Mobile Adhoc Network Protocols Simulation: Distance Vector vs Source Routing Comparison

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Abstract—**Mobile ad hoc network (MANET) is an autonomous system of mobile nodes connected by wireless links. Each node operates not only as an end system, but also as a router to forward packets. The infrastructureless of this networks and frequent topology changes increase the need to routing strategies to be implemented in order to provide efficient end-to-end communication. Several routing protocols are proposed, they are mainly classified as proactive, reactive and hybrid routing protocols. In this paper, we simulate a proactive routing protocol (DSDV) and two reactive routing protocols (AODV and DSR) using the famous simulator NS2. We conducted some tests for each routing protocol focusing on the throughput. This metric was tested versus the node's velocity, the network load and the traffic type.**

Keyword: Mobile ad hoc, routing, NS-2, AODV, DSR, DSDV

I. Introduction

Increased use of laptop computers and the increase in people's mobility have fuelled the demand for wireless networks [1]. The term wireless networking refers to a technology that enables two or more computers to communicate using standard network protocols through radio or infrared signals. There are two different approaches for enabling wireless communication between two hosts. The first approach is to form an infrastructure network where each node communicates each other by the aid of an existing infrastructure (base station or access point) carry data as well as voice. One of the major problems posed in this approach is the handoff problem, which tries to handle the situation when the connection should be smoothly handed over from one base station to another base station without noticeable delay and packet loss. The second approach of wireless networking is to form a mobile ad hoc network where each node communicate each other directly without the need of any preexisting infrastructure or base stations, In this approach nodes required to act as routers as well as end systems. One interesting research area in MANET is routing. Routing in the MANETs is a challenging task and has received a tremendous amount of attention from researches [2]. This has led to development of many different routing protocols for MANETs, and each author of each proposed protocol argues that the strategy proposed provides an improvement over a number of different strategies considered in the literature for a given network scenario. Therefore, it is quite difficult to determine which protocols may perform best under a number of different network scenarios. The routing protocol must be able to keep up with the high degree of node mobility that often changes the network topology drastically and unpredictably. The objective of this paper is to understand and evaluate the most widely used protocols which are AODV, DSDV and DSR based on the simulation tool with NS-2 using different scenarios and performance metrics such as: packet delivery fraction, throughput, average end to end delay, packet loss and normalized overhead.

The rest of the paper is organized as follows. Section 2 presents an introduction of mobile ad hoc networks. Section 3 shows the classification of routing protocols for ad hoc networks and describe some of these protocols. The simulation environment, the results and the results analysis are presented in Section 4. Finally, the conclusion of this work is presented in Section 5.

II. Mobile Ad hoc Networks

Wireless networks are collection of mobile devices without using cables; these devices communicate each other through radio frequencies in air.

- Wireless networks have many advantages:
- Mobile users are provided with access to real-time information even when they are away from their home or office.
- Setting up a wireless system is easy and fast and it eliminates the need for pulling out the cables through walls and ceilings.
- Network can be extended to places which cannot be wired.
- Wireless networks offer more flexibility and adapt easily to changes in the configuration of the network [1].

Yet, on the other hand, its main disadvantages are:

- Interference due to weather, other radio frequency devices, or obstructions like walls.
- The total Throughput is affected when multiple connections exists [1].

Wireless networks can be either infrastructure where wireless hosts can be connected with the wireless system by the help of specific devices called access points (base stations) when they roam from one place to the other.

In infrastructureless (Ad Hoc), each mobile node communicates with each other without need of any base station.

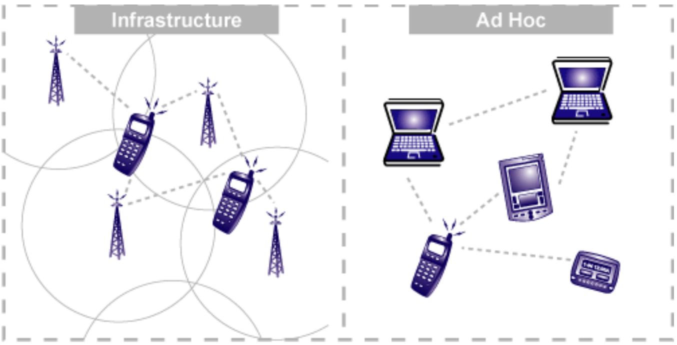

Figure 1. Ad hoc network vs. infrastructure network

A) MANETs Architecture

The architecture of an Ad Hoc network can be divided into two types - peer-to-peer structure and hierarchical structure.

