Performance Comparison of Multihop Wireless ADHOC Routing Protocols AODV, OLSR & TORA

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Abstract— **A mobile adhoc network can be defined as the collection of nodes which can move from one place to other and the network can be formed without any pre-existing network infrastructure. Since nodes are mobile so primary objective of the routing protocol is to create and maintain routes for the correct and efficient data transfer between the nodes in a timely manner. The nodes use radio frequency communication among them for any type of data transmission. The data transmission between these mobile nodes is carried out without any centralized work station. The flexibility with which the formation of these mobile adhoc networks (MANET) can be steered, makes them highly desirable for the present day multimedia communications. This paper is a comprehensive performance evaluation of network parameters throughput, end to end delay and packet delivery ratio on the basis of mobility of nodes, number of nodes, transmission power of nodes and size of the data packets using three commonly used MANET routing protocols Adhoc On-Demand Distance Vector (AODV), Optimized Link State Routing(OLSR) and Temporary Ordered Routing Algorithm(TORA). OPNET ver 14.0 simulator has been used for the extensive performance comparison of above mentioned protocols.**

***Index Terms*—AODV, OLSR, TORA, Throughput, Route Discovery Time, MANET**

I. INTRODUCTION

The era of wireless network came into existence in 1970 when computers were very bulky and any communication used to happen by wired network. During 90`s when laptop revolutionize the computer industry , the necessity of a new network infrastructure being felt in which nodes are light weight and can move from one place to other, without depending on any central entity for bi-directional data transmission. This type of network [1] in which nodes are mobile and can be set up without any wires, without any communication infrastructure and no administrative intervention is required is called mobile adhoc network(MANET). The main challenging issue [2] in designing a MANET are: (i) Dynamic topology of the network (ii) Energy constraint of nodes (iii) Prone to eavesdropping (iv) Network partition (scalability)

So designing a routing protocol for such type of highly vulnerable environment is a cumbersome task as compared to wired network. Recently more attention is being paid to increase the quality of service (QoS) parameters [3], [4] of the network like throughput , average end to end delay and packet delivery ratio. Many routing protocols are available for the data transmission in MANET. An extensive research is being done to select the best routing protocol regarding dynamic topology change, mobility of nodes, transmission power of nodes and number of nodes in the network with reasonable degradation of network parameters.

Mobile Adhoc Network: The topology of adhoc network can be well understood by graph theory [5] G = (N,L) here N represents no. of mobile nodes in MANET, L = set of wireless connection between any two nodes . Each node has a wireless transmission range r depending on the wireless channel characteristic as well as on the transmission power of node.

Any wireless connections $(i, j) \in L$ between two nodes (X,Y) will exist if and only if $d(N_i, N_j) \le r$

All the neighbors of node n can be defined mathematically

$$N_r(n) = \{N_n \mid d(n,x_p) \le r, n \ne x_p, \forall p \in N, p \le| N |\}$$

Where d is a distance function and for two dimensional plane

$$d = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$$

Any path [6] between two nodes i, j is a sequence of nodes P_{ij} = $(n_i,n_1,n_2,\ldots\ldots\ldots\ldots\ldots\ldots..n_j)$ where (n_i,n_1), $(n_1,n_2)\ldots\ldots\ldots\ldots\ldots\ldots\ldots..$ and (n_y,n_{y+1}) for $1 \le y \le K-1$ are wireless connection, with no node being repeated more than once.

Due to the mobility of nodes, set of wireless links between any two nodes and the distance change with time, so always new links are replaced by older one to provide connectivity.

Paper Outline The rest of the paper is organized as follows: Section II provides the broad classification of the MANET routing protocols. Section III describes the relevant literature survey of the protocols and their operation. Review of the paper shows that no detailed analysis and comparison of the protocols taken for simulation have been done so far. Section IV gives the overview of the routing

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protocols used for simulation. Section V has the simulation statistics and the results obtained for various scenarios. Finally section VI concludes the paper and presents the findings of the whole research in a lucid manner achieved through extensive study and simulation.

