Reactive and Proactive Routing Protocol Performance Evaluation for Qualitative and Quantitative Analysis in Mobile Ad Hoc Network

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Abstract- A mobile ad hoc network (MANET) is a network consisting of a set of wireless mobile nodes that communicate with each other without centralized control or established infrastructure. Every node in MANET moves arbitrarily making the multi-hop network topology to change randomly at unpredictable times. There are several familiar routing protocols like DSDV, AODV, DSR, and OLSR which have been proposed for providing communication among all the nodes in the network. This paper presents Qualitative and Quantitative Analysis of Reactive and Proactive Routing Protocol Performance Evaluation in Mobile Ad Hoc Network for protocols such as OLSR, DSDV, AODV and DSR based on metrics such as security, multicasting, Packet delivery ratio and average end-to-end delay, Routing load by using the NS-2 simulator. The results shows that there is no routing protocol in the current stage without modifications that can provide efficient routing to any size of network, regardless of the number of nodes and the network load and mobility. AODV shows better performance than DSDV, OLSR, and DSR.

Index Terms- AODV, OLSR, DSDV, DSR, Routing protocols, NS-2.

I. INTRODUCTION

A mobile ad hoc network (MANET) is a network comprising wireless mobile nodes (MNs) that communicate with each other without centralized control or established infrastructure [1]. One of the distinctive features of MANET is, each node must be able to act as a router to find out the optimal path to forward a packet. As nodes may be mobile, entering and leaving the network, the topology of the network will change continuously. MANETs provide an emerging technology for civilian and military applications. Since the medium of the communication is wireless, only limited bandwidth is available. Another important constraint is energy due to the mobility of the nodes in nature.

Routing protocols are divided into two categories: Proactive and Reactive. Proactive routing protocols are table-driven protocols and they always maintain current up-to-date routing information by sending control messages periodically between the hosts which update their routing tables. The proactive routing protocols use link-state routing algorithms which frequently flood the link information about its neighbors [2.] Reactive or on-demand routing protocols create routes when they are needed by the source host and these routes are maintained while they are needed. Such protocols use distance-vector routing algorithms [3].

This paper provides an analysis and performance evaluation of reactive and proactive routing protocols that may be suitable for high speed wireless communications. The evaluation is conducted in two phases. In the first phase, comparison of the protocols based on qualitative metrics is done to locate those that may fit the evaluation criteria. In the second phase, evaluation of the selected protocols is done from the first phase based on quantitative metrics in a mobility scenario. Therefore, the objectives are: i) to compare them and select those protocols based on qualitative metrics that most satisfy the IETF design considerations; ii) to evaluate the selected protocols through extensive simulations under the same network parameters and mobility scenario. The rest of this paper is organized as follows. The next section provides an overview of the related work in the area of evaluation of routing protocols for wireless ad hoc networks. Routing protocols for MANET are discussed in Section 3.The protocols under considerations are discussed in section 4. In Section 5, the performance metrics is described under which evaluation has been done. In Section 6, four routing protocols based on qualitative metrics are evaluated. Results from extensive ns-2 simulations based on quantitative metrics are presented in Section 7. Section 8 concludes this paper.

II. RELATED WORK

A number of routing protocols have been proposed and implemented for MANETs in order to enhance the bandwidth utilization, higher throughputs, lesser overheads per packet, minimum consumption of energy and others. All these protocols have their own advantages and disadvantages under certain circumstances. MANET Routing Protocols possess two properties such as Qualitative properties (distributed operation, loop freedom, demand based routing & security) and Quantitative properties (end-to-end throughput, delay, route discovery time, memory byte requirement & network recovery time). Obviously, most of the routing protocols are qualitatively enabled. A lot of simulation studies were carried out in the paper [4] to review the quantitative properties of routing protocols.

Performance comparison of AODV and DSR routing protocols in a constrained situation is done in [5]. The authors claim that the AODV outperforms DSR in normal situation but in the constrained situation DSR out performs AODV, where the degradation is as severe as 30% in AODV whereas DSR degrades marginally as 10%.

Perkins et all [6] show the performance of two on demand routing protocols namely DSR and AODV. Though both AODV and DSR use on demand route discovery, they have different routing mechanics. The authors observe that for application oriented metrics such as delay, throughput DSR outperforms AODV when the numbers of nodes are smaller. AODV outperforms DSR when the number of nodes is very large. The authors do show that DSR consistently generate less routing load than AODV.

