On the Forward Path Detection Time Metric for Evaluation of Ad Hoc Routing Protocols

Hanin Almutairi, John DeDourek, Przemyslaw Pochec
Faculty of Computer Science
University of New Brunswick
Fredericton, Canada
e-mail: {hanin.almutairi, dedourek, pochec}@unb.ca

***Abstract*—When considering the performance of an ad hoc network, and the impact of routing protocols on it, one factor at play is the time required for setting up the forwarding path. This delay can make a significant impact on the estimate of the steady state throughput particularly when the data transmissions during the performance evaluation are short and the routing path changes often. In this short paper, we quantify the difference in the forward path detection time for two sample routing protocols: one proactive and the other reactive. Our results show significantly shorter path set up times for the Ad hoc On Demand Distance Vector (AODV) vs Destination Sequenced Distance Vector (DSDV) protocol.**

Keywords-Ad hoc routing; performance metrics; AODV; DSDV; MANET; M2ANET.

I. Introduction

Multiple factors impact the performance of ad hoc networks. Typical metrics used in comparison between different configurations include the packet delay and the packet delivery ratio [1]. Calculation of these (and other) performance metrics can be affected by the time preceding the actual transmission, which is needed to set up the routing. In our experiments with Mobile Ad hoc Networks (MANETs), we noted a significant difference in the network performance when switching from one routing protocol to another [2]. On a closer inspection, we noted that the actual data transmission (as opposed to the exchanges of control information between the nodes) did not start immediately in some experiments. This set up time, which we call the Forward Path Time Detection (FPTD) time, may have a significant impact on the interpretation of the results of the performance evaluation of an ad hoc network as the actual instantaneous throughput may be significantly different form the calculated average when a significant delay in setting up the routing is not taken into account.

In Section II, we review the three principal metrics used in network simulation and define one secondary metric explored in this paper. Section III is the description of the experiments where we observed the differences in path set up time (FPTD). The analysis of the results is in Section IV and the conclusion is in Section V.

II. State of the Art

A MANET is created from a group of mobile wireless nodes exchanging messages with one another [3]. Multi-hop transmissions are possible when routing is used to forward packets to more distant nodes. A deployment of a MANET is characterized by the physical parameters of transceivers at each node, the number of nodes used, their movement pattern and the routing and transmission protocols used. They all impact the performance of the network.

Given a MANET with its many complicated deployment characteristics, simulation can be applied to evaluate its performance. In network simulation, and for MANETs in particular, different performance metrics are used to evaluate the network operation [1]. The communication channel throughput, measured as data delivery rate from the source to the destination is the obvious principal metric. It depends on the physical characteristics of the wireless channel between the network nodes, and additionally on the network conditions, such as the location and the velocity of the nodes, that may vary significantly in a MANET due to the mobility of its nodes.

To account for all kinds of transmission impairments, the Packet Delivery Ratio (PDR) is commonly used. PDR is the ratio of the number of packets received by the destination to the number of the packets sent by the source (or generated by the source agent). PDR is affected by the changes (and disconnections) of the forwarding path due to the mobility of the MANET nodes.

End-to-End Delay, or packet delay, is the average transmission time for the data packet from when it is sent from the source until it reaches the destination. The delay time includes any delays caused by routing, buffering, queuing, retransmission, or propagation.

The FPTD time is the set up time between the request to send at the source node and the detection of the first forwarding path. Due to the highly dynamic nature of MANETs, some routing protocols take a longer time than other protocols to find the route and forward the packets from the source to the destination. This delay in finding the first forwarding path may affect other network performance measures, in particular the PDR.

III. Experiments with M2ANETs

Experiments that led us to use the FPTD metric were concerned with the performance evaluation of the novel configuration of a MANET we called Mobile Medium Ad hoc Network (M2ANET). We introduced the concept of a

Mobile Medium in our seminal paper on M2ANETs in 2011 [4]. A M2ANET realizes the connection between two hosts with the cloud of nodes serving as the data communication medium (aka Mobile Medium) and forming the communication channel. Any particular connection in the Medium does not matter as long as the channel between communicating users of the M2ANET can be formed. As a consequence, M2ANETs exhibit fault-resilience, given that they are not operating with a single point of failure. The performance of M2ANETs was evaluated for different node densities [4][5], different movement patterns [6][7], with self-organizing nodes [2] and in the presence of competing flows [8]. Examples of other networks operating on a similar principle include the Google Loon project [9], Facebook's flying internet service [10] and a swarming micro air vehicle network (SMAVNET II) [11].

In our typical M2ANET simulation [2][4]-[8], the random mobility model was used as a reference case scenario, mostly because it is a standard model used in network simulation. The model used was the Random Way Point (RWP) model available in ns2 [12]. In RWP, nodes are moved in a piecewise linear fashion, with each linear segment pointing to a randomly selected destination and the node moving at a constant, but randomly selected speed. In our experiments, the mobile nodes forming the Mobile Medium moved at random speeds with an average speed of 4 m/s within a square area 1000 m by 1000 m. The main communicating nodes 0 and 1 were stationary. The source and destination nodes were located at (50,400) and (950,600) coordinates, respectively. The simulation details are summarized in Table 1.