1) Peer-to-Peer

As shown in Figure 2, each mobile node has the same status in a peer-to-peer structure. Each node can move randomly and establish point-to-point wireless connection with each other, automatically. Information can be exchanged among the nodes, directly.

2) Hierarchical

In this type of architecture (see Figure 3), the whole network is organized into different clusters. Each cluster is a subnet and includes one cluster head with multiple cluster members. The cluster head and cluster members move randomly and are self-organized, and use the same radio frequency to connect with each other. The cluster head, however, uses another radio frequency to communicate with the other cluster heads. In the hierarchical structure, the status of the cluster head is more important than the cluster members. These cluster heads link among themselves to provide the backbone of an Ad Hoc network. The traffic flow is higher in the backbone than on the other links. Thus, some cluster members that are located far away from the backbone, do not need to participate in some of the routing processes [3].

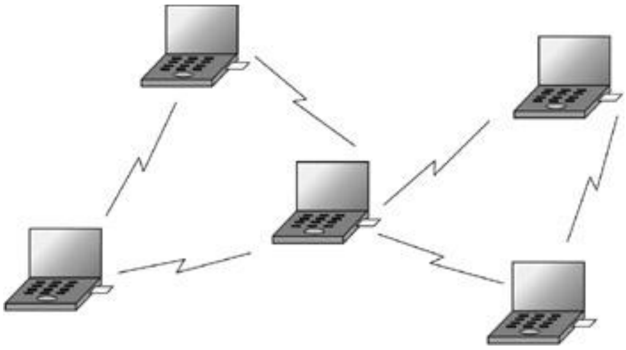

Figure 2. Peer-to-peer Structure of Ad Hoc Network.

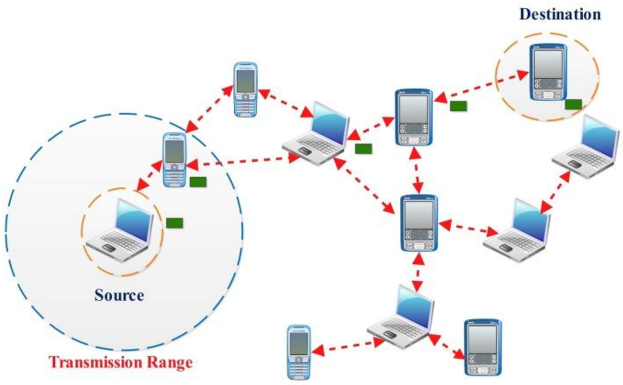

Figure 3. Hierarchical Structure of Ad Hoc Network.

B) Characteristics of MANET

Mobile Ad Hoc networks inherit the characteristics of wireless networks, in addition they have:

- Dynamic network topology
- Multi-hop connection
- Limited resources
- Unreliable links

C) Applications of MANET

Ad hoc networking is gaining importance with the increasing number of widespread applications. Ad hoc networking can be applied anywhere where there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use. Typical applications include [4]:

- Military battlefield
- Sensor Networks
- Automotive Applications
- Commercial sector
- Personal Area Network (PAN)

D) MANET Challenges

Regardless of the attractive applications, the features of MANET introduce several challenges that must be studied carefully before a wide commercial deployment can be expected. These include [4]:

1) Routing

Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task, because routes between nodes may potentially contain multiple hops, which is more complex than the single hop communication.

2) Security and Reliability

An ad hoc network has its particular security problems due to nasty neighbor relaying packets. The feature of distributed operation requires different schemes of authentication and key management. Further, wireless link characteristics introduce also reliability problems, because of the limited wireless transmission range, the broadcast nature of the wireless medium, mobility-induced packet losses, and data transmission errors.

3) Quality of Service (QoS)

Providing different quality of service levels in a constantly changing environment will be a challenge. The inherent stochastic feature of communications quality in a MANET makes it difficult to offer fixed guarantees on the services offered to a device. An adaptive QoS must be implemented over the traditional resource reservation to support the multimedia services.

