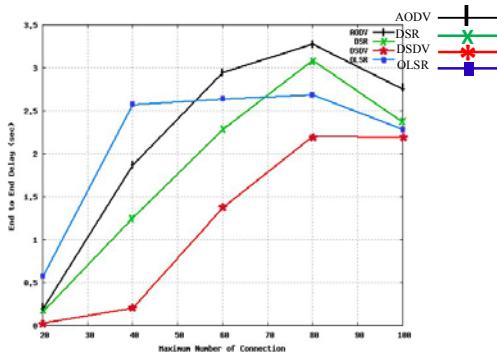


Figure-3. E2E delay vs traffic load.

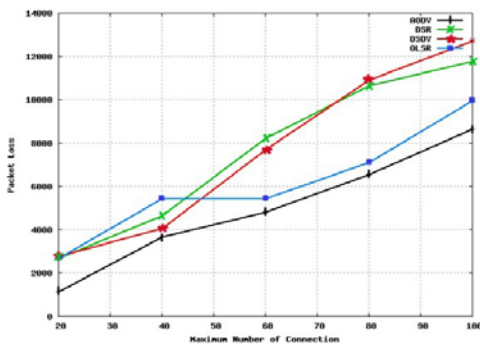


Figure-4. PL vs traffic load.

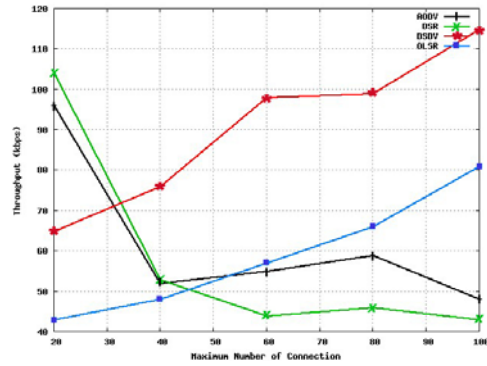


Figure-5. Throughput vs traffic load.

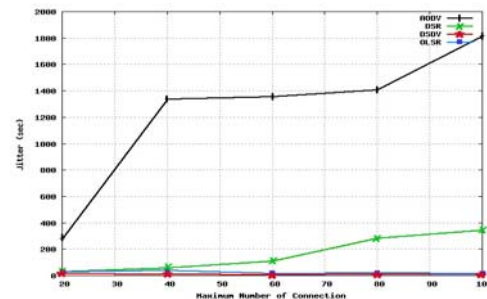


Figure-6. Jitter vs traffic load.

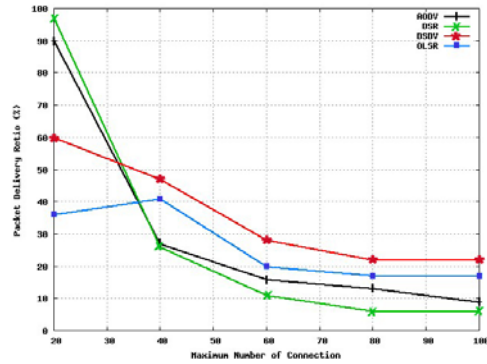


Figure-7. PDR vs traffic load.

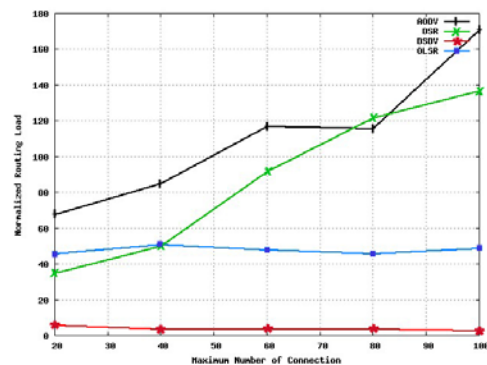


Figure-8. NRL vs traffic load.

A. End-to-end delay result

End-to-End delay is small for DSDV as compared with OLSR, DSR and AODV as illustrated in



Figure-3. This is because DSDV is a proactive protocol, where all routing information is already stored in the table. DSDV takes less time when compared with others. When traffic load differences occur, no effect exists on the DSDV protocol performance.

OLSR has a better performance when compared to DSR and AODV, but it is not better than DSDV. Because OLSR maintains a routing table for every possible route and two hop neighbor knowledge needed, then the end-to-end delay increases as the number of connections increases. This, this study indicates that DSDV reliability is better than OLSR, AODV, and DSR.

B. Packet loss result

As illustrated in Figure-4, performance of DSDV and DSR are worse. As traffic load increases, performance decreases because of the increases of the load compared to the limited bandwidth. Each packet in OLSR and DSDV are dropped if the MAC layer cannot find an alternative route to deliver. DSDV and DSR drop more packets than OLSR and AODV do.

