A Simplified Approach to Analyze Routing Protocols in Dynamic MANET Environment

Satveer Kaur, Jagpal Singh Ubhi

***Abstract-** The fundamental characteristic which differentiates MANETs from other wireless or wired network is mobility and node density. Mobile Wireless Ad Hoc Networks (MANET) is a network without infrastructure, where every node functions as transmitter, router and data sink. Therefore, MANET routing protocols are designed to adaptively cater for dynamic changes in topology while maximizing throughput and packet delivery ratio, and minimizing delay, aggregate good put, average jitter and minimum packet loss. In this paper, the MANET is implemented by using Ad Hoc Demand Vector (AODV), Dynamic Source Routing (DSR), and Dynamic MANET on Demand (DYMO), Optimized Link State Routing (OLSR) and Zone Routing Protocol (ZRP) and simulated on QualNet5.0 simulator. The effect of mobility and density of nodes changing in MANET is investigated and compared a number of reactive, hybrid and proactive routing protocols including AODV, DSR, DYMO, OLSR and ZRP. The simulative study on MANET routing protocols aims to determine the performance of current MANET routing protocols with respect to mobility and node density factors. Results vary when we change the node density. The results of this network are tabulated along with a comprehensive analysis which compares throughput, packet delivery ratio, end to end delay, aggregate good put, average jitter value and packet dropping with node density.*

***Keywords:** MANET, QualNet5.0, AODV, DSR, DYMO, OLSR and ZRP.*

I. INTRODUCTION

In recent years, wireless multi-hop networks such as ad hoc networks, sensor networks and vehicular networks have been very important subject for research. A Mobile Ad Hoc Network (MANET) is a collection of wireless mobile terminals that are able to dynamically form a temporary network without any aid from fixed infrastructure or centralized administration. In recent years, MANET is continuing to attract the attention for their potential use in several fields. In order to ensure effective operation as the total number of nodes in the MANET becomes very large, the overhead of the employed routing algorithms should be low and independent of the total number of nodes in MANET. Mobility, node density and the absence of any fixed infrastructure make MANET very attractive for mobility and rescue operations and time-critical applications. Because of the nodes are free to move randomly, the topology of network may change rapidly and may be unpredictable, which makes the traditional protocol not suitable for MANET.

The Mobility influences ongoing transmissions, since a mobile node that receives and forwards packets may move out of range. The movement pattern of MANET nodes is characterized by mobility models and each routing protocols exhibits specific characteristics of these models [1]. In order to find the most adaptive and efficient routing protocol for dynamic MANET topologies, the behaviour of routing protocols needs to be analyzed at varying node speeds, number of traffic nodes, network size, as well as node density [2] . The above discussion leads us to believe that it is first understand and evaluate the performance of routing protocols in different mobility scenarios before selecting a protocol for a particular scenario. Most previous studies with routing protocols select the Random Waypoint mobility model for simulations. In this paper, we presented the results for various proactive, hybrid and reactive protocols like Ad Hoc On Demand Vector (AODV), Dynamic Source Routing (DSR), Dynamic MANET On Demand (DYMO), Optimized Link State Routing (OLSR) and Zone Routing Protocol (ZRP).The performance analysis is restricted to performance metrics.

II. MANET ROUTING PROTOCOLS: A BRIEF OVERVIEW

MANET routing protocols are IP based and may use unicast, multicast or hybrid approaches and should allow for interaction with standard wired IP services rather than being regarded as a completely separate entity [3]. Figure 1 shows the categorization of different routing protocols of MANET.

