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A Performance Evaluation of Proactive and Reactive Routing Protocols for Wireless Mobile Ad Hoc Networks using Network Simulator 2

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Abstract— A Mobile Ad-hoc Network (MANET) is a collection of self organized wireless mobile nodes dynamically forming a temporary network without the aid of any fixed and physical infrastructure and centralized administration control stations. Routing in Ad-hoc networks is a challenging due to mobility of nodes. Each node in a MANET serves as a router and performs mobility functionalities in an autonomous way. Guaranteeing delivery and the capability to handle dynamic connectivity are the most important issues for routing protocols in mobile ad hoc networks. In this paper the Network Simulator 2 (ns2) is used in order to compare and evaluate DSDV(Destination-Sequenced Distance Vector), DSR(Dynamic Source Routing) and AODV(Ad Hoc On Demand Distance Vector) routing protocols which are the most popular routing protocols for MANETs. Reactive protocols DSR and AODV as well as a Proactive Protocol DSDV were studied and their characteristics with respect to different mobility are analyzed based on end-to-end delay, packet delivery fraction, normalized routing load and the total of dropped packets, using the Network Simulator (NS2) .

Index Terms— MANET, Proactive, Reactive, DSDV, DSR, AODV, Routing Protocols, ns2

1 INTRODUCTION

A mobile ad hoc network is a collection of wireless mobile nodes that dynamically establishes the network in the absence of fixed infrastructure(Figure 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. A node can move anytime in an ad hoc scenario and, thus a routing protocol is needed which can adapt to the dynamically changing wireless topology. MANETs have many applications: they can be used in search and rescue operations, in military communication and operations, in commercial and civilian environments, in home and enterprise networks, in entertainment, in sensor networks and in education [1], [2].

One of the important research areas in MANET is establishing and maintaining the ad hoc network through the use of routing protocols. Though there are so many routing protocols available, this paper considers Destination-Sequenced Distance Vector(DSDV), Dynamic Source Routing(DSR) and Ad hoc On-Demand Distance Vector(AODV) for performance comparisons [5]. As a tool in this work, we use the Network Simulator 2 (NS-2) which is an open source freeware software which has become a popular tool for modeling networks at many academic communities and universities [3], [4]. This paper attempts to compare these three popular routing protocols mentioned above by constructing a simulation scenario. The rest of the paper is organized as follows:

in Section 2. a brief overview of the DSDV, DSR and AODV routing protocols is provided. The simulation scenario and the simulation results are described in Section 3. and Section 4. respectively. The paper is concluded in Section 5.

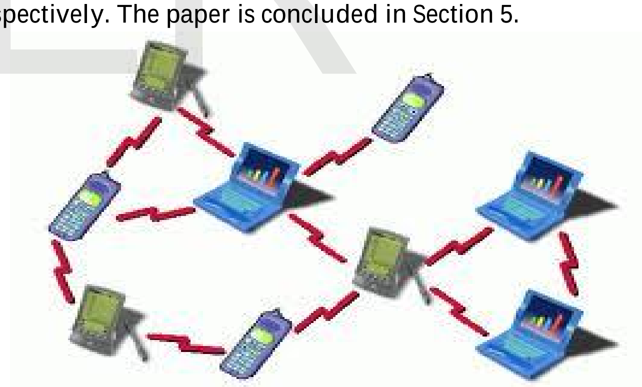

Figure 1. Mobile Ad-Hoc Network

2 MANET ROUTING PROTOCOLS

In this section, a brief description of Proactive and Reactive routing protocols is given.

2.1 Proactive (Table-Driven) Routing Protocols

It maintain one or more routing tables in every node in order to store routing information about other nodes in the MANET.

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These routing protocols attempt to update the routing tables information either periodically or in response to change in network topology in order to maintain consistent and up-to-date routing information. The advantage of these protocols is that a source node does not need a route-discovery procedures to find a route to a destination node. The drawback of these protocols is that maintaining a consistent and up-to-date routing table requires substantial messaging overhead, which consumes bandwidth and power uage, and decreases throughput, especially in the case of a large number of high-mobility mobile nodes. The most popular type of Table driven protocols is the Destination Sequeced Distance Vector routing(DSDV).

