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To Analyze MANET Routing Protocol using Mobility Model

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Abstract: **A wireless Ad-Hoc network [7, 8] is a collection of mobile/semi mobile nodes with no pre-established infrastructure forming a temporary network. Each of the nodes has a wireless interface and communicates with each other over either radio or infrared media. Laptop computers and personal digital assistances (PDAs) that communicate directly with each other. Nodes in the Ad-Hoc network are often mobile, but can also consist of stationary nodes, such as access points to the Internet. Semi-mobile nodes can be used to deploy relay points in areas where relay points might be needed temporarily. The mobile nodes can receive and forward packets as a router. Routing is a critical issue in MANET. Therefore focus in this paper is to compare the performance of three routing protocols AODV,DSDV and OLSR for wireless ad hoc networks in a simulated environment using Random Waypoint (RW) Mobility Model, Freeway (FW) Mobility Model, Manhattan Grid (MH) Mobility Model and Reference Point Group (RPGM) Mobility Model against different parameters considering UDP as the transport protocol with CBR as traffic generator for by varying no. of nodes in terms of packet delivery ratio, end to end delay, routing overhead and throughput.**

Keywords: MANET, IETF, DSDV, OLSR, AODV, DSR, PDA, FSR, GSR, MPR, TC.

I. INTRODUCTION

A wireless network is a growing new technology that will allow users to access services and information electronically, irrespective of their geographic position. Wireless networks [3] can be classified in two types:

- Infrastructure based network
- Infrastructure less (ad hoc) networks.

Infrastructure based networks

Infrastructure based network consists of a network with fixed and wired gateways [4,5]. A mobile host interacts with a bridge in the network (called base station) within its communication radius. The mobile unit can move geographically while it is communicating. When it goes out of range of one base station, it connects with new base station and starts communicating through it. This is called handoff. In this approach the base stations are fixed.

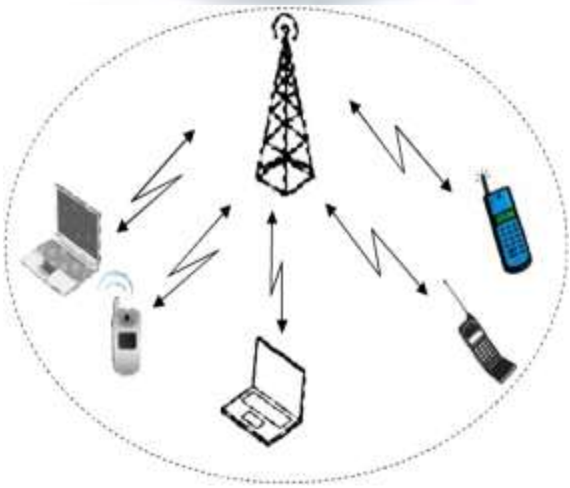

Figure 1.1: Infrastructure based network

Infrastructure less Networks

A Mobile ad hoc network is a group of wireless mobile computers (or nodes); in which nodes collaborate by forwarding packets for each other to allow them to communicate outside range of direct wireless transmission. Ad hoc networks require no centralized administration or fixed network infrastructure such as base stations or access points, and can be quickly and inexpensively set up as needed [5,6].

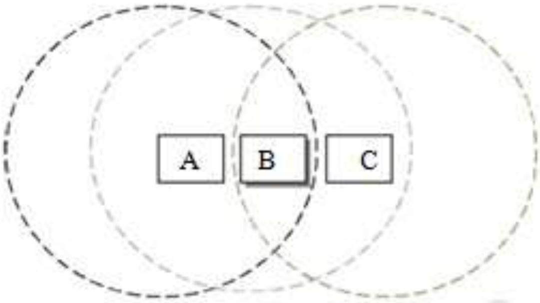

Figure 1.2: Infrastructure less Network

Infrastructure less network is a collection of independent mobile nodes that can communicate to each other via radio waves. The mobile nodes can directly communicate to those nodes that are in radio range of each other, whereas others nodes need the help of intermediate nodes to route their packets. These networks are fully distributed, and can work at any place without the aid of any infrastructure. This property makes these networks highly robust. Ad-hoc networks are highly dynamic in nature since they can form and deform quickly, without the need for any infrastructure setup and system administration. They can be deployed anytime and anywhere (indoors and outdoors), be it at battlefields or conference rooms.

