COMPARATIVE ANALYSIS OF LINK STATE AND DISTANCE VECTOR ROUTING PROTOCOLS FOR MOBILE ADHOC NETWORKS

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ABSTRACT *Mobile Adhoc networks are primarily classified for their dynamic topology and lack of infrastructure. The key role of Adhoc network routing protocols is to establish routes efficiently and accurately among nodes and ensure the packet delivery in time. In this work the technique has selected two proactive, tables driven routing protocols from Distance Vector Routing (DVR) and Link State Routing(LSR) and evaluated their performance on the basis of specified network parameters. The results of a detailed simulation for mobile Adhoc networks, comparing two proactive, table driven routing protocols: OLSR as a candidate from LSR and DSDV as a representative from DVR in various scenarios of mobility, scalability and traffic load. Finally the paper discussed the functionality and behavior of both the protocols and their comparison based on simulation results.*

Key words: Adhoc Networks, Protocols, Routing, Analysis, Comparison.

INTRODUCTION

A Mobile Adhoc Network is composed of mobile nodes/devices which interact among each other under the restraint environment of wireless medium. As the nodes keep on moving, the topology they form may change very frequently over time. In Manets, the network is distributed or decentralized and routing and message delivery is the responsibility of all incorporated nodes.

The function of routing protocols is to broadcast the routes and selects the best optimal path. Routers employ routing protocols to forward packets. These routing schemes are classified as Link State Routing (LSR) and Distance Vector Routing (DVR). The categorization depends on the parameters of routing table. In distance vector the best optimal path is chosen by determining "the distance" whereas in link state routing optimal path is selected by analyzing the "state" of each and every link in routes towards the destination; therefore discovering the route with lowest total metric to arrive at the destination.

RELATED WORK

The authors in [1][2][3] compare ad hoc routing protocols under different network parameters. The authors in [4] match up routing protocols namely Adhoc on Demand Distance Vector Routing (AODVR), Dynamic Source Routing (DSR) and Source-Tree Adaptive Routing (STAR); they employed both simulators i.e. GlomoSim and Networks Simulator2 in order to run their simulations. They considered a comparatively small geographical region. A detailed work was done by [1] since the authors carried out a detailed evaluation among DSR and AODVR using several performance parameters. Node pause time is taken as the basic mobility parameter. The majority of the earlier work is restricted to simulate proactive and reactive routing protocols for mobile ad hoc networks. In contrast to [1] this paper defines the technique that broaden annotations to the class of dynamic routing protocols namely as distance vector and link state. Paper examined and discussed the behavior of protocols from each of the classes mentioned above.

ROUTING PROTOCOLS CLASSIFICATION

Dynamic routing protocols are classified on the basis of information that routers share with each other and how that information is used further to construct their routing tables. Following is the content based classification of routing protocols.

- Distance Vector protocols(DV)
- Link State protocols(LS)

The majority of protocols existing in the networks fall into either of the above two categories as shown in figure-1.

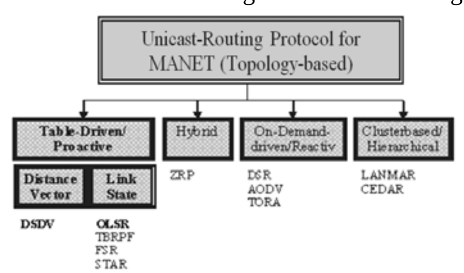

Figure 1 MANET: Mobile Ad hoc Network (Internet Engineering Task Force (IETF) working group)

DVR Protocols

These protocols have designed on the concept of Bellman and Ford [5],[6],[7] shortest path algorithm. In DVR protocol the routing table logs the list of all accessible destinations. The distance is measured using a number variable to reach the destination and to the next hope to destination. Moving from one hop to another ultimately leads to the destination. Irrespective of any change in topology each node broadcasts routing information on peroidic basis.

