Comparative study of Routing Protocols for Mobile Ad-Hoc Networks

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Abstract—**A mobile ad-hoc network (MANET) is a collection of nodes, which are able to connect on a wireless medium forming an arbitrary and dynamic network. Implicit in this definition of a network is the fact that links, due to node mobility and other factors, may appear and disappear at any time. This in a MANET implies that the topology may be dynamic - and that routing of traffic through a multi-hop path is necessary if all nodes are to be able to communicate. In this paper, a detailed simulation based performance study and analysis is performed on the Ad-hoc routing protocols like Ad-hoc On- Demand Distance Vector (AODV), Optimized Link State Routing (OLSR), Fisheye State Routing Protocol (FSR) over such kind of networks. The performance differentials are investigated using varying Pause Time and number of nodes. Based on the simulation results, how the performance of each protocol can be improved is also recommended. Simulations of protocols to analyze their performance in different conditions were performed in QualNet 4.0 simulator.**

Keywords: Ad Hoc Networks, routing protocol, FSR, AODV, OLSR.

I. Introduction

In areas in which there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use, wireless mobile users may still be able to communicate through the formation of an *ad hoc network [1] [2]*. In such a network, each mobile node operates not only as a host but also as a router, forwarding packets for other mobile nodes in the network that may not be within direct wireless transmission range of each other. Each node participates in an ad hoc routing protocol that allows it to discover "multi-hop" paths through the network to any other node. The idea of ad hoc networking is sometimes also called *infrastructureless networking [1]*, since the mobile nodes in the network dynamically establish routing among themselves to form their own network "on the fly." Some examples of the possible uses of ad hoc networking include students using laptop computers to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battlefield, and emergency disaster relief personnel coordinating efforts after a hurricane or earthquake.

Many different protocols have been proposed to solve the multihop routing problem in ad hoc networks, each based on different assumptions and intuitions.

This paper is the first to provide a realistic, quantitative analysis

comparing the performance of a variety of multi-hop wireless ad hoc network routing protocols. It present results of detailed simulations showing the relative performance of three ad hoc routing protocols Ad-hoc On- Demand Distance Vector (AODV) [9], Optimized Link State Routing (OLSR) [5], and Fisheye State Routing Protocol (FSR) [11].

All simulations are carried out with qualnet4.0 simulator [12] with a scenario of 60 mobile nodes. And comparative study is performing with variation in pause time and number of node.

The rest of this paper is organized as follows. Section II briefly describes the ad-hoc routing protocols. Section III discusses the most important on-demand routing protocols. Section IV presents a comparative study of various protocols. Section V represents a conclusion of the paper.

II. Routing Protocols

The primary goal of routing protocols in ad-hoc network is to establish optimal path (min hops) between source and destination with minimum overhead and minimum bandwidth consumption so that packets are delivered in a timely manner. A MANET protocol [2] should function effectively over a wide range of networking context from small ad-hoc group to larger mobile Multihop networks. As figure 1 shows the categorization of these routing protocols.