An Ad-Hoc network uses no centralized administration. This is to ensure that the network will not collapse just because one of the mobile nodes moves out of the transmission range of the others. Nodes should be able to enter/leave the network as they wish. Because of the limited transmitter range of the nodes, multiple hops may be needed to reach other nodes. Ad-Hoc networks are also capable of handling topology changes and malfunctions in nodes. It is fixed through network reconfiguration. For instance if a node leaves the network and causes link breakages delay, both the network will still be operational.

The attributes [9] of these networks are summarized as follows:

- Communication via wireless means.
- Nodes can perform the roles of both hosts and routers.
- Bandwidth-constrained, variable capacity links.
- Energy-constrained Operation.
- Limited Physical Security.
- Dynamic network topology.
- Frequent routing updates.

Routing in MANET

Mobile Ad-hoc networks are self-organizing and self-configuring multihop wireless networks, where the structure of the network changes dynamically. This is mainly due to the mobility of the nodes. Nodes in these networks utilize the same random access wireless channel, cooperating in an intimate manner to engaging themselves in multihop forwarding. The node in the network not only acts as hosts but also as routers that route data to/from other nodes in network [15]. In mobile ad-hoc networks there is no infrastructure support as is the case with wireless networks, and since a destination node might be out of range of a source node transferring packets; so there is need of a routing procedure. This is always ready to find a path so as to forward the packets appropriately between the source and the destination. Within a cell, a base station can reach all mobile nodes without routing via broadcast in common wireless networks.

The properties that are desirable in Ad-Hoc Routing protocols are [13]:

i). Distributed operation: The protocol should be distributed. It should not be dependent on a centralized controlling node. This is the case even for stationary networks. The dissimilarity is that the nodes in an ad-hoc network can enter or leave the network very easily and because of mobility the network can be partitioned.

ii). Loop free: To improve the overall performance, the routing protocol should assurance that the routes supplied are loop free. This avoids any misuse of bandwidth or CPU consumption.

iii). Demand based operation: To minimize the control overhead in the network and thus not misuse the network resources the protocol should be reactive. This means that the protocol should react only when needed and should not periodically broadcast control information.

iv). Unidirectional link support: The radio environment can cause the formation of unidirectional links. Utilization of these links and not only the bi-directional links improves the routing protocol performance.

v). Security: The radio environment is especially vulnerable to impersonation attacks so to ensure the wanted behavior of the routing protocol we need some sort of security measures. Authentication and encryption is the way to go and problem here lies within distributing the keys among the nodes in the ad-hoc network.

vi). Power conservation: The nodes in the ad-hoc network can be laptops and thin standby mode to save the power. It is therefore very important that the routing protocol has support for these sleep modes.

vii) Multiple routes: To reduce the number of reactions to topological changes and congestion multiple routes can be used. If one route becomes invalid, it is possible that another stored route could still be valid and thus saving the routing protocol from initiating another route discovery procedure.

viii). Quality of Service Support: Some sort of Quality of service is necessary to incorporate into the routing protocol. This helps to find what these networks will be used for. It could be for instance real time traffic support.

The following are the problems of routing in MANET [12]:

i). Asymmetric links: Most of the wired networks rely on the symmetric links which are always fixed. But this is not a case with ad-hoc networks as the nodes are mobile and constantly changing their position within network

ii). Routing Overhead: In wireless ad hoc networks, nodes often change their location within network. So, some stale routes are generated in the routing table which leads to unnecessary routing overhead.

iii). Interference: This is the major problem with mobile ad-hoc networks as links come and go depending on the transmission characteristics, one transmission might interfere with another one and node might overhear transmissions of other nodes and can corrupt the total transmission.

iv). Dynamic Topology: Since the topology is not constant; so the mobile node mightmove or medium characteristics might change. In ad-hoc networks, routing tables must somehow reflect these changes in topology and routing algorithms have to be adapted. For example in a fixed network routing table updating takes place for every 30sec. This updating frequency might be very low for ad-hoc networks.

