Comparative Performance Simulation of DSDV AODV and DSR MANET Protocols in NS2

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Abstract. Mobile Ad hoc Networks (MANET) are self-configured and infrastructure less networks with autonomous mobile nodes. Due to the high flexibility, these kind of networks are heavily used in rescue operations, military missions etc. Many routing protocols for this kind of networks exist. This article presents a comparative and quantitative performance study of DSDV, AODV and DSR routing protocols using different simulation models in NS2. Performance metrics like PDR, E2E Delay and Throughput are analyzed under varying network, traffic and mobility parameters like number of nodes, traffic flows, mobility speed and pause time. Results show that AODV outperforms DSDV and DSR in all the performance metrics. DSDV performs better than DSR in terms of PDR and E2E delay. DSR gives 20-30 higher Throughput than DSDV. Performance metrics are highly influenced by network topology parameters like number of nodes and number of traffic flow connections. Mobility parameters like speed and pause time have slight impact on performance.

1 Introduction

MANETs are networks with nodes that are mobile and can be connected dynamically and arbitrarily making the topology very flexible. The communicating devices are auto configurable and there is no need for extra infrastructure. Each of the network activities such as discovering the topology, sending messages or routing messages is performed by each node. Typical examples of these networks are research of rescue operations, military operations etc. [1].

Fig. 1. Examples of MANETS

MANETs need efficient algorithms in order to properly depict the network topology, route packets and adopt to the many changes. Many routing algorithms have been designed. They usually fall in two categories:

1. Table-driven routing algorithms
2. On-demand routing algorithms

DSDV (Destination-Sequent Distance Vector) is a Table-driven (proactive) routing protocol wears AODV (Ad hoc on-demand Distance Vector) and DSR (Dynamic Source Routing) are examples of On-demand (reactive) routing protocols. The main goal of this paper is to present a quantitative performance comparison of the above protocols for MANETs. Three performance metrics have been analyzed: PDR (Packet Delivery Ratio), Average End-to-End delay and Throughput. The performance analysis is done simulating networks with different topology (number of nodes), traffic (number of connections) and mobility (speed and pause time) parameters. The simulations are performed using NS-2.35 in Ubuntu 13.04 Linux. NS2 which is one of the best known discrete event network research simulators that supports many MANET routing protocols like AODV, DSDV, TORA, DSR etc. [2]. NS2 instructions are used to define the topology and traffic model of the network and motion of mobile nodes. The generated trace files are further processed with AWK scripts to get the values of performance metrics. The results show that AODV outperforms the other two protocols in every simulation. DSDV is better than DSR in terms of PDR and Average E2E delay. DSR gives better throughput than DSDV (20-30 % higher). AODV gives stable performance results wears DSR is highly influenced by the varying network parameters.

The rest of the paper is organized as follows: Section 2 summarizes related works about MANET routing simulations, Section 3 describes the MANET routing protocols that are further analyzed, section 4 presents some of the most important network performance metrics, section 5 describes the simulation models for the varying parameters that are used, section 6 presents the simulation results wears section 7 concludes.

2 Related Work

Routing performance simulations for Ad hoc networks have been subject to different research papers. In [3] Yinfei Pan presents a qualitative and quantitative performance analysis of routing protocols, comparing AODV and DSR using NS2 simulations. He uses fixed values for number of nodes and speed (low values) and varies number of sources and pause time. Very high values of pause time are used in order to have very little mobility and mimic sensor networks. He concludes that AODV outperforms DSR mainly in stressful situations (high traffic load). In [4] the authors perform a similar survey (the same protocols). They simulate the protocols varying the number of sources (for traffic load) and the pause time (for mobility) keeping number of nodes and speed constant. They conclude that AODV and DSR perform better than DSDV in in high mobility scenarios and that AODV outperforms DSR in higher load scenarios.

