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A Review and Performance Analysis of Reactive and Proactive Routing Protocols on MANET

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Abstract

MANET is a spontaneous system of mobile nodes where each node plays the role of router and mobile station. They can join or disconnect from the network any time and transfer packets in peer-to-peer mode or a multicast mode. Nodes are connected by way of wireless links and form a random topology graph. Network topology may change rapidly and erratically, so it can considerably affect packet routing in terms of network throughout, load and delay. Multiple hops can locate between diversity of node's route as a consequence form the communication as expanded complexity. In this paper the performance of three well-known MANET routing protocols - Ad hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Optimized Link State Routing (OLSR) - has bees been investigated. Furthermore, all above mentioned protocols are compared based on three important performance metrics which are average end-to-end packet delay, network load as well as network throughput.

Keywords: AODV, DSR, mobile Ad-hoc Networks, OLSR, routing protocol

1. Introduction

Ad hoc wireless networks, include a set of distributed nodes that are linked with each other wirelessly and are geographically spread over a defined area. Nodes can be the host computer which acts as router. Nodes communicate with each other directly without an access point or any intermediate devices and without fixed organization or administration. Each node is equipped with transmitter and receiver antenna. An important feature of this network is that it is dynamic and it has adaptive topology as a result of nodes mobility. Nodes in this network are arbitrary and they continually change their position so it requires a suitable routing protocol that has the ability to adapt to these changes with low network delay. Generally, in an efficient network, low network load and latency is demanded since it causes higher throughput. Proper network routing and security are challenges of today's network.

In a MANET network, nodes do not have advance knowledge about the topology that is used in the network. In MANET there is a theory when a new node arrives in the network, it should announce its presence in the network and then listen to its neighbours. In this way, the node will gain information about other nodes, which are close to it and learn ways how to contact them and what are the routes. Therefore, by this way all other nodes know where the other neighbours are and the routes to send traffic to them and find out at least one route to other nodes.

Routing protocols between any two mobile nodes of this network is difficult because each mobile node can arbitrarily move in the network and it is even possible that the node be removed from the network randomly and suddenly. This means that an optimum path may appear a few seconds after being removed from the network and recalculating for optimum routing should take place. MANET routing protocols are categorized into three categories active, reactive and hybrid (Karlsson, Dooley, & Pulkkis, 2012). These whole categories are known as flat routing protocol. In this class of routing protocols, all nodes have common duty in term of route discovery. All nodes are identical in terms of software, hardware and routing function and refuse any sort class between the

nodes. All nodes preserve global routing information and information is flooded to all nodes. There are other types of routing protocol beside flat such as hierarchical routing and geographical position assisted routing (Hong, Xu, & Gerla, 2002).

1.1 MANET Reactive Routing Protocols

Reactive MANET protocol (RMP) creates a method in which the routing between nodes is done only on demand so they don't maintain routing information in nodes unless this is a communication in the network. Routes are discovered only when the source is attempting to communicate with another node. When a node wants to communicate with another node it is called the route discovery process in the network, which usually happen by flooding route request packets, over networks (Kumar, Reddyr, & Nagendra, 2010) so considerable delay is observed and network clogging emerges by flooding algorithm (Al-Humoud, 2011) since appropriate route is generated before communication (See Figure 1). Source router sends packets to destination router and it is possible for routing packet to pass from other intermediate nodes in MANET and detect the route to update routing information of each network's nodes. This protocol is effective when the route discovery is less than the process of data transmission; it will be repeated because the traffic generated by the routing discovery is more than the available bandwidth of network (Sargolzaey et al., 2009). Examples of Reactive protocols are: Ad hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Associativity Based Routing (ABR) and Temporally-Ordered Routing Algorithm (TORA).