4) Internetworking

Addition to the communication within an ad hoc network, inter-networking between MANET and fixed networks is often expected in many cases. The coexistence of routing protocols in such a mobile device is a challenge for the harmonious mobility management.

5) Power Consumption

For most of the mobile terminals, the communication-related functions should be optimized for lean power consumption. Conservation of power and power-aware routing must be taken into consideration.

III. Routing in MANETs

All communications between devices in a network based on routing [5]. Routing is the act of moving and forwarding packets of data from a source to a destination by providing the shortest path between them using routing algorithms or protocols. Unlike wired and wireless infrastructure networks routing confine on specific devices (centralized administrator, base stations), routing in MANETs represent a complex task due to the high mobility of nodes, unpredictable topology and every node operate as a router and user at the same time. This means that routing information should be updated more regularly than in wired networks.

Routing based on construction of routing tables which are formed by the adaptive routing protocol. Several protocols and algorithms proposed for MANETs each one try to modify routing table and increase routing performance.

The routing protocols used on wired networks do not perform well on networks involving mobility and rapid membership changes. More effective routing protocols are required. In Ad Hoc networks, we need new routing protocols because of the following reasons [5]:

- Nodes in Ad Hoc networks are mobile and topology of interconnections between them may be quite dynamic.
- Existing protocols exhibit least desirable behavior when presented with a highly dynamic interconnection topology.
- Existing routing protocols place too heavy a computational burden on each mobile computer in terms of the memory-size, processing power and power consumption.
- Existing routing protocols are not designed for dynamic and self-starting behavior as required by users wishing to utilize Ad-Hoc networks.
- Existing routing protocols like Distance Vector Protocol take a lot of time for convergence upon the failure of a link, which is very frequent in Ad Hoc networks.
- Existing routing protocols suffer from looping problems either short lived or long lived.

A) Properties of Ad-Hoc Routing protocols

For every developed routing protocol, some desirable properties are required such as [6]:

- Distributed operation
- Loop free
- Demand based operation
- Security
- Resources optimization
- Multiple routes
- Scalability
- Topology maintenance

B) Traditional routing mechanisms

The most known routing mechanisms are [7]:

1) Distance Vector Protocols

In distance vector protocols, each router over the network sends the neighboring routers, the information about destination that it knows how to reach.

Moreover to say the routers sends two pieces of information first, the router tells, how far it thinks the destination is and secondly, it tells in what direction (vector) to use to get to the destination. When the router receives the information from the others, it could then develop a table of destination addresses, distances and associated neighboring routers, and from this table then select the shortest route to the destination. Using a distance vector protocol, the router simply forwards the packet to the neighboring host (or destination) with the available shortest path in the routing table and assumes that the receiving router will know how to forward the packet beyond that point. The best example for this is the routing information protocol (RIP).

2) Link-State Protocols

In link state protocols, a router doesn't provide the information about the destination instead it provides the information about the topology of the network. This usually consist of the network segments and links that are attached to that particular router along with the state of the link i.e., whether the link is in active state or the inactive state. This information is flooded throughout the network and every router in the network then builds its own picture of the current state of all the links in the network.

3) Source Routing

Source routing means that each packet must carry the complete path that the packet should take through the network. The routing decision is therefore made at the source. The advantage with this approach is that it is very easy to avoid routing loops. The disadvantage is that each packet requires a slight overhead.

4) Flooding

Many routing protocols uses broadcast to distribute control information, that is, send the control information from an origin node to all other nodes. A widely used from of broadcasting is flooding and operates as follows: The origin node sends its information to its neighbors.

C) Classification of routing Protocols in MANETs

Routing is the essential task of transferring packets form source node to destination, or can be described as the process of path finding. A lot of routing algorithms have been proposed for mobile ad hoc networks and most of them have been implemented as protocols. These protocols are classified into three main categories: proactive, reactive and hybrid [8].

1) Proactive protocols

These protocols are also called as Table-Driven routing protocols since they maintain the routing information even before it is needed [8]. Each and every node in the network maintains routing information to every other node in the network. Routes information is generally kept in the routing tables and is periodically updated as the network topology changes. Many of these routing protocols come from the link-state routing.

