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A Performance Comparison of Proactive and Reactive Routing Protocols of Mobile Ad-hoc Network (MANET)

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Abstract: Mobile Ad-hoc NETwork (MANET) is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration. To support MANET, many routing protocols are already designed, such as DSDV, DSR, AODV, TORA, OLSR, WRP, ZRP and many more. This study analyzes these three routing protocols using Network Simulator version no 2 (ns-2). The performance of these protocols are compared in terms of their packet delivery fraction, average end-to-end delay, normalized routing load and routing overhead (packets) for 50 nodes and 100 nodes model with various numbers of sources. However, performance comparison and comparative analysis of these protocols for above mention metrics has not yet been performed. This study does that comparison and pointed out the relative strengths and weakness of those proactive and reactive routing protocols.

Key words: Mobile Ad-hoc NETwork (MANET), DSDV, AODV, OLSR, ns-2, nam etc

INTRODUCTION

Recently, there has been tremendous growth in the sales of laptop, handheld computers, PDA and portable computers. These smaller computers nevertheless can be equipped with megabytes/gigabytes of disk storage, high-resolution color displays, pointing devices and wireless communications adapters. Moreover, since many of these small computers operate for hours with battery power, users are free to move without being constrained by wires. To support such type of scenario MANET is designed. Ad-hoc networks differ significantly from existing networks. MANET has several salient characteristics such as, dynamic topologies, bandwidth-constrained, variable capacity links, energy-constrained operation and limited physical security. The increased possibility of eavesdropping, spoofing and denial-of-service attacks should be carefully considered. Already several routing protocols are designed which are mentioned above. To judge the merit of routing protocols, both qualitative and quantitative metrics are needed. Most of the routing protocols ensure the qualitative metrics. For this reason, quantitative metrics are used for performance comparison. This study use packet delivery fraction, average end-to-end delay, normalized routing load and routing overhead (packets) for 50 nodes and 100 nodes model with 10, 20, 30 sources for performance evaluation.

Performance comparison among some set of MANET routing protocols is already done by the researchers such as among PAODV, AODV, CBRP, DSR and DSDV (Boukerche, 2004) among DSDV, DSR, AODV and TORA (Broch *et al*., 1998) among SPF, EXBF, DSDV, TORA, DSR and AODV (Das *et al*., 1998), among DSR and AODV (Des *et al*., 2000), among STAR, AODV and DSR (Hong, 1994) and among AMRoute, ODMRP, AMRIS and CAMP (Broch *et al*., 1998). This study compares performance of DSDV, OLSR and AODV routing protocols.

ROUTING PROTOCOLS OF MANET

Among several routing protocols, only necessary (for this study) three routing protocols DSDV, OLSR and AODV are described next

Destination-Sequenced Distance-Vector (DSDV): Highly dynamic Destination-Sequenced Distance-Vector (DSDV) routing protocol (Charles and Pravin, 2004) is an improved version of the well known distance vector Bellman-Ford routing algorithm. It acquires the loop free properties, which is not present in Bellman-Ford algorithm, in case of link breakage. Each node in the network maintains for each destination a preferred neighbor. Each data packet contains a destination node identifier in its header. When a node receives a data packet, it forwards the packet to

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the preferred neighbor for its destination until the packet reaches to its ultimate destination. Routing information is advertised by broadcasting or multicasting the packets which are transmitted periodically and incrementally. The DSDV protocol requires each mobile station to advertise its own routing table to each of its current neighbors. Broadcast data packets contain sequence number (also destination address and number of hops) of which the recent one is always preferred as the basis for making forwarding decisions. The receiver making an increment to the number of hops metric and also advertises routes received in broadcast packets. The broken link is described by a metric of infinity. When a link to the next hop is broken any route through the next hop is immediately assigned infinity metric and an updated sequence number. Then this information is enclosed with a broadcast packet to others.