Ahmed and Alam [7] compare three routing protocols (DSR, AODV, and TORA) through simulations conducted with a discrete-event simulator (OPNET Modeler 10.5 version).Simulation results indicate that under specific simulation parameters TORA presents a higher performance than AODV and DSR.

In Kumar et al. [8], a comparison of the performance of two prominent on-demand reactive routing protocols for MANET (DSR and AODV) is presented, along with the traditional proactive DSDV protocol.

In Divecha et al. [9] the effects of various mobility models on the performance of DSR and AODV are studied. For experimental purposes, four mobility scenarios are presented: Random Waypoint, Group Mobility, Freeway and Manhattan models. Performance comparison has also been conducted across varying node densities and number of hops. The experimental results illustrate that the performance of routing protocols varies across different mobility models, node densities and length of data paths.

In Rahman and Zukarnain [10] the performance comparison between three routing protocols, namely AODV, DSDV and an improvement of DSDV, is presented. The authors use three network metrics, namely packet delivery ration, end-to-end delay, and routing overhead.

In [11] four different routing protocols like AODV, TORA, DSDV and DSR are compared. It is shown through simulation results that DSR generates less routing load than AODV. AODV suffers from end to end delay while TORA has very high routing overhead. The better performance of DSR is because it exploits caching aggressively and maintains multiple routes to the destinations.

A comparison of Link State, AODV and DSR protocols for two different traffic classes, in a selected environment is done in [12].It is claimed that AODV and DSR perform well when the network load is moderate and if the traffic load is heavy then simple Link State outperforms the reactive protocols .

This paper evaluates quantitatively in detail two MANET protocols (AODV and OLSR) based on three evaluation parameters (network load, network mobility, node density) with focus on the Random way point Mobility (RWP) model.

III. MOBILE AD HOC NETWORK ROUTING PROTOCOLS

There are many ways to classify the MANET routing protocols, depending on how the protocols handle the packet to deliver from source to destination. But Routing protocols are broadly classified into three types such as Proactive, Reactive and Hybrid protocols [13].

3.1. Proactive routing protocols

In this category, every node in the network has one or more routes to any possible destination in its routing table at any given time. Data received from the upper transport layer are immediately transmitted, as at least one route to the destination is already in the node's routing table. Proactive protocols presents low latency but medium to high routing overhead. This is due to the nodes periodically exchange control messages and routing table information in order to keep up-to-date routes to any active node in the network. However, a node, wasting process recourses and bandwidth, may never use some of these routes. Proactive protocols can better address security vulnerabilities, because of the periodic exchange of control messages and routing table information. Thus a loss or modification of any route update can be overcome by the next scheduled update. In this category, we evaluate two proactive protocols, named Optimized Link State Routing (OLSR) [14], Destination Sequenced Distance Vector (DSDV) [15].

3.2 Reactive Protocols

These types of protocols are also called as On Demand Routing Protocols where the routes are not predefined for routing. A Source node calls for the route discovery phase to determine a new route whenever a transmission is needed. This route discovery mechanism is based on flooding algorithm which employs on the technique that a node just broadcasts the packet to all of its neighbors and intermediate nodes just forward that packet to their neighbors. This is a repetitive technique until it reaches the destination. Reactive techniques have smaller routing overheads but higher latency. Example Protocols**:** DSR, AODV

3.3 Hybrid Protocols

Hybrid protocols are the combinations of reactive and proactive protocols and takes advantages of these two protocols and as a result, routes are found quickly in the routing zone. Example Protocol**:** ZRP (Zone Routing Protocol), GPSR (Greedy perimeter stateless routing).

IV. DESCRIPTION OF ROUTING PROTOCOLS UNDER CONSIDERATION.

4.1 Ad hoc On Demand Distance Vector Routing Protocol

As AODV protocol is a flat routing protocol it does not need any central administrative system to handle the routing process. AODV tends to reduce the control traffic messages overhead at the cost of increased latency in finding new routes. The AODV has great advantage in having less overhead over simple protocols which need to keep the entire route from the source host to the destination host in their messages. The RREQ and RREP messages, which are responsible for the route discovery, do not increase significantly the overhead from these control messages. AODV reacts relatively quickly to the topological changes in the network and updating only the hosts that may be affected by the change, using the RRER message. The Hello messages, which are responsible for the route maintenance, are also limited so that they do not create unnecessary overhead in the network. The AODV protocol is a loop free and avoids the counting to infinity problem, which were typical to the classical distance vector routing protocols, by the usage of the sequence numbers. [19].