In proactive routing protocols, paths towards all destinations are periodically refreshed even if not used. Normally, these protocols require nodes to broadcast information about their neighbors, and based on this information, each node in the network computes the minimum path to every possible destination. DSDV, OLSR, WRP and CGSR are typical protocols based on proactive routing algorithm in Ad Hoc networks.

a) Destination-Sequenced Distance-Vector Routing (DSDV)

Destination-Sequenced Distance-Vector Routing (DSDV) is a table-driven routing scheme for ad hoc mobile networks based on the classical Bellman-Ford algorithm. It was developed by C. Perkins and P.Bhagwat in 1994 [5]. The main contribution of the algorithm was to solve the Routing Loop problem and count to infinity by introducing sequence number. Each node maintains routs to all reachable destinations in the network.

Each route entry is tagged with a sequence number indicating its freshness, the sequence numbers are generally even if a link is present; else, an odd number is used. The number is generated by the destination or a node which detect a link broken, and the emitter needs to send out the next update with this number. The sequence number is used to distinguish stale routes from new ones and thus avoid the formation of loops. Routes for the same destination are selected based on the following rules:

- A route with a newer sequence number is preferred;
- In the case that two routes have a same sequence number, the one with a better cost metric is preferred.
- Every mobile node maintains a routing table that lists:
- All available destinations;
- The next hop;
- The number of hops to reach the destination;
- The sequence number assigned by the destination node.
- A node exchanges routing tables with its neighbors periodically or whenever a change in topology is detected. The routing table updates can be sent in two ways:
- A full dump update: sends the full routing table to the neighbors.
- An incremental update: only sends those entries with a metric change since the last update.
- When the network is relatively stable, full dumps updates are sent infrequently and smaller incremental updates more frequently.

2) On Demand Routing Protocols (Reactive)

On-demand routing protocols create routs only when needed by source node to send a packet of information to destination node. When a node requires a route to destination, it initiates a route discovery process within the network, when a route found or many possible routes discovered then the node choose a specific route with smaller metric (shortest path).

This approach of routing tries to eliminate the routing tables and reduce the need of updating these tables in contrast with proactive routing protocols which maintain all tables up-to-date at every node. In reactive routing protocols routes is always available with reduce of network traffic and power consumption but on demand routing suffer longer delay while route discovery.

In the following sections described some of reactive routing protocols such as AODV and DSR.

a) Ad hoc On Demand Distance Vector Routing (AODV)

AODV stands for Ad-Hoc On-Demand Distance Vector and is, as the name already says, routes are discovered, established, and maintained only when needed. It is jointly developed in Nokia Research Centre of University of California, Santa Barbara and University of Cincinnati by C. Perkins and S. Das. It borrows most of the advantageous concepts from DSR and DSDV algorithms. The on demand route discovery and route maintenance from DSR and usage of node sequence numbers from DSDV make the algorithm cope up with topology and routing information. AODV is capable of both unicast and multicast routing [9]. To ensure loop freedom, sequence numbers which are created and updated by each node itself, are used. These allow also the nodes to select the most recent route to a given destination node.

AODV protocol mainly based on two phases: route discovery that is done with route request (RREQ) and route reply (RREP) messages and route maintenance represented by route error (RERR).

Route Discovery

The aim of route discovery is to set up a bidirectional route from the source to the destination [9]. When a node wishes to communicate with another node it first checks its own routing table which store the destination, next hop IP addresses and the destination sequence number. If an entry for this destination node exists. If this is not the case, the source node has to initialize a route discovery. This is done by creating a RREQ message, including the hop count to destination, the IP address of the source and the destination, the sequence numbers of both of them, as well as the broadcast ID to identify the RREQ message. This ID and the IP address of the source node together form a unique identifier of the RREQ. When the RREQ is created, the source node broadcasts it and sets a timer to wait for reply.

If an intermediate node has a route entry for the desired destination in its routing table, it compares the destination sequence number in its routing table with that in the RREQ. If the destination sequence number in its routing table is less than that in the RREQ, it increments the RREQ’s hop count and rebroadcasts the RREQ to its neighbors. Otherwise, it unicasts a route reply packet to its neighbor from which it was received the RREQ.

When the source node receives no RREP as a response on its RREQ a new request is initialized with a higher TTL and wait value and a new ID. It retries to send a RREQ for a fixed number of times after which, when not receiving a response, it declares that the destination host is unreachable.