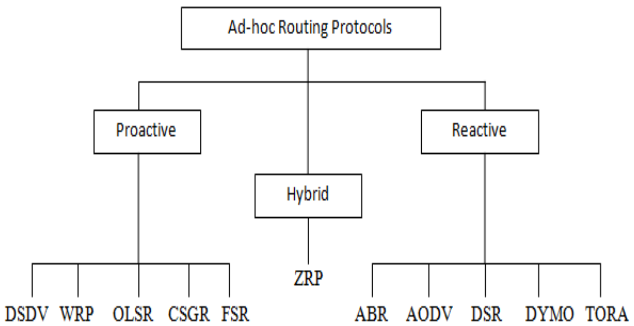

Figure 1: Categorization of Routing Protocols in MANET

A. Reactive Routing Protocols

In reactive (also known as Demand based) routing protocols, a route is discovered only when it needed. Nodes only maintain routes to active destinations. The communication overhead is reduced at the expense of delay due to route search. These protocols are significant for the Adhoc environment since battery power is conserved both by not sending the advertisements and by not receiving [4]. All nodes

Manuscript Received on February 16, 2015.
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maintain the discovered routes in their routing tables. However, only valid routes are kept and old routes are deleted after an active route timeout. A serious issue for MANETs arises when link failures occur due to high node mobility; at the same time new links may also be established between previously distant nodes. This significantly increases the network broadcast traffic with rapid link make/break effect of intermediate nodes. Figure 2 shows the path discovery process for a reactive routing protocol [5].

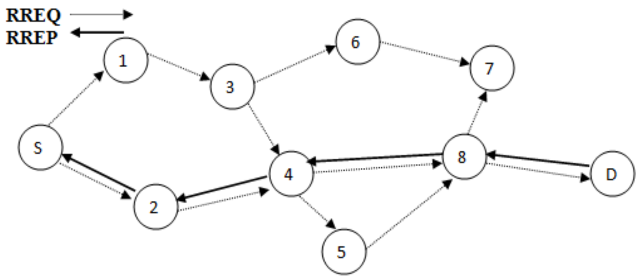

Figure 2: Route Discovery Process

1. Adhoc on Demand Distance Vector (AODV): Adhoc on Demand Distance Vector is a reactive protocol implies that it only requests a route when it needs one and does not require that the mobile nodes maintains routes to destinations that are not communicating [6]. AODV guarantees loop free routes by using sequence numbers that indicate how new, or fresh, a route is. AODV require s each node to maintain a routing table containing one route entry for each destination that the node is communicating with. Each route entry keeps track of certain fields such as Destination IP Address, Destination sequence number, Next Hop, Hop Count. To find a path to a destination a node using AODV broadcasts a route request (RREQ) packet. The RREQ contains the node's IP address, current sequence number, broadcast ID and most recent sequence number for the destination known to the source node. The destination node on receipt of RREQ, unicasts a route reply (RREP) packet along the reverse path established at the intermediate nodes during the route discovery process. In case of a link failure, a route error (RERR) packet is sent to the source and destination nodes. By the use of sequence numbers, the source nodes are always able to find new valid routes [7].

2. Dynamic Source Routing (DSR): Like AODV, DSR establishes a route to the destination when a source node requests one. DSR uses the source routing strategy. It uses source routing which means that the source must know the complete hop sequence to destination. Each node maintains a route cache, where all routes it knows are stored. The route discovery process is initiated only if the desired route cannot be found in the route cache. To limit the number of route requests propagated, a node processes the route request message only if it has not already received the message and its address is not present in the route record of the message.DSR uses source routing, i.e. the source determines the complete sequence of hops that each packet should traverse. This requires that the sequence of hops is included in each packet's header. A negative consequence of this is the routing overhead every packet has to carry. However, one big advantage is that intermediate nodes can learn routes from the source routes in the packets they receive. Since finding a route is generally a costly operation in terms of time, bandwidth and energy, this is a strong argument for using source routing [8]. Another advantage of source routing is that it avoids the need for up-to-date routing information in the intermediate is included in the packets. Finally, it avoids routing loops easily because the complete route is determined by a single node instead of making the decision hop-by-hop [9].