4.2 Dynamic Source Routing (DSR) Protocol

The Dynamic Source Routing (DSR) is a reactive unicast routing protocol that utilizes source routing algorithm [17]. In DSR, each node uses cache technology to maintain route information of all the nodes. There are two major phases in DSR such as: i) Route discovery ii) Route maintenance. When a source node wants to send a packet, it first consults its route cache [18]. If the required route is available, the source node sends the packet along the path. Otherwise, the source node initiates a route discovery process by broadcasting route request packets. Receiving a route request packet, a node checks its route cache. If the node doesn't have routing information for the requested destination, it appends its own address to the route record field of the route request packet. Then, the request packet is forwarded to its neighbors. If the route request packet reaches the destination or an intermediate node has routing information to the destination, a route reply packet is generated. When the route reply packet is generated by the destination, it comprises addresses of nodes that have been traversed by the route request packet. Otherwise, the route reply packet comprises the addresses of nodes the route request packet has traversed concatenated with the route in the intermediate node's route cache. The advantage of this protocol is reduction of route discovery control overheads with the use of route cache and the disadvantage is the increasing size of packet header with route length due to source routing.

4.3 Optimized Link State Routing Protocol

Optimized Link State Protocol (OLSR) [2] is a proactive routing protocol, so the routes are always immediately available when needed. OLSR is an optimization version of a pure link state protocol. So the topological changes cause the flooding of the topological information to all available hosts in the network. To reduce the possible overhead in the network protocol uses Multipoint Relays (MPR). The idea of MPR is to reduce flooding of broadcasts by reducing the same broadcast in some regions in the network. OLSR uses two kinds of the control messages: Hello and Topology Control (TC). Hello messages are used for finding the information about the link status and the host's neighbors. TC messages are used for broadcasting information about own advertised neighbors which includes at least the MPR Selector list. The proactive characteristic of the protocol provides that the protocol has all the routing information to all participated hosts in the network. However, as a drawback OLSR protocol requires each host periodically to send the updated topology information throughout the entire network. This increases the protocols bandwidth usage. But the flooding is minimized by the MPRs, which are only allowed to forward the topological messages.

4.4 Destination-Sequenced Distance-Vector (DSDV) protocol

The Table-driven DSDV protocol is a modified version of the Distributed Bellman-Ford (DBF) Algorithm that was used successfully in many dynamic packet switched networks [15]. The Bellman-Ford method provided a means of calculating the shortest paths from source to destination nodes, if the metrics (distance-vectors) to each link are known. DSDV uses this idea, but overcomes DBF's tendency to create routing loops by including a parameter called Destination-sequence number. In DSDV, each node is required to transmit a sequence number, which is periodically increased by two and transmitted along with any other routing update messages to all neighboring nodes. On reception of these update messages, the neighboring nodes use the following algorithm to decide whether to ignore the update or to make the necessary changes to its routing table:

Step 1: Receive the update message. Step 2: Update the routing table if any one of the following condition satisfies:
i) Sn > Sp; ii) Sn=Sp , Hop count is less ,Otherwise, ignore the update message. Here, Sn and Sp are the Sequence numbers of new message and existing message respectively. When a path becomes invalid, due to movement of nodes, the node that detected the broken link is required to inform the source, which simply erases the old path and searches for a new one for
sending data. The advantages are latency for route discovery is low and loop-free path is guaranteed. The disadvantage is the huge volume of control messages.

V. PERFORMANCE EVALUATION METRICS

The Internet Engineering Task Force MANET working group suggests two different types of metrics for evaluating the performance of routing protocols for MANETs in RFC 2501 [22]. In accordance with RFC 2501, routing protocols should be evaluated in terms of both qualitative metrics and quantitative metrics. In the phase, the routing protocols are located that may be suitable in high speed wireless communications based on qualitative metrics. In the second phase, the selected protocols are evaluated from the first phase based on quantitative metrics.