TABLE I. SIMULATION PARAMETERS

Parameters	
Simulator	ns-2.34
Channel Type	Channel / Wireless Channel
Network Interface Type	Phy/WirelessPhy
Mac Type	Mac/802.11
Radio-Propagation Type	Propagation/Two-ray ground
Interface Queue Type	Queue/Drop Tail
Link Layer Type	LL
Antenna	Antenna/Omni Antenna
Maximum Packet in ifq	50
Area (n * n)	1000 x 1000m
Source node location	(50, 400)
Destination node location	(950, 600)
Source Type	CBR over UDP packetSize_ 512 interval_ 0.05
Simulation Time	500 s
Routing Protocol	AODV and DSDV

The data traffic for the data flow was modelled with the Constant Bit Rate (CBR) traffic generator and sent using User Datagram Protocol (UDP) over simulated Mobile Medium network with four different node densities from 10 to 40 nodes. Node density indicates the total number of mobile nodes in the 1000 m by 1000 m square region modelled in the experiments. Each mobile network scenario was simulated three times for a 500 second simulation run time and the average results was taken. While, in general, the network performance can be characterized using a variety of metrics, in this paper we focus solely on FPTD.

IV. RESULTS AND ANALYSIS

In our analysis here, we focus on the performance of two routing protocols: reactive AODV and proactive DSDV [13][14].

In an experiment with a network formed by very few nodes (10 nodes), AODV took an average 190 seconds out of 500 second simulation run time to detect the first forwarding path (Figure 1). However, when the number of nodes increased, the FPTD metric dropped significantly: for 20 nodes the delay to detect the forwarding path was down to 25 seconds. In a network with 40 nodes, the delay was only 1.2 seconds. Detecting the forwarding paths early increases the PDR and the network performance in general.

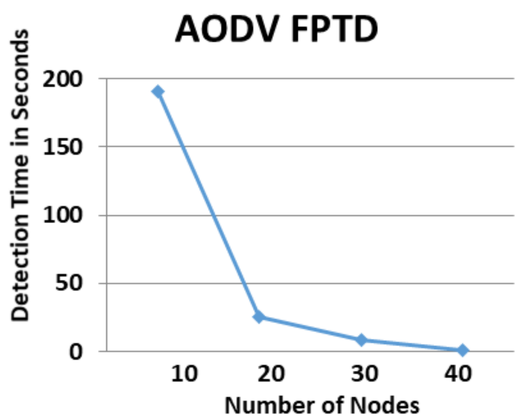

Figure 1. FPTD for AODV routing

In the experiments with a MANET running DSDV routing, due to the proactive nature of DSDV, detecting forwarding paths takes a longer time compared with the experiments over AODV (Figure 2).

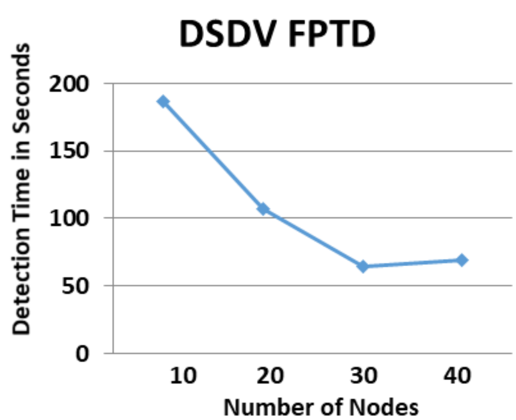

Figure 2. FPTD for DSDV routing.

DSDV displays a poor ability to detect the routes quickly in highly dynamic mobility networks and it takes more time advertising good routes and recovering broken ones. In a mobile network with only 10 mobile nodes, DSDV took an average of 187 seconds to detect the first forwarding path, which is at par with AODV. However, it took as much as 106 seconds to detect the first forwarding path in 20 mobile node density scenario compared with 25 seconds for AODV with the same node density. The FPTD for a network with 40 nodes is 69 seconds for DSDV, which is 50 times more than FPTD in AODV experiments. Longer FPTD times mean longer period of idling in a network before the first packet is sent and consequently less time spent actually transmitting data and lower PDR.

In the two series of experiments, the protocols exhibited very long FPTD delays and performed similarly when the number of nodes forming the network was very small (10 nodes). This is likely caused by a very sparse positioning of nodes over 1000x1000 m simulation area, with no forwarding path existing at all until the mobile nodes get into favorable positions making the source to destination connection feasible. At higher nodes densities (40 nodes) the feasibility of the path is almost certain, and the FPTD delay is primarily determined by the performance of the routing protocol, with AODV showing clear advantage.

V. Conclusion and Future Work

Performance metrics that use averages calculated over the experiment simulation time can be skewed by the phenomena particular to some ad hoc routing protocols. While experimenting with M2ANETs, we observed significant differences in the path set up times between AODV and DSDV. In a reasonably dense ad hoc network, the DSDV set up times were at high multiples of AODV set up times: four times larger in a network with 20 nodes vs 50 times larger in a network with 40 nodes. This difference in set up times may need to be taken into consideration when comparing performance measures for the networks using different classes of protocols: reactive *vs* proactive.

In future, we plan to propose different types of performance metrics that would better reflect the steady state performance of ad hoc networks and that are unaffected by the differences in set up times.

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