3. Dynamic MANET on Demand (DYMO): DYMO routing protocol enables reactive, multi-hop unicast routing between participating DYMO routers. The basic operations of the DYMO protocol are route discovery and route maintenance. During route discovery, the originator's DYMO router initiates dissemination of a RREQ throughput the network to find a route to the target's DYMO router. During this hop-by-hop dissemination process, each intermediate DYMO router receives the RREQ, it responds with a RREP sent hop-by-hop toward the originator. When the originator's DYMO router receives the RREP, the routes can be established between the originating DYMO router and the target DYMO router in both directions [10]. In order to react to changes in the network topology nodes maintains their routes and monitors their links. When a data packet is received for a route or link that is no longer available for the source of the packet is notified. A Route Error (RERR) is sent to the packet source to indicate that the current route is broken. Once the source receives the RERR, it can perform route discovery if it still has packets to deliver.

B. Proactive Routing Protocols

In proactive schemes, also known as table driven approaches, every node continuously maintains the complete routing information of the network. When a node needs to forward a packet, the root is readily available; thus there is no delay in searching for a root. However for a highly dynamic topology, the proactive schemes spend a significant amount of scarce wireless resources in keeping the complete routing information correct [11]. However, when frequency of link breakage is high, the proactive routing protocols need a higher rate routing table updates, which lower the network performance.

1. Optimized Link state Routing: OLSR employs three mechanisms for routing;(1)periodic HELLO messages for neighbour sensing. (2) control packet flooding using Multi-Point Relay (MPR) and (3) path selection using shortest path first algorithm. Each node, by using its two-hop neighbours is accessible. Nodes then rebroadcasts only those messages that are received from nodes who selected it as an MPR. This mechanism efficiently reduces the broadcast control overhead and thus each node has a partial topology graph of the whole network. Each node selected as an MPR, transmits Topology Control (TC) messages to broadcast its presence to its MPR selector set. TC messages contain originating nodes address and its MPR selector set. Once routes are available to source node, it selects the optimal path using shortest path first algorithm [12].

C. Hybrid Routing Protocols

1. Zone Routing Protocol (ZRP): The Zone Routing Protocol or ZRP combines the advantages of both pro-active

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and re-active protocols into a hybrid scheme, taking advantage of pro-active discovery within a node's local neighbourhood and using a reactive protocol for communication between these neighbourhoods. Both a purely pro-active or purely reactive approach to implement a routing protocol for a MANET has their disadvantages. ZRP is not so much a distinct protocol as it provides a framework for other protocols. The separation of nodes local neighbourhood from the global topology of the entire network allows for applying different approaches. These local neighbourhood are called are called zones. Each node may be within multiple overlapping zones and each zone may be of a different size. The size of the zone is not determined by geographical measurement, but is given by a radius of length ρ, where ρ is the number of hops to the perimeter of the zone. Figure 3 shows an example routing zones with ρ=2.

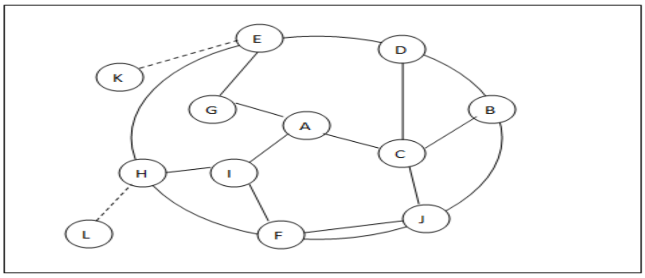

Figure 3: Routing Zone of node A with ρ=2

In above mentioned example, node A has multiple routes to node F, including one that has a hopcount of c> ρ. Since it also has a route with c<= ρ, F still belongs to A's zone. Node G is out of A's zone. The nodes on the perimeter of the zone (i.e. with a hopcount hc= ρ) are referred to as peripheral nodes (E,D,B,J,F,H), node with hc< ρ are interior nodes.