5.1. Qualitative metrics

These metrics include:

i) *Security:* The wireless environments, along with the nature of the routing protocols in MANETs, which require each node to participate actively in the routing process, introduce many security vulnerabilities. Therefore routing protocols should efficiently support security mechanisms to address these vulnerabilities.

ii) *Loop freedom*: This refers mainly, but not only, to all protocols that calculate routing information based on the Bellman–Ford algorithm. In a wireless environment with limited bandwidth, interference from neighboring nodes' transmissions and a high probability of packet collisions, it is essential to prevent a packet from 'looping' in the network and thus consuming both processing time and bandwidth.

iii*) Sleep mode*: In general, nodes in a MANET use batteries for their energy source. The protocol should be able to operate, even though some nodes are in 'sleep mode' for short periods, without any adverse consequences in the protocol's performance.

iv) *Unidirectional link support*: Nodes in the wireless environment may be able to communicate only through unidirectional links. It is preferable that routing protocols are able to support both unidirectional and bidirectional links.

v) *Multicasting*: Multicasting support is important especially for the transmission of real-time data (for example, multimedia data) in many nodes at the same time.

vi) *On-demand routing behavior*: Owing to bandwidth limitations in the wireless network, on-demand, or reactive-based, routing minimizes the dissemination of control packets in the network, increases the available bandwidth for user data, and conserves the energy resources of the mobile nodes. Reactive routing protocols introduce a medium to high latency.

Therefore, a routing protocol for MANETs should keep a balance between latency and routing overhead, energy consumption, and node participation in the routing process, and should employ security Mechanisms. For high speed wireless communications, low latency and high packet delivery ratio are more important than low routing overhead. Energy consumption is not always a high issue in vehicular communications, as nodes may well be suited in vehicular platforms with adequate energy resources. However, for portable radio devices, energy consumption is an important issue.

5.2. Quantitative metrics

Quantitative metrics include:

i) *Route acquisition time*: it indicates how much time does a protocol need to discover a route? This is a main concern in reactive routing protocols, as the longer the time is, the higher the latency is in the network.

ii) *Out-of-order delivery*: The percentage of packets that are delivered out of order may affect the performance of higher-layer protocols such as TCP, which prefers in-order data delivery of packets.

iii) *Efficiency*. Additional metrics can be used to measure the efficiency of the protocol. One can use them to measure the portion of the available bandwidth that is used by the protocol for route discovery and maintenance. Another measurement calculates the packet delivery ratio over the total number of packets transmitted and the energy consumption of the protocol for performing its task.

iv) *End-to-end data throughput and delay*: these metrics can be used to measure the effectiveness of the routing protocol. Design considerations that increase delay and minimize data throughput can be revealed by these metrics.

All the above quantitative metrics should be based on the same network attributes, such as network density, mobility, data density, bandwidth, energy resources, transmission and receiving power, antenna types, etc. In this paper for performance evaluation, the general ideas described in RFC 2501 is followed , and use four quantitative metrics similar to those in Das et al. [16]. The packet delivery ratio and average end-to-end delay are more important for best-effort traffic. The normalized routing load will be used to evaluate the efficiency of the routing protocol. All these metrics are defined as follows:

Packet Delivery Ratio: This is the number of packets sent from the source to the number of received at the destination.

Average end-to-end delay: This is the average time delay for data packets from the source node to the destination node.

Normalized routing load: The normalized routing load is defined as the fraction of all routing control packets sent by all nodes over the number of received data packets at the destination nodes. This metric discloses how efficient the routing protocol is. Proactive protocols are expected to have a higher normalized routing load than reactive ones. The larger this fraction is, the less efficient the protocol is.

VI. PERFORMANCE EVALUATION BASED ON QUALITATIVE METRICS

In this section the evaluation results based on qualitative metrics is presented. The evaluation process requires studying the protocols and finding their attributes that satisfy the evaluation criteria of RFC 2501. This initial selection of protocols for further evaluation depends on their performance here. Table 1 shows the qualitative performance comparison.

Table 1: The qualitative performance comparison

Qualitative metrics	Proactive protocols		Reactive protocols	
	OLSR	DSDV	AODV	DSR
i) *Security*	No	No	No	No
ii) *Loop freedom*	Yes	Yes	Yes	Yes
ii*i) Sleep mode*	Yes	No	No	No
iv)*Unidirectional link support*	Yes	No	No	Yes
v) *Multicasting*	No	No	Yes	No
vi)*On-demand routing behavior*	Proactive	Proactive	Reactive	Reactive

6.1 Security:

None of the proactive protocols addresses the security vulnerabilities that are obvious in wireless networks. The proper function of these protocols is based on an assumption that all the nodes exist and operate in a secure environment where link- and physical-layer security mechanisms are in place. However, CGSR seems to be the most vulnerable amongst DSDV and OLSR and an attack on nodes that act as cluster heads may have severe consequences in the network performance. DSDV is more secure than OLSR, as OLSR functionality is based on the proper behavior of the Multipoint Relay Nodes (MPRs). Although security is a major concern in vehicular communications, it is found that the security mechanisms will increase processing time, power consumption, and latency. Note that reactive routing protocols already suffer from high latency in the network.

