M2ANET Performance under Multiple Competing Data Flows

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***Abstract*—A Mobile Ad hoc Network (MANET) is a network of wireless mobile devices capable of communicating with one another without any reliance on a fixed infrastructure. A Mobile Medium Ad hoc Network (M2ANET) is a set of mobile forwarding nodes functioning as relays for facilitating communication between the users of this Mobile Medium. The performance of a Mobile Medium depends not only on the forwarding node density, their distribution and movement but also is affected by the traffic load present in the Medium. The traffic in the Mobile Medium may be due to multiple users using the Medium or due to rogue users performing a Denial of Service (DOS) attack. We investigate the performance of a Mobile Medium serving multiple users under different routing protocols, focusing on the performance of the Ad hoc On-demand Distance Vector (AODV) routing protocol. The simulation results show that the packet delivery is only moderately affected (Packet Delivery Ratio (PDR) dropped form 93% to 83% in the sample network) by the presence of a competing flow in the Medium, due to the resilience of ad hoc networks. On the other hand, in the same network, the packet delay is affected significantly (four fold increase in packet delay, from 0.2s to 0.8s, in the sample network).**

Keywords-MANET; M2ANET; performance; delivery ratio; delay; multiple data flows; DOS.

I. INTRODUCTION

A MANET is a set of mobile devices that cooperate with each other by exchanging messages and forwarding data [1]. A Mobile Medium Ad hoc Network (M2ANET) proposed in [2] is a particular configuration of a typical MANET where all mobile nodes are divided into two categories: (i) the forwarding only nodes forming the so called Mobile Medium, and (ii) the communicating nodes, mobile or otherwise, that send data and use this Mobile Medium for communication. The advantage of this M2ANET model is that the performance of such a network is based on how well the Mobile Medium can carry the messages between the communicating nodes and not based on whether all mobile nodes form a fully connected network. An example of a M2ANET is a cloud of autonomous drones released over an area of interest facilitating communication in this area. The movement of nodes in a M2ANET can be preplanned by the user, selected at random or purposefully controlled for the best network performance. When the mobile nodes are designed to guide their movement themselves, we call such a network a Self-organizing Mobile Medium Ad hoc Network (SMMANET) [3].

As in any network, the performance depends on many factors: link data rates, protocol used and, for MANET type networks, node density and movement pattern. The traffic pattern and network congestion will also have an impact on M2ANET performance. In this paper, we set out to investigate the effect of additional users on M2ANET performance. These new users can be legitimate users of the M2ANET or even some rogue nodes purposely interfering with legitimate M2ANET operations.

In Section II, we present background on M2ANETs and their operation. The simulation experiment investigating the presence of multiple flows in a M2ANET on its performance is presented in Section III, with results analyzed in Section IV. The conclusion is in Section V.

II. STATE OF THE ART

We introduced the concept of a Mobile Medium in our seminal paper on M2ANETS in 2011 [2]. 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. Examples of networks operating on a similar principle include the Google Loon project [4], Facebook's flying internet service [5] and a swarming micro air vehicle network (SMAVNET II) [6].

Despite the possibility that the nodes forming a Mobile Medium can operate in a manner similar to traditional MANETS using the same type of hardware nodes and the same routing protocols, the means of investigation of M2ANETs are different from traditional approaches to investigating ad hoc networks as they rely on different performance metrics. Specifically, the performance of any individual links and the connectivity between the M2ANET nodes does not matter directly. What is important is the performance of the channel through the Mobile Medium allowing the users of the M2ANET to communicate successfully. For example, the question whether all the nodes in the Mobile Medium are connected together is of no importance.

Our past investigation of M2ANETs centered on the following issues: node density in the Mobile Medium, node

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movement pattern and the cooperation among the nodes.