II. ROUTING PROTOCOLS

Routing Protocols: Routing protocols for MANET can be broadly classified into three category:

A. *Proactive or Table Driven Routing Protocols*

In proactive routing , every node maintains a list of path for every destination available in network in advance. Nodes send Hello message periodically to check the connectivity information via intermediate nodes. So if a route already exist between any two nodes, data communication can start without any delay otherwise traffic packet should wait in buffer until node finds a path for concerned destination. A lot of network resources like bandwidth and energy of nodes consume only in maintaining routes. So this approach is not suitable for highly dynamic network scenario.

e.g. Destination Sequence Distance Vector (DSDV) [16], Fisheye State Routing (FSR), Wireless Routing Protocol (WRP), Optimized Link State Routing(OLSR) [10] and Cluster Head Gateway Switch Routing (CGSR).

B. *On Demand Routing Protocols (Reactive)*

In contrast to proactive approach, on demand routing [7] is based on route acquisition theory only when a node wants to communicate with other node. Source node initiates path discovery process by broadcasting route request (RREQ) packet to its neighbors which in turn retransmit RREQ packet up to final destination node. Once route discovery process is completed, it is maintained until data transfer is complete either destination or any intermediate node changes its location. A route discovery process is needed for every unknown destination. So communication overhead is reduced at the cost of latency in path finding process.

e.g. Adhoc On Demand Distance Vector (AODV) [8], Dynamic Source Routing (DSR), Cluster Based Routing Protocol (CBRP), Assosciativity Based Routing (ABR), Location Aided Routing(LAR).

C. *Hybrid Routing Protocols*

In this section we discuss the working of routing protocols termed as hybrid routing protocols. Here each node maintains the network topology information upto m hops. In this type of routing protocol, node can simultaneously support both source initiated on-demand routing for some destination and destination initiated proactive routing for other destinations.

e.g. Zone Routing Protocol(ZRP), Zone Based Hierarchical Link State Routing(ZHLS), Temporary Ordered Routing Algorithm(TORA) [12], Core Extraction Distributed Adhoc Routing (CEDAR).

III. LITERATURE REVIEW

In [1] Internet Engineering Task Force(IETF) has defined mobile adhoc network in its very original form and its properties. In [5] Gupta et al. have compared MANET protocols AODV, DSR and TORA for network characteristic average end to end delay and packet delivery ratio for different pause time duration. 50 node model has been deployed in the simulation with number of source varies in the network from 10, 20 and 50.

In [8] C.E.Perkins and E.M.Royer proposed a new reactive algorithm which creates route on demand by broadcasting the RREQ packet to all neighbors. Now a days this routing protocol is considered as the base for on demand routing protocols. To maximize the life time of adhoc mobile network, the power consumption rate of each node must be evenly distributed and overall transmission power for each connection request must be minimized. In [10] Optimized Link State Routing (OLSR) protocol has been discussed from the RFC 3626 published by Internet Engineering Task Force (IETF). Paper [11] discusses the willingness feature of the OLSR protocol for maximally using the batter power left of source by increasing the willingness of node for carrying data traffic.

In [13] mobile adhoc routing protocol Adhoc on Demand Distance Vector(AODV), Dynamic Source Routing(DSR) and Temporary Ordered Routing Algorithm(TORA) have been compared for wireless LAN throughput vs. simulation result. TORA provides moderate throughput result as compared AODV and OLSR. In [14] OPNET simulator has been studied which is a open source software with its modules and given protocols and their attributes. In [15] mobility models have been discussed to explore how network characteristic changes with mobility. Entity mobility model and group mobility model have been used for the simulation purpose. [16] is the destination sequence vector routing where route table is maintained for all the nodes in the network. [18] is based on the energy related information of the node. Intermediate nodes with low residual energy will not be selected in path discovery process between source and destination node. Residual energy will be calculated by free space path loss model. This algorithm will not give good result if network topology changes frequently due to higher mobility of nodes. In [19] Jamali et al. has modified Adhoc on demand distance vector(AODV) algorithm for obtaining stable quality of service based on route life time that is calculated using mobility information, residual energy and the hop count.