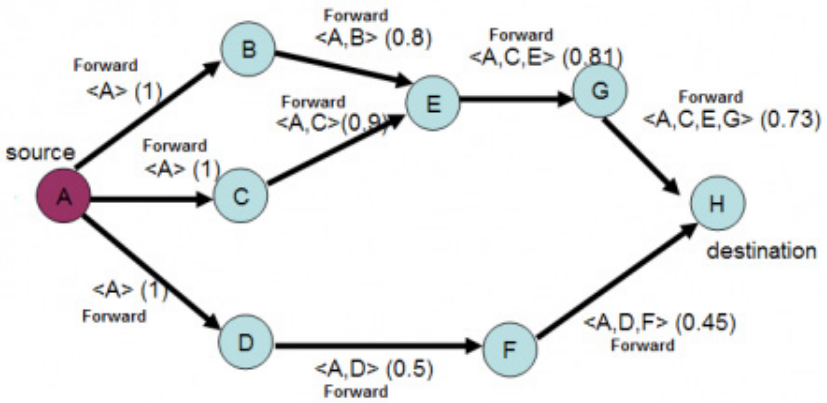

Figure 1. Route discovery through flooding algorithm

1.2 MANET Proactive Routing Protocols

Proactive MANET protocol (PMP) was introduced in the first MANET generation based on ordinary routing algorithm in fixed networks such as Link State and Distance Vector. As a result, this algorithm preserves table of information relating to routing in each node for routing protocol. In considering the mobility and changing topologies in the network which is the main characteristic of difference between MANET and fixed network, data are modified and updated with any changes to ensure the consistency of tables in different nodes. Generally, in this type of routing protocols, network paths already exist and as soon as the arbitrary node attempts to send data to another node, it can identify and use the available route that is based on the information already collected so there is no noticeable delay. Routing information in each node is periodically sent as packet data containing control information to other nodes in a defined duration such as the broadcasting method. Then, each node of the network saves the network topology in the form of graph and updates as necessary only when there is a change or a new link is added. In a Proactive routing protocol all available paths are kept between all pairs of mobile node regardless of whether the routes are currently in use. Therefore, when communication is necessary, the originating node knows the route to the destination so there is no need to wait for route discovery phase to prepare and find the path. As a consequence of keeping the routing table in each node, data is transmitted with less delay (Kuosmanen, 2002) however the cost of maintaining all topology information in all nodes is quite high because of plenty of control packets to keep the paths information over all the nodes (Xu et al., 2010). Destination-Sequenced Distance-Vector Routing (DSDV), Fisheye State Routing (FSR) and Optimized Link State Routing (OLSR) are as examples of Proactive Routing protocols.

1.3 MANET Hybrid Routing Protocols

Hybrid MANET protocol refers to those protocols that are developed based on combination of both reactive and proactive routing protocols. Generally, these routing protocols employ Distance Vector to find the shortest path and routing information send request for update to the rest of neighbour nodes in case any changes occurred in network topology. Each node in the network provides a routing zone for itself and it keeps all required routing paths information in that certain zone (Abolhasan et al., 2004). For instance, Zone Routing Protocol (ZRP), ZHLS, SHARP and NAMP are categorised under Hybrid Routing Protocols.

Table 1 demonstrates comparison of three above mentioned categories of routing protocols.

Table 1. Comparison of three main categories of routing protocol

	Reactive	Proactive	Hybrid
Network organization	Flat	Flat Hierarchical	Hierarchical
Topology dissemination	On-demand	Periodical	Both
Mobility handling	Available when needed	Always available	Both
Route latency	Route maintenance	Periodical updates	Both
Communication overhead	Low	High	Medium

The rest of this paper is organized as follows. The overview of routing protocols implementation has been described in the next section. The simulation scenarios, description of network topology and required simulation parameters for analysis of proactive routing protocols are explained in Section 3. Moreover, the performance evaluation metrics are discussed in Section 4. Protocols comparison and obtained results have been discussed in Sections 5 and 6 respectively before conclusions are drawn in Section 7.