The node density in general indicates how many mobile forwarding nodes are present in an area of interest where wireless communication is to be supported by means of the Mobile Medium. The smaller the area and the larger the number nodes the better the performance that the M2ANET offered to the users of the Medium [2]. For a M2ANET to operate efficiently, the available mobile nodes need to be positioned and moved over the area of coverage. Having the forwarding nodes mobile contributes to greater resiliency of the implementation, because new nodes move in and take over form the failing ones [7], and allows for the use of aerial drones, like micro air vehicles/planes [6], with hard limits on the sustained minimum velocity. M2ANET mobile nodes can move at random [8], in groups [9], along fractal paths [10] or can even be cooperating among themselves like an intelligent swarm, to best facilitate the demand from M2ANET users [3].

Our past investigations of M2ANETs focused on the Mobile Medium operating autonomously and serving a pair of users, similar to having two users connecting wirelessly with a line of sight link. In this paper, we set out to investigate the behavior of the Mobile Medium in the presence of multiple data flows being carried simultaneously in a M2ANET. There are many practical scenarios that correspond to this model: (i) a simple scenario where multiple users rely on the same Mobile Medium to carry their data and (ii) a malicious attack scenario, where rogue nodes inject data into the Mobile Medium in an attempt to interfere with the legitimate traffic.

III. PERFORMANCE OF A M2ANET IN THE PRESENCE OF COMPETING FLOWS

The performance of the Mobile Medium in the presence of competing flow is investigated using the ns2 simulator [11] in a simulated generic scenario with a preset number of Mobile Medium nodes moving randomly in a bounded region. As in the previous studies [2][3][7]-[10], the performance of the Mobile Medium is measured at different forwarding node densities by varying the number of nodes in the M2ANET network. Experiments with three different MANET routing protocols: AODV, Destination Sequenced Distance Vector (DSDV), and Dynamic Source Routing (DSR) are conducted [12]. Three user scenarios are investigated: a pair of users communicated through the Mobile Medium without any other traffic present (so called "no DOS" scenario), and the same but with one or two other flows active across the Medium (DOS1 and DOS2 scenarios). In the multi flow scenarios, the additional flows, for the sake of argument, are considered as rogue flows that are interfering with the original flow (thus the name DOS1/2: Denial Of Service with one/two rogue flow(s) scenario) and only the performance of the first (principal) flow is investigated. In order to investigate the potential interference between data flows in the Mobile Medium, the locations of the sources and destinations were selected so that straight line paths between pairs of users would intersect with one another, Figure 1.

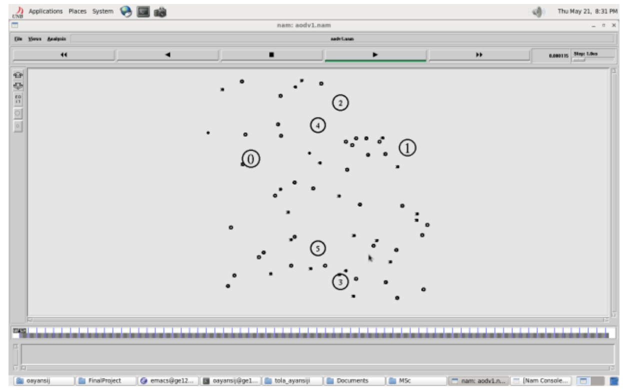

Figure 1. Screen shot of the simulation showing a M2ANET network with two communicating nodes 0 and 1, and four rogue nodes 2 to 5.