In [20] Naserian et al. have Focused on how to reduce routing overhead and provided a new mathematical framework for quantifying the overhead of reactive routing protocols such as Dynamic Source Routing (DSR) and Ad hoc On-Demand Distance Vector Routing (AODV) in wireless ad hoc networks with random location of the nodes. In [21] Location Aided Routing(LAR) has been discussed from two prospects. In worst case LAR assumes that coordinates and the velocity of destination node is known. Source node predicts the location of destination node based on the velocity of node and its movement duration of time, with this information it makes a square expected zone. LAR distance relies on the distance between intermediate node and destination to determine if an RREQ message will be broadcasted or not. In second case, each node knows only its own coordinates and

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does not have any information regarding velocity and coordinate of destination node. Expected zone is defined by flooding angle α. Intermediate nodes make an angle θ with destination node and based on the comparison between α and θ, RREQ packets will be rebroadcasted.

IV. Overview of The Protocols

The shortest path is one of the most common criteria adopted by the conventional routing protocols in MANET but the nodes along shortest path may be used often for relaying data for different routes resulting in exhaustion of its battery faster so network may become disconnected leaving disparity in the energy and eventually disconnected sub network. With the help of performance comparison of routing protocols one can select optimum best available protocol for one`s requirement. As each protocol has its advantages and limitations, so none of them can give best performance under every condition. To see how on varying the different network parameters, the quality of service of network affects, three MANET protocols have been selected for study each under above mentioned category - Adhoc On-Demand Distance Vector(AODV), Optimized Link State Routing(OLSR) and Temporary Ordered Routing Algorithm(TORA).

1) Adhoc On-Demand Distance Vector (AODV)

This routing protocol is an enhanced version of DSDV(Destination Sequenced Distance Vector) which initiate route discovery process on demand [8] and maintains the path till data completion. It can support unicast, broadcast and multicast routing scheme. AODV broadcast the RREQ packet to all its neighbors and the destination unicast the route reply (RREP) message to the source via intermediate nodes. The count to infinity problem has been solved by assigning sequence number to each route request and route reply message. The significant advantage of AODV is that it adds very less overhead to the transmitting data packet to increase throughput. AODV relies on dynamically maintaining routing table at each intermediate node which consist of following details [9] :

- Destination Address
- Next Hop Address
- No. of hops (metric)
- Destination sequence number
- Active neighbors for the route
- Expiration time for route table entry

2) Optimized Link State Routing (OLSR)

OLSR is a table driven and proactive routing protocol particularly suited for large and dense networks where a large subset of nodes are transmitting data to other subset and source destination pair is changing over time. OLSR is better than other table driven protocol because of its multi-point-Relay(MPR) key feature. Each node in the network chooses a set of nodes among its symmetric 1-hop neighbors which is called multipoint relay (MPR) set for this node. Only MPR node can forward the control traffic. If any topological change occurs anywhere in the network MPR [10] idea reduces the flooding of topological information in the network. The neighbors of any node X which have not been selected in its MPR set receive and execute control traffic but do not retransmit these message so overhead of the flooding message and size of control message decreases.

OLSR uses two types of control messages [11] (i) Hello Message (ii) Topology Control Message. Each node sends hello message to all one hop neighbors and based on the link status receiving from nodes prepares

- A list of address of neighbors to which there exist a symmetric link
- A list of address of neighbors which have asymmetric link status
- A list of neighbors which have been selected as MPR.

Topology control message is used for topology declaration and it advertises the link states of the nodes.

3) Temporary Ordered Routing Algorithm (TORA)

This routing protocol is a member of class link reversal algorithm which can support both types of routing on demand and proactive simultaneously. TORA [12] is well suited for sparse traffic patterns in which nodes changes their location frequently so source node maintains multiple routes for the same destination. The control messages are confined to the node which change its location for disseminating the topology change information. TORA uses three types of control messages [13] : query(QRY), update(UPD) and clear (CLR). Source node sends query packet to the neighboring nodes to discover the path for the destination. Update message is used during route building and route maintenance process in which each node assigns metric value (height) to other nodes and data packets can be send from upper metric node to lower metric node i.e. downstream flow of packets towards destination. The significance of height concept is that it provides a loop free, multipath routing structure for data transmission. Clear packets are used to erase old and invalid routes occurring in the network due to node movement.