Link State Routing Protocols

Link State (LS) protocols employ Dijkstra shortest path algorithm in order to reach next hop. The methodology adapted by LS protocols is similar to distributed database systems. The routing database is replicated throughout the routing realm. Each node starts with identifying the state of each link to its neighbors. Hello messages are used to sense neighbor node. A simple sending and receiving of Hello message confirms the existence of neighbor. This information is then flooded to other routing nodes, finally constituting a routing database. Hence the link state (LS) database is kept updated all the time by the above mentioned flooding methodology [8]. Therefore, subject to any change in topology each node contains sufficient information to create a net vision of entire network and consequently compute the optimal path to destination using Dijkistra algorithm.

MATERIAL AND METHODS

This paper, presents the outcome of a thorough simulation, comparing two dynamic proactive routing protocols: DSDV as a representative from DVR; OLSR as a candidate from LSR for mobile Adhoc networks in a variety of scenarios of mobility, scalability and traffic load.

This paper represents an analysis for the performance of Link State Protocols and Distance Vector Protocols in Mobile Adhoc networks. The network environment parameters for comparative analysis are data rate, no of nodes and maximum node moving speed; upon which specified performance metrics have been evaluated.

Destination Sequenced Distance Vector (DSDV)

DSDV protocol belongs to the class of proactive routing protocol and is a variant of Bellman-Ford shortest path algorithm [6],[8]. DSDV was designed to transfer data packets on the arbitrary interconnection structured network. In DSDV every node logs and preserves the routing table. Routing table helps the nodes in transmission of data exchange within the network. The designing goals for the protocol are

- Maintain the ease of Bellman-Ford.
- Prevent the looping problem.
- Stay compatible in cases where a base station is accessible.

The Optimized Link State Routing (OLSR) Protocol

OLSR is used for mobile and wireless ad-hoc networks. In order to find out and differentiate link state information OLSR uses Hello messages. Individual nodes use shortest hop forwarding path to compute the next hop destination [9] [10][11].

OLSR is more appropriate for situations in which the links vary over time due to mobility. It requires no extra control traffic to be spawned as routes are continuously maintained for all of the acknowledged destinations.

Approach and Methods

For analysis and testing of Routing Protocols over wireless ad hoc networks following software tools have been used.

1. Network Simulator , Version 2.28
2. Gnuplot, Version 3.7

A mobile ad-hoc network has been deployed for experimental setup. Simulation software is being used for tests related to wireless network performance [12].

NS-2 is a software tool mainly used in networks related research area as it offers substantial support for simulating different types of wired and wireless networks. It is used to simulate a very wide range of applications of protocols, different types of networks, network elements and various traffic and mobility models [13].

Experimental Setup

The selection of simulation parameters subjects to change with the aim of drawing conclusions from the results. These parameters have been set in accordance with the simulation purpose as each simulation requires high computation and processing cost. Following is the list of simulation parameters.

- Nodes
- Speed
- Data rate

Specific scenarios are defined for simulation environment to analyze the behavior of routing protocols i.e., OLSR & DSDV. The area size is 700m × 700m for all the simulations. An average of ten simulations is used to represent a data point in the graph.

The scenarios are defined by varying one parameter and keeping all the others constant. For adequate evaluation, both the protocols have been evaluated on identical mobility patterns and traffic scenarios.

The Random Waypoint model is the default mobility model in NS2 that is used to generate the mobility patterns. Constant Bit Rate (CBR) traffic is used at application layer using packets of size 512 bytes. The User Datagram Protocol (UDP) operates at transport layer.

Performance Parameters

The details of parameters that have been used to evaluate the performance of link state (LS) and distance vector protocols are given below.

Average end-to-end Delay

It refers to the delay encountered in the successful transmission of the packet from the source node to the specified destination. It includes all potential delays starting from buffering of packets, route discovery time, queuing time, retransmission time, propagation time and transfer times. Thus it is defined as a time period that a packet takes to move from source to destination at application layer. It is an imperative parameter for the assessment and analysis of the performance in routing protocols.