In the mobile network simulation, the random mobility model is used as a reference case scenario, mostly because it is a standard model used in network simulation. The base case model used is the Random Way Point (RWP) model available in ns2 [11]. 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. The mobile nodes forming the Mobile Medium move at random speeds with an average speed of 4 m/s. The main communicating nodes 0 and 1 are stationary. The source and destination nodes are located at (200,650) and (900,700) 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 Packets in ifq	50
Area (n * n)	1000 x 1000m
Source Type	CBR over UDP packetSize_ 512 interval_ 0.05
Simulation Time	300 s
Routing Protocol	AODV, DSDV, DSR

The data traffic for each flow is modelled with the CBR traffic generator and sent using UDP over simulated Mobile Medium networks with five different node densities from 20 to 120 nodes. Node density indicates the total number of mobile nodes in the 1000 m by 1000 m square region modelled in the experiments. The delivery ratio is the ratio of the number of packets successfully received at the destination node to the number of packets sent during each simulation experiment. The packet delivery time (delay) is the difference between the time the packet was received at the destination and the time the same packet was sent from the source node. Each mobile network scenario has been simulated three times for a 300 second simulation run time and the average results taken.

IV. RESULTS AND ANALYSIS

The Mobile Medium performed as expected (matching the packet delivery rate results of previous studies, e.g., [2]) when presented with a single flow to transmit and no other flows interfering with it, i.e., no DOS. When additional flows were present in the Mobile Medium the performance decreased. The decrease was more pronounced for DSDV and DSR, and very moderate for AODV, in the presence of moderate disturbance to the Mobile Medium (only one additional rogue flow in DOS1), Figure 2. Better performance of AODV can be attributed to it being reactive and distributed [1][12].

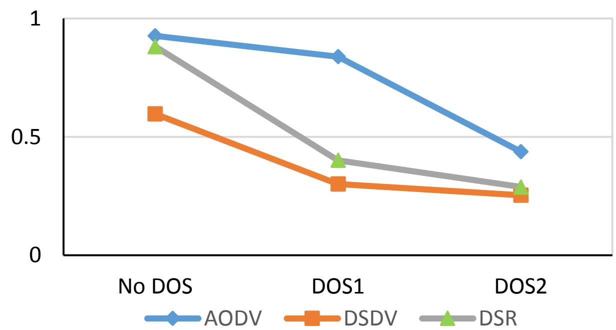

Figure 2. Delivery ratio for three scenarios.

Further investigation of the DOS1 scenario shows that the AODV advantage is present over the full range of node densities, Figure 3 and 4. Finally, with more significant load in the Mobile Medium, i.e., in the presence of two rogue flows in DOS2, the delivery ratio for all tested routing protocols dropped similarly to just below 50%, as seen in Figure 2.

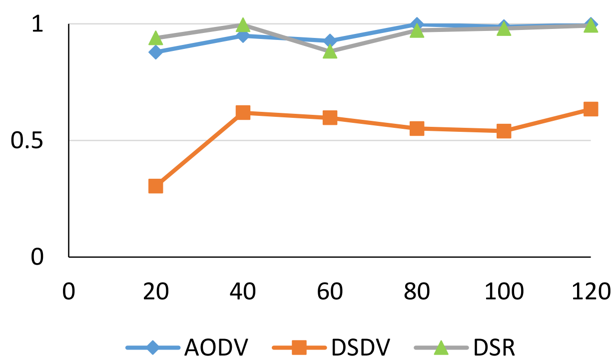

Figure 3. Packet delivery ratio vs number of nodes, no DOS.

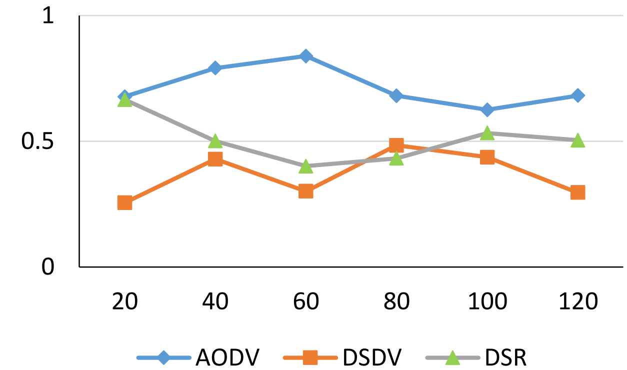

Figure 4. Packet delivery ratio vs number of nodes, DOS1.