Table 1 provides the comparison of three MANET routing protocols for different parameters of execution:

Characteristic	AODV	OLSR	TORA
Routing Philosophy	Reactive	Proactive	Both proactive and Reactive
Route Latency	When Needed	Always Available	Both
Communication Overhead	Low	High	Medium
Frequency of Updates	As needed	Periodically	Based on mode of operation
Worst Case	Full Flooding	Pure Link State	Full Flooding

Table 1: Comparison of MANET Routing Protocols

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V. SIMULATION AND RESULT

Simulation of above mentioned protocols have been done in OPNET [14] (Optimized Network Engineering Tool) ver 14.0 which is object oriented modeler tool developed in C language. The random way point mobility model [15] has been used for the movement of nodes in which node moves from one place to other with a constant velocity then stops for a fixed pause time and again changes its location.

The transmission range is calculated by free space path loss model [18]. By this model received power at any node can be calculated by the formula

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2$$

Here p_t = Transmission power of wireless device that is transmitting data in dBm.
g_t = Transmitting antenna gain in dBi
g_r = Receiving antenna gain in dBi
f = frequency of wireless signal in MHz
r = transmission range in km

In more compact form after taking logarithmic, the above mentioned formula can be converted for calculating the range of routers with the help of transmitter power, receiver sensitivity and their antenna gain. The network area dimension must be comparable to transmission range of router so that sufficient intermediate hops should be traversed between the source and destination for data transmission and the simulated environment matches the realistic network scenario as close as possible.

$$r = \frac{10^{(p_t+g_t+g_r-p_r)/20}}{41.88 f}$$

Term	Notation	Value
Frequency	F	2442 MHz (all IEEE 802.11b devices)
Transmission power	P_t	7dBm (0.005W)
T/x Antenna Gain	G_t	1 dBi
R/x Antenna Gain	G_r	1 dBi
Receiver Sensitivity	P_r	-90 dBm

Table 2: For a standard wi-fi router, parameters values

$$r = \frac{10^{(7+7+7+90)/20}}{41.88 f} = 872 mtr$$

Taking the parameters values of a standard wi-fi router used in the simulation [17] mentioned in table 2, range of the router comes out to be 876 mtr and the network area for the simulation has been taken into consideration is 1500x1500m^2. The standard parameters that have been used for the experiment have been listed in table 3.

Parameter	Value
Simulator	OPNET ver 14.0
Protocol Studied	AODV, OLSR & TORA
Simulation Time	600 sec
Transmission Range	876 mtr
Simulation Area	1500mX1500m
Pause Time	10 sec
Bandwidth	11Mbps

Table 3: The main characteristics of the simulation

1) Throughput:

It is defined as the total amount of data received from the sender to time taken for the receiver to get the last packet in bits per sec. In case of throughput with change in velocity, it has been plotted in Fig.1 for 10 nodes with constant packet size of 1024 bytes. The throughput of AODV increases gradually as we increase the velocity of nodes. The throughput of OLSR and TORA always lag behind AODV at higher velocity. At lower velocity OLSR due to its table driven nature provides route in advance so less control packet are transmitted so throughput is higher than AODV and TORA.

As we increase the number of nodes in the network keeping the mobility of nodes constant 30m/s, (Fig.2) throughput increases consistently in case of all three routing protocols, since more number of packets are generated for each node and they contribute to large number of data bits transmitted per sec. Throughput with varying transmission power has been plotted in fig 3. With highest transmission power of 40mW ,range comes out to be 2456mtr so network area is considered to be 3000m X 3000m and constant node velocity of 30m/s. As transmission power of node increases, less number of hops are needed between source and destination so less packet overhead is transmitted and more data bits is received at destination node, throughput increases with increase in transmission power of all three routing protocols.