2. Implementation of Routing Protocols

2.1 Ad hoc On-demand Distance Vector Routing Protocol (AODV)

Ad hoc On-demand Distance Vector (AODV) routing protocol is developed based on the network demand by mobile nodes. The route is made only when originating node needs to send data packets to destination. This protocol employs destination sequence number to find new routes. Route determination is started when source node requests connection with other nodes but there is no defined route that has been saved in its routing table. AODV will then allow them to create multi hop route number and this number is defined as a number of hops of routing messages in the MANET and presented by Time to Live (TTL), which is located on the IP header of packet. Each node maintains two separate counters, Domain Sequence Number (DSN) and hop count. Source node starts the routing discovery process by broadcasting the route request (RREQ) packets to other neighbour nodes. Neighbour nodes respond to the originating node of RREQ by sending route reply (RREP) to originating node. If they could not find appropriate route to destination, they will broadcast RREQ to neighbour nodes and increase the hop count. It is also possible that each node receive a broadcast packet request from neighbour nodes. If intermediate nodes received RREQ packets with the same source address and broadcast ID, it will remove the continual RREQ and will be stopped for further rebroadcast. On the other hand, if a node receives RREQ and it does not have a specified route in the routing table then the node will broadcast the packet while increasing the hop count until the intermediate nodes are able to respond to the RREQ if their sequence number (DNS) is not less than the number which exists on the packet header of RREQ. Otherwise intermediate nodes broadcast the RREQ again by increasing the hop count and send it to the neighbour nodes and store this address in their routing cache. When a packet received by nodes, which have an alive path to the destination, then an inverse route, is created to the sender of the RREQ. While RREP is moving to originative node, the hop count rises in the route to the origin and is saved. Final sequence number of hop count is kept for identifying the destination. Origin node, finally, receives RREPs from other nodes and will update its routing table with the lowest hop count and shortest path, so sending data packets from origin to destination is started (Goel & Sharma, 2009). In case a better route with the shortest hop count is recognized, then its routing information will be updated immediately. On the other hand, if each node in the direction of the route is broken down, then failed route errors (RERR) should be sent. Therefore, the routing discovery and route maintenance continually occurs in an AODV routing protocol (Kumar et al., 2011).

2.2 Dynamic Source Routing Protocol (DSR)

In Dynamic Source Routing, origin node generates Route Request (RREQ), which is sent over data packet and it specifies source node as well as destination. Afterwards, the packet sends using flooding algorithm in MANET. Each node receives RREQ packet and does not know about the route to the destination so merge its name on the list which is located on packet's header then broadcast packet. As a result, when the packet reaches to desired destination, the destination node contains all the information regarding the nodes, which are located in the route direction between source node to destination node and their sequence number. Destination node generates Route Response (RREP) and adds it to the header of RREQ packet then returns back to the source node (Baraković et al., 2009). The intermediate nodes in the reverse path are extracted from the stored list and those intermediate nodes will be used to send back the mentioned packet to source node. So that, the packet passes the reverse path to reach the source node. After this process, the sender can insert the destination route into the sending packet's header to share this information with intermediate nodes. As a result, the routing protocol is known as Dynamic routing protocol. If each node cannot transmit the data packet to other nodes in the MANET, then a Route Error (RERR) data packet is generated and retransmitted it on the route. By this method, the receiver nodes of RERR are aware of the disconnection between the nodes. Hence, the discovery route process is called again. Routing caching cause routing discovery decreased and routes maintained among nodes that need to communicate so can reduce overhead of rout maintenance (Beaubrun & Molo, 2010). In DSR protocol size of packet header is increased by route length from source routing also flood of root request can reach entire nodes in the network.

2.3 Optimised Link State Routing Protocol (OLSR)

Optimized Link State Routing is one of the famous proactive routing protocols which are developed and available in library of most network simulators. Since nodes in MANET continually exchange topology of network, as a consequence, optimal link is always available between each pair of nodes in the MANET. There is an optimization in the OLSR routing protocol compared to other link state routing protocol and it is a result of the Multipoint Relay (MPR). In this protocol, all nodes are responsible for organising their own neighbour node list as a set of MPR (Wong et al., 2008). This set is defined in the way, which covers all the nodes as far as two hops from the source node. Nodes, which are chosen as MPR node, known as *N*, and then it continuously sends information over the MANET network based on the nodes that are specified to *N* nodes. All the neighbour nodes of *N* node and process receive these continuous messages but only the nodes that exist in MPR's set are retransmitted again. This mechanism helps to reduce MANET's control header and only set of nodes were introduced to all the nodes as N nodes in the overall network. Eventually, with the aid of control messages that MPRs sent in the network, partial topology is created and nodes in network can use it for routing (Doghri et al., 2011).