6.2 Loop freedom:

All studied proactive protocols are loop-free. OSLR, as a modification of the link state algorithm, does not introduce any loops into the routing process, except for oscillations when the link costs depend on the amount of traffic carried by the link. In the MANET scheme, however, link cost depends on the number of hops from a source to a destination, thus avoiding oscillations. DSDV addresses known problems that the Distance Vector algorithm introduces, with the use of destination sequence numbers.

All tested reactive protocols are loop-free. No protocol addresses security vulnerabilities that exist in a wireless ad hoc network. However, there are certain proposals for providing secure routing at Layer 3 for all tested protocols.

6.3 Sleep mode

As for the ‘sleep mode’ operation, only OLSR considers some extensions in its current existing design to support such an operation. In a wireless ad hoc network, in which nodes depend mainly on batteries for their energy source, the sleep mode is a serious attribute that should be supported by any routing protocol. None of the reactive protocols supports the 'sleep mode', another important factor for power preservation, especially in battery-powered mobile nodes. AODV will consume more power than DSR owing to the exchange of periodic HELLO messages.

6.4 Unidirectional link support

DSDV does not support unidirectional links. However, unidirectional links exist in wireless Communications and they should be supported in order to take advantage of any possible paths from a source node to a destination node. In MANETs, especially, there is no such 'luxury' as ignoring any possible paths, as routing protocols should take advantage of any link to calculate routes in the network. OLSR designers take into account these limitations of the wireless network and support both bidirectional and unidirectional links.

Only DSR in its current state, without any modification, can support both bidirectional and unidirectional links. However, DSR will introduce high routing overhead as routing information is stored at the data packets' header. Thus DSR will not scale well in large networks if communicating nodes are located at opposite edges of the network.

6.5 Multicasting: DSDV, OLSR, DSR do not provide multicasting. Only AODV provide multicasting.

6.6 On-demand routing behavior: AODV and DSR shows on demand behaviour and OLSR and DSDV shows proactive behavior.

By summarizing the above results, it is seen that OLSR is closer to the IETF MANET working group design recommendations. Indeed, OLSR has been designed with high respect to RFC 2501. Perhaps the only visible disadvantage is the high routing overhead. However, it is mainly up to the network designer to decide what he really needs from a network. In military communications, where the main concerns are timely and reliable data delivery, OLSR may fit well as a routing protocol. If the concern is utilization of the biggest part of the available bandwidth, leaving a small part for control messages, then OLSR is not the appropriate choice .Finally, given qualitative metrics and the attributes of the above protocols, **OLSR** is chosen for further evaluation in this simulations.

Given qualitative metrics and the attributes of the three protocols, it is suggested that **AODV** would be good candidates for the routing protocol in mobile ad hoc wireless networks. Therefore AODV is chosen for further evaluation in these simulations.

VII. PERFORMANCE EVALUATION BASED ON QUANTITATIVE METRICS

The MANET network simulations are implemented using NS-2 simulator [23]. Nodes in the simulation move according to a model that we call Random Waypoint Mobility model [24]. Each node is then assigned a particular trajectory. The simulation period for each scenario is 200 seconds and the simulated mobility network area is 2000 m x 1000 m rectangle. In each simulation scenario, the nodes are initially located at the center of the simulation region. The nodes start moving after the first 10 seconds of simulated time. The MAC layer protocol IEEE 802.11 is used in all simulations with the data rate 11 Mbps. The transmission range is 500m. The application used to generate is CBR traffic and IP is used as Network layer protocol.

The packet size 512 bytes. The node speeds is taken as min. 2m/s and max. 7 m/s. the no. of nodes are taken as 50.The Performance evaluation, as well as the design and development of routing protocols for MANETs, requires additional parameters which is addressed in RFC developed by Internet Engineering Task Force (IETF).

7.1 Effect of varying the network load

In this set of simulations, the number of data packets sent by the sources is increased from 5 packets/s to 20 packets/s keeping all other network parameters unchanged. The demand for efficient routing and wireless medium utilization for data traffic is higher in this scenario; it will observe how the two protocols can scale in that demanding network. In this scenario, it is observed that with a packet rate of more than 25 packets/s both protocols present a very low packet delivery ratio (below 50%), making any comparison at those rates meaningless.