In [5] and [6] the authors analyze the performance of AODV protocol only. The first paper shows results of PDR, End to End delay, Normalized Routing Load and Throughput metrics wears the second measures PDR, End to End delay and Packet loss. The simulations are performed under varying network size (varying number of nodes) scenarios keeping the other parameters constant. The authors of [5] conclude that AODV performs better in larger network sizes. In [6] the tabular results presented show that there is a nonlinear change (ups and downs) in the values of the measured metrics. S. S. Tyagi and R. K. Chauhan conduct a similar study [7]. They evaluate the protocols by means of PDR, Average E2E, packet loss and routing overhead. Varying number of nodes (10-200), speed (10-100 m/s), pause time (0-1000 seconds) and simulation time. They conclude that AODV performs better than DSR in dense environments and both AODV and DSR perform better than DSDV.

In this paper I try to study AODV, DSDV and DSR under more realistic scenarios. In case of MANETs every network parameter can change, thus I perform simulations varying all modeling parameters like number of nodes (for different devices in the network), number of traffic flows (for different traffic loads in the network), speed (for different mobility speed of devices) and pause time (for different pause time of the devices). I also use sensible varying values for these parameters in order to have realistic simulation scenarios and results and I focus on the effect this parameters have on the different performance metrics.

3 MANET Routing Protocols

Based on the rouging techniques they implement, routing protocols for MANETs may be categorized into two types, Proactive (table driven) and Reactive (on-demand). Other category of MANET routing protocols which is a combination of both proactive and reactive is referred as Hybrid. Proactive routing protocols require that each node of the network keep and maintain up-to-date routing information stored in one or more tables that represent the entire topology of the network. These tables are updated regularly so that when a route is needed it is already known. Having and maintaining available routes in advance for every possible request is the main characteristic of proactive protocols.

Reactive routing protocols, also called on-demand protocols, collect routing information, establish and maintain routes only when they are needed. Route discovery mechanism is used to find paths from the source to the destination. When a node (source) needs to send data to another node (destination) it invokes the route discovery mechanism which consists of sending route request packets. This gives a high latency, however there is no transmission of unnecessary control messages through the network. The discovered route is kept in a table or cache which is updated according to the many network changes.

Hybrid protocols tend to combine the pros of proactive and reactive routing protocols. These protocols organize nodes into zones based on their location and distance from each other. Inside a certain zone routing is performed using proactive protocols while on-demand protocols are applied for routing between different zones.

3.1 DSDV

DSDV is a well-known proactive protocol based on Bellman-Ford algorithm with certain adaptations [8] and is considered to be successor of distance vector in wired networks. It calculates and chooses the shortest path (with minimal distance) among multiple paths to send packets from source to destination. Each of the mobile nodes keeps a routing table which lists all the reachable destinations, the number of hops to the destination and the sequence number originated by the destination node. The sequence number is used to distinguish stale routes from new ones and thus avoid the formation of loops. Routes with recent sequence number are the ones used wears those with older sequence number are discarded. The tables store information for routing and are updated by control packets exchanges between the nodes. Each node transmits updates periodically to maintain the consistency to the changes in topology of the network. These periodic small updates are also called "incremental" updates. When there are significant changes in the network (hence in the table) the nodes transmit the entire table to their neighbors performing the so-called "full dumps". When the network is relatively stable, incremental updates are sent to avoid extra traffic and full dump are relatively infrequent. In a fast-changing network, incremental packets can grow big so full dumps will be more frequent.

3.2 AODV

AODV is a reactive protocol that belongs to the class of Distance Vector Routing Protocols. It starts a route discovery process only when a node has data packets to transmit and there is no route path (or when the route is stale or broken) towards the destination node [9]. The routing table of each node contains the necessary information about the route from source to destination and sequence numbers to avoid loops (in this aspect it is similar to DSDV). AODV operation is based on Route Request (RREQ), Route Replay (RREP) and Route Error (RERR) packets. First it broadcasts query packets (RREQ) to its neighbors. If a neighbor has a route to the destination it replies with route reply packet (RREP), otherwise the neighbor rebroadcasts the RREQ packet to its neighbors until some query packets reach the destination. At this time a RREP packet is transmitted back the route or RREQ packet to the source. Now the source has a route to the destination and can start transmitting data packets. If a line break occurs while the route passing through it is still active, the node upstream (from source to destination) of that break sends a RERR packet to the source. After receiving this packet, the source will start generating RREQ messages to find a new route.