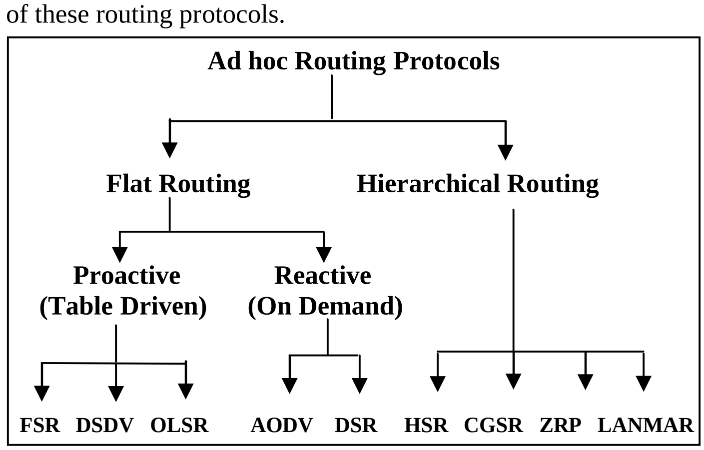

Figure 1: Hierarchy of Routing Protocols in MANET

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Reactive routing protocols [1] [3] are on-demand protocols. These protocols do not attempt to maintain correct routing information on all nodes at all times. Routing information is collected only when it is needed, and route determination depends on sending route queries throughout the network. The primary advantage of reactive routing is that the wireless channel is not subject to the routing overhead data for routes that may never be used. While reactive protocols do not have the fixed overhead required by maintaining continuous routing tables, they may have considerable route discovery delay. Reactive search procedures can also add a significant amount of control traffic to the network due to query flooding. Because of these weaknesses, reactive routing is less suitable for real-time traffic or in scenarios with a high volume of traffic between a large numbers of nodes. Routing information is collected in the route discovery process. The minimum information required by a node to send data is the next hop in the route. If this next hop information is unavailable, broadcasting is performed. In this procedure, the originating node sends a broadcast message requesting the desired route. Nodes that have routing information will respond to the broadcast. The originating node then chooses a route from the responses. In the case the route is not initially known and needs to be determined, there is an initial setup delay. Many reactive protocols limit this delay through the use of a route cache for established routes.

In a network utilizing a proactive routing protocol [2], every node maintains one or more tables representing the entire topology of the network. These tables are updated regularly in order to maintain up-to-date routing information from each node to every other node. To maintain the up-to-date routing information, topology information needs to be exchanged between the nodes on a regular basis, leading to relatively high overhead on the network. One the other hand, routes will always be available on request. Many proactive protocols stem from conventional link state routing, including the Optimized Link State Routing protocol (OLSR)

Wireless hierarchical routing is based on the idea of organizing nodes in groups and then assigning nodes different functionalities inside and outside a group [1] [3]. Both routing table size and update packet size are reduced by including in them only part of the network (instead of the whole); thus, control overhead is reduced. The most popular way of building hierarchy is to group nodes geographically close to each other into explicit clusters. Each cluster has a leading node (*cluster head*) to communicate to other nodes on behalf of the cluster. An alternate way is to have implicit hierarchy. In this way, each node has a local scope. Different routing strategies are used inside and outside the scope. Communications pass across overlapping scopes. More efficient overall routing performance can be achieved through this flexibility. Since mobile nodes have only a single omni-directional radio for wireless communications, this type of hierarchical organization will be referred to as *logical hierarchy* to distinguish it from the physically hierarchical network structure.

A. Ad hoc On-demand Distance Vector (AODV):

AODV [8] [9] routing protocol is based on DSDV and DSR [7] algorithm. It uses the periodic beaconing and sequence numbering procedure of DSDV and a similar route discovery procedure as in DSR. However, there are two major differences between DSR and AODV. The most distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry the destination address. This means that AODV has potentially less routing overheads than DSR. The other difference is that the route replies in DSR carry the address of every node along the route, whereas in AODV the route replies only carry the destination IP address and the sequence number.

The Ad hoc On-Demand Distance Vector (AODV) routing protocol is intended for use by mobile nodes in an ad hoc network. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and unicast route determination to destinations within the ad hoc network. It [9] uses destination sequence numbers to ensure loop freedom at all times (even in the face of anomalous delivery of routing control messages), avoiding problems (such as “counting to infinity”) associated with classical distance vector protocols.

The primary objectives of AODV protocol are:

1. To broadcast discovery packets only when necessary,
2. To distinguishes between local connectivity management (neighborhood detection) and general topology maintenance and
3. To disseminate information about changes in local connectivity to those neighboring mobile nodes those are likely to need the information. AODV decreases the control overhead by minimizing the number of broadcasts using a pure on-demand route acquisition method. AODV uses only symmetric links between neighboring nodes.

In AODV, each node maintains two separate counters:

1. Sequence Number, a monotonically increasing counter used to maintain freshness information about the reverse route to the Source and
2. Broadcast-ID, which is incremented whenever the source issues a new Route Request message. Each node also maintains information about its reachable neighbors with bi-directional connectivity.

Managing the sequence number is crucial to avoiding routing loops. A destination becomes unreachable when a link breaks or it is deactivated. When these conditions occur, the route is invalidated by operations involving the sequence number and marking the routing table entry state as invalid.