Packet Delivery Ratio (PDR)

It is the ratio of packets that have been delivered successfully by the total number of packets that are spawned by CBR sources[14]. Higher packet delivery ratio (PDR) value depicts lower packet loss rate. So from data delivery point of view the higher the ratio, the faster and efficient the routing protocol is. For real time communication, sometimes the protocols with higher PDR may not be taken as efficient as the packets that have reached their destination late are considered to be worthless although delivered successfully.

Packet Delivery Ratio =

$$\frac{\text{Total number of Packets (Successfully delivered)}}{\text{Total Number of Packets (Transmitted)}} \quad (1)$$

Normalized Overhead Load

It is a fraction of the overall routing/control packets to the entire packets that lead to successful delivery. The number of overhead packets for the routing protocols at the transport layer includes the packets that were sent for route detection and preservation e.g. Hello messages, Route REQs, Route REPs and Route ERRs" [14].

Normalized Overhead Load =

$$\frac{\text{Total number of control/ routing Packets}}{\text{Number of Successfully Delivered Packets}} \quad (2)$$

SIMULATION OUTCOME AND ANALYSIS

Impact of Number of Nodes

The experimental scenario designed parameters are: Pause time =20 sec, Data rate = 500 kbps, Vmax = 5m/s, Area = 700 x 700, Simulation time = 200 sec, step size =5 and

number of nodes = 25 to 60.
The simulation outcomes are shown in the following Figure-2.

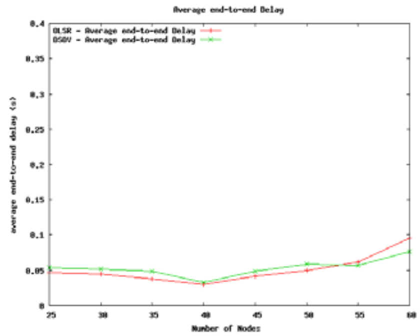

Figure 2 Average end-to-end Delay w.r.t different Number of nodes

As from the above chart, the data latency is increased by the increase of traffic load. The reason behind is longer queuing latency for acquiring wireless channel besides additional requests for route discovery and re-discovery. Those routing protocols suffer more in heavy workloads that have higher computation delay.
OLSR reveals lower average end-to-end delay as opposed to DSDV except for some denser points. From figure-2 it is clear that OLSR grows in a more steep fashion with dense network than DSDV. In DSDV, incrementing node number will increase overhead of routing messages. The lower values of average end-to-end delay demonstrate on-time transmission of packets which is a vital feature of many real time applications as shown in Figure 3.

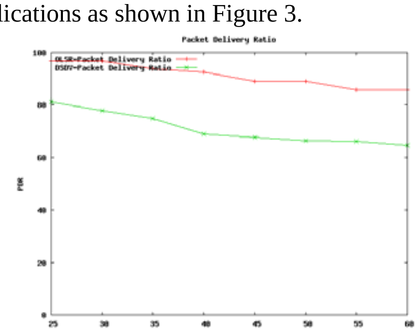

Figure 3 Packet Delivery Ratio w.r.t different Number of nodes

The packet delivery ratio of OLSR protocol seems to be elevated than the corresponding DSDV routing protocol at every data point with the increasing number of nodes. The performance of DSDV degrades rapidly as the network size grows. PDR decreases with the increase of traffic flow but still at each data point OLSR performs better than DSDV. The reason can be that, as number of nodes increases, the overall traffic load also increases. Therefore at some time the utmost throughput incurs by the nodes cannot conform to the actual traffic load. As a result, queues at nodes start getting overflow; therefore, the packets at the end of the queues may get dropped at source as well as at intermediate nodes.
Figure-3 depicts the packet delivery ratio in growing traffic load. The PDR for each of the protocols degrades unanimously. Furthermore, the ratio of congestion and collision of packets at the nodes also increases as the traffic load amplify. The value of normalized routing load increases as the network becomes dense as shown in Fige-4. In denser networks, intermediate nodes on busy route have greater probability of droping packets due to congestion. Route discovery and maintenance packets are sent when an intermediate node is down so more control packets flood into the networks to find new route so increasing Normalized Overhead Load (NOL).