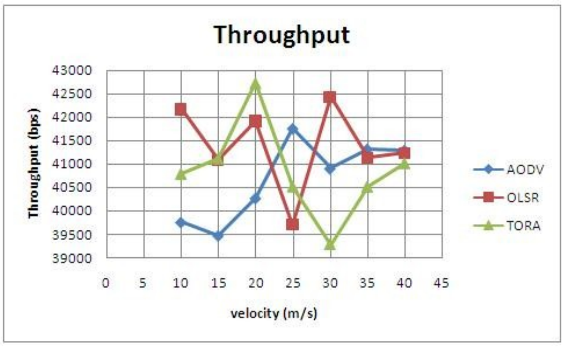

Fig 1: Thorughput versus mobility of nodes

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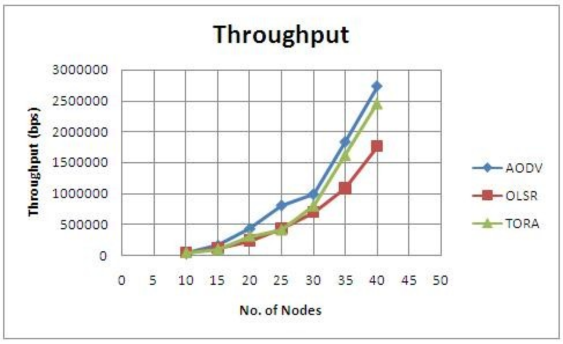

Fig 2: Throughput versus number of nodes

Fig 3: Throughput versus Transmission power of nodes

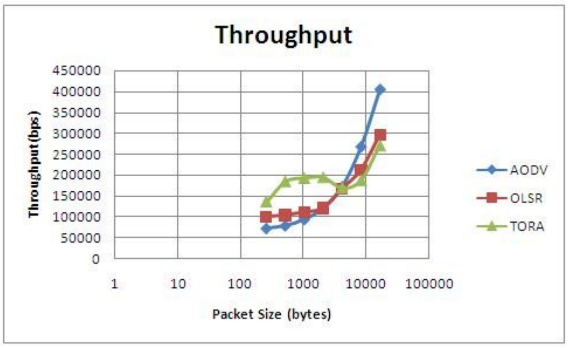

Fig 4: Throughout versus packet size of data

Throughput with varying packet size has been plotted in Fig. 4 On horizontal axis packet size is drawn in logarithmic scale. As packet size increase, large number of data bit will be created from source physical layer and more data bits will be received at the receiver`s application layer.

2) End to End Delay

It is average delay between the time at which the data packet is originated on the source and the time packet reaches at the destination. Lost packet are not counted for measuring end to end delay. When any data packet originates at the source, time consumes in following three process to reach to the destination:

- Route Discovery Phase
- Queuing or buffering at the intermediate nodes
- Retransmission of packets due to TTL (Time to Live) time out

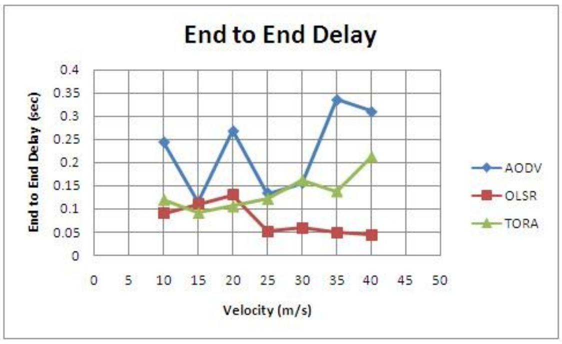

Fig 5: End to End Delay Versus mobility of nodes

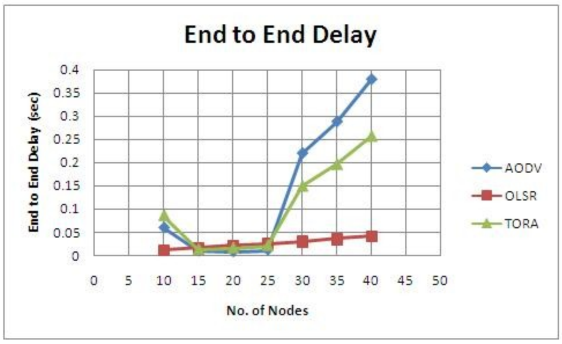

Fig 6: End to End Delay versus number of nodes

End to end delay is plotted in fig. 5 with varying velocity. The average end to end delay for TORA lies between AODV and OLSR due to its proactive and on demand nature simultaneously. As we increase the velocity, AODV routing protocol takes more time from the creation of MANET packets at its source to the execution at destination. Change in mobility causes frequent change in topology so more time consumes in finding new routes and erasing older routes entries at intermediate nodes.