Optimized Link State Routing (OLSR): Optimized Link State Routing protocol (OLSR) (Clausen *et al*., 2001; Jacquet *et al*., 2000) is based on link stare algorithm and it is proactive in nature. OLSR is an optimization over a pure link sate protocol (Boukerche, 2004) as it compact the size of information send in the messages and reduces the number of retransmissions. It provides optimal routes in terms of number of hops. For this purpose, the protocol uses multipoint relaying technique to efficiently flood its control messages (Clausen *et al*., 2001). Unlike DSDV and AODV, OLSR reduces the size of control packet by declaring only a subset of links with its neighbors who are its multipoint relay selectors and only the multipoint relays of a node retransmit its broadcast messages. Hence, the protocol does not generate extra control traffic in response to link failures and additions. OLSR is particularly suitable for large and dense networks (Clausen *et al*., 2001). In OLSR, each node uses the most recent information to route a packet. Each node in the network selects a set of nodes in its neighborhood, which retransmits its packets. This set of selected neighbor nodes is called the Multipoint Relays (MPR) of that node. The neighbors not belong to MPR set, read and process the packet but do not retransmit the broadcast packet received form node N. For this purpose each node maintains a set of its neighbors, which are called the MPR Selectors of that node. This set can change over time, which is indicated by the selectors in their HELLO messages. The smaller set of multipoint relay provides more optimal routes. The path to the destination consists of a sequence of hops through the multipoint relays from source to destination In OLSR, a HELLO message is broadcasted to all of its neighbors containing information about its neighbors and their link status and received by the node which are one hop away but they are not relayed to further nodes. On reception of HELLO messages, each node would construct its MPR Selector table. Multipoint relays of a given node are declared in the subsequent HELLO messages transmitted by this node.

Ad-hoc On-demand Distance Vector Routing (AODV): Ad-hoc On-demand Distance Vector (AODV) (Perkins and Royer, 1999) is another variant of classical distance vector routing algorithm. Like DSDV, AODV provides loop free routes in case of link breakage but unlike DSDV, it doesn’t require global periodic routing advertisement. AODV experiences unacceptably long waits frequently before transmitting urgent information because of its on demand fashion of route discovery (Perkins and Royer, 1999). In AODV, each host maintains a traditional routing table, one entry per destination. Each entry records the next hop to that destination and a sequence number generated by the destination, which indicates the freshness of this information. AODV uses a broadcast route discovery mechanism where source node initiate route discovery method by broadcasting a Route Request (RREQ) packet to its neighbor. The RREQ packet contains a sequence number and a broadcast id. Each neighbor satisfied with the RREQ replies with the route reply packet adding one in the hop count field. Unlike DSDV, in AODV if a node cannot satisfy the RREQ, it keeps track of the necessary information in order to implement the reverse and forward path setup that will accompany the transmission of the RREP. The source sequence number is used to maintain freshness information about the reverse route to the source and the destination sequence number specifies how fresh a route to the destination must be before it can be accepted by the source The source node can begin data transmission as soon as the first RREP is received. Hence, the first sending of data packet to the destination is delayed due to route discovery process.

SIMULATION ENVIRONMENT

The implementations of all three protocols are based on the CMU Monarch extension. Recently, the Monarch research group in CMU extended ns-2 with support for simulating the physical, data link and MAC layer of multihop wireless networks. The Distributed Coordination Function (DCF) of IEEE 802.11 for wireless LANs is used as the MAC layer. An unslotted CSMA/CA technique is used to transmit these packets. The radio model uses shared-media radio with a nominal bit-rate of 2Mb/sec and a nominal radio range of 250 meters. A detailed description of simulation environment and the models are given in (Broch *et al*., 1998).