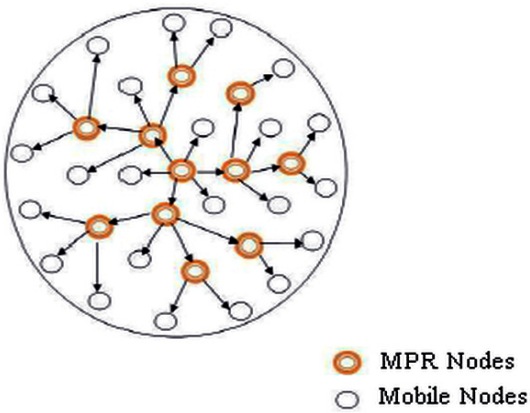

Figure 2. MPR nodes in OLSR

In the routing computation, each node produces its own routing table based on shortest hop path algorithm. In OLSR, the routing protocol can reduce the overhead by decreasing the number of selected MPR in the network.

2.4 Zone Routing Protocol (ZRP)

ZRP is considered as a hybrid routing protocol which is developed by combination of active and reactive protocols. The main idea behind developing this routing protocol was to reduce the control overhead of proactive routing protocols and also to decrease the latency of route discovery in reactive routing protocols. This routing

protocol tries to divide the network into regions with different sizes. Each region uses the proactive routing technique to discover available paths between neighbours. Furthermore, this protocol employs vector routing to find the shortest distance. In case any changes occur in network topology all paths information will be updated immediately. By applying this protocol over network, each node determines its own zone and all routing and data communication will be performed and maintained inside this zone. By using aforementioned technique, this algorithm makes use of advantages of both methods together.

A proactive routing protocol, Intra-zone Routing Protocol (IARP), is used inside routing zones, and a reactive routing protocol, Inter-zone Routing Protocol (IERP), is used between routing zones. A route to a destination within the local zone can be established from the source's proactively cached routing table by IARP. Therefore, if the source and destination of a packet are in the same zone, the packet can be delivered immediately. Most of the existing proactive routing algorithms can be used as the IARP for ZRP. For routes beyond the local zone, route discovery happens reactively. The source node sends a route request to the border nodes of its zone, containing its own address, the destination address and a unique sequence number.

Table 2. Characteristics of routing protocols

	AODV	DSR	OLSR	ZRP
Loop Free	Yes	Yes	Yes	Yes
Multiple Routes	No	Yes	Yes	No
Unidirectional Link Support	No	Yes	Yes	No
QOS Support	No	No	Yes	No
Multicast	Yes	No	Yes	No
Security	No	No	No	No
Periodic Broadcast	Yes	Yes	No	Yes
Power Efficiency	No	No	No	No
Simulator	OPNET-QualNet-NS-2, NS-3, etc.	OPNET-QualNet-NS-2, NS-3, etc.	OPNET-QualNet-NS-2, NS-3 , etc.	OPNET-QualNet-NS-2, NS-3 , etc.

3. Performance Evaluation and Simulation Scenarios

In this paper, MANET's performance is carried out in three scenarios. Although there are several available network simulators including academic and commercial versions such as NS-2, NS-3, QualNet, OMNeT++ and etc (Köksal, 2008), here OPNET 14.5 Modeller is used to evaluate the performance of routing protocols with three proposed scenarios. The network delay, network load and network throughput are investigated by applying ADOV, DSR and OLSR routing protocols. Required details of three mentioned performance metrics will be explain in the next section (Section 4).

All the devices were dragged to this project editor work place from the object palette such as Application Definition, Profile Definition, Mobility Configuration, fix WLAN server and quantity of mobile nodes deployed randomly in the simulation area. Finally all applications and mobile nodes are configured and appropriate protocol is chosen for each scenario. In the MANET project, 15 WLAN stations are defined as a base quantity. This is an arbitrary value but it sufficiently mimics a small MANET. The effect of number of nodes on the performance metrics have been evaluated in each scenario. As mentioned before, in each scenario three different protocols are implemented which are AODV, DSR and OLSR. It is considered that the IPv4 addresses are implemented in all nodes and the FTP is selected as a high load from available options as high, medium and low load. This amount of traffic, which shows as packet size, is defined to 50 Kbytes and generated throughout entire of MANET. The number of simultaneous links between nodes is determined by the Inter-Request Time parameter. This parameter is the time in seconds between consecutive FTP requests. In our work, the time between each client's file transfer requests is exponentially distributed with mean of 360 seconds.