3.3 DSR

DSR is a reactive source routing protocol, which means that the sender knows the complete route to the destination. The routes to any given node are stored in a route cache at the source and are part of every transmitted packet, thus routing loops cannot be formed as they would be immediately detected. A route discovery mechanism takes place when the source does not have any route to the destination. The source broadcasts a route discovery packet to all its neighbor nodes. This request packet contains the address of the destination host which is referred as the target of route discovery, the source's address, a route record field and a unique identification number. Each node receiving a RREQ packet rebroadcasts it, unless it is the destination or it has a route to the destination in its cache. In the latter case it sends a route reply (RREP) message to the initiator. Both RREQ and RREP packets are also source routed. The broadcasting goes on until the destination is found. The RREQ builds up the path traversed across the network and RREP routes itself back to the source by traversing it backward. The route carried back by the RREP packet is cached at the source for future use. If any link on a source route is broken, the source node is notified using a route error (RERR) packet. The source removes any route using this link from its cache. A new route discovery process must be initiated by the source if this route is still needed.

4 Performance Metrics

There are many network performance metrics which can be evaluated in order to get an overview of the performance of routing protocols [10]. In this paper, AODV, DSDV and DSR performance is analyzed and compared using the metrics described below.

4.1 Packet Delivery Ratio

Packet Delivery Ratio (PDR) is the ratio of all the data packets successfully received by the destinations to those generated by the sources. It describes the delivery capabilities of the network. Higher values of this metric means better performance of the protocol.

PDR = (Packets Received / Packets Sent)*100 (1)

4.2 Average End-to-End Delay

Average End-to-End Delay is defined as average time taken by data packets to propagate from source to destination across the network. This includes all possible delays caused by buffering during routing discovery latency, queuing at the interface queue, and retransmission delays at the MAC, propagation and transfer times etc. Higher value of end-to-end delay means that the network is congested and hence the routing protocol does not perform well. It is calculated as follows:

End to end Delay = Σ (arrive time - send time) / No. Delivered Packets (2)

4.3 Throughput

Throughput is the average rate at which the total number of data packet is delivered successfully from one node to another per unit time. It is calculated as follows:

Throughput = (No. delivered packet * packet size)/total duration of simulation. (3)

Higher Throughput means better performance of the protocol.

5 Simulation Model

In the following sections I present the models (network, mobility and traffic models) and the parameters used in the simulations.

5.1 Network Model

The physical network of a MANETs consists of mobile nodes such as laptops, PDAs and wireless phones. It is self-configuring and there is no need for other infrastructure. The communicating devices have routing capabilities and operate both as hosts and routers to forward data packets to each other. They move freely in a random way and usually multiple hops are needed to exchange data between each two nodes. To model the network I used a rectangular and constant simulated area of 900x600 meters. I also used typical NS2 parameters like the standard Two-Way-Ground as a radio propagation model for the Wireless channels and Omni-Directional Antenna model. The network interface type is the standard IEEE 802.11. To observe the effect of increasing the number of communicating devices I use a varying number of mobile nodes (6 values) from 8 to 53 in step of 9. The default value for the number of nodes (number of nodes in simulation in which this parameter doesn't change) is 30.

5.2 Mobility Model

The mobility model describes how speed, acceleration and direction of the node changes over time. It is very important as it changes the characteristic of the mobile nodes and thus effects network and routing protocol performance. In order to check the performance of a protocol for an ad hoc network, the protocol should be tested under realistic conditions such as limited transmission range, limited buffer space for storage of messages and realistic movement characteristics of mobile nodes. There are various mobility models [11] such as Random Walk Mobility Model, Random Waypoint Mobility Model, Reference Point Group mobility Model etc. CMU Scenario Generator (setdest executable) is a tool that implements in NS2 "Random Waypoint" model (algorithm) which is the one used for these simulations. It randomly generates the positions and the movements of the mobile nodes and writes them in a mobility scenario file which implements the desired mobility model.