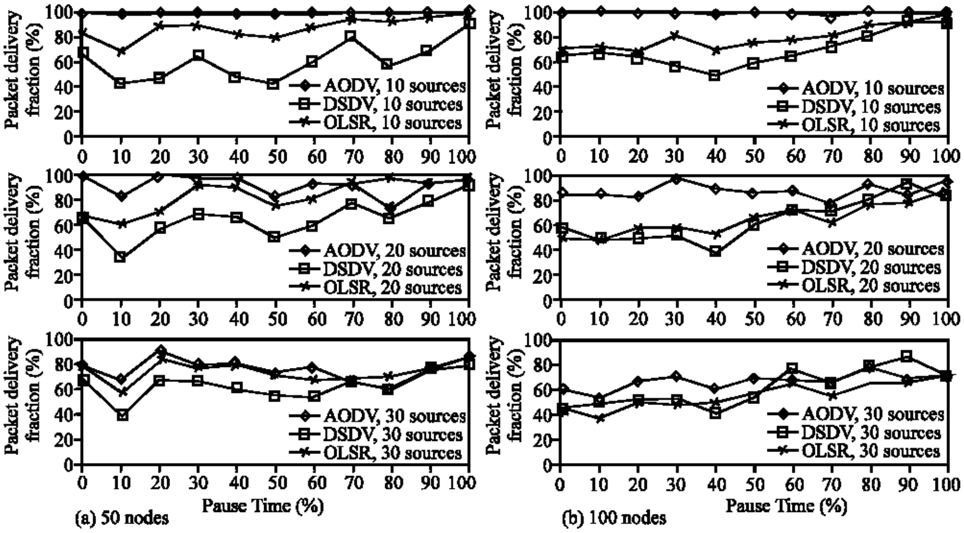


Fig. 1: Packet delivery fraction for the 50-node and 100-node model with various numbers of sources

Simulation in this study are done in two steps

- Performing the simulations for DSDV, AODV and OLSR protocols and providing an overview.
- Calculating the overhead corresponding to each of these protocols in several representative network configurations with some realistic assumptions regarding the topology changes and network conditions beforehand.

The traffic and mobility model: The traffic and mobility model in this study is different from the common traffic and mobility model used in (Broch *et al.*, 1998; Das *et al.*, 1998; Perkins and Royer, 2000) using the same simulator. This traffic model is designed for dense area of mobile nodes and used reasonable mobility/traffic speed in any metropolitan city. Traffic sources are Constant Bit Rate (CBR). By changing the total number of traffic sources, we get scenarios with different traffic loads (10, 20 and 30 sources), the packet rate at the source node is 4 packets/sec. The source destination pairs spread randomly over the network. Only 512 byte data packets are used. The number of source destination pairs and the packet sending rate in each pair is varied to change the offered load in the network. The mobility model uses the random waypoint model (Broch *et al.*, 1998) in a rectangular field. Two field configurations are used:

- 800m×800m fields for 50 nodes
- 1200m×800m fields for 100 nodes.

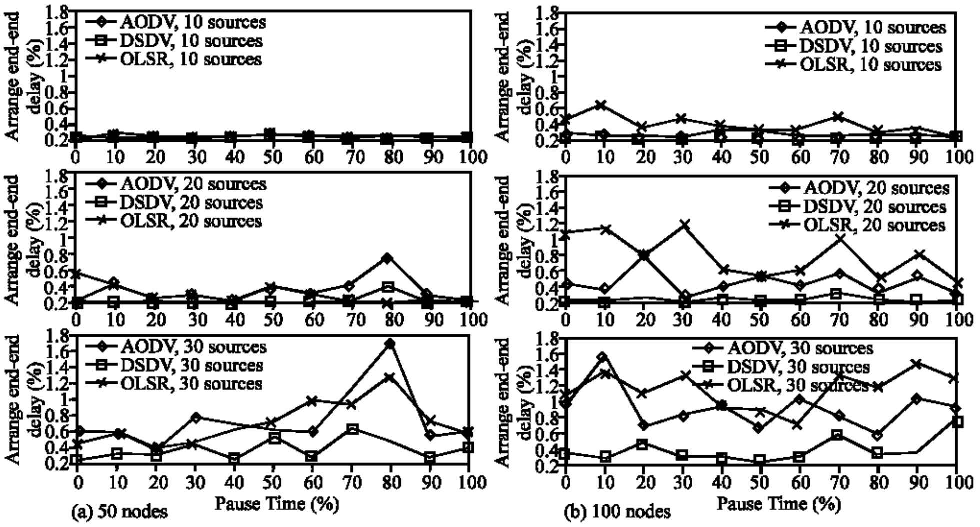
Here each packet starts its journey from a random source location to a random destination with a randomly chosen speed, which is uniformly distributed between 0-10m s^{-1}. This speed is reasonable compared with the traffic speed inside a metropolitan city. The total simulation is run for 100 seconds. The simulation is run with mobility patterns generated for 11 different pause times.