The results of simulation scenarios have been analysed and discussed for AODV, DSR and OLSR routing protocol in Section 5. The behaviour and performance of three mentioned protocols measured in terms of three considered parameters, which are network delay, network load and throughput. It is intended to gain high throughput with low network load and network delay and this behaviour creates an efficient routing protocol. In

the MANET project, 15 WLAN stations are defined as a base quantity. This is an arbitrary value but it sufficiently mimics a small MANET. We are more concerned on how the metrics change when the number of nodes is increased. We then double the quantity of nodes to 30 to see how the performance metrics will be affected. In the second scenario the quantity of nodes increased to 60 WLAN stations and investigates performance of MANET during these changes. General configuration parameters of scenarios in OPNET 14.5 Modeler are illustrated in Table 3.

Table 3. Simulation parameters

Parameter	Value(s)
Transmitter ranges	250 m
Bandwidth	2 MBit
Simulation Time	360 Sec
Number of nodes	15-30-60
Environment Size	1000 X 1000 m
Traffic Type	FTP
Packet Rate	4 packet/s
Packet Size	512 Byte
Speed of mobile node	100 m/s
Channel Buffer Size	256000 bits
Transmit Power	0.005 W
Pause Time	150 sec
Routing protocol	AODV, DSR, OLSR
Mobility Algorithm	Random waypoint

4. Performance Metrics

Delay refers to total latency by a packet to traverse the network and reach to its destination. Generally, it is ideal to reduce end-to-end delay between nodes. The time taken for the packets to generate from source and after that transmitted across the network and passed from other nodes until the packet reaches the appropriate node is called end-to-end delay. This parameter is employed by internal algorithm that exists on each protocol so it is intended to decrease this time. Hence, efficient routing protocol should be selected which brings low delay otherwise a high delay is faced which is unpleasant. Choosing proper protocol depends on how the application is sensitive to delay and this is based on algorithm that is used in the routing protocols. For example, in a rescue situation the intended delivery time of message has to be at minimal level and measured in seconds.

Network load represents the total load in bit/sec submitted to wireless LAN layers by all higher layers in all WLAN nodes of the network (Al-Ani, 2011) and consequently result of bandwidth being used and buffer availability. It is ideal to reduce network load and the efficient network can cope with high load traffic coming through the network because it has a large impact on network protocols.

High network load will affect the MANET and cause traffic delay latency on delivery of packets to reach the channel and therefore bring collision for network (Hsu et al., 2004).

Throughput is one of the dimensional parameters of the network which gives the fraction of the channel capacity used for useful transmission to select a destination at the beginning of the simulation i.e., information whether or not data packets are correctly delivered to the destinations (Malany et al., 2009). The receiver throughput is defined as the total amount of data a receiver node actually receives from all the senders node divided by the time it takes for receiver node to get the last packet. The average throughput is defined as the average receiver throughput divided by the number of senders (Nguyen et al., 2006).

5. Protocols Comparison

The main characteristic of AODV routing protocol is that routes are created only on demand and destination's sequence numbers are employed for latest routing discovery to destination. One of the drawbacks of AODV routing protocol is the intermediate node that cause inconsistent routing when sequence number of source node is a too old and intermediate node has larger value than originating node and also do not contain a destination sequence number (Aggarwal et al., 2011). Overhead occurs when there are too many RREP as a result of RREQ from the originating node. Additionally, continuous Hello messages that used up limited network bandwidth and can consequently cause congestion in the MANET. Despite that, AODV on the overall has a low network load because routes are created on demand by the originating nodes.

DSR routing protocol is a good method and certainly leads to result but it increases uses more bandwidth. This is due to the bigger size of the packet's header that is transmitted in the MANET. The size of packet header has direct relation with distance of source node to destination. This bigger size of packet is a result of more intermediate nodes specified as route in the packet's header. One of the major drawbacks of DSR is that a large quantity of data packets are transmitted over MANET so whenever the MANET's nodes increased, the data packets and also packet headers grow as well which in turn consumes more network bandwidth.