Speed of nodes play an important role in MANETs and is a parameter that can be set to reflect the degree of mobility and the dynamicity of the topology. As the transmission range of each node is limited it causes many connection breaks (many others became possible) and thus affects the performance of the protocol. In this model, for the nodes' speed I use 6 values from 6 m/s to 51 m/s in step of 9. The default value of speed (when it doesn't change) is 28 m/s. After reaching the destination, the node stops for some time which is called the "pause time". It is another parameter which affects the network topology and consequently the performance of the routing protocol. For pause time 6 values are used, from 3 seconds to 48 seconds in step of 9. The default value for pause time is 25 seconds. The mobile node randomly selects the next destination in the simulation area and chooses a speed uniformly distributed between the minimum speed and maximum speed. It travels with a speed value uniformly chosen in that interval. As soon as the mobile node arrives at the destination, it stays again for the indicated pause time before repeating the process [11].

5.3 Traffic Model

Traffic density is another key parameter that affects the overall network and protocol behavior in MANETs. In other words, number of connections between the mobile nodes and other parameters like packet size, packet rate etc. influence the performance metrics we are interested in. I have used CBR (UDP) traffic as it doesn't vary in the different simulations. Using CBR for comparison purposes is important in order to get fair results. Varying traffic (i.e. TCP) could make the load unpredictable and corrupt the simulation results. I have used 512 Bytes constant packet size and 4 packets/sec packet rate (16 kbps traffic flows). To have a good modeling of the traffic flows the source-destination pairs must be chose and spread randomly over the network. To facilitate this NS2 provides cbrgen.tcl tool as a generator of CBR and TCP connections between wireless nodes, written in traffic pattern files. The generated file contains all the traffic flow information the simulation needs. To model the behavior of the protocols in different traffic densities of the network I vary the maximal number of connections (number of source-destination pairs) between the nodes, using 6 values, from 7 to 52 with step of 9. The default number for the maximal connections is 29.

5.4 Simulation Setup

The goal of all the simulations in this paper is to present a quantitative relation between network performance metrics such as packet delivery ratio, throughput and e2e delay and other varying network parameters like the number of nodes, number of connections, mobility speed and pause time. There is a total of 24 simulations (4 parameters x 6 values each) for each of the three routing protocols. To gather fair comparison results of the three protocols, identical mobility and traffic scenarios are used for each of them. Also for a better estimation of the performance metrics I ran 3 simulations for every combined scenario for a total of 216 simulations (and .tcl files).

Using the above discussed models and setdest and cbrgen.tcl tools I generated the mobility and traffic scenario files. Traffic and mobility files are included in the simulation at the time of execution [12]. Every simulation is run for 200 seconds. To run the simulations I have used NS-2 version 2.35 built on Ubuntu 13.04 Linux. Figure 2 shows a simulation screenshot taken from NAM. I used AWK scripts to process the trace files and plot the graphs of the metrics for each protocol.

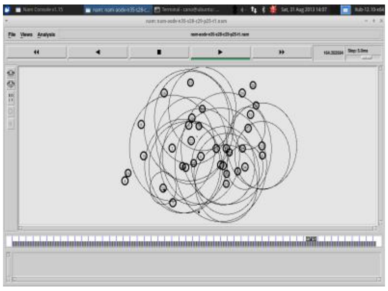

Fig. 2. Simulation Screenshot

6 Analysis of Results

The trace files generated by the simulations were processed using AWK scripts [13]. The following graphs were plotted using the average values of PDR, Average E2E delay and Throughput under varying number of nodes, connections, speed and pause time.

6.1 PDR

The graphs clearly reveal that AODV outperforms the other two protocols. AODV achieves PDR values that are higher than 60 % in all measurements. DSDV comes second with PDR values at around 50 %. In terms of PDR, DSR is the worst with delivery rates lower than 40 %.

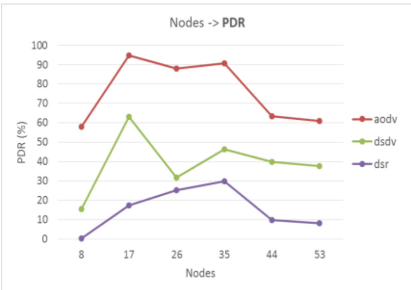

Fig. 3. PDR vs. Number of Nodes

Fig. 4. PDR vs. Number of Connections

It seems that PDR is highly influenced by number of nodes for each of the protocols (Fig. 3). The monotony of the graphs is similar for each protocol. For a low number of nodes PDR is also low, probably because in a sparse network there are not enough intermediate nodes to route the packets. The best values of PDR come for 26-35 nodes. For more nodes PDR starts to decrease slowly for each of the protocols. Fig. 4 shows a slight influence of the number of connections on PDR. PDR decreases gradually in the case of reactive protocols like AODV and DSR. DSDV presents a slight increase of PDR values and stabilizes at around 43 %. For high number of connections PDR doesn't change much.