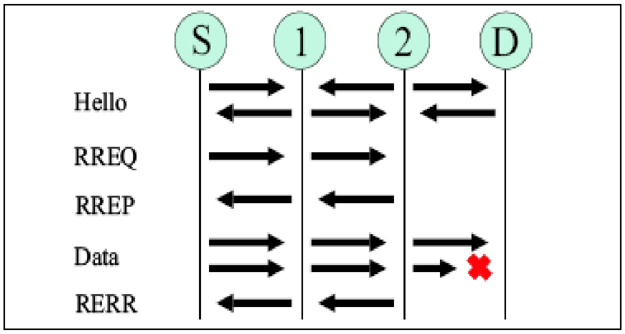


Figure 2: AODV Protocol Messaging

When a route to a new destination is needed, the node broadcasts a RREQ to find a route to the destination shown in figure 2. Each node receiving the request caches a route back to the originator of the request, so that the RREP can be unicast from the destination along a path to that originator. A route can be determined when the RREQ reaches a node that offers reach ability to the destination (e.g., the destination itself). The route is made available by unicasting a RREP back to the origination of the RREQ. For nodes monitoring the link status of next hops for active routes, when a link break in an active route is detected, the broken link is invalidated and a RERR message is typically transmitted to notify other nodes that the loss of that link has occurred. The RERR message indicates the destination that is no longer reachable by way of the broken link.

B. Optimized Link State Protocol (OLSR)

OLSR [5] [7] is a point-to-point routing protocol based on the traditional link-state algorithm. In this strategy, each node maintains topology information about the network by periodically exchanging link-state messages. The novelty of OLSR is that it minimizes the size of each control message and the number of rebroadcasting nodes during each rout hello messages, each node selects a subset of one hop neighbors, which covers all of its two hop Neighbors. For example, in Fig. 4, node A can select nodes B, C, K and N to be the MPR nodes. Since these nodes cover all the nodes, which are two hops away. Each node determines an optimal route to every known destination using its topology information (from the topology table and neighboring table), and stores this information in a routing table. Therefore, routes to every destination are immediately available when data transmission begins update by employing multipoint replaying (MPR) strategy. To do this, during each topology update, each node in the network selects a set of neighboring nodes to retransmit its packets. This set of nodes is called the multipoint relays of that node. Any node which is not in the set can read and process each packet but do not retransmit. To select the MPRs, each node periodically broadcasts a list of its one hop neighbors using hello messages. From the list of nodes in the hello messages, each node selects a subset of one hop neighbors, which covers all of its two hop neighbors.

For example, in Figure 3, node can select nodes B, C, K and N to be the MPR nodes. Since these nodes cover all the nodes, which are two hops away. Each node determines an optimal route (in terms of hops) to every known destination using its topology information (from the topology table and neighboring table), and stores this information in a routing table. Therefore, routes to every destination are immediately available when data transmission begins. OLSR [5] is based on the following mechanisms:

- Neighbor sensing based on periodic exchange of HELLO messages.
- Efficient flooding of control traffic using the concept of multipoint relays.
- Computation of an optimal route using the shortest-path algorithm.

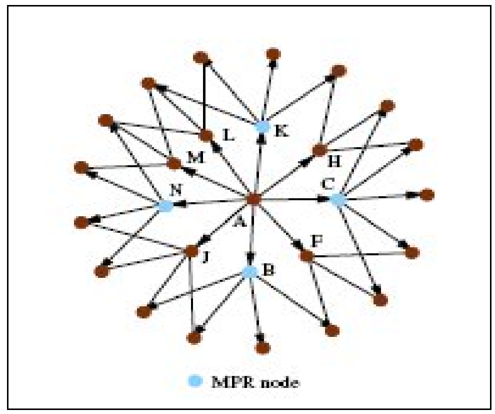


Figure 3: Multipoint relays

Figure 4 shows an example a node, say node A, periodically broadcasts HELLO messages to all immediate neighbors to exchange neighborhood information (i.e., list of neighbors) and to compute the MPR set. From neighbor lists, node A figures out the nodes that are two hops away and computes the minimum set of one hop relay points required to reach the two-hop neighbors. Such set is the MPR set. Figure 2 illustrates the MPR set of node A. The optimum (minimum size) MPR computation is NP-complete. Efficient heuristics are used. Each node informs its neighbors about its MPR set in the HELLO message. Upon receiving such a HELLO, each node records the nodes (called MPR *selectors*) that select it as one of their MPRs. In routing information dissemination, OLSR differs from pure LS protocols in two aspects. First, by construction, only the MPR nodes of A need to forward the link state updates issued by A. Second, the link state update of node A is reduced in size since it includes only the neighbors that select node A as one of their MPR nodes. In this way, partial topology information is propagated, that is, say, node A can be reached only from its MPR selectors. OLSR computes the shortest path to an arbitrary destination using the topology map consisting of all of its neighbors and of the MPRs of all other nodes. OLSR is particularly suited for dense networks. When the network is sparse, every neighbor of a node becomes a multipoint relay. The OLSR then reduces to a pure LS protocol.