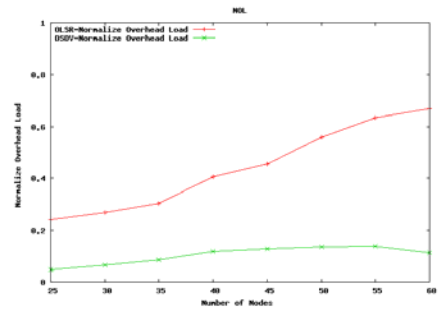

Figure 4 NOL with different Number of nodes

OLSR is based on two different control messages, i.e. HELLO and Topology Control (TC). [9]. Therefore the NOL of OLSR would always be greater than that of DSDV.
The Normalized Overhead Load (NOL) is constantly low and grows very steadily for DSDV since the routing packets are sent only for the period of the route discovery and route maintenance. There is no exchange of Hello messages in DSDV as in OLSR. Consequently, the overhead load exercised by DSDV is always low.
The mobile nodes make use of Hello messages to learn the network topology and the selection of their multipoint distribution relays (MPRs) in OLSR based routing [9][10]. It can be seen clearly from figure-4 that OLSR based routing incurs relatively more computational cost in terms of overhead than that of DSDV routing protocol in denser networks.

Impact of Maximum Node Moving Speed

The experimental scenario designed parameters are: Pause time =20 sec, Data rate = 500 kbps, Area = 700 x 700, Simulation time = 200 sec and Vmax = 5m/s to 25 m/s. The results are shown below in figure-5.

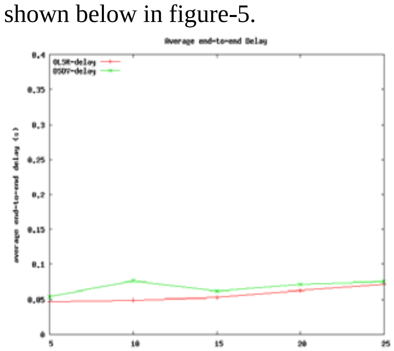

Figure 5 Average end-to-end delay w.r.t mobility

It is evident from figure-5 that OLSR works reasonably well than that of DSDV routing protocol. The delay revealed by OLSR is perpetually less than 1ms even at 25m/s. It is also observed that delay incurred by DSDV is always higher than OLSR even in high mobility environments. Therefore, we conclude that for high mobility environment, OLSR based networks generate lower delay than those of DSDV.
The rationale may possibly is that in high mobility environments topology changes and route breakage is very

frequent and thus more routing packets are transmitted which results in high latency in finding/maintaining the routes.

DSDV retains just one route per destination and this is the key reason for the abridged performance of DSDV. DSDV faces the shortage of proxy routes and stale routes entries in the routing table; therefore it leads to elevated end-to-end delay in high mobility scenarios. Overall in high mobility environment the delay of OLSR is reasonably lower than DSDV as shown in Figure 6.

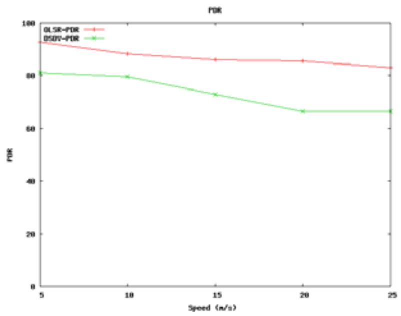

Figure 6 PDR w.r.t mobility

Packet delivery ratio of both protocols seems to be declining with increase in mobility because link breakages will be frequent and maintaining and finding routes will gradually require more routing traffic. Hence, fewer channels will be used for data transmission, resulting in lower values of PDR.

Due to mobility the frequency of link changes and route changes unswervingly influence the overhead and adaptability of routing protocols. From figure-6 we have seen that the packet delivery ratio of OLSR is better than that of DSDV. The packet delivery ratio decreases as node mobility increases. However, OLSR performs undoubtedly well than DSDV even in high mobility.