II. REVIEW OF EXISTING ROUTING PROTOCOLS OF AD HOC NETWORKS

Routing is a difficult problem in a MANETs. A lot of solutions have been proposed trying to address a sub-space of the problem domain. Because of complexity and diversity, Internet Engineering Task Force (IETF) has not determined a standard of routing. Figure 2.1 shows the classification of Routing Protocols in MANETs. It is clear from the diagram that we can classify the MANET routing protocols into two major categories [14, 15, 16].

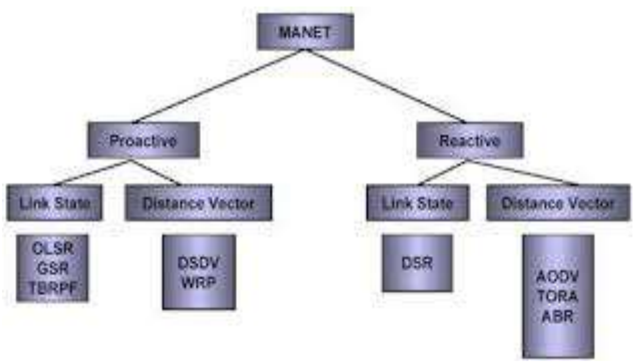

Fig 2.1 Classification of routing protocol

1. **Proactive routing protocol**
2. **Reactive routing protocol.**

1. Proactive Routing Protocols

Proactive MANET protocols are also called as table-driven protocols and will actively determine the layout of the network. Through a regular exchange of network topology packets between the nodes of the network, at every single node an absolute picture of the network is maintained. There is hence minimal delay in determining the route to be taken. This is especially important for time-critical traffic [16, 17].

When the routing information becomes worthless quickly, there are many short-lived routes that are being determined and not used before they turn invalid. Therefore, another drawback resulting from the increased mobility is the amount of traffic overhead generated when evaluating these unnecessary routes. This is especially altered when the network size increases. The portion of the total control traffic that consists of actual practical data is further decreased. Lastly, if the nodes transmit infrequently, most of the routing information is considered redundant. The nodes, however, continue to expend energy by continually updating these unused entries in their routing tables as mentioned, energy conservation is very important in a MANET system design. Therefore, this excessive expenditure of energy is not desired. Thus, proactive MANET protocols work best in networks that have low node mobility or where the nodes transmit data frequently. Examples of Proactive MANET Protocols include [14]:

- Optimized Link State Routing (OLSR)
- Fish-eye State Routing (FSR)
- Destination-Sequenced Distance Vector (DSDV)
- Cluster-head Gateway Switch Routing Protocol (CGSR)

Advantage: route to a destination is always available; there is no initial delay when a route is needed. Disadvantage: high overhead; slow to converge.

Destination-Sequenced Distance-Vector Routing (DSDV)

Destination-Sequenced Distance-Vector Routing protocol [17, 18] is a table-driven algorithm based on the classical Bellman-Ford routing mechanism. The improvements made to the Bellman-Ford algorithm include freedom from loops in routing tables. Every mobile node in the network maintains a routing table in which all of the possible destinations within the network and the number of hops to each destination are recorded. DSDV tags each route with a sequence number and considers a route r more favorable than r’ if r has a greater sequence number or if both have the same sequence number but r has a lower metric (hop count). Each node in the network advertises a monotonically increasing even sequence number for itself.

- New updates are sent as even numbers.
- Broken links are sent as odd numbers (one higher than sent by D).
- Information travels fast, and used by all nodes to detect that it is broken.

Each of these broadcasts should fit into a standard size NPDU, thereby decreasing the amount of traffic generated. The mobile nodes maintain an additional table where they store the data sent in the incremental routing information packets. New route broadcasts contain the address of the destination, the number of hops to reach the destination, the sequence number of the information received regarding the destination, as well as a new sequence number unique to the broadcast. The route labeled with the most recent sequence number is always used. In the event that two updates have the same sequence number, the route with the smaller metric is used in order to optimize (shorten) the path. Mobiles node also keep track of the settling time of routes, or the weighted average time that routes to a destination will fluctuate before the route with the best metric is received. By delaying the broadcast of a routing update by the length of the settling time, mobiles node can reduce network traffic and optimize routes by eliminating those broadcasts that would occur if a better route were discovered in the very near future.