OLSR routing protocol is presented to MANET but without the consideration of quality of service (QOS); it is designed in a way that leads to good quality routings (Leguay et al., 2006). Routing which is selected by this routing protocol is only efficient in quantity of optimal hops so selecting MPR nodes for routing quality service should introduce optimal quality link to other nodes. Optimal link is a route that can allocate enough high bandwidth in compare to other links. If two paths are same to each other in term of bandwidth, the one with less network delay will be chosen.

Table 4. Mean values of delay, network load and throughput for AODV, DSR and OLSR in proposed scenario

Node	Parameter	AODV	DSR	OLSR
15	Delay (sec)	0.001	0.006	0.00062
	Network Load (bit/sec)	42000	41000	44000
	Throughput (bit/sec)	60000	30000	162500
30	Delay (sec)	0.002	0.006	0.0009
	Network Load (bit/sec)	84000	94000	100000
	Throughput (bit/sec)	200000	100000	740000
60	Delay (sec)	0.0028	0.0273	0.001
	Network Load (bit/sec)	215000	200000	214000
	Throughput (bit/sec)	1265625	178571	4500000

There is an obvious conclusion that OLSR performance - which belongs to the proactive routing protocol (table driven) - is the best in term of network delay and throughput for the scenarios and DSR routing protocol which belongs to the reactive (on-demand) protocol is performed well in terms of network load compared to AODV and OLSR routing protocols. DSR operates entirely on demand, with no periodic activity of any kind required at any level within the network. For example, DSR does not use any periodic routing advertisement, link status sensing, or neighbour detection packets, and does not rely on these functions from any underlying protocols in the network. DSR uses source routing and route caches and does not depend on any periodic or timer-based activities (Periyasamy & Ranjithkumar, 2011).

6. Results and Discussion

In this paper AODV, DSR and OLSR protocols have been discussed and also each of above-mentioned protocols has been evaluated and compared through simulation using OPNET simulator. To fulfill this study, delay, network load and throughput of each scenario is measured by way of graphs. Quantity of nodes was changed in 15 nodes, 30 nodes and finally 60 nodes. All metrics are displayed in average. The three different scenarios are made in the OPNET Modeler 14.5. Simulation was performed in six minutes (360 Sec) duration each time and project parameters were estimated for analysis and performance.

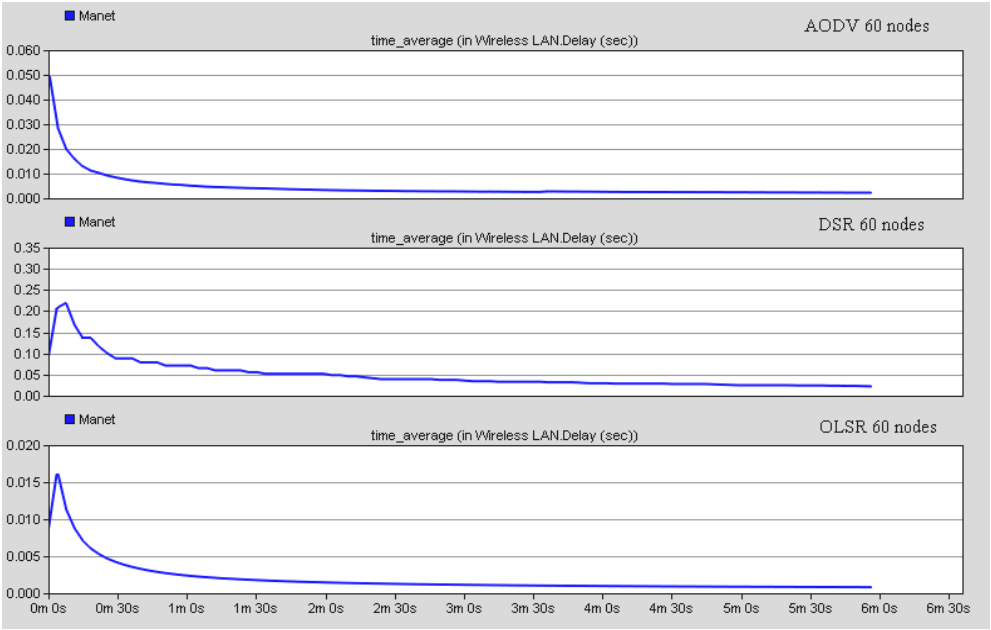

Figure 3. Delay, network load and throughput of AODV 60 nodes

Figure 3 illustrates the average network end-to-end delay in scale of tie for 60 nodes in AODV, DSR and OLSR routing protocols.