As long as the route remains active, it will continue to be maintained. A route is considered active as long as there are data packets periodically travelling from the source to the destination along that path. Once the source stops sending data packets, the links will time out and eventually be deleted from the intermediate node routing tables.

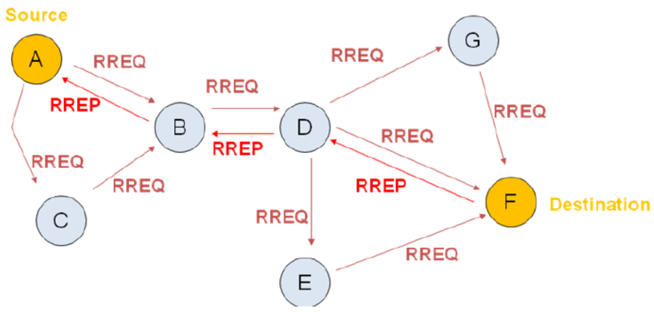

Figure 4. AODV route discovery

In AODV protocol, each node keeps track of its local connectivity, i.e., its neighbors. This is performed by using periodic exchange of HELLO messages. If a route in the ad hoc network is broken then some node along this route will detect that the next hop router is unreachable based on its local connectivity management. If this node has any active neighbors that depend on the broken link, it will propagate route error (RERR) messages to all of them. A node that receives a RERR will do the same check and if necessary propagate the RERR further in order to inform all nodes concerned, so if the source node still desires the route, it can reinitiate route discovery [10].

b) Dynamic Source Routing Protocol (DSR)

Dynamic source routing protocol (DSR) is an on-demand, source routing protocol, whereby all the routing information is maintained (continually updated) at mobile nodes.

DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration. The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance", which work together to allow nodes to discover and maintain routes to arbitrary destinations in the ad hoc network.

An optimum path for a communication between a source node and target node is determined by Route Discovery process. Route Maintenance ensures that the communication path remains optimum and loop-free according the change in network conditions, even if this requires altering the route during a transmission [10].

Route discovery

When a node S wants to send a packet to the destination D, it first searches its Route Cache for a suitable route to D. If no route from S to D exists in S’s route cache, S initiates Route Discovery and sends out a Route REQuest (RREQ) message to find a route. The RREQ message contains: Initiator ID, the Target Id and the Unique Request Id and an empty Address List.

When a node receives a RREQ message it examines the Target ID to determine if it is the target of the message. If the node is not the target it searches its own route cache for a route to the target. If a route is found it is returned. If not, the nodes own id is appended to the Address List and the RREQ is broadcasted. If a node subsequently receives two RREQ with the same Request id, it is possible to specify that only the first should be handled and the subsequent discarded. If the node is the target it returns a RREP message to the initiator. This RREP message includes the accumulated route from the RREQ message.

Route maintenance

Since nodes move in and out of transmission range of other nodes and thereby creates and breaks routes, it is necessary to maintain the routes that are stored in the Route Cache. When a node receives a packet it is responsible for confirming that the packet reaches the next node on the route

If a node detects a break in the route, it must return a RERR message to the original sender of the packet, identifying the link over which the packet could not be forwarded. When the concerned node receives the RERR message, it removes this broken link from its cache. If it has in its Route Cache another route to the destination (for example, from additional RREPs from its earlier Route Discovery, or from having overheard sufficient routing information from other packets), it can send the packet using the new route immediately. Otherwise, it may perform a new Route discovery for this target [4].

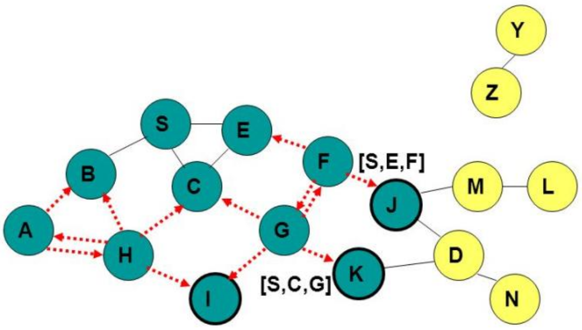

Figure 5. DSR Route Discovery I (RREQ)