In DSDV, congestion is the major reason for packet drop. DSDV easily leads to congestion as compared to OLSR. We can clearly observe the significant difference in PDRs at each data point. Such performance is considered as a primary factor for real time traffic transmissions.

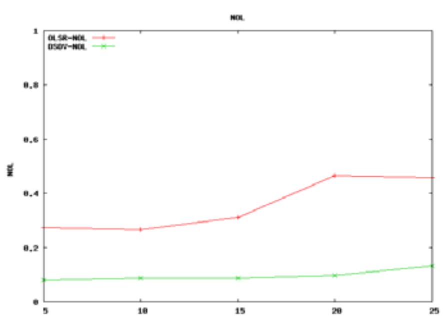

Figure 7 NOL w.r.t mobility

The routing overhead seems to escalate as node moving speed increases for each of the protocols as shown in figure-7. But still OLSR routing overhead is much higher at every data point. There is a higher prospect of moving out of the transmission range for the nodes that exist on the way point of busy routes for the upstream and downstream nodes. However, the overhead of DSDV protocol keeps stable in contrast to OLSR in high mobility scenarios.

With the increase of mobility, source nodes spawn additional route requests packets to discover a novel route to arrive at the destination. Link breakages will be frequent and maintaining and finding routes will require more and more routing traffic.

The reason for higher NOL of OLSR has already been discussed in previous section. Therefore NOL is proportional to node moving speed. It is evident that the OLSR routing protocol outperforms than DSDV by transmitting additional routing packets in the network as shown in figure-7. These control messages are crucial for keeping the routing table up-to-date

Impact of Data Rate

The experimental scenario designed parameters are: Pause time =20 sec, Area = 700 x 700, Simulation time = 200 sec , Vmax = 5m/s and Data rate = 500 kbps to 1000 kbps. The results are shown below in Figure 8.

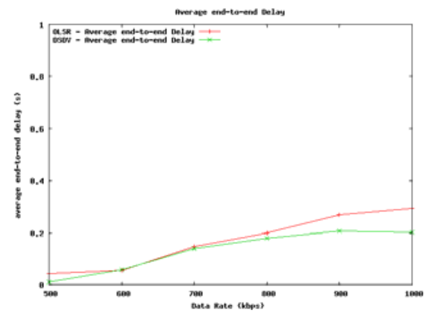

Figure 8 Average end-to-end delay w.r.t data rate

Figure-8 shows that the performance of DSDV routing protocol is slightly better than the OLSR under some low data rates. The end-to-end delay incurred by DSDV based network increases steadily as the data rate of traffic flow increases. In both protocols, the utmost delay is more or less around 3.0 ms at 1000 kbps. Comparatively, with growing traffic flow and data rate, OLSR delay seems to grow in a more steep fashion than DSDV after 700kb.

The average end-to-end delay exercise by OLSR is higher than DSDV at low data rates. This is because OLSR use to transmit more routing packets than DSDV. Therefore, initially it encounters high route discovery time which in turn comprises higher values of average end-to-end delay at low data rates.

In OLSR, routing packets like Hello messages and Topology Control (TC) messages are always sent out on priority basis while the data packets are queued at nodes. In DSDV based routing the optimal route adopted by the routing algorithm is able to afford sufficient data rate usually when the network has low traffic within it. Hence the delay is not lofty at low data rates. Overall the average end-to-end delay is more stable in OLSR even though the network load increases whereas DSDV performs well with low data rates.

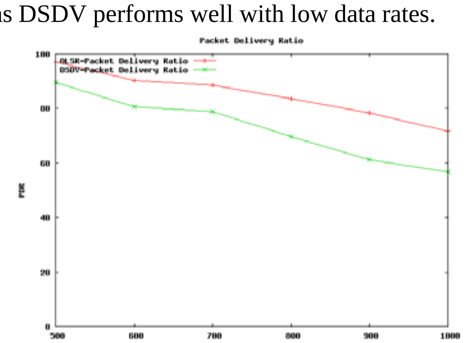

Figure 9 PDR w.r.t data rate

OLSR shows much higher PDR than that of DSDV as shown in figure-9. On the other hand the value of PDR starts declining with increase in the data rate of traffic flow but still at each data point OLSR outperforms the DSDV. Such behavior may be due to the reason that, as number of nodes increases, the overall traffic load also increases. Therefore at some time the utmost throughput incurs by the nodes cannot conform to the actual traffic load. As a result, queues at nodes start getting overflow; therefore, the packets at the end of the queues may get dropped at source as well as at intermediate nodes.