2.2 Reactive (On-Demand) Routing Protocols

It initiate a route discovery mechanism by the source node to discover the route to the destination node when the source node has data packets to send to the destination node. After discovering the route, the route maintenance is initiated to maintain this route until the routes no longer required or the destination is not reachable.The main advantage of these protocols is that overhead messaging is less. One of the drawbacks of these protocols is the delay of discovering a new route. The different types of Reactive routing protocols are : Dynamic Source Routing (DSR) and Ad hoc On-Demand Distance Vector routing (AODV).

2.3 Description of Routing Protocols

a) Dynamic Source Routing

The Dynamic Source Routing DSR protocol [5], [7] is a reactive protocol. It is an on-demand routing protocol that is based on the concept of source routing. This means that the source determines the complete path from the source node to the destination node, which ensures routing to be trivially loop-free in the network. The protocol is designed for use in multi hop ad hoc networks comprised of mobile nodes. It allows the network to be completely self-organized and selfconfigured without the need of any network infrastructure or administration. DSR does not use periodic routing messages like DSDV, thus reducing the overhead introduced by the protocol. In this way battery consumption is also reduced and large routing updates are avoided. Moreover, it is supported by the MAC layer to identify link failure. The DSR routing protocol discovers routes and maintains information regarding the routes from one node to other by using two main mechanisms:

- Route discovery – finds the route between a source and destination
- Route maintenance – in case of route failure, it invokes another route to the destination.

As the route is part of the packet itself, routing loops, short lived or long lived, cannot be formed as they can be immediately detected and eliminated. This property of DSR opens up the protocol to a variety of useful optimizations. If the destination alone can respond to route requests and the source node is always the initiator of the route request, the initial route may be the shortest. The DSR packet carries all information pertaining to route in its preamble (header) thus permitting the intermediate nodes to cache the routing information in their route tables for future use. Route maintenance is the mechanism by which the node keeps record of the dynamic changes of the network topology. In other words, the source node checks for any link failure between source and destination. If a link failure is found between source and destination, the source node tries to find another route to the destination or invokes route discovery.

b) Ad-Hoc On Demand Distance Vector

The AODV [6], [9] routing protocol is a reactive routing protocol; therefore, routes are determined only when needed. The following messages are used in AODV protocol: Hello message, Route Request(RREQ) message, Route Reply(RREP), and Route Error(RERR) message. Hello messages may be used to detect and monitor links to neighbors. If Hello messages are used, each active node periodically broadcasts a Hello message that all its neighbors receive. Because nodes periodically send Hello messages, if a node fails to receive several Hello messages from a neighbor, a link break is detected. When a source has data to transmit to an unknown destination, it broadcasts a Route Request (RREQ) for that destination. At each intermediate node, when a RREQ is received a route to the source is created. If the receiving node has not received this RREQ before, is not the destination and does not have a current route to the destination, it rebroadcasts the RREQ. If the receiving node is the destination or has a current route to the destination, it generates a Route Reply (RREP). The RREP is unicast in a hop-by-hop fashion to the source. As the RREP propagates, each intermediate node creates a route to the destination. When the source receives the RREP, it records the route to the destination and can begin sending data. If multiple RREPs are received by the source, the route with the shortest hop count is chosen. As data flows from the source to the destination, each node along the route updates the timers associated with the routes to the source and destination, maintaining the routes in the routing table. If a route is not used for some period of time, a node cannot be sure whether the route is still valid; consequently, the node removes the route from its routing table. If data is flowing and a link break is detected, a Route Error (RERR) is sent to the source of the data in a hop-by-hop fashion. As the RERR propagates towards the source, each intermediate node invalidates routes to any unreachable destinations. When the source of the data receives the RERR, it invalidates the route and reinitiates route discovery if necessary.

c) Destination Sequenced Distance Vector

The Destination-Sequenced Distance Vector (DSDV) routing protocol [2], [8], [10] is a proactive routing protocol which is based on the Bellman-Ford algorithm. Each node in the network maintains a routing table which contains all available destinations with associated next hop towards them, metric and destination sequence numbers. Routing tables are updated by exchanging periodic messages (routing information) between mobile nodes. Each node periodically broadcasts its routing table to its neighbors. Broadcasting of the information is done with Network Protocol Data Units (NPDU) in two ways: a full dump and an incremental dump. A full dump requires multiple NPDUs, while the incremental requires only one NPDU to fit in all the information. A receiving node updates its table if it has received a better or a new route. When an information packet is received from another node, the receiver compares the new sequence number with the available sequence number for that entry. If that sequence number is larger, the entry will be updated with the new sequence number. If the information arrives with the same

sequence number, the metric entry will be required. If the number of hops is smaller than the previous entry, the table will be updated. Update is performed periodically or when a significant change in the routing table is detected since the last update. If the network topology changes frequently, a full dump will be carried out, since an incremental dump will cause less traffic in a stable network topology. Route selection is performed according to the metric and sequence number criteria. The sequence number represents also the time indication that the destination node sends, allowing routing table update. If two identical routes are possible, the route with the larger sequence number will be saved and used, while the other will be destroyed.