Fig. 5. PDR vs. Speed

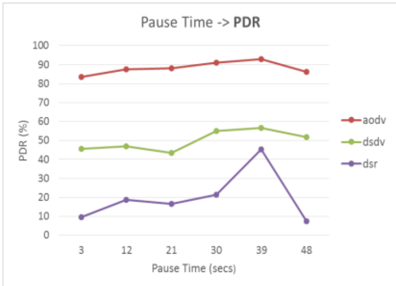

Fig. 6. PDR vs. Pause Time

Speed has no significant effect on PDR values for AODV and DSR (Fig. 5). In case of DSR, PDR drops considerably as soon as the speed goes up. AODV gives 93 % delivery for very low speed values and stabilizes between 80 – 90 % even when the speed goes up. DSDV starts with 60 % delivery for low speed and submits a slight and gradual decrease. On the other hand DSR starts very good at 60 % and then drops at around 10 %. Pause time doesn't influence much on PDR either (Fig. 6). In case of AODV the delivery rate is within 84 – 93 %. DSDV achieves 46 – 58 % delivery and DSR 8 – 55 %. In all the cases there is a slight increase of PDR. This is something normal as high values of pause time mean less mobility (and more stability) in the network.

6.2 Average E2E

In terms of Average End-to-End delay, DSDV and AODV perform very similarly never exceeding 1.5 seconds boundary. DSR performs worse and is highly influenced by the varying network metrics.

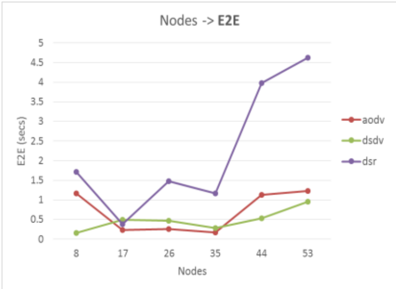

Fig. 7. E2E vs. Number of Nodes

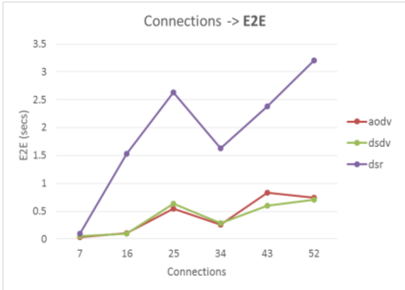

Fig. 8. E2E vs. Number of Connections

Fig. 7 shows a high negative effect of number of nodes on the delay of DSR. It starts with moderate values (1.7 seconds) and keeps staying within 1.5 seconds boundary for low and medium number of nodes. For more than 35 nodes it rises significantly. AODV and DSDV present moderate delays and are less influenced than DSR. For nodes up to 35 their E2E is lower than 0.5 seconds. For even more congested networks E2E rises above 1 second even for both AODV and DSDV. Number of connections has a very similar impact in the E2E of the three protocols (the monotonies are very similar). In all the cases it tends to rise (more traffic means higher delays). DSDV and AODV present identical behavior with E2E rising up to 0.65 seconds, then falling down to 0.3 and then rising again. In the case of DSR E2E amplitudes are much higher. It goes up to 2.6 second for 25 connections. Then it falls to 1.6 seconds and rises again exceeding 3 seconds.