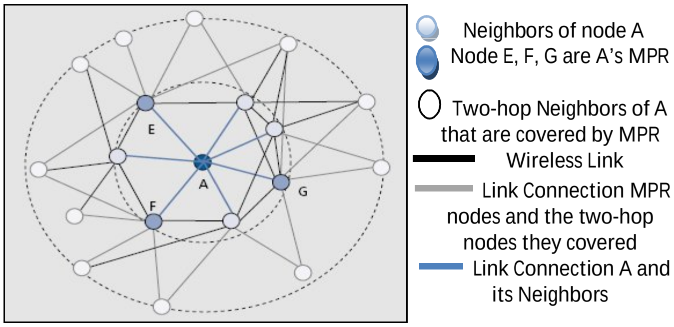


Figure 4: OLSR an illustration of multipoint relays.

C. FISHEYE STATE ROUTING PROTOCOL (FSR)

FSR [11] [8] is an implicit hierarchical routing protocol. It uses the "fisheye" technique proposed by Kleinrock and Stevens, the eye of a fish captures with high detail the pixels near the focal point. The detail decreases as the distance from the focal point increases. In routing, the fisheye approach translates to maintaining accurate distance and path quality information about the immediate neighborhood of a node, with progressively less detail as the distance increases. The FSR concept originates from Global State Routing (GSR).GSR can be viewed as a special case of FSR, in which there is only one fisheye scope level. As a result, the entire topology table is exchanged among neighbors. Clearly, this consumes a considerable amount of bandwidth when network size becomes large. The link state packets are exchanged periodically instead of event driven. Through updating link state information with different frequencies depending on the scope distance, FSR scales well to large network size and keeps overhead low without compromising route computation accuracy when the destination is near. By retaining a routing entry for each destination, FSR [11] avoids the extra work of "finding" the destination and thus maintains low single packet transmission latency. As mobility increases, routes to remote destinations become less accurate. However, when a packet approaches its destination, it finds increasingly accurate routing instructions as it enters sectors with a higher refresh rate. FSR is suitable for large and highly mobile network environments as it triggers no control messages on link failures. Broken links won't be included in the next link state message exchange. This means that a change on a link far away does not necessarily cause a change in the routing table. FSR introduces the notion of multilevel fisheye scope to reduce routing update overhead through reducing the routing packet sizes and update frequency.

Figure 5 illustrates how the fisheye technique is applied to a MANET. When the size of a network increases, sending update messages may potentially consume the bandwidth. FSR uses the fisheye technique to reduce the size of the update message without affecting routing. In the figure, three fisheye scopes are defined with respect to the focal point, node 11.

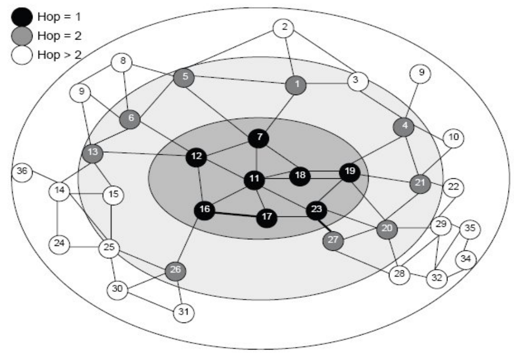


Figure 5: Fisheye scope

Each scope is defined by the set of nodes that can be reached by a certain number of hops. The figure illustrates three scopes of size 1, 2, and greater than 2 hops. Selection of scope levels and radius are dependent upon individual network requirements. Routing overhead is reduced by modifying how often entries are propagated from the central node. Nodes within the smaller scope receive updates more frequently than those in the larger scopes. Because of this frequency modification, overhead can be reduced. However, while neighboring nodes are receiving timely updates, large latencies are created from more distant nodes. Compensating for this latency increase is the fact that as the packets get closer to the central node, the routes are increasingly more accurate.

III. SIMULATION ENVIRONMENT

The overall goal of this simulation study is to analyze the performance of different existing wireless routing protocols in WMNs environment. The simulations have been performed using QualNet version 4.0 [12], a software that provides scalable simulations of Wireless Networks and a commercial version of GloMoSim. In our simulation, we consider a network of 60 nodes (one source and one destination) that are placed randomly within a 1500m X 1500m area and operating over 180 seconds. Multiple runs with different pause time and number of nodes are conducted for each scenario and collected data is averaged over those runs.