III. RANDOM WAYPOINT MOBILITY MODEL

In mobile adhoc networks, the movement of nodes is characterized by a rate of change of speed and direction. Random Waypoint Model (RWP) is the most widely used and studied mobility model. Its 3-tuple is (V_{max}, T, V_i); where the node velocity is uniformly distributed from 0 to V_{max}, T is the pause time and V_i is the direction or advance vector. In RWP model, a node randomly chooses a destination, called waypoint and moves towards it in a straight line with constant velocity, which is selected randomly from 0 to V_{max}. After reaching the waypoint, the node pauses for some time and then repeats the same procedure. Mathematically, if currently a node is at point d(x-1, y-1) then the next waypoint is given as:

$$d(x, y)=d(x-1,y-1) + V_i$$

However, surveys [13] [14] on mobility models and impact on routing performance verify that the analysis of protocol performance using just Random Waypoint Model is not enough.

IV. PERFORMANCE METRICS

Simulations have been performed in network simulator, QualNet5.0, to determine the impact of density of nodes on performance of routing protocols. We evaluate five MANET protocols (AODV, DSR, DYMO, OLSR, and ZRP) against Random Waypoint Mobility Model. The performance is studied for three types of networks: (1) small networks of 25 to 50 nodes with area 1500 x 1500 m^2, (2) medium size network of 75 nodes with area 1500 x 1500 m^2, and (3) large network of 100 nodes with area 1500 x 1500 m^2. Table 1 shows the simulation parameters.

TABLE 1: Simulation Parameters List

Parameters List		
Experiment Parameter	**Experiment Value**	**Description**
Simulation Time	399 S	Simulation Duration
Terrain Dimension	[1500*1500]m	X,Y Dimension of motion
No. of mobile nodes	25,50,75,100	No. of nodes in a network
Node Placement	Random Waypoint	Change Direction randomly
Mobility Speed	0-10 mps	Mobility of nodes
No. of Connection	8	Connections
Mobility Model	Random	Mobility direction
Routing Protocols	AODV,DSR,DYMO, OLSR,ZRP	Path-finding
MAC Protocol	802.11DCF,802.11MAC	Wireless Protocol

The comparison is drawn by measuring the following performance parameters:

- **Packet Delivery Ratio (PDR)** is defined as the ratio of data packets delivered successfully to destination nodes and the total number of data packets generated for those destinations. PDR characterizes the packet loss rate, which limits the throughput of the network. The higher the delivery ratio better is the performance of the routing protocol. PDR is determined as:

$$PDR= (P_r / P_s) \times 100$$

Where P_r is the total packets received and P_s is the total packets sent. Figure 4 shows the fraction of the originated application data packets each protocol was able to deliver, as a function of nodes. In the above experiment, for DSR and AODV, packet delivery ratio is increase when the number of nodes decreased, with both protocols maximum delivering 17 and 23 of the packets. From these results, a simple conclusion had been made that DSR has a higher packet delivery ratio followed by AODV, DYMO, ZRP and OLSR.

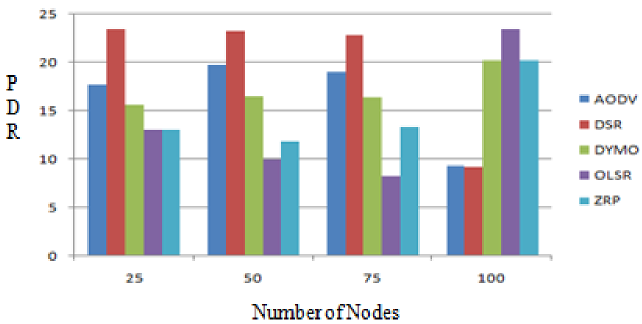

Figure 4: Packet Delivery Ratio

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- **Average End to End Delay** (D_{avg}) indicates that the time taken for a packet to travel from the source node application layer of the destination node. It also includes the route discovery wait time that may be experienced by a node when a route is initially not available. The average end to end delay is computed as:

$$D_{avg} = \Sigma (t_r - t_s) / P_r$$

where t_s is the packet send time and t_r is the packet receive time for the same packet at destination. The average delay increases for all routing protocols as shown in figure 5. It has been shown that DSR, AODV and DYMO have a longer delay compared to OLSR and ZRP. When requesting a new route, DSR first searches the route cache storing routes information it has learned over the past routing discovery stage and has not used the timer threshold to restrict the stale information which may lead to a routing failure, moreover, DSR needs to put the route information not only in the route reply message but also in the data packets which relatively make the data packets longer than before. Both of the two mechanisms make DSR to have a long delay than the rest there [15].