End-to-end delay describes the latency duration starting in the first node which generates data packets until the last bit of data packets at initialled node arrives at the destination node. Simulation runs in six minutes as y-axis presents time in second and x-axis shows time in minute. In the starting time MANET needs to establish their node's table and because of this, a lot of packet is sent to other nodes to find the appropriate route. Due to the traffic load it is clearly seen that at first there is a peak of traffic and after that it gradually declines until routing protocol is set up in the MANET. In addition each node knows the route so a number of packets are decreased and as a result delay is declined. Generally minimum value of average network delay is preferred in network.

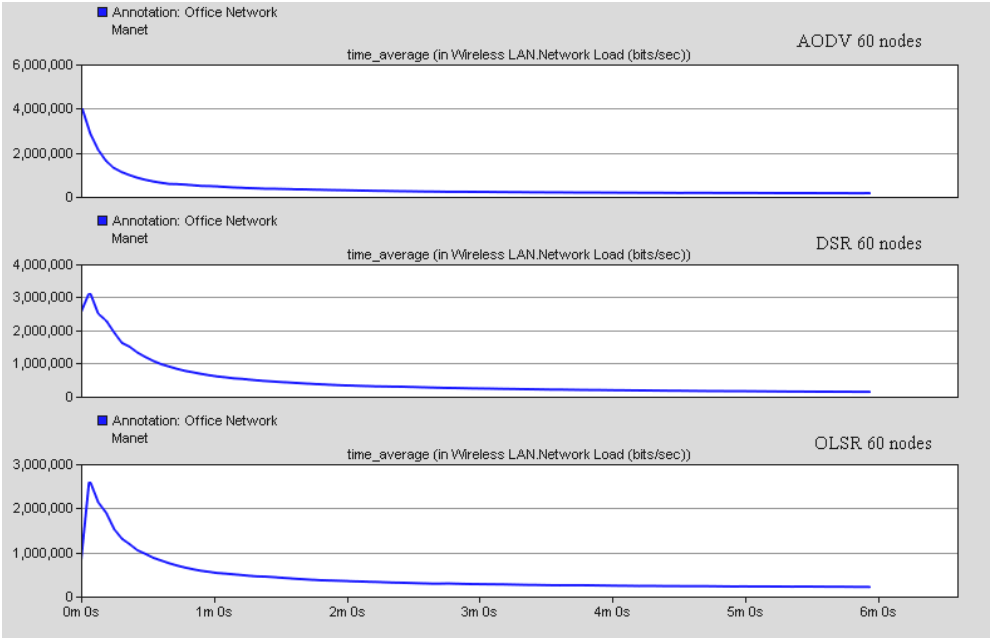

Figure 4. Delay, network load and throughput of DSR 60 nodes

Figure 4 represents the average network load in scale of bits/sec for 60 nodes in AODV, DSR and OLSR routing protocols.

Network load is the total load that is impacted by the entire higher layer in all WLAN nodes in network. Network load is mainly a result of exploited bandwidth, buffer availability and processing time at intermediate nodes. Indeed, network load is a key parameter with a potentially large impact on network protocols. Network delay causes a load in the network and therefore there is more delay in the starting time for establishing connection between nodes in MANET as a result there is a peak load at the first and after that it gradually decreased when connection was established. X-axis represents time and Y-axis represents data rate in bit/sec. Generally the lowest network load is demanded by all wireless networks otherwise, it causes congestion in the network.