3 Simulation Scenario

a) Performance Metrics

In order to evaluate the performance of ad hoc network routing protocols, the following metrics were considered:

End-to-End Delay(E2E): This metric includes all possible delay that may be caused by: buffering during route discovery, queuing at the interface queue, retransmission delay at the MAC layer, propagation and transfer time. It is defined as the time taken for a data packet to be transmitted across a MANET from source to destination. The E2E metric is given by:

$$E2E = T - T$$

, where, Tr is the time that a packet is received and Ts the time that this packet was injected into the network.

Packet Delivery Fraction(PDF): It is the number of data packets delivered to the destination divided by the total number of packets generated by the sources. This metric shows the reliability of the routing protocol. The higher the ratio is, the more complete and reliable is the routing protocol. PDF is given by:

$$PDF = Pr / Ps$$

, where Pr is the total number of packets received by a destination and Ps the total number of packets sent by the source node.

Normalized Routing Load(NRL): It is the number of routing packets transmitted by each node in a network divided by the number of data packets received from the receiver nodes. Essentially, it is a metric that indicates the effectiveness of the routing protocol as it pertains to the extra load in the network, the additional packages of information. NRL is given by:

$$NRL = Routing\_Packets / Total\_Received\_Packets$$

Number of Packets dropped: The number of data packets that are not successfully sent to the destination during the transmission.

b) Simulation Environment

There are two approaches used to evaluate routing protocols: using simulation or performing experiments on real time. In both cases, the performance metrics as well as the network context are equally important. In this work, the characteristics and behavior of the DSDV, AODV and DSR routing protocols especially in the initial condition of the communication between nodes for a very short duration. During the initial condition, the routing protocols will behave varyingly due to the differences in the mechanism of route discovery. The route discovery process will be affected by the mobility of each and every nodes of the network. So during the initial phase of communication, the behavior of the routing protocol and the characteristics of communication will significantly differ from normal conditions. The main goal of the study is to measure such characteristics during the initial condition of the network.

c) Simulation parameters

The following simulation parameters have taken for the simulation.

Simulator	NS 2.26
Packet Size	512 bytes
Packet Type	TCP (FTP)
Topography	X=600 , Y=600
Antenna Type	Omni Antenna
Propagation	Two Ray Ground
Number of Nodes	20
Number of Sending Nodes	10
Pause Time (sec)	0,10,20,30,40
Routing Protocol	AODV/DSDV/DSR
Maximum Node Speed (m/s)	20

The table below shows the performance of the routing protocols DSDV, AODV, and DSR with respect to different metrics considered above.

Destination Sequence Distance Vector:

Pause Time (ms)	E2E (ms)	PDF	NRL	Total Dropped Packets
0	8,68	73,9	1,69	1373
10	9,94	78,5	1,63	1136
20	10,51	71	1,9	1612
30	12,81	70,2	2,26	1669

Table 2: DSDV Performance with different metrics

Ad hoc On Demand Distance Vector:

Pause Time (ms)	E2E (ms)	PDF	NRL	Total Dropped Packets
0	12,32	99,14	1,89	42
10	11,7	99,55	1,8	24
20	14,86	99,12	2,15	52
30	14,27	99,22	2,12	48

Table 3: AODV Performance with different metric

Dynamic Source Routing :

Pause Time (ms)	E2E (ms)	PDF	NRL	Total Dropped Packets
0	11,44	99,28	1,5	84
10	12,95	100	1,52	41
20	23,78	99,67	1,72	111
30	15,19	99,2	1,83	96

Table 4: DSR Performance with different metrics

4 Simulation Results

In terms of end-to-end delay, DSDV is the best performer. As routing information is constantly updated in the proactive protocols, routes to every destination are always available and up-to-date, and hence end-to-end delay can be minimized as shown in Fig.A

