The Advantage of Moving Nodes in Formations in MANETs and M2ANETs

Abdullah Alshehri, John DeDourek, Przemyslaw Pochec
Faculty of Computer Science
University of New Brunswick
Fredericton, Canada
E-mail: {j0lp6, dedourek, pochec}@unb.ca

***Abstract*—MANETs are self-configuring infrastructure-less mobile networks characterized by dynamically changing topology and intermittent connectivity. Performance of MANETs depends on the movement pattern of their nodes. We propose, and simulate in network simulator NS-2, a novel group mobility model, a towing formation, and show its advantage in controlling the movement of mobile nodes in a MANET. In the towing formation model, one of the nodes within each formation acts as a leader, with the other nodes, called followers, trailing closely. We show the impact of the number of towing formations in a MANET network, the number of nodes in each towing formation, and the distance between the nodes in each towing formation on the data traffic through a MANET. The greater the number of formations and the greater the size of each formation, the better the throughput.**

Keywords-MANET; group mobility; formations; NS-2.

I. INTRODUCTION

In recent years, we observed a heightened interest in mobile networks for use in emergency situations and disaster recovery. Ideally, such networks would have a limited reliance on (existing) fixed infrastructure, be easy to set up and resilient to disruptions resulting from hazardous environments and infrastructure breakdown.

The general model of a Mobile Ad hoc Network (MANET) fits very well the emergency deployment scenarios. MANET is a network consisting of mobile autonomous nodes that forward the data among themselves without, as opposed to cellular networks, the need for any fixed infrastructure [19]. Nodes are relatively inexpensive and therefore can be used in large numbers if necessary, to facilitate communication. The new M2ANET model [4] proposes to use a large number of mobile nodes to create a “cloud” of routing nodes, a mobile medium, to facilitate communication between designated senders and receivers. In M2ANET, when two stations cannot communicate directly, a large number of routing nodes is dispersed between them and acts as the medium forwarding and routing messages.

In many situations (i.e., military communications, emergency relief, search and rescue) members participating in the effort are organized into teams, often with a designated leader: an officer leading a platoon of soldiers, a coordinator giving directions to a rescue team, etc. Given the available resources, it may be advantageous (and economical) to organize the members into teams. The leaders may possess special qualities, skills, intelligence and equipment that distinguish them from the rest of the team.

If mobile networks were to be organized on some of the same principles, we might designate some mobile network nodes as leaders. We may then equip these nodes with special facilities like advance control and guidance with GPS etc., and perhaps even a powered motion facility (e.g. an engine), while the other nodes may be left more limited in these functions and may only need, for instance, to be guided or even to be towed by a leader. Such an approach would simplify the control (i.e., decision made at a node, which way to move next) of movement in a MANET with a large number of nodes: one would only need to guide (a limited number of) leaders while the followers would simply tag along. In case of simple physical towing, neither a guidance system on a towed node, nor any type of communication between the leader and the followers would be required. One example of such a scenario where the leader is responsible for the direction of movement of another object is aerotowing a glider by a powered plane; another application is a multiple decoy system towed behind a warship [21].

In this paper, we propose a group mobility strategy based on the above scenario where some mobile nodes can independently choose their movements, while the other nodes are limited in their movements, and limited to following the leaders (designated nodes). In MANETs, small changes to the movements of nodes can lead to changes in network topology and therefore affect the performance characteristics, such as throughput. We study the impact of having the nodes moving in formations on the performance of a MANET running the AODV routing protocol [14].

In Section II, we present background on MANETs. In Section III, dynamic mobility control strategy for MANET with formations is proposed based on group behavior. Experiments with different group sizes and lengths are described, including simulation set up, results and analysis in Sections IV and V. Finally, we present the conclusion and future work, in Section VI and Section VII, respectively.

II. STATE OF THE ART

MANET is a kind of wireless network that consists of a group of mobile nodes that communicate with each other without relying on fixed infrastructure [19]. The Mobile Medium Ad hoc Network (M2ANET) is a kind of a MANET where the mobile nodes are divided into two

 ISBN: 978-1-61208-284-4

categories: nodes that forward the data only and cannot be a source or the final destination of any transmission, and the nodes that can originate and receive data [4]. The forwarding nodes form a cloud of mobile medium that enables communication between transmitting nodes. The data communication through the mobile medium is affected by the properties of the medium: node density, speed, and especially the movement patterns, etc.

The mobility models have been developed to represent the node distribution and the movements [5][6][7]. They capture the properties of node location, time-varying node speed, and the distinct behaviors of the nodes, for example following different movement paths. These statistical properties of network connectivity are studied and identified with the mobility model [8][9][11][12][13].

The closest to our towing group mobility model is the Reference Point Group Mobility (RPGM) proposed by Hong et al. [9]. In our towing model, the nodes in a group follow the group leader, while in RPGM it is the "logical center" that determines the group motion behavior.

III. THE STRATEGY: MOVING IN FORMATIONS

A. *Preliminary*

We assume that all of the nodes have the same communication range R. The nodes inside the range are called neighbors, and two or more neighbors can communicate. Each node has its location, which is simply denoted as L (v). The location information can be maintained using Global Positioning System (GPS), or by using an inertial guidance system. In the experiments we initially place the clusters of nodes belonging to formations randomly at different locations in area n x n (Fig. 1). Within each cluster one node is arbitrarily designated as a leader (node with lowest index assigned during the simulation is used). We test the communication between one source, S, and one destination, D, in every scenario where both S and D are stationary and positioned at the opposites sides of the experimental area. The number of relay (forwarding) mobile nodes depends on the scenario.

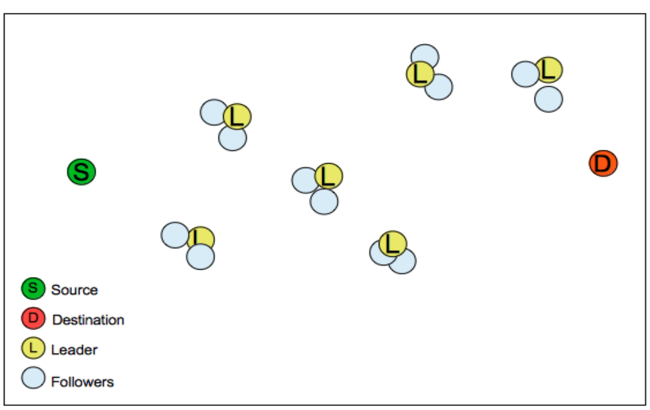

Figure 1. The initial placement of the leaders and the followers.

B. *The Movment of the Leader and the Followers in the Towing Group Mobility Model*

We propose a simple model for moving the nodes in a formation: each designated leader moves in a random direction following the random way point mobility model [20], while the followers retrace the path of the leader following it at a predetermined distance. The direction chosen by the leader not only defines the motion of the group leader itself, but it also provides the general motion trend of the whole formation.

In the first set of experiments, the distance between the followers ranges from 100 - 110 meters. In the second set, the distance was 150 - 210 m. In the simulation we assume that the leader L randomly chooses the direction of the next move, and sends information to the followers N including coordinates and movements. The movement of the followers is directly affected by the movement of its group leader, where every group member eventually lands on the same X and Y coordinates earlier visited by the leader. Every follower, N, sends directional information to the next N+1 in the same formation F and follows L, etc. When the movement of groups of nodes is viewed as an animation it looks like if the leader was towing a number of nodes behind it (Fig. 2).