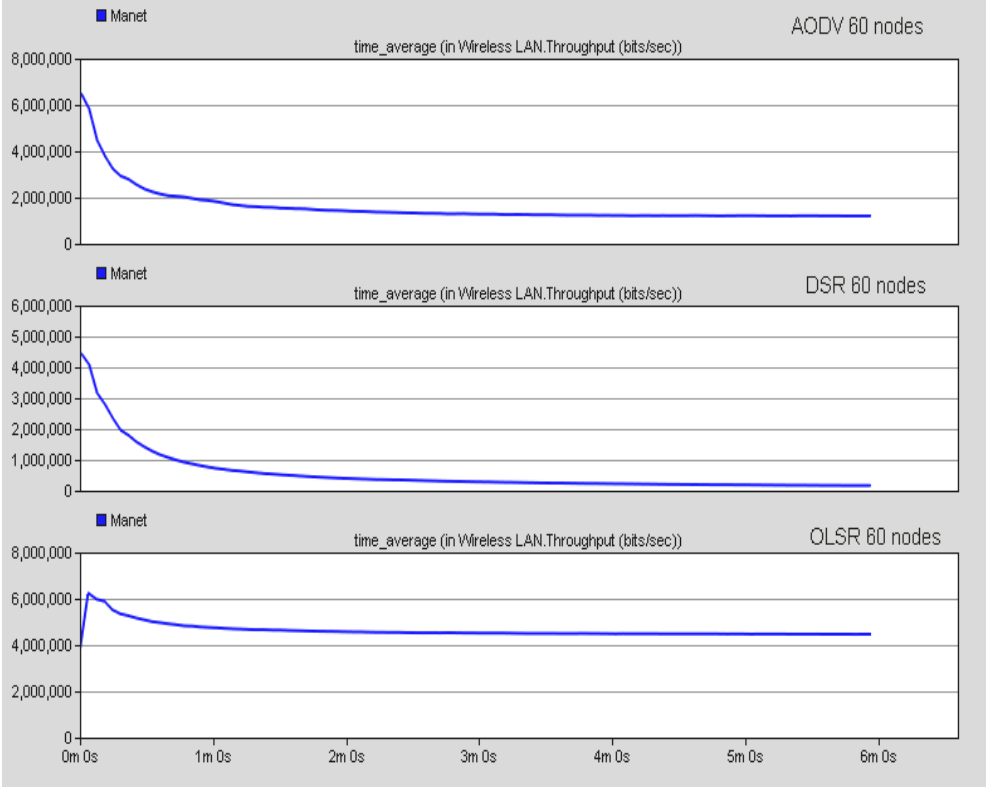

Figure 5. Delay, network load and throughput of OLSR 60 nodes

Figure 5 shows the average network throughput in scale of bit/sec for 60 nodes in AODV, DSR and OLSR routing protocols. Which shows the amount of packets generated at source node and is correctly received by a destination node. High throughput is demanded by MANET and all Wireless LAN networks. The choice of selecting routing protocols can impact on the throughput. Fraction of the channel capacity used for useful transmission is less at the beginning of the simulation so there is a high level of throughput at beginning time and after that because channel capacity is more engaged, there is decrease in throughput. Traffic load which stems from node's exchanged data is generated so as a result throughput is decreased to make its form to a steady level.

Finally it is demonstrated with attention to the simulation among AODV, DSR and OLSR protocols that OLSR routing protocol outperforms compared to other routing protocols in terms of network delay, network load and throughput in 60 mobile nodes and for 15 and 30 nodes there are reasonable and similar trend of network delay, load and throughput like 60 nodes.

It is clear from Figure 3 the network delay of OLSR routing protocol is the lowest among other routing protocol and DSR routing protocol has the highest network delay. AODV routing protocol has the highest value between other routing protocols. The Figure 3, 4 and 5 are demonstrated that OLSR routing protocol has the best perform compare to AODV and DSR with low network delay and high throughput.

7. Conclusion

DSR routing protocol has a reasonable and appropriate average network load in the analysis that was done but DSR also has the largest values in average network delay compared to other routing protocols. AODV performs better than DSR in terms of average network delay and network throughput. From the simulation and analysis, it is perceived that performance of routing protocols vary with network and choosing accurate routing protocols according to the network finally influences the efficiency of that network in an impressive way.

DSR exploits caching aggressively and maintains multiple routes per destination. It is demonstrated that traffic load for these two types of reactive protocol are less than the one which belongs to proactive protocol by the end of this simulation. This paper investigate three different protocols has shown OLSR has better performance in MANET according to the simulation result but is not always the best in the entire network, its performance would effect and change with different type of network and variation on scalability and mobility. Finally choosing accurate routing protocol according to the network can lead to large throughput and efficiency.

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