Optimized Link State Routing (OLSR)

OLSR [19, 20] is a proactive IP routing protocol for mobile ad hoc networks. It can also be implemented in any ad hoc network. Lately, it is also used in WiMAX Mesh (Backhaul). OLSR is classified as proactive due to its nature. Nodes in the network use topology information derived from HELLO packets and Topology Control (TC) messages to discover their neighbors. Not all nodes in the network route broadcast packets. Only Multipoint Relay (MPR) nodes route broadcast packets. Routes from the source to the intended destination are built before use. Each node in the network keeps a routing table. This makes the routing overhead for OLSR higher than any other reactive routing protocol such as AODV or DSR. However, the routing overhead does not increase with the number of routes in use since there is no need to build a new route when needed. This reduces the route discovery delay.

In OLSR, nodes send HELLO messages to their neighbors at a predetermined interval. These messages are periodically sent to determine the status of the links. For example, if node X and node Y are neighbors, node X sends the HELLO message to node Y. If node Y receives the message, the link is said to be asymmetric. The same holds true for the HELLO message sent by node Y to node X. If the two-way communication is possible, the link is symmetric as shown in Figure 2.2 below. These HELLO messages contain all the information about all their neighbors. This makes a node in the network build a table with information about its multiple hop neighbors. In addition, once these symmetric connections are made, a node chooses a minimal number of MPR nodes that broadcast TC messages with link status information at a predetermined TC interval. A TC message contains information about which MPR node each node in the network has selected. TC messages also handle the calculation of routing tables.

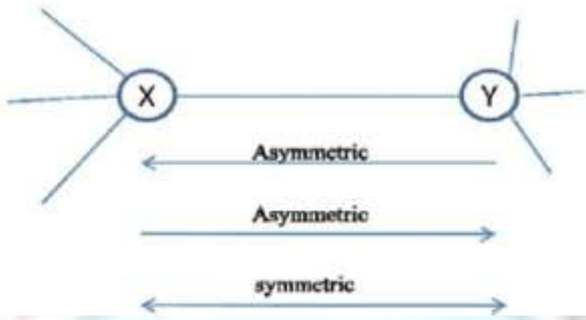

Figure 2.2 HELLO messages in MANET using OLSR routing protocol

2. Reactive Routing Protocols

Portable nodes- Notebooks, palmtops or even mobile phones usually compose wireless ad-hoc networks. This portability also brings a significant issue of mobility. This is a key issue in ad-hoc networks. The mobility of the nodes causes the topology of the network to change constantly. Keeping track of this topology is not an easy task, and too many resources may be consumed in signaling. Reactive routing protocols were intended for these types of environments. These are based on the design that there is no point on trying to have an image of the entire network topology, since it will be constantly changing. Instead, whenever a node needs a route to a given target, it initiates a route discovery process on the fly, for discovering out a pathway [15, 16].

The different types of On Demand driven protocols are [14]:

- Ad hoc On Demand Distance Vector (AODV)
- Dynamic Source routing protocol (DSR)
- Temporally ordered routing algorithm (TORA)
- Associatively Based routing (ABR)
- Signal Stability-Based Adaptive Routing (SSA)
- Location-Aided Routing Protocol (LAR)

Advantage: less overhead due to “route-messages”.
Disadvantage: source must wait until route is discovered

Ad hoc On-demand Distant Vector Routing (AODV)
The Ad Hoc On-demand Distance Vector Routing (AODV) protocol [21, 22] is a reactive unicast routing protocol for mobile ad hoc networks. As a reactive routing protocol, AODV only needs to maintain the routing information about the active paths. In AODV, routing information is maintained in routing tables at nodes. Every mobile node keeps a next-hop routing table, which contains the destinations to which it currently has a route. A routing table entry expires if it has not been used or reactivated for a pre-specified expiration time. Moreover, AODV adopts the destination sequence number technique used by DSDV in an on-demand way.