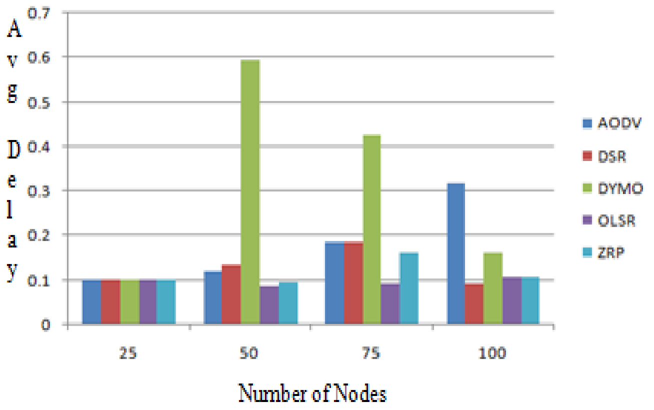

Figure 5: Average End to End Delay

- **Throughput:** It is the average rate of successful message delivery over a communication channel. The average end to end throughput is shown in figure 6 which reflects the usage degree of the network resources for the typical routing protocols. With and offered load of 1 packets/sec, the maximum throughput is approximately 6kbps. Throughput increases quickly for DSR and DYMO with decreased number of nodes. OLSR on the other hand, performs when number of nodes is increased. In detail, when the number of nodes is smaller than or equal to 75, then DSR shows the better throughput characteristic than the other protocols.

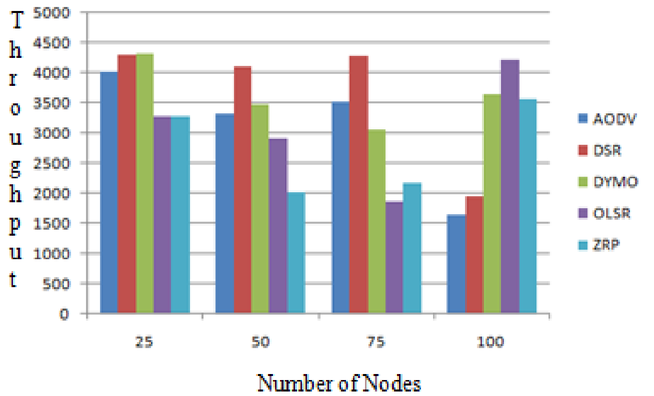

Figure 6: Throughput

- **Average Jitter Value:** It signifies the packets from the source will reach the destination with different delays. A packet's delay varies with its position in the queries of the routers along the path between source and destination as shown in Figure 7.

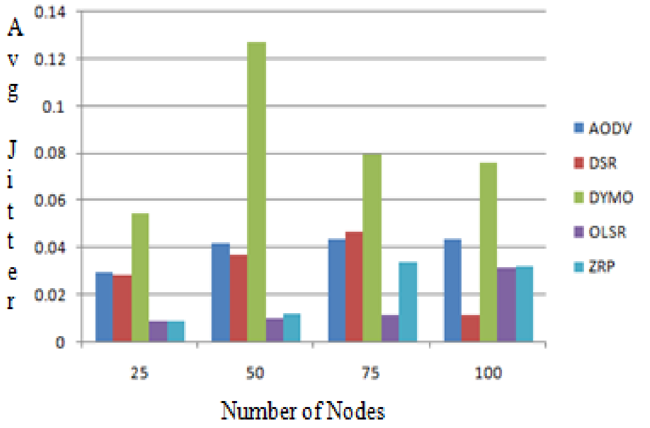

Figure 7: Average Jitter Value

- **Average Packet Loss:** This is the number of packets lost due to incorrect or unavailable routes and MAC layer collisions. Figure 8 shows the relationship between the network size and the average packet dropped of the typical protocols which indicates the reliable degree of each protocol. Except DSR, the rest protocols have lower data dropped of the originated data packets when the network is smaller (with the number of nodes 25, 50, 75). AODV and DYMO perform well, which explains their higher reliability. However, with the number of nodes increasing, the two protocols have a greater packet dropped especially for DSR. With 75 nodes, DSR's average packet dropped comes to 60% nearby.