Figure 7.1(a) shows the packet delivery ratio of the protocols. Both protocols have an identical performance at low rates (5 packets/s). AODV performs better than OLSR in all cases, whereas OLSR has, again, the worst performance. Although 50 nodes are placed in an area of 2000mx1000m to avoid Interference, nodes are still in close proximity, especially within the clusters. This scenario does not favor OLSR: It is noticed by analyzing the ns-2 trace files that OLSR produces a large size of route update packets that require higher transmission time than that of AODV. AODV does not suffer from that periodic exchange of link state information, as routes are discovered in an ad hoc fashion. By analyzing also the trace files, it is observed that data packets are dropped by AODV for the following reason: in AODV, the source node will send an RREQ message if a route to the destination node does not exist. After the second transmission of the RREQ message, if the source node does not receive a RREP message within a time interval it will drop the first packet in the queue and repeat the same procedure for the second data packet in the queue. However, when any intermediate node cannot find a valid route to the destination node by repeating the above procedure, it will drop not only the first packet but also all data packets from its queue, thereby degrading the protocol's performance.

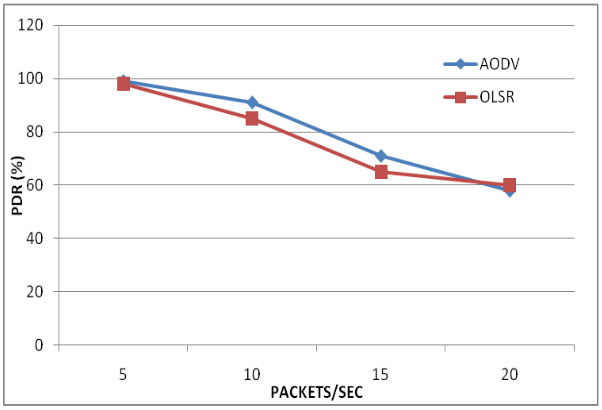

Fig.7.1 (a): PDR for varying network load.

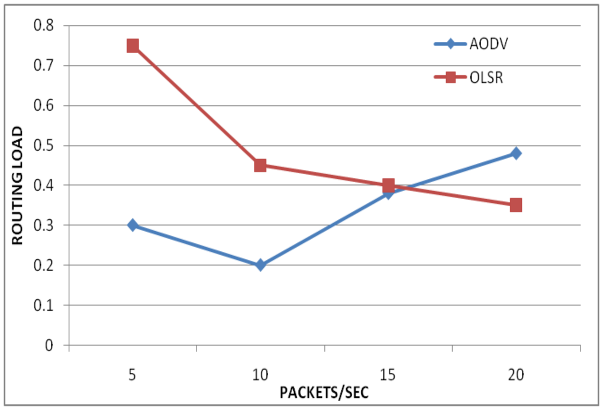

Fig.7.1 (b): Routing load for varying network load.

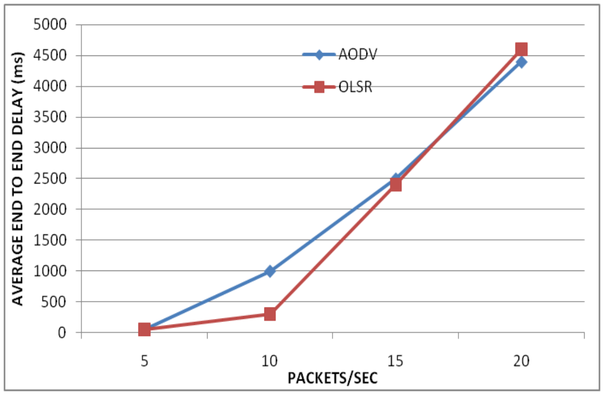

Fig.7.1(c): Average end to end delay for varying network load.

Figure 7.1(b) shows the normalized routing load. OLSR presents high routing load in low traffic (5 packets/s), which drops significantly in higher traffic. The reason is that OLSR generates the same amount of routing packets regardless of whether AODV has a lower routing load than OLSR, However, AODV was designed for networks with a larger number of nodes and higher mobility than that in our simulation.

Figure 7.1(c) shows the end-to-end delay. It is expected OSLR to have better performance than the other AODV. However, the end-to-end delay in OLSR increases when the data traffic increases. The explanation lies in the low mobility of the network. As nodes do not change their positions very frequently, there exists a high level of network congestion at certain regions of the network because none of the three protocols employs any mechanism for load balancing, data traffic is not evenly distributed in the network, and high end-to-end delays result.