The Packet Delivery Ratio (PDR) of DSDV protocol is generally less than OLSR protocol. Generally, the reason behind is that host node acquires more delay in order to find a suitable optimal route, while at the same time it also send packets from application layer. As queues get overflow, the packets at the end of queue begin to drop.

Another reason could be that all of the dropped packets are lost in DSDV due to a stale routing table entry. Furthermore, every packet that MAC layer may possibly not be able to deliver is dropped because DSDV routing table maintains one route for each destination and it takes time to search for alternate paths as shown in figure 9.

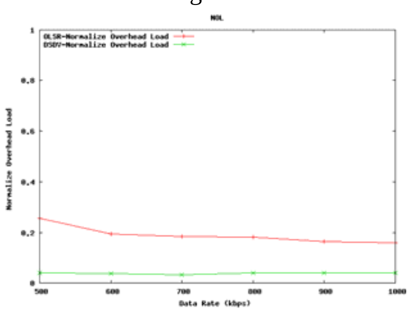

Figure 10 NOL w.r.t data rate

In Figure-10, with the increase of data rate, routing overhead decreases in OLSR. The Normalized Overhead Load(NOL) of OLSR would always be greater than that of DSDV due to larger number of routing packets (Hello and Topology Control) [11]. In OLSR, Hello messages are sent sporadically, that is, on periodic basis regardless of the network load.

The NOL is constantly low and grows very steadily for DSDV since the routing packets are sent only for the period of the route discovery and maintenance. Consequently, the overhead load exercised by DSDV is always low as observed in Figure-10.

CONCLUSION AND FUTURE WORK

The simulations results have shown that each class i.e., Link State and Distance Vector has its own merits and demerits; therefore, not a single class is appropriate for all network environments. It is concluded that each class delivers better results for some performance parameters at the expense of others.

LSR Protocols get better performance for adhoc networks in terms of Packet Delivery Ratio (PDR) but endure more protocol overhead as compared to Distance Vector Protocols. The OLSR protocol works more effectively and efficiently in denser networks and high node mobility environments. OLSR demands to have some bandwidth constantly since it has to receive the topology information and thus results in high protocol overhead. Packet delivery ratio of both protocols declined in high mobility scenarios.

DSDV is more appropriate to establish ad-hoc networks for lesser number of mobile nodes. Distance Vector Protocols improve the performance adhoc networks in terms of NOL but attain low Packet Delivery Ratio (PDR) relative to LSR Protocols. Distance vector protocols demonstrate approximately constant overhead, despite of mobility or traffic load, so the delay is quite constant. According to simulations, DSDV delivers best results for small networks.

Finally, we conclude that OLSR performs well in terms of PDR at high network load and mobility. But it is not good for some other metrics e.g., NOL. DSDV performs badly in terms of PDR because of heavy flooding in route discovery but constitutes lower average end to end delays and NOL by having no periodic Hello updates and less route discovery time. At higher mobility environments DSDV performs poorly as the PDR drops to 60%.

Hence LSR protocols give better performance for denser network, high network load and mobility environments while Distance Vector protocols are well suited for small and low mobility networks.

The analysis has been performed considering random way point mobility model. We can also extend this work by analyzing the behavior of LSR and DVR protocols using other mobility models for adhoc networks since mobility models have significant effect on the performance of protocols.

Secondly, we have given the same priority to all kind of traffic whereas in real time scenarios traffic may be distinguished to have different priorities. The simulations may be design to analyze the behavior of link state and distance vector class using different priorities of traffic.

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