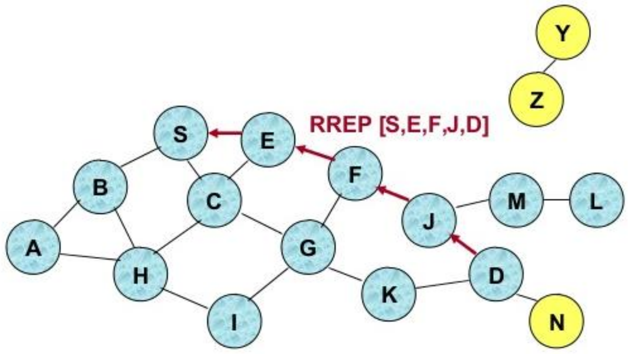

Figure 6. DSR Route Discovery II (RREP)

IV. Simulation Results and Analyses

A) *Simulation environment*

Our simulation is based on the NS-2 simulator on Ubuntu operating system, we choose as mobility model the random waypoint which is very widely used in simulation studies of MANET. We also choose as traffic model the CBR (Constant Bit Rate) traffic over UDP. The simulation is based on the routing protocols AODV, DSR and DSDV.

B) *Performance metrics*

There are different kinds of parameters for the performance evaluation of the routing protocols [11]. These have different behaviors of the overall network performance. We will evaluate parameters for the comparison of our study on the overall network performance.

The throughput is defined as the total data packets received divided by the total duration of the simulation, it is expressed in (packet/sec). If a protocol shows high throughput so it is the efficient and best protocol than the routing protocol which have low throughput.

C) *Simulation parameters*

We have conducted the simulation of the DSDV, AODV and DSR protocols in different situations in order to show the behavior and the performance of each one. The evaluation parameters are:

1) *Network load*

this parameter represents the percentage of pairs (source, destination) over the network nodes for AODV, DSR and DSDV.

2) *Speed*

speed has an important affect on the protocol behavior, especially if it combined with the nodes movement, this make the topology changes.

3) *Traffic type*

the traffic defines the type of data has been forwarded between source and destination in term of packet transmission rate which is constant in CBR traffic and variable in Exponential and Pareto.

4) *Topology size*

the topology size defines the movement area of mobile nodes, so it limits the movement boundaries.

D) Simulation scenarios

Based on the parameters mentioned before, these are the selected scenarios:

TABLE I. SCENARIO1 (NETWORK LOAD)

Simulation environment	
Number of nodes	50
Simulation time	30 sec
Area size	4000x4000
Queue length	50
Traffic parameters	
Type	CBR
Packet size	512 bytes
Interval	0.005 sec
Network load	
20%, 40%, 60%, 80%	

TABLE II. SCENARIO2 (CHANGING SPEED)

Simulation environment	
Number of nodes	50
Simulation time	30 sec
Area size	4000x4000
Queue length	50
Traffic parameters	
Type	CBR
Packet size	512 bytes
Interval	0.005 sec
Speeds	
1000, 2000,3000,4000, 5000	

TABLE III. SCENARIO 3 (TRAFFIC TYPES)

Simulation environment	
Number of nodes	50
Simulation time	30 sec
Area size	4000x4000
Queue length	50
Traffic types	
CBR, Exponential, Preto	

TABLE IV. SCENARIO 4 (TOPOLOGY SIZE)

Simulation environment	
Number of nodes	50
Simulation time	30 sec
Queue length	50
Traffic parameters	
Type	CBR
Packet size	512 bytes
Interval	0.005 sec
Topology sizes	
1000x1000, 2000x2000, 3000x3000, 4000x4000	

E) Results and analysis

The results are obtained from the trace files using AWK, and plotted in graphs using EXCEL.

The next figure shows the throughput versus network load:

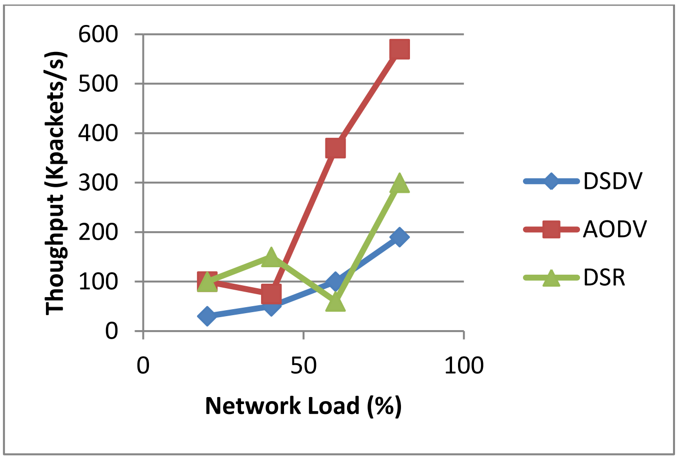

Figure 7. throughput vs network load

The above graph shows that:

- For DSDV: As the network load increases the throughput increases slowly, but it still less than AODV and DSR due to its proactive nature.
- For AODV: The network load throughput decreases because of route discovery process, after that it increases.
- For DSR: As the network load increases the throughput increases; yet, we found that the throughput decreases when the load ranges between 40 and 60%.

The next figure shows the throughput versus the velocity

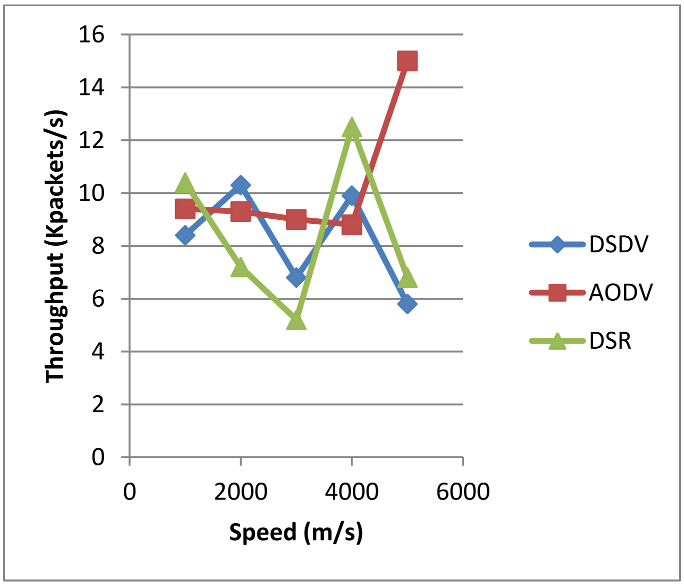

Figure 8. throughput vs speed

The throughput of both DSDV and DSR fluctuates when velocity is increased, while AODV throughput generally increases as speed increase.

The next figure shows the throughput versus traffic:

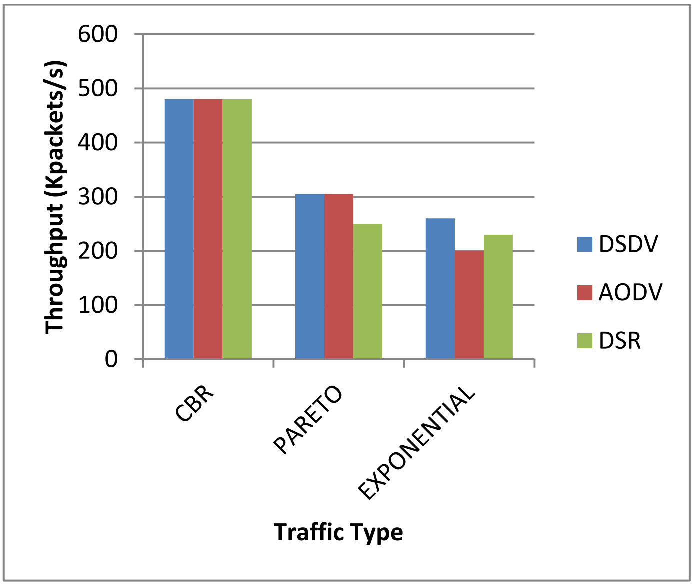

Figure 9. throughput vs traffic

For the CBR traffic, the throughput is the same for each protocol, while for the Exponential traffic and pareto throughput is less due to the burst (transmission exist) time and the idle time (no data transmission).