In AODV, when a source node wants to send packets to the destination but no route is available, it initiates a route discovery operation. In the route discovery operation, the source broadcasts route request (RREQ) packets (Figure 2.3). A RREQ includes addresses of the source and the destination, the broadcast ID, which is used as its identifier, the last seen sequence number of the destination as well as the source node’s sequence number. Sequence numbers are important to ensure loop-free and up-to-date routes. To reduce the flooding overhead, a node discards RREQs that it has seen before and the expanding ring search algorithm is used in route discovery operation. The RREQ starts with a small TTL (Time-To-Live) value. If the destination is not found, the TTL is increased in following RREQs.

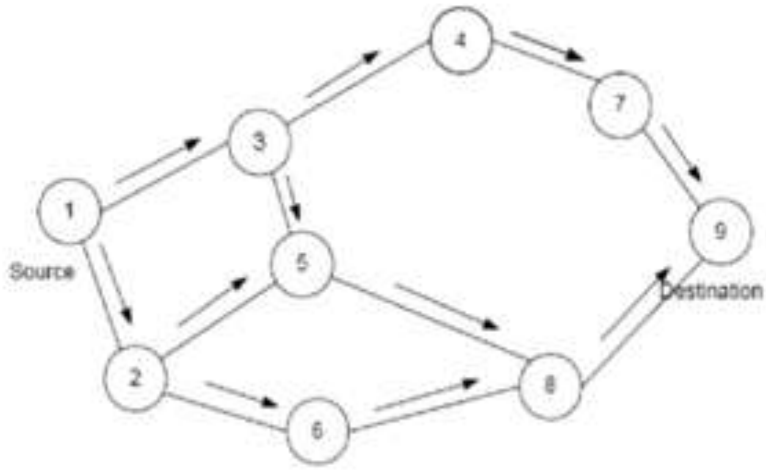

Figure 2.3: The Route Request packets flooding in AODV

III. OBJECTIVE

The ad hoc routing protocols can be broadly divided into two classes: Table driven routing protocols and On-Demand routing protocols. The primary objective of the current research work is to compare the performance of three MANET routing protocols (Destination-Sequenced Distance-Vector (DSDV), Optimized Link State Routing (OLSR) and Ad-hoc On-Demand Distance-Vector (AODV) protocol) using various mobility models (Random Way Point Mobility Model (RWP), Reference Point Group Mobility Model (RPGM), Freeway Mobility (FW) Model and Manhattan Grid Mobility (MG) Model). The performance differentials are analyzed using varying node mobility, network load, maximum speed and types of traffic (CBR). This evaluation is to be carried out through exhaustive literature review and simulation using Network Simulator (NS-2.34) under Linux (Red Hat) environment.

The main objectives of the research work are as under:

- To have understanding of Mobile Ad Hoc Networks.
- To understand and implement the various Mobility Models.
- Implement and analyze the performance of Reactive and Proactive MANET routing protocols with varying network loads and various type of traffics (CBR).

IV. SIMULATION

According to dictionary, Simulation can be defined as — reproduction of essential features of something as an aid to study or training. In simulation, we can construct a mathematical model to reproduce the characteristics of a phenomenon, system, or process often using a computer in order to information or solve problems. Nowadays, there are many network simulators that can simulate the MANET. In this section we will introduce the most commonly used simulators.

Simulation Environment

NS-2 is both compatible for Linux and Window environment. There is a UNIX emulator (such as Cygwin) required to be installed on the Windows system before installing the NS software. We require a hard disk of around 70-80GB to store the simulation files. This was chosen on the fact that simulation of 50-100 nodes run for a simulation time of 900 seconds for DSDV, OLSR and AODV could generate a NAM file of about 200-350 MB and TRACE file of around 400-450 MB. The average time taken for each simulation of 50 nodes is about 20-25 minutes.

Architecture of NS

NS-2 [41, 42, 43, 44] is an event driven network simulator that simulates variety of IP networks. NS was developed for network research and for providing support for network simulation in Ad hoc networks.