7.2 Effect of varying network mobility

In this set of simulations, the mobility of nodes is varied. A mobility scenario is started in which the nodes have a low velocity of 5 m/s. The node velocity is increased up to 20 m/s. A constant data rate of 10 packets/s is kept and a constant number of 20 connections. It is observed that, at higher data rates with increasing mobility, the performance of the protocols decreases. The decreased performance is large, mainly due to network congestion, in a way that makes any comparison meaningless.

Figure 7.2(a) shows the packet delivery ratio of the protocols. OLSR protocol presents a similar performance as AODV, having the best performance at all mobility rates. Here it is observed again that protocol have a better performance when the speed of the nodes is 10 m/s and 15 m/s, because the network load is more evenly distributed among the nodes at higher mobility rates.
Figure 7.2(b) shows the normalized routing load. OLSR has the same behavior, while the AODV performance increases when nodes move at higher speeds.

Figure 7.2(c) shows the end-to-end delay of the protocols. OLSR has the lower end-to-end delay at low and high mobility as compare to AODV.

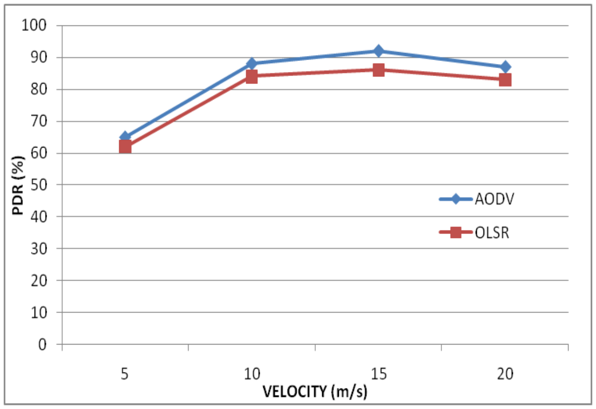

Fig.7.2 (a): PDR for varying network mobility.

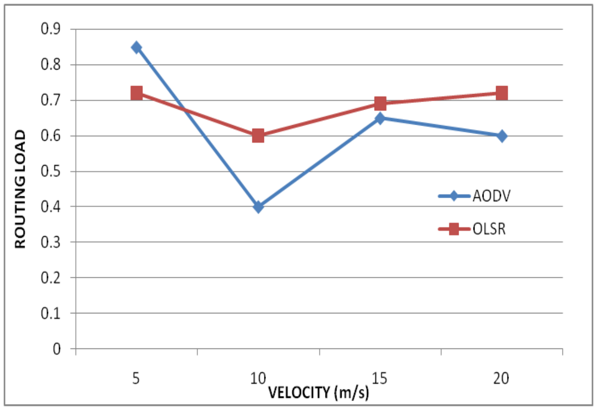

Fig.7.2 (b): Routing load for varying network mobility

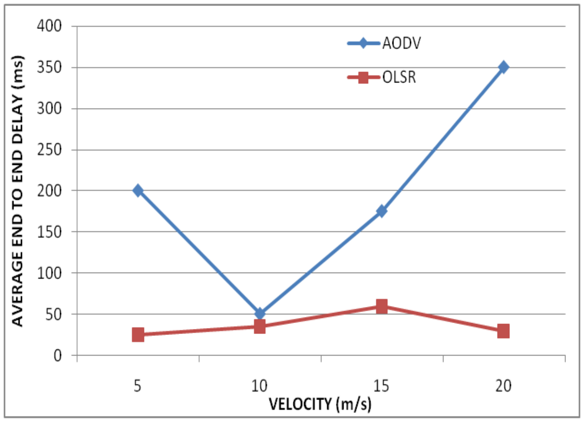

Fig.7.2 (c): Av. end to end delay for varying network mobility.