The investigation of packet delivery times shows significant increases in the average packet delays when a second flow is present, DOS1 scenario. In the single flow scenario, no DOS, the delays were well below 0.5s in all experiments across all node densities, Figure 5. With the second flow present, the DOS1 scenario, the delays increased in general, with the most significant delay in the range of 5s registered in the DSR experiments, Figure 6. For the best performing protocol, AODV, the delays were below 0.2s in the single flow scenario and up to 0.79s in the DOS1 scenario.

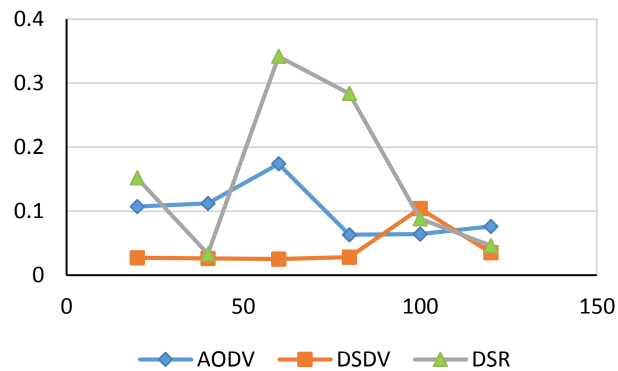

Figure 5. Average delay [sec] vs number of nodes, no DOS.

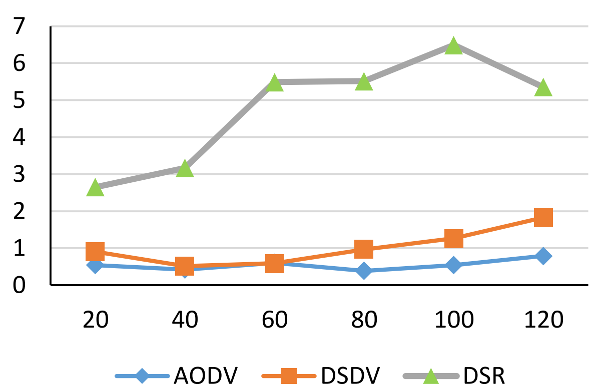

Figure 6. Average delay [sec] vs number of nodes, DOS1.

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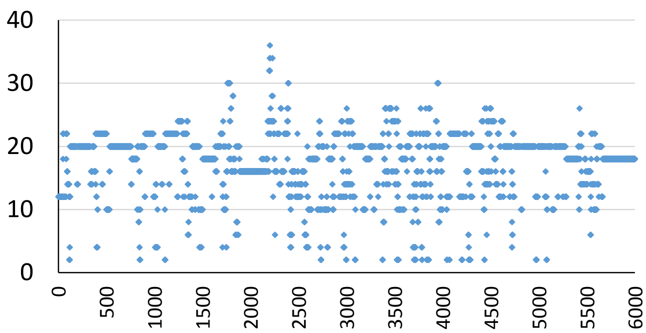

Figure 7. AODV: path lenght for each packet sent, DOS1.

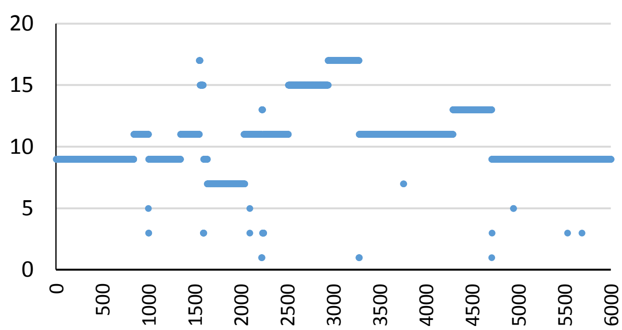

Figure 8. AODV: path lenght for each packet sent, no DOS.