Random traffic connections of CBR are setup between mobile nodes using a traffic-scenario generator script. It is used to create CBR and TCP traffics connections between wireless mobilenodes. For the simulations carried out, traffic models were generated for 50 nodes and 100 nodes with CBR traffic sources, with maximum connections of 10, 20 and 30 at a rate of 8kbps. Mobility models were created for the simulations using 50 nodes and 100 nodes, with pause times of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 seconds, maximum speed of 20m/s, topology boundary of 800×800 and 1200×800 and simulation time of 100secs.

SIMULATION RESULTS

In this study simulation results for packet delivery fraction, simulation results for average end-to-end delay, simulation results for normalized routing load and simulation results for routing overhead are described simultaneously.

Simulation results for packet delivery fraction (%): In Fig. 1, the value of Packet Delivery Fraction (PDF) for 50 and 100 mobile nodes and pause times are plotted. The PDF value of AODV is high (above 95%) when the numbers of sources are less but when the numbers of sources increase the PDF values of AODV decline. It



(a) 50 nodes

(b) 100 nodes

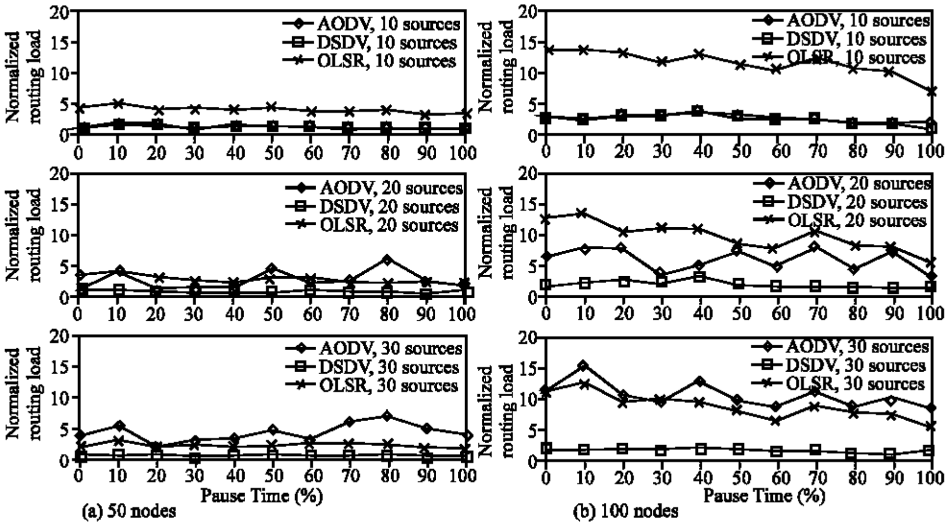
Fig. 2: Average end-end delay for the 50-node and 100-node model with various numbers of sources

occurs because of on-demand characteristics of AODV, which consumes much traffic in the route discovery phase. OLSR performs average in the lower pause time but in higher pause time when workload and numbers of sources are high its PDF is higher than DSDV but less than AODV, it performs alike AODV. But when workload and numbers of sources are high it performs the worst. It occurs, because of OLSR is proactive in nature and the selection of bi-directional multipoint relays needs hello packets to transmit. DSDV has the lowest value of PDF when workload and numbers of sources are low, because of its considerable amount of flooding in route discovery phase. But DSDV performs relatively well in greater pause time i.e. when nodes are almost stationary. Hence, this can be concluded that AODV shows better performance with respect to packet delivery fraction among these three protocols.

Simulation results for average end-end delay: In Fig. 2, the average end-to-end delay versus pause times are plotted. From the Fig. this is clear that DSDV has the shortest end-end delay than OLSR and AODV. On average case OLSR shows better performance than AODV when the numbers of mobile nodes are 50 but in the 100 nodes scenario it performs badly than AODV. As every intermediate node tries to extract information before forwarding the reply, AODV needs more time in route discovery. Hence the transmission of packets are reduces which results in greater end-end delay. As OLSR and DSDV are proactive in nature the route discovery time is little even in the intermediate node. The transmission of packets takes less time than on-demand protocol AODV. The highest end-to-end delay of DSDV for 50 and 100 nodes and 10, 20 and 30 sources is not more than 0.4 sec where as AODV has the highest delay of more than 1.6 sec and OLSR has the highest delay of 1.4 sec Hence, DSDV gives relatively better performance than other 2 protocols.