Table 4.1: Comparison of the three simulators

Simulators	Free	Open Source	Programming Language
NS-2	Yes	Yes	C++, TCL
GloMoSim	Limited	Yes	Parsec
OPNET Modeler	No	No	C

The NS simulator is a tool that is used to simulate the Ad hoc networks for different loads, topologies and for implementing different protocols. The NS simulator is written in two languages C++ and a script language called OTcl. NS version consists of two major parts:

- An OTcl (Object Oriented Tcl) interpreter
- A C++ library

Mobility Models

To evaluate the performance of a protocol for an ad-hoc network, it is necessary to test the protocol under realistic conditions, especially including the movement of the mobile nodes. Survey of different mobility models [27] [46] [47] have been done. This includes the Random Waypoint (RW) Mobility Model, Reference Point Group Mobility (RPGM) Model, Freeway Mobility (FW) Model and Manhattan Grid (MH) Mobility Model that is used in our work. Mobility models are used in NS2 to generate the node movement scenario and such scenario can be generated by software called Mobility Generator which is based on a frame work called Important (Impact of Mobility Patterns on Routing in Ad-hoc NeTwork, from University of Southern California [46]) [48, 49], which upon inputs of number of nodes, mobility model and scale (area) generates the TCL script for mobility. Background traffic, using TCL script is also employed along with the traffic, which we have monitored. These mobility generator tools are used to generate a rich set of mobility scenarios used to evaluate the protocol performance in Mobile Ad Hoc Network. The tools include the Reference Point Group Mobility (RPGM) model, Freeway (FW) Mobility Model and Manhattan Grid (MH) Mobility Model.

Different mobility models can be differentiated according to their spatial and temporal dependencies.

- Spatial dependency: It is a measure of how two nodes are dependent in their motion. If two nodes are moving in same direction then they have high spatial dependency.
- Temporal dependency: It is a measure of how current velocity (magnitude and direction) are related to previous velocity. Nodes having same velocity have high temporal dependency.

V. PERFORMANCE METRICS

Different performance metrics are used in the evaluation of routing protocols. They represent different characteristics of the overall network performance. RFC2501 [9] describe a number of quantitative metrics that can be used for evaluating the performance of MANET routing protocols. The following metrics are used in my research work for evaluating the performance of routing protocols (AODV, DSDV & OLSR) for various mobility models:

Packet Delivery Fraction:

Packet Delivery Fraction (PDF) is the ratio between the number of packets transmitted by a traffic source and the number of packets received by a traffic sink. It measures the loss rate as seen by transport protocols and as such, it characterizes both the correctness and efficiency of ad hoc routing protocols. It represents the maximum throughput that the network can achieve. A high packet delivery ratio is desired in a network.

PDF = (Pr/Ps)*100

Where Pr is total Packet received & Ps is the total Packet sent.

Routing Overhead:

It is the total number of control or routing (RTR) packets generated by routing protocol during the simulation. All packets sent or forwarded at network layer is consider routing overhead. Mobile ad hoc networks are designed to be scalable. As the network grows, various routing protocols perform differently. The amount of routing traffic increases as the network grows. An important measure of the scalability of the protocol, and thus the network, is its routing overhead. It is defined as the total number of routing packets transmitted over the network, expressed in bits per second or packets per second. Some sources of routing overhead in a network are cited in [53] as the number of neighbors to the node and the number of hops from the source to the destination. Other causes of routing overhead are network congestion and route error packets.

Mobile nodes are faced with power constraints and as such, power saving is a major factor to consider in implementation of MANETs. Furthermore, radio power limitations, channel utilization and network size are considered. These factors limit the ability of nodes in a MANET to communicate directly between the source and destination. As the number of nodes increases in the network, communication between the source and destination increasingly relies on intermediate nodes. Most routing protocols rely on their neighbors to route traffic and the increase in the number of neighbors causes even more traffic in the network due to multiplication of broadcast traffic.

Contention for transmission slots among various nodes in a MANET also become more pronounced as the network grows. The frequency of broadcasts is increased due to frequent link failures caused by node mobility. How effective a routing protocol is in dealing with these challenges under the constraints of network congestion and low bandwidth is therefore paramount in MANETs. Routing overhead is thus used as a measure to gauge the effectiveness of routing protocols.