Random Way Point [3] (RWP) Mobility model is used in our experiments with lognormal shadowing model. The transmission power of the routers is set constant at 20 dBm and the transmission range of the routers is 250 meters. The data transmission rate is 2Mbits/s. At the physical layer 802.11b and at MAC layer MAC 802.11.s is used. The traffic source is implemented using Constant Bit Rate (CBR), sending at a rate of 1 packets/s. The packet size without header is 512 bytes. The length of the queue at every node is 50 Kbytes where all the packets are scheduled on a first-in-first-out (FIFO) basis.

To evaluate the performance of routing protocols, both qualitative and quantitative metrics are needed. Most of the routing protocols ensure the qualitative metrics. Therefore, we use four different quantitative metrics to compare the performance. They are

• Packet Delivery Ratio: The fraction of packets sent by the application that are received by the receivers [3].

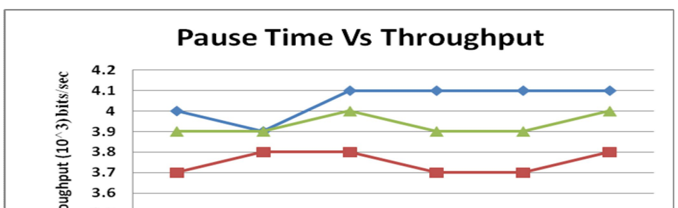
• Average Jitter: Jitter [8] is the variation in the time between packets arriving, caused by network congestion, timing drift, or route changes.

• Average End-to-end delay: End-to-end delay indicates how long it took for a packet to travel from the source to the application layer of the destination. [6].

• Throughput: The throughput is defined as the total amount of data a receiver R receives from the sender divided by the times it takes for R to get the last packet [8]

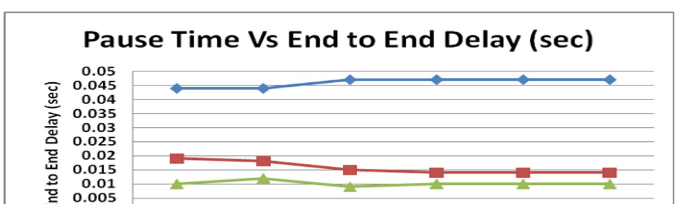
IV. RESULT AND DISCUSSION

The performance differentials in this simulation are investigated using varying Pause Time and Number of Nodes. Pause time is varied from 0 sec to 100 sec. On the other hand, number of nodes is increased from 10 nodes to 60 nodes. The results gained from simulations are illustrated in Figure 6 to 12.



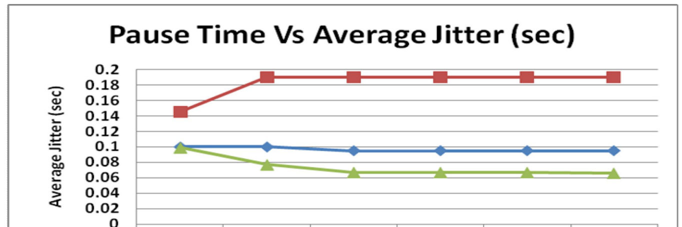
	0	20	40	60	80	100
AODV	4	3.9	4.1	4.1	4.1	4.1
OLSR	3.7	3.8	3.8	3.7	3.7	3.8
FSR	3.9	3.9	4	3.9	3.9	4

Figure 6: Pause time Vs Throughput



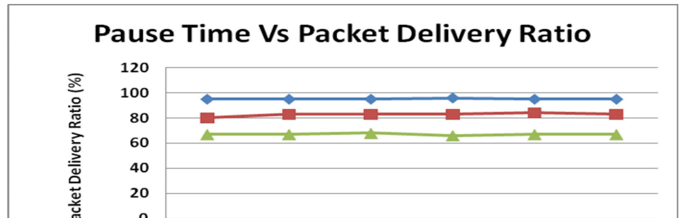
	0	20	40	60	80	100
AODV	0.044	0.044	0.047	0.047	0.047	0.047
OLSR	0.019	0.018	0.015	0.014	0.014	0.014
FSR	0.01	0.012	0.009	0.01	0.01	0.01

Figure 7: Pause time Vs End to End Delay



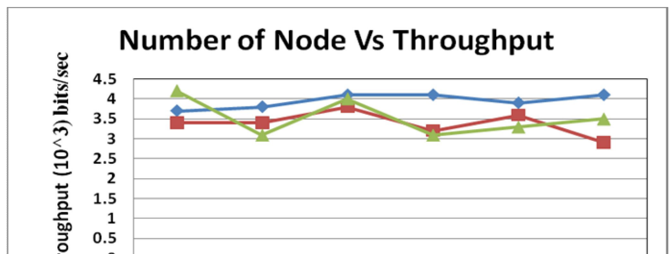
	0	20	40	60	80	100
AODV	0.1	0.1	0.095	0.095	0.095	0.095
OLSR	0.145	0.19	0.19	0.19	0.19	0.19
FSR	0.099	0.077	0.067	0.067	0.067	0.066