In fig. 6 when there is more traffic in the network due to higher number of nodes, mobility causes higher route discovery process. AODV operates on full flooding technique for finding path in the network with high overhead. OLSR involves link sensing and neighbor detection algorithm for route discovery process. Link sensing is accomplished by periodically generating hello message over the interfaces and assigning nodes symmetric and asymmetric links. TORA`s performance is not as competitive as proactive protocols because clear (CLR) control packets are responsible for substantially erasing routes which become invalid and old due to network partition. With increase in transmission power range of the router (fig. 7) increases so less number of hops are needed between source and destination during path discovery process, average end to end delay decrease with increase in transmission power. Fig 8 provides the comparison between end to end delya for varying data packet size. As per the result, end to end delya for AODV and TORA always remain higher than OLSR. For OLSR maximum end to end delay is 0.06 sec and for AODV it is 0.233 sec.

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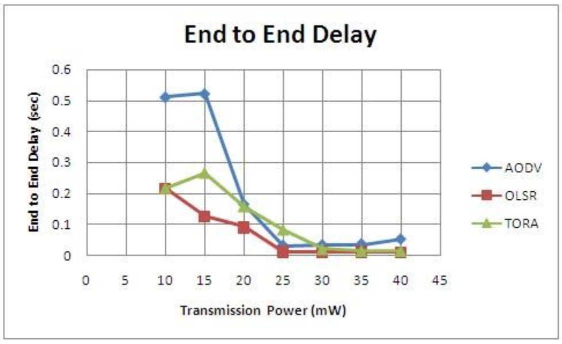

Fig 7: End to End Delay versus Transmission Power of node

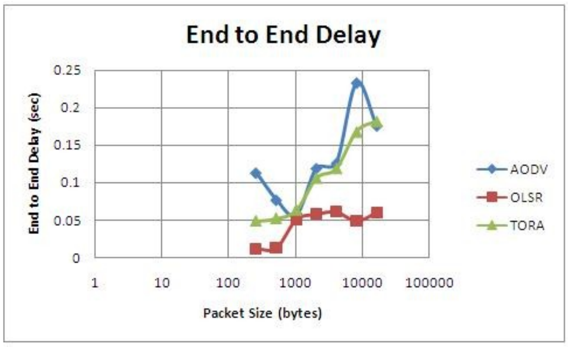

Fig 8: End to End Delay versus Data Packet Size

3) **Packet Delivery Ratio:**

Packet Delivery Ratio is defined as the number of packets successfully received at the application layer to the number of packets send from source application layer. For the best result, packet delivery ratio should be as close as to unity. Due to packet loss in data transmission the total number of packets received at the receiver is always less than the total number of packets sent from the source. As per our results (fig. 9) AODV delivers almost 85 percent of packets at the receiver application layer while the packet delivery ratio for the OLSR decrease as we increase the velocity. At higher velocity AODV and TORA routing protocol delivers fairly same number of packets at the receiver application layer.