Overhead = Number of RTR packets

Normalized Routing Load:

Number of routing packets “transmitted” per data packet “delivered” at destination. Each hop-wise transmission of a routing is counted as one transmission. It is the sum of all control packet sent by all node in network to discover and maintain route

.

NRL = Routing Packet/Received Packets

Average End-to-End Delay (second):

The packet end-to-end delay is the average time that packets take to traverse the network. This is the time from the generation of the packet by the sender up to their reception at the destination’s application layer and is expressed in seconds. It therefore includes all the delays in the network such as buffer queues, transmission time and delays induced by routing activities and MAC control exchanges.

Various applications require different levels of packet delay. Delay sensitive applications such as voice require a low average delay in the network whereas other applications such as FTP may be tolerant to delays up to a certain level. MANETs are characterized by node mobility, packet retransmissions due to weak signal strengths between nodes, and connection tearing and making. These cause the delay in the network to increase. The end-to-end delay is therefore a measure of the how well a routing protocol adapts to the various constraints in the network and represents the reliability the routing protocol.

$D = (T_r - T_s)$

Where Tr is receive Time and Ts is sent Time.

Packet Loss:

It occurs when one or more packets fail to reach to their destination.

Packet Loss % = (1-Pr/Ps)*100

Where Pr is total number of Received Packets and Ps is total number of Sent Packets.

Throughput (packet/second):

It is the rate at which network send or receive data. The ratio of the total amount of data that reaches a receiver from a sender to the time it takes for the receiver to get the last packet is referred to as throughput [54]. It is expressed in bits per second or packets per second. Factors that affect throughput in MANETs include frequent topology changes, unreliable communication, limited bandwidth and limited energy [54]. A high throughput network is desirable.

Throughput = Pr/Pf

Where Pr is the total number of Received Packets and Pf is the total number of Forwarded Packets.

VI. CONCLUSIONS

In this research, we have compared three MANET routing protocols, namely, Ad hoc On-Demand Distance Vector (AODV), Destination Sequence Distance Vector (DSDV) and Optimized Link State Routing (OLSR) with respect to packet delivery ratio, routing overhead, normalized routing load, average end-end delay, packet loss and throughput using Random Waypoint (RWP) Mobility Model, Freeway (FW) Mobility Model, Manhattan Grid (MH) Mobility Model and Reference Point Group (RPGM) Mobility Model considering UDP as transport protocols with CBR as traffic generator. The performance comparison are carried out using various Mobility Models, network load and type of traffic (CBR) with respect to maximum speed. Simulation results indicate that for CBR traffic, AODV (Reactive) routing protocol performed significantly better than DSDV and OLSR (Proactive) routing protocols in all assumed conditions, but at the cost of higher routing overhead cost and real time delivery of packet, whereas throughput and routing overhead is better of DSDV in this type of traffic. Routing overhead of DSDV is always low as compared to AODV and OLSR in both type of traffic (CBR). Throughput of Proactive (DSDV and OLSR) routing protocols is always better than Reactive (AODV) routing protocol. Therefore OLSR and DSDV are well suited for high capacity networks.

From this research work, we concluded that among the protocols considered, there is no single one with an overall superior performance. One protocol may be superior in terms of routing overhead while other may be superior in terms of packet delivery ratio, average end-end delay or throughput. The choice of a particular routing protocol will depend on the intended use of the network. Factor considering in this research affecting the performance of MANET protocols are network load and speed. Network load has a profound effect on the performance where speed affects the performance only in some instances. Generally, Proactive routing protocol not perform well in CBR traffic and in high capacity links, where Reactive routing protocol gives better result in CBR traffic and in low capacity network. Finally, whether a routing protocol is proactive or reactive, has profound effects on how the performance of protocols in various scenarios. The simulation results also suggest that all considered MANET routing protocols with Reference Point Group (RPGM) Mobility Model has optimized results for varying network load and type of traffic (CBR) followed by Random Waypoint (RWP) Mobility Model, Manhattan Grid (MH) Mobility Model and Freeway (FW) Mobility Model.

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