Further investigation of the AODV protocol indicates that increase in packet delays may be attributed to much longer forwarding path lengths, and more frequent path changes. In the network with two flows, DOS1, up to 34 hops were registered for packet 2200 on Figure 7, compared to the path length reaching only 17 in a network with a single flow, no DOS scenario in Figure 8.

V. Conclusion and Future Work

Previous studies showed the dependence of the performance of a Mobile Medium on network infrastructure characteristics: the forwarding node density, movement pattern, routing protocol etc. In this paper, we showed how the Mobile Medium performance is affected by the presence of multiple flows in the network. Introducing competing flows in the Mobile Medium network results in gradual degradation of packet delivery ratio, from close to 93% for AODV for a single flow scenario, down to 83% for two flows and only 44% for three flows. The decrease is even more significant for DSDV and DSR. What is more significant, the Mobile Medium experiences a drastic increase in average packet delays when the second flow is added across all investigated configurations. The AODV average delays increased from less than 0.2s up to 0.79s. The delays for the worst performing DSR increased from 0.79s to 6.48s.

The Mobile Medium, while showing a great resilience to packet loss with a moderate traffic increase, is expected to experience significant delays in packet delivery when the traffic carried through the medium increases.

Future work could focus on investigation of AODV class routing protocols (on-demand, reactive) centering on maintaining high delivery ratio while improving on packet delays.

References

[1] S. Basagni, M. Conti, S. Giordano, and I. Stojmenovic (Eds.), Mobile Ad Hoc Networking, New York, Wiley-IEEE Press, 2001.

[2] J. DeDourek and P. Pochec, "M2ANET: a Mobile Medium Ad Hoc Network", Wireless Sensor Networks: Theory and Practice, WSN 2011, Paris, France, Feb. 2011, pp. 1-4.

[3] H. Almutairi, J. DeDourek, and P. Pochec, "Node Movement Control Based on Swarm Intelligence for a Mobile Medium Ad hoc Network", The Eight International Conference on Advances in Future Internet, AFIN2016, July 27, 2016, Nice, France, pp. 1-8.

[4] H. Hodson, "Google's Project Loon to float the internet on balloons", New Scientist, October 2013.

[5] J. Brustein, "Facebook's Flying Internet Service, Brought to You by Drones", Bloomberg Businessweek, March 4, 2014.

[6] A. J. Pacheco, et al., "Implementation of a Wireless Mesh Network of Ultra Light MAVs with Dynamic Routing; Proceedings of the IEEE Globe Work; Anaheim, CA, USA. 3–7 December 2012, pp. 1591–1596

[7] K. Patel, J. DeDourek, and P. Pochec, "M2ANET Performance Under Variable Node Sleep Times", Third International Conference on Advances in Future Internet, AFIN2011, Nice, France, Aug. 2011, pp. 31-34.

[8] M. Alzaylaee, J. DeDourek, and P. Pochec, "Linear Node Movement Patterns in MANETS", The Ninth International Conference on Wireless and Mobile Communications ICWMC 2013, Nice, France, July 21-26, 2013, pp. 162-166.

[9] A. Alshehri, J. DeDourek, and P. Pochec, "The Advantage of Moving Nodes in Formations in MANETs and M2ANETs", The Ninth International Conference on Wireless and Mobile Communications ICWMC 2013, Nice, France, July 21-26, 2013, pp. 228-232.

[10] H. Alseef, J. DeDourek, and P. Pochec, "A Method for Custom Movement Generation in Wireless Mobile Network Simulation", The Seventh International Conference on Emerging Networks and Systems Intelligence, EMERGING 2015, July 19 - 24, 2015, Nice, France, pp. 27-32.

[11] H. Ekram and T. Issariyakul, Introduction to Network Simulator ns2, Springer, 2009

[12] S. K. Sarkar, T. G. Basavaraju, and C. Puttamadappa, Ad Hoc Mobile Wireless Networks, Principles, Protocols, and Applications, Auerbach Publications Taylor & Francis Group, 2007.

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