C. Throughput result

As shown in Figure-5, it is understood that under low traffic AODV has a maximum throughput, whereas the throughput of DSDV is maximum under high traffic. As the density of the network increases, the performance of DSDV becomes better than AODV, OLSR and DSR, and this is mainly attributed to the avoidance of a loop free by DSDV and latency resulting from the discovery of a route.

D. Jitter result

Jitter given by DSDV, as well as OLSR is the least when the traffic is low and high, which is illustrated in Figure-6. It is noted here that OLSR and DSDV with random way point mobility of nodes deliver data packets efficiently in both models of traffic because PDR relies on the neighborhood information periodic broadcast.

E. Packet delivery ratio result

When a traffic load is less, AODV and DSR's performances are better in terms of packet delivery ratio, which is shown in Figure-7. As the number of nodes increases when the network traffic increases, then PDR performance diminishes. When comparing DSDV with DSR, AODV and OLSR, DSDV's performances are better when there are more numbers of connections in the network. DSR and AODV's performances are good, but they decrease as the number of connections in the network increases.

F. Normalized routing load result

As Figure-8 demonstrates, AODV has a higher normalized routing load when compared with DSDV, OLSR and DSR due to its request broadcasting. As the connections increase, request propagation also increases. For confirming the connectivity of every node pair, AODV uses HELLO Message. This results in bigger

overhead than that of DSDV. In moderate traffic, DSR's performance is better than AODV because DSR uses source routing, as well as the packet header length is not large at low to moderate traffic. At high-traffic, OLSR performs better than DSR as flooding is minimized by OLSR using MPR.

Second scenario: Effect of mobility

To study the mobility effect on the network, pause time varied from 10, 20, 30, 40 and 50 sec. and the maximum number of connections was 50. Figures-9-14 show the mobility effect for AODV, DSR, DSDV, and OLSR protocols regarding the various performance metrics.

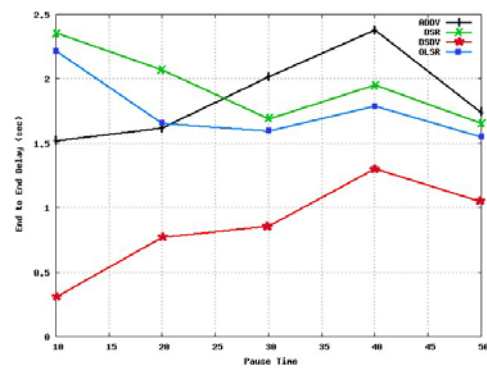


Figure-9. E2E delay vs mobility.

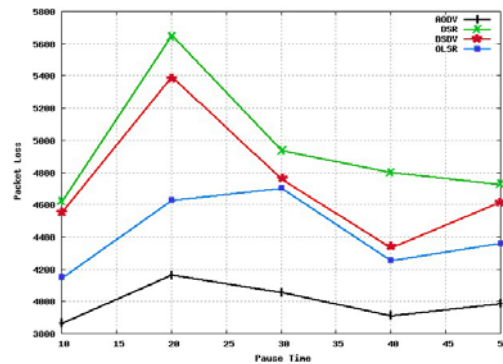


Figure-10. PL vs mobility.

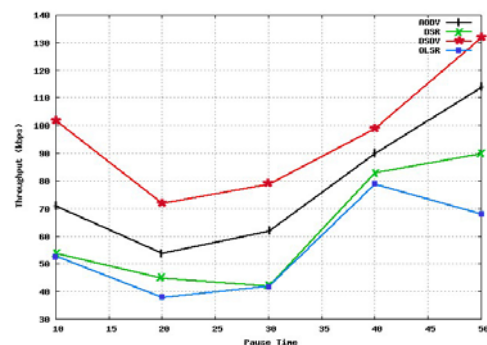


Figure-11. Throughput vs mobility.

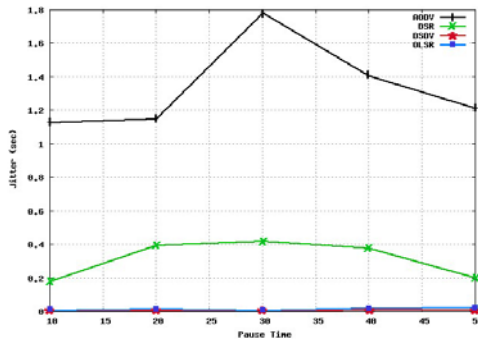


Figure-12. Jitter vs mobility.