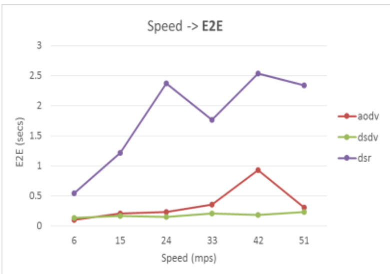

Fig. 9. E2E vs. Speed

Fig. 10. E2E vs. Pause Time

Speed also presents different delay impact in the protocols (Fig. 9). In all the cases the delays rise gradually for higher speeds. It has a similar effect on DSDV and AODV which start with very low delays (around 0.1 seconds) and go up to 0.3 seconds. In the case of DSR the impact is worse. First it rises rapidly from 0.5 to 2.4 seconds. Then it stabilizes within 2 - 2.5 seconds boundary. Pause time also presents a significant negative impact on DSR delays (Fig. 10). E2E of DSR is highly variable with no clear tendency (random ups and downs). It is within 1.2 – 2.6 seconds with considerably different values for each pause time value. AODV and DSDV are very stable and similar. There is almost no impact of pause time on their E2E. Their E2E never exceeds 0.3 seconds.

6.3 Throughput

The results show that AODV is still the best protocol even in terms of Throughput. However DSR is very close and shows similar behavior. They both outperform DSDV which never passes 125 kbps.

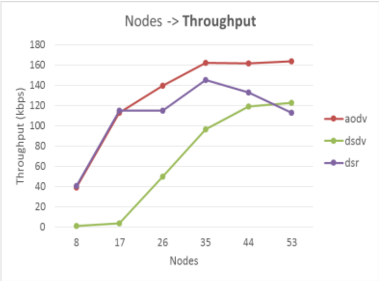

Fig. 11. Throughput vs. No. of Nodes

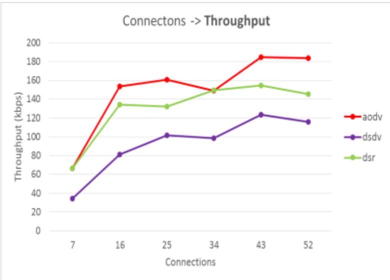

Fig. 12. Throughput vs. No. of Connections

Fig. 11 shows that throughput is highly influenced by the number of network nodes (Fig. 11). For few nodes (sparse network) Throughput is very low for all the protocols. It grows rapidly and reaches 160 kbps in case of AODV. The best values are for 35 – 44 nodes. More network nodes does not change Throughput values in the case of AODV and DSDV. DSR starts decreasing gradually for more than 35 nodes. Number of connections has the same impact (Fig. 12). Throughput is very low for 7 traffic flows. It rises gradually and stabilizes for medium number of connections. It keeps rising a little and then it stays at around 185 kbps for AODV, 150 kbps for DSR and 120 kbps for DSDV.

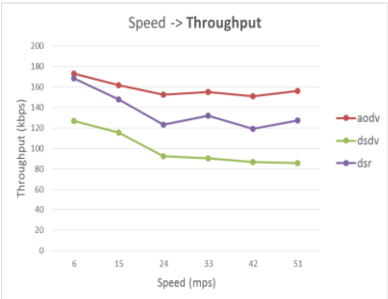

Fig. 13. Throughput vs. Speed

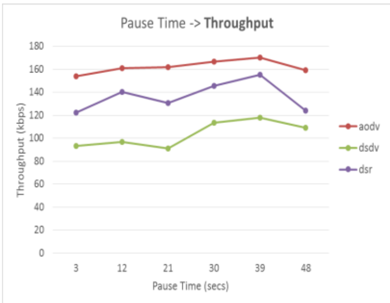

Fig. 14. Throughput vs. Pause Time

Fig. 13 and shows that speed of mobile nodes has a negative influence over throughput. Throughput decreases for low until medium speed values. Then it stabilizes at 155 – 85 kbps. Increasing pause time has a positive impact on throughput especially in the case of AODV and DSR (Fig. 14). It increases gradually for all the protocols and reaches it maximum for 39 seconds of pause time. Further increase of pause time exhibits a slight decrease.

7 Conclusions

The results show that AODV outperforms the other two protocols giving better values for all of the tree metrics. DSDV is better than DSR in terms of PDR and E2E Delay. On the other hand DSR outperforms DSDV in terms of Throughput (20-30 % better). The three protocols usually show similar performance behavior (tendency) under the effect of the network parameters. DSR is highly influenced by the varying network parameters, wears DSDV and AODV tend to be more stable. Performance is highly influenced by number of nodes (usually positively) and number of traffic flows (usually negatively). Speed and pause time present slight and contradictory impact on performance metrics as they increase (the former) and decrease (the latter) the overall mobility in the network.

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