Figure 8: Pause time Vs Average Jitter



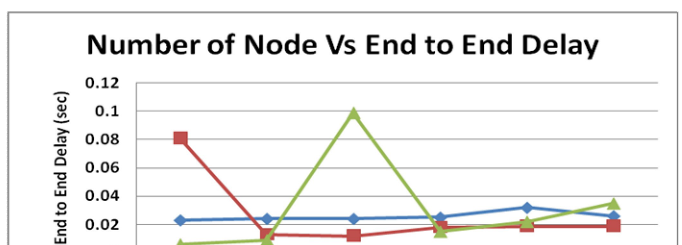
	0	20	40	60	80	100
AODV (%)	95	95	95	96	95	95
OLSR (%)	80	83	83	83	84	83
FSR (%)	67	67	68	66	67	67

Figure 9: Pause time Vs Packet Delivery Ratio



	10	20	30	40	50	60
AODV	3.7	3.8	4.1	4.1	3.9	4.1
OLSR	3.4	3.4	3.8	3.2	3.6	2.9
FSR	4.2	3.1	4	3.1	3.3	3.5

Figure 10: Number of Node Vs Throughput



	10	20	30	40	50	60
AODV	0.023	0.024	0.024	0.025	0.032	0.026
OLSR	0.081	0.013	0.012	0.018	0.019	0.019
FSR	0.006	0.009	0.099	0.015	0.022	0.035

Figure 11: Number of Node Vs End To End Delay

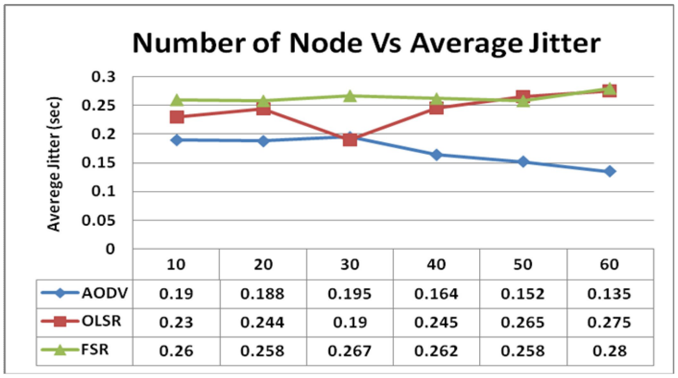


Figure 12: Number of Node Vs Average Jitter

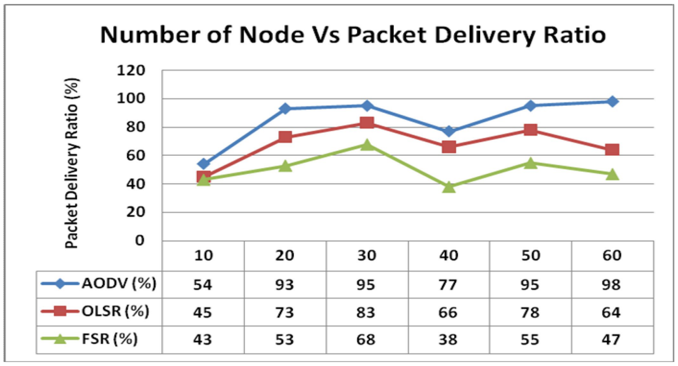


Figure 13: Number of Node Vs Packet Delivery Ratio

From figure 6 to 9 it has observed that performance of AODV is better than OLSR and FSR, when pause time is varying. But calculation of average jitter for OLSR is better than oAODV and FSR. In other hand performanc of AODV is also well ewhen number of node is varying. But OLSR again providing better average jitter in this situation.

V. CONCLUSION

This paper presents a brief description of several routing protocols which are proposed for ad-hoc mobile networks and also provides a classification of these protocols according to the routing strategy (i.e. table driven, on-demand and hybrid routing protocol). It has also presented a comparison of AODV, OLSR and FSR, and reveals their features, differences and characteristics. The performance of these protocols is analyzed with QualNet4.0 simulator with scenario of 60 nodes. The observations are made with variation in pause time and number of nodes in network. After analysis in different situations of network it can be practical that AODV perform glowing than OLSR and FSR.

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