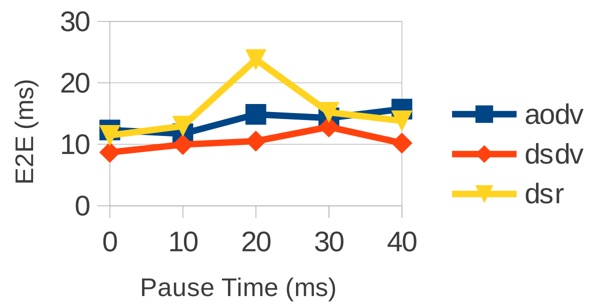

Figure A: End-To-End delay for AODV, DSDV and DSR

In terms of PDF with respect to varied pause time, DSR performs well when the number of nodes is less, which is shown in Fig.B. The performance of AODV is consistently uniform and DSDV performance is poor than reactive protocols.

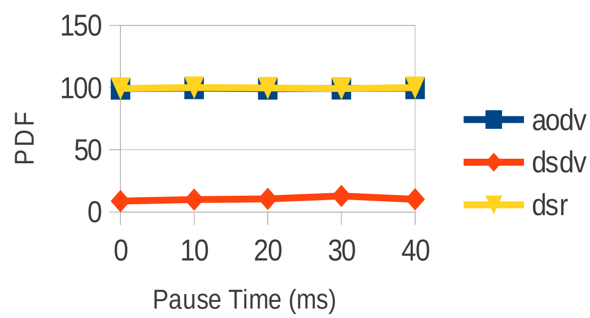

Figure B.Packet Delivery Fraction for AODV,DSDV and DSR

In terms of Normalized Routing Load with respect to varied pause time, DSR is found to be less when compared to AODV and DSDV because of DSR aggressive caching techniques, which is observed in Fig.C .

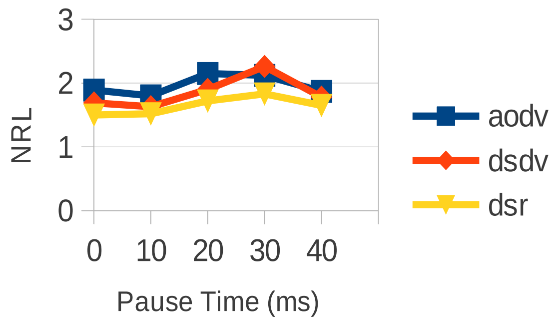

Figure C.Norm. Routing Load for AODV,DSDV and DSR

In terms of packets dropping, DSDV performance is worst when mobility is high. This is because of the reason that it keeps only one route per destination. Therefore lack of alternate routes and presence of stale routes in routing table when nodes are moving at higher rate leads to packet drops, which is shown in Fig.D

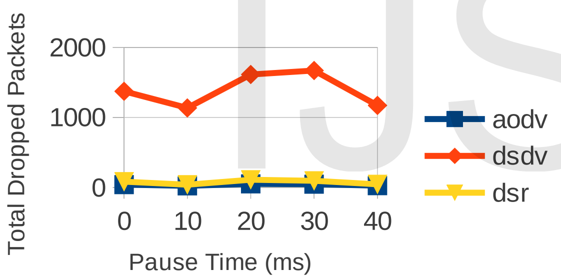

Figure D. Dropped Packets for AODV, DSDV and DSR

5 Conclusion

In this paper, we used the Network Simulator 2 in order to simulate a scenario and compare the On-Demand (DSR and AODV) and Table-Driven (DSDV) routing protocols by varying the pause time and measure the metrics like end-end delay, dropped packets, routing load and packet delivery fraction. The results indicate that the performance of the two on demand protocols namely DSR and AODV is superior to the DSDV routing protocol. It is also observed that DSR outperforms AODV in less stressful situations, i.e smaller number of nodes. AODV outperforms DSR in more stressful situations. The poor delay and packet delivery fraction of DSR is mainly due to caching and lack of mechanisms to expire stale routes. The routing load is consistently low for DSR and AODV than in comparison with DSDV especially for large number of nodes. This is due to the fact that in DSDV the routing table exchanges would increase with larger number of nodes. The results indicate that as the number of nodes in the network increases DSDV would be better with regard to the packet delivery fraction, but it may have considerable routing load. As far as packet delay and dropped packets fraction are concerned, DSR/AODV performs better than DSDV with large number of nodes. Hence for real time traffic AODV is preferred over DSR and DSDV. For less number of nodes and less mobility, DSDV's performance is superior.

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