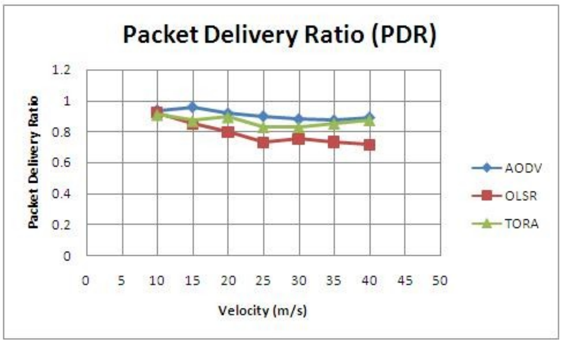

Fig 9: Packet Delivery Ratio versus mobility of nodes

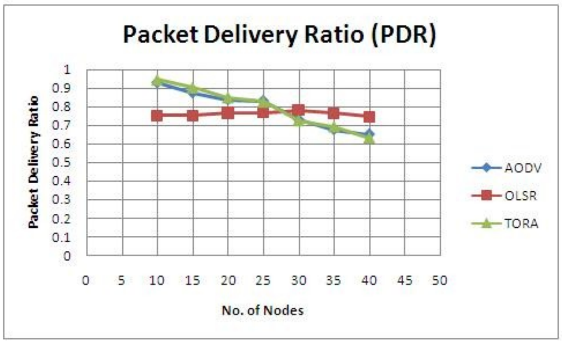

Fig 10: Packet Delivery Ratio versus number of nodes

With higher number of nodes in the network (fig.10) AODV and OLSR show consistent fall in packet delivery ratio. Proactive routing protocols have fewer packet drops as compared to AODV and TORA as alternate routing table entries can be assigned in situation of link failure. In fig. 11 packet delivery ratio smoothly increases with increase in transmission power. With higher transmission power data packets are relayed by less intermediate hops so buffering of data packets while route discovery in progress has likely effect in improving performance of AODV, OLSR and TORA. With increase in packet size floating in the network (fig.12) worsen the number of packets receiving at the destination. AODV drops considerably less amount of packets in comparison to OLSR and TORA because of high expiration time of the route at the intermediate nodes.

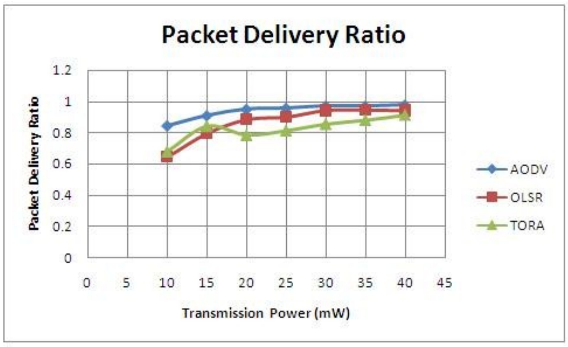

Fig 11: Packet Delivery Ratio versus Transmission power

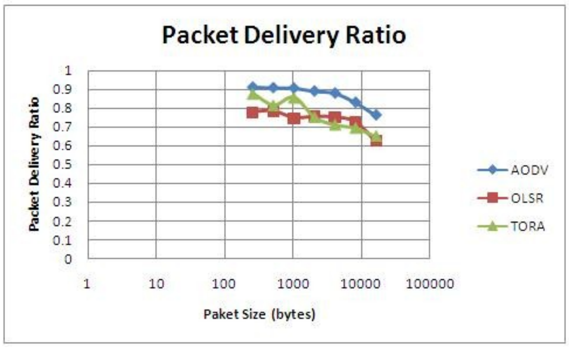

Fig 12: Packet Delivery Ratio versus Data packet size

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VI CONCLUSION

This is a comprehensive performance evaluation of three commonly used MANET routing protocols AODV, OLSR and TORA. Quality of service has been determined of the network by measuring throughput, end to end delay and packet delivery ratio at packet level using OPNET simulator. In MANET there is no adhoc routing algorithm which takes care of each parameter like transmission power, number of nodes, packet size and mobility of nodes and provide best result in each circumstances.

Followings are the main conclusion that can be summarized from the experimental results:

- Increase in the density of the nodes leads to increase in throughput.
- Increase in the packet size of the data packets causes increase in throughput.
- Increasing the nodes in the network increase average end to end delay.
- Increase in the transmission power of the source node yields decrease in average end to end delay
- Increase the size of data packet size reduces the packet delivery ratio at the destination node.

OLSR shows more fluctuation in throughput as compared to AODV and TORA at higher velocity while TORA always gives moderate result as compared to AODV and OLSR for varying mobility of nodes and the number of nodes in the network. With increase in transmission power, all the three protocols AODV, OLSR and TORA show sharp decrease in end to end delay but packet delivery ratio for the similar network scenario keeping all other network parameter constant show gradual rise in performance.

FUTURE WORK

This research work is dedicated to comparing manet routing protocols under various network condition and the results can be used in designing the new routing algorithm with improved network quality of service. Further more in depth analysis of the routing protocols can be done on the basis of other routing parameters.

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