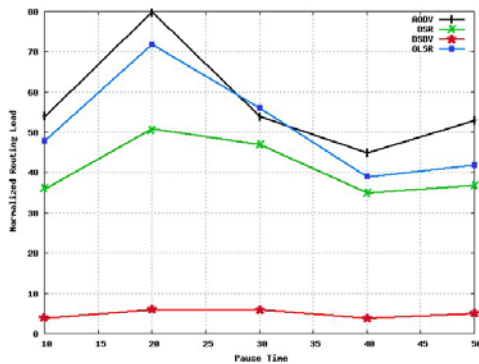


Figure-13. PDR vs mobility.

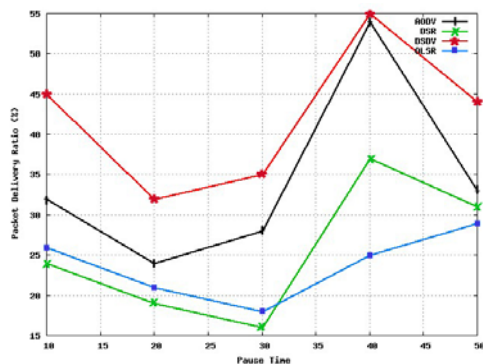


Figure-14. NRL Vs Mobility.

A. End to end delay result

As shown in Figure-9, the delay is better in DSDV when compared to OLSR, DSR and AODV because of DSDV holding optimal paths to the destinations in their routing table, where it can send packets of data to the destination immediately. High end to end delay is justified because of DSR and AODV delivering more packets to the destination. These two protocols guarantee the delivery by compromising the cost incurred in delaying the delivery. Furthermore, DSR and AODV need more routing packets for maintaining the transmission of data packets because of congestion.

B. Packet loss result

Figure-10 shows that DSDV and OLSR incur the highest packet loss, as both are proactive, and they have all information related with each node. The performance of DSDV decreases as it drops more numbers of packets at higher mobility. This is attributed to the single route for every destination, as maintained by DSDV. Because there are no alternate routes, the packets undeliverable by MAC layer are dropped. In the case of AODV and DSR, packets are allowed to stay in the send buffer before the route is discovered. On discovery, data packets are sent on the route to the destination.

C. Throughput result

In Figure-11, it is shown that as network mobility rate increases, throughput decreases because of the high packet drop in such high traffic. DSDV at lower and higher pause time performs well, but when the pause time increases, its performance increases; the performance is best at high pause times. AODV and DSR, the two On-demand protocols, drop a significant number of packets during route discovery because route acquisition time is proportional to the distance from the source to the destination. DSR has higher drop rate than AODV. Hence, when a route expires, AODV drops some packet, thereby making use of route expiry for new route discovery. OLSR protocol does not guarantee finding the best route of bandwidth, then it has to be concluded that OLSR is not stable with regards to the throughput.

D. Jitter result

Figure-12 indicates that AODV jitter is high at the beginning, as the source node needs to put the whole information of route in the data packet each time before sending to the destination. Hence, the delay in node processing is increased, which results in an increased jitter value. This establishes the fact that jitter is less in DSDV and OLSR as compare with the other two protocols, AODV and DSR.

E. Packet delivery ratio result

DSDV performance is better with regards to the packet delivery ratio, as shown in Figure-13, irrespective of the changes in the mobility when nodes in DSDV always maintain the optimal path to destinations in their routing table, and the table is updated periodically. At moderate traffic, the packet delivery ratio in DSR is lower compared to AODV because of the number of hops increasing with an increase in traffic. When mobility increases, DSR has a lower performance because of its stale route cache issue and source path routing.

F. Normalized routing load result

NRL result is illustrated in Figure-14. At higher and lower mobility, when the routing load is increased, DSDV has the best performance. Routing overhead of AODV is more than that of DSDV, DSR and OLSR, as it generates more control packets for finding new routes to



the destination. When nodes are at higher mobility, this increases NRL. Thus, it can be concluded that DSDV is the best protocol, which suits dynamic networks.

Table-4. Results analysis.