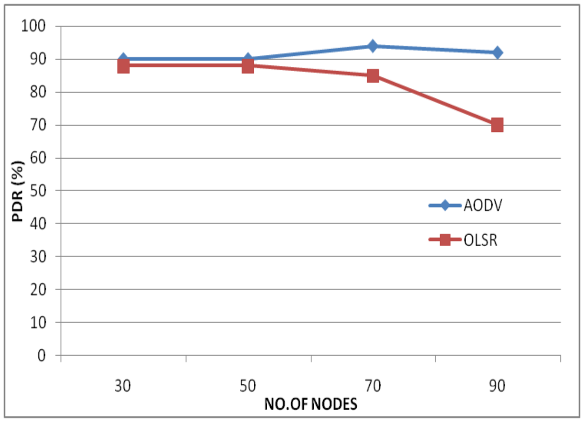

Fig.7.3 (a): PDR for varying node density

7.3 Effect of varying node density

In this set of the simulation, the number of nodes is varied in the network. The objective of this is to investigate the impact of node density on the protocol's performance. The same simulation area is used as in the previous simulations and gradually increases the number of nodes in the network. A desirable property of a protocol is to have stable behavior regardless of the number of nodes in the network. A small number of nodes in a large simulation area will result in low connectivity due to the large distances between nodes. In contrast, a large number of nodes in a small simulation area will result in signal interference, as nodes are located very close to each other. Both protocols have a similar packet delivery ratio, except in the case of 90 nodes, in which OLSR Performance drops significantly compared to that of AODV (Figure 7.3 a).

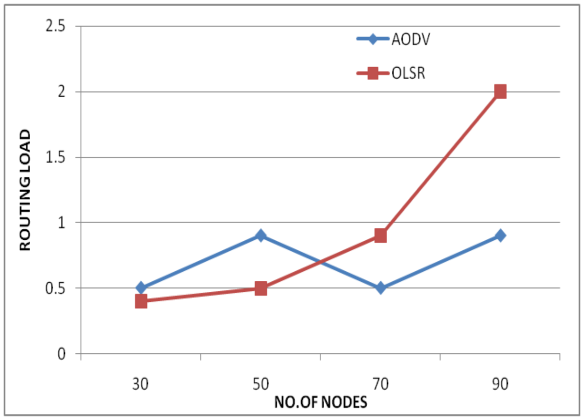

Fig.7.3 (b): routing load for varying node density.

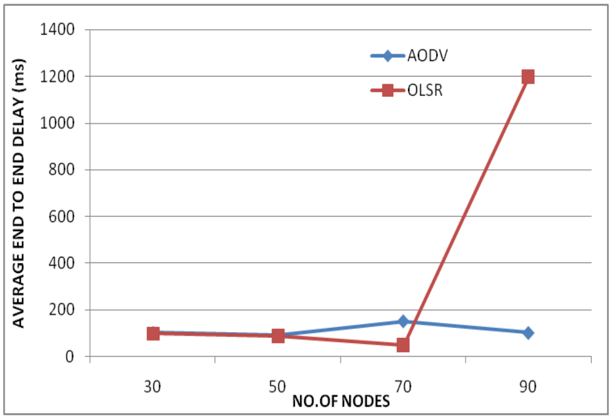

Fig.7.3 (c): average end to end delay for varying node density

Figure 7.3 (b) shows the normalized routing load. AODV has a higher normalized routing load than OLSR in the case of 30 and 50 nodes. However, AODV scales well when the number of nodes in the network increases. OLSR has a lower normalized routing load than AODV in the case of 30 and 50 nodes, which increases exponentially with 90 nodes. This is not a desirable property of a protocol, as that high routing load reveals the OLSR inefficiency to operate properly in a network with an increasing number of nodes. This is a direct result of the OLSR proactive behavior, but it is expected that the proposed optimization of the Link State algorithm with the implementation of the MPRs would result in a much lower normalized routing load, thereby increasing OLSR performance.

The direct result of a congested network is a high end-to-end delay, which increases exponentially in the case of 90 nodes, as we see in Figure 7.3(c). AODV present small fluctuations in terms of the end-to-end delay, but generally its performance is stable in all cases.

VIII. CONCLUSION

In this paper, the performance of the four MANET Routing protocols such as DSDV, AODV, OLSR and DSR was analyzed qualitatively and then using NS-2 simulations OLSR and AODV was analyzed for qualitative metrics. It is observed that OLSR had the lowest performance in terms of the packet delivery ratio in all of the simulations. OLSR presented the lowest end-to-end delay in almost all of the simulations, and in most cases the end-to-end delay was independent of the varying simulation parameters. OLSR is a good compromise when combining the protocol performance, in terms of the packet delivery ratio and the end-to-end delay. It is concluded that OLSR is the most efficient protocol for time-sensitive applications such as voice and video transmission. In networks with a small number of nodes and low mobility, AODV did not suggest a good solution as a routing protocol. However, AODV had better performance in networks with higher mobility and a greater number of nodes. Simulation results in those networks suggest that AODV presented a higher packet delivery ratio than OLSR. In addition, AODV performance in terms of end-to-end delay was very close to that of OLSR. It was concluded that AODV was the appropriate protocol for any kind of application (voice, video, file transfer, etc.) in networks with high mobility that consist of up to 90 or more nodes.

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