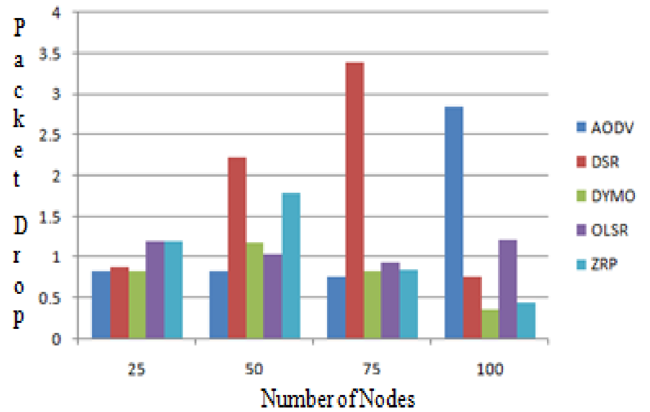

Figure 8: Average Packet Loss

V. RESULTS AND CONCLUSIONS

Every protocol being simulated using the same parameters that had been discussed to ensure the simulation produced accurate results. From the observation, the objective of this project which is to evaluate the QoS performances for five MANET protocols: AODV, DSR, DYMO, OLSR and ZRP are fulfilled. The analysis has been done through simulation using commercial and highly reliable QaulNet5.0 simulator.

These performances metrics considered are the packet delivery ratio, average end to end delay, throughput, average jitter value and packet loss. Table 2, 3, 4 & 5 summarised the performances comparison of five routing protocols for mobile ad hoc networks. "1" denotes for the best performance while "5" for the worst performance.

Table 2: Performance Comparison with 25 nodes

Metrics	Protocols				
	AODV	DSR	DYMO	OLSR	ZRP
Packet Delivery Ratio	2	1	3	4	4
Average end to end delay	1	1	1	1	1
Throughput	3	2	1	4	4
Average jitter	4	3	5	1	1
Packet Loss	1	2	1	3	3

Table 3: Performance Comparison with 50 nodes

Metrics	Protocols				
	AODV	DSR	DYMO	OLSR	ZRP
Packet Delivery Ratio	2	1	3	5	4
Average end to end delay	3	4	5	1	2
Throughput	3	1	2	4	5
Average jitter	4	3	5	1	2
Packet Loss	1	4	3	2	3

Table 4: Performance Comparison with 75 nodes

Metrics	Protocols				
	AODV	DSR	DYMO	OLSR	ZRP
Packet Delivery Ratio	2	1	3	5	4
Average end to end delay	3	4	5	1	2
Throughput	2	1	3	5	4
Average jitter	3	4	5	1	2
Packet Loss	1	5	2	4	3

Table 5: Performance Comparison with 100 nodes

Metrics	Protocols				
	AODV	DSR	DYMO	OLSR	ZRP
Packet Delivery Ratio	3	4	2	1	2
Average end to end delay	5	1	4	2	3
Throughput	5	4	2	1	3
Average jitter	4	1	5	2	3
Packet Loss	5	3	1	4	2

In this paper, we have analyzed the behaviour of MANET routing protocols under Random Waypoint Model. The results of our extensive QualNet5.0 simulations clearly indicate the significant impact that node mobility pattern has on routing performance. We observe that an increase in node density has different impact on all routing protocols under various mobility patterns, i.e. a degradation of the network performance. However, the degree of degradation varies for different combinations of protocols. The performance of RWP model provides a baseline to judge the quality of routing protocols when there is no group movement. The work done in this research aims to develop an understanding of the effects of mobility pattern on routing performance. In future, we intend to study mobility models to determine the MANET protocol best suited to military mobile adhoc networks.

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