Protocol Name	E2E Delay		PL		Throughput		Jitter		PDR		NRL	
	Traffic Load	Mobility	Traffic Load	Mobility	Traffic Load	Mobility	Traffic Load	Mobility	Traffic Load	Mobility	Traffic Load	Mobility
AODV	Highest in high traffic	Better than OLSR and DSR when the mobility increase	Best	Best performance	Higher throughput than DSDV, and OLSR but less than DSR under low traffic load	Consistent and better than DSR and OLSR in low and high mobility	Worse and degrade when the traffic load increase in the network	Worse	Performance well when the traffic load is less but it drastically when the traffic load is increased	Better than OLSR and DSR under low and high mobility	Consistent and worse NRL when increasing traffic load	Worse performance
DSR	Better than AODV and OLSR in low traffic, but better than AODV in high traffic	Higher E2E delay than AODV, OLSR, and DSDV under high mobility	Degrade when traffic load increase in the network	Worse performance	Best under low traffic load	Under low mobility better than OLSR	Better than AODV but less than OLSR and DSDV	Better than AODV but less than OLSR and DSDV	Performance well when the traffic load is less but it drastically when the traffic load is increased	Least remains constant as the mobility higher in the network	Consistent and worse NRL when increasing traffic load	Better than AODV and OLSR when mobility decreased or increased
DSDV	Best performance	Best	Worst	Better than DSR	Best performance	Best	Consistent and least Jitter when increasing traffic load	Consistent and least Jitter when increasing mobility	Best	Best under low and high mobility	Consistent and least NRL when increasing traffic load	Consistent and least NRL
OLSR	Better than AODV and DSR in high traffic	Under low mobility OLSR had lower E2E delay than AODV, and DSR	Better than DSDV and DSR	Better than DSDV and DSR	Under high traffic load better than AODV and DSR,	Least	Consistent and least Jitter when increasing traffic load	Instable but better than DSR and AODV	Better than DSR and AODV	Least remains constant as the mobility lower in the network	Remains constant as the traffic load increase in the network	Instable performance but better than AODV

The eligibility of a routing protocol can be analyzed by metrics which measure its performance and suitability. This metric should be independent of any given routing protocol.

As Table-4 demonstrates, DSDV protocol provides higher throughput and packet delivery ratio with less jitter, end-to-end delay and normalized routing load for low or high-traffic load and mobility because DSDV always gets the best path to destination, based on its routing table, and this table is being updated periodically. However, DSDV still has performance limitations with packet loss parameter in which AODV shows higher performance than DSDV, and the other two protocols like DSR and OLSR. In Table-5, we present a comparison of the current work with other related works.

Table-5. Comparison of this work with existed works.

Study Name	Performance Comparison of AODV/DSR On-demand Routing Protocols for Ad Hoc Networks in Constrained Situation	Performance Comparison of Routing Protocols For Mobile Ad Hoc Networks	CBR Performance Evaluation over AODV and DSDV in RW Mobility Model	Performance Analysis of AODV, DSDV and DSR in MANETs	Performance Analysis of Reactive and Proactive Routing Protocols in MANET
Year	2005	2006	2009	2011	2014
Protocols	AODV and DSR	DSDV, AODV, DSR and TORA	AODV and DSDV	AODV, DSDV and DSR	AODV, DSR, DSDV and OLSR



Number of Nodes	50	40	50	25-200	200
Simulation Area	1000 * 1000m	700m* 700m	500 * 500m	1000* 1000m	1000 * 1000m
Parameters		Paused time	Varying number of connections and speed	Varying number of connection and nodes	varying pause time and number of connections
Performance Metrics	Packet delivery ratio	Weighted path optimality, End-to-End delay, deviation of network's load and jitter	End-to-End delay and Dropped packet	End-to-End delay, normalized routing load, packet delivery fraction and throughput	End-to-End delay, packet lost, throughput, jitter, packet delivery ratio and normalized routing load
Results	DSR is outperformed by AODV in usual situation. At the same time, in constrained situation AODV is outperformed on DSR. In this case, the degradation is severe as 30% in AODV, whereas DSR degradation is 10%.	TORA and DSDV had good performance in the network with lower mobility. On the other hand, DSR and AODV had quite good performance in all the mobility conditions.	CBR has best performance over AODV than DSDV, and it has more stable performance in lower mobility speeds in comparison to higher mobility speeds	AODV yields better performance compared with DSDV and DSR	DSDV gives great improvement for using network resources, especially when the maximum number of connection is high with low mobility

CONCLUSIONS

A quantitative comparison of the ad-hoc routing protocols is difficult because the simulations are not dependent on one another and use various metrics and simulators for each of them. This study achieves a realistic comparison of the reactive and proactive protocols, which are DSDV, OLSR, DSR and AODV used in MANET at high and low traffic and mobility under 200 nodes (high density).

The simulation results match the expectations which were based on the theoretical analysis. Additionally, it is found that the performance significantly varies with a different maximum number of connection and mobility. Hence, the results obtained from a specific scenario can be individually treated and cannot be applied to any other scenarios. From Table 4, it is obviously noted that DSDV performs better than OLSR, AODV and DSR, because this

protocol always gets the ideal path to the destination, and the routing table is updated periodically.

In any artificial disaster, especially in terrorist attacks, there will be a low or a high number of connections and mobility of network nodes or users at the event time. Thus, this leads to overload on the available network resources. Based on the obtained results, DSDV gives a great improvement for using network resources, especially when the maximum number of connections is high with low mobility, thus making it a better routing protocol that can be used in the disasters and emergency recovery applications.

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