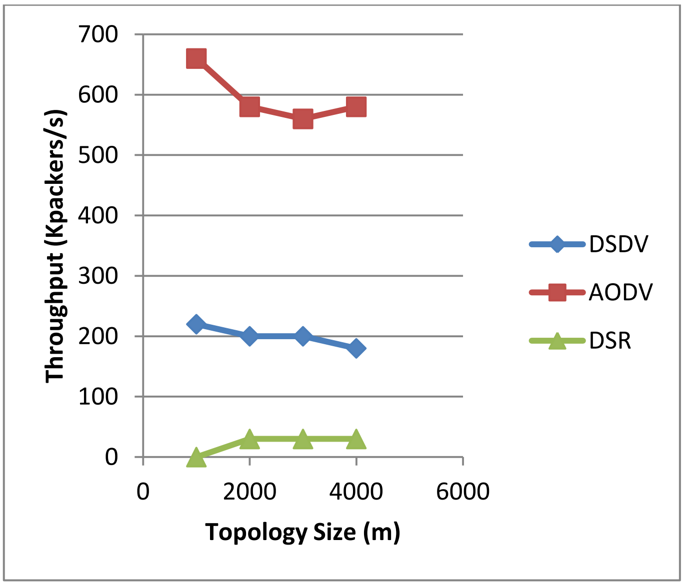

Figure 10. throughput vs topology size

For each protocol as the topology size increase, the throughput decreases because as we extend the topology there is the possibility to extend the distance between nodes.

V. CONCLUSION

In this paper, we aimed to present and simulate some routing protocols for mobile ad hoc networks which take a large portion and attention of computer science networking research. We also try to conduct experimental simulations of the three most popular routing protocols: Destination sequence Distance Vector (DSDV), Dynamic Source Routing (DSR) and Ad hoc On Demand Vector (AODV) based on the famous simulator NS-2.

The performance evaluation of routing protocols must take in consideration a lot of metrics and simulation parameters, which needs on the other hand a lot of time and effort in order to obtain a fair analysis and extract the best protocol. As future work, we suggest the followings:

Evaluating these protocols using other performance metrics to improve the found results, such as energy consumption and end-to-end delay.

REFERENCES

[1] Gorantala, Krishna. "Routing protocols in mobile ad-hoc networks." A Master'thesis in computer science, pp-1-36 (2006).

[2] Raheja, Kanishka, and Sunil Kr Maakar. "A Survey on Different Hybrid Routing Protocols of MANET." (IJCSIT) International Journal of Computer Science and Information Technologies 5.4 (2014): 5512-5516.

[3] Han, Qi. Using ACK reply to improve performance of dynamic source routing protocol for mobile ad hoc networks. Diss. University of Malaya, 2010.

[4] Bai, Fan, Narayanan Sadagopan, and Ahmed Helmy. "IMPORTANT: A framework to systematically analyze the Impact of Mobility on Performance of RouTing protocols for Adhoc NeTworks." INFOCOM 2003. Twenty-second annual joint conference of the IEEE computer and communications. IEEE societies. Vol. 2. IEEE, 2003.

[5] Perkins, Charles E., and Pravin Bhagwat. "Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers." ACM SIGCOMM computer communication review. Vol. 24. No. 4. ACM, 1994.

[6] Misra, Rajiv, and C. R. Mandal. "Performance comparison of AODV/DSR on-demand routing protocols for ad hoc networks in constrained situation." Personal Wireless Communications, 2005. ICPWC 2005. 2005 IEEE International Conference on. IEEE, 2005.

[7] Cano, J-C., and Pietro Manzoni. "A performance comparison of energy consumption for mobile ad hoc network routing protocols." Modeling, Analysis and Simulation of Computer and Telecommunication Systems, 2000. Proceedings. 8th International Symposium on. IEEE, 2000.

[8] Royer, Elizabeth M., and Chai-Keong Toh. "A review of current routing protocols for ad hoc mobile wireless networks." IEEE personal communications 6.2 (1999): 46-55.
[9] Ade, S. A., and P. A. Tijare. "Performance comparison of AODV, DSDV, OLSR and DSR routing protocols in mobile ad hoc networks." International journal of information technology and knowledge management 2.2 (2010): 545-548.
[10] Mittal, Shaily, and Prabhjot Kaur. "Performance Comparison of AODV, DSR and ZRP Routing Protocols in MANET's." Advances in Computing, Control, & Telecommunication Technologies, 2009. ACT'09. International Conference on. IEEE, 2009.
[11] Gupta, Anuj K., Harsh Sadawarti, and Anil K. Verma. "Performance analysis of AODV, DSR & TORA routing protocols." International Journal of Engineering and Technology 2.2 (2010): 226.