Simulation results for normalized routing load: In Fig. 3, the value of normalized routing load versus pause times are plotted. From the Figure this is clear that DSDV has lowest routing load, which not more than 2 for various number of nodes and sources. In case of 50 nodes, routing load of AODV is varied from 1-4 and in case of 100 nodes it varied from 2.5 to 15 due to its wide range flooding of route request packets and the numbers of route discoveries. OLSR performs average in case of low source but when the sources are increased, it performs badly. As the broadcasting of HELLO messages are limited to one hop, more routing occurs for increased network load and mobility compare to other two protocols. Hence, DSDV outperforms the other two protocols in terms of routing load.

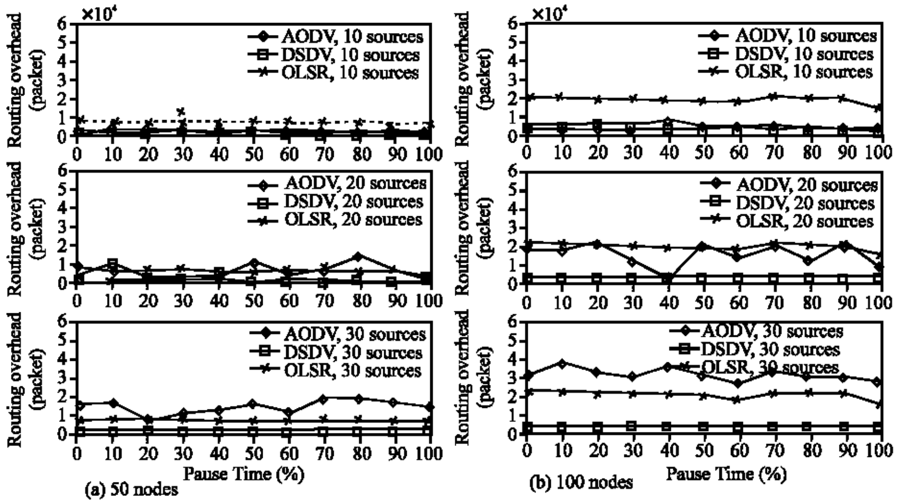
Simulation results for routing overhead (Packets): In Fig. 4, the routing overhead in packets i.e. the number of routing packets sent during the simulation versus various pause times are plotted. Without the periodic hello messages, DSDV transmits less routing packets than other two protocols. DSDV transmits 3352 packets when pause time is 10 sec and the number of mobile node is 100. With the increasing number of sources and network load the routing overhead of AODV are more than OLSR. AODV transmits more routing packets when the load and mobility is high because of the organized



(a) 50 nodes

(b) 100 nodes

Fig. 3: Normalized routing load for 50-node and b 100-node model with various numbers of sources



(a) 50 nodes

(b) 100 nodes

Fig. 4: Routing overhead (packets) for 50-node and 100-node model with various numbers of sources

way of selecting multipoint relays and hello messages, which are not forwarded more than one hop away, OLSR maintains constant routing overhead at each workload condition for 50 nodes as well as 100 nodes. It proves that OLSR performs well when the network load and mobility is high enough.

CONCLUSION

In this study the performance of DSDV, OLSR and AODV is compared with respect to four performance metrics. From the comparison, this is clear that no protocol is absolute winner. At low network load AODV performs better in case of packet delivery fraction but it performs badly in terms of average end-end delay, routing load and routing packets. At high network load and mobility OLSR performs well with respect to packet delivery fraction. However, this is clear that when network load and mobility is low, AODV performs well among the three and when load and mobility is high, OLSR performs well in case of some metrics not for all. DSDV performs poorly in terms of packet delivery fraction due to its wide range of flooding in route discovery. But DSDV performs well in terms of average end-to-end delay, normalized routing load and routing overhead, due to less route discovery time in intermediate node and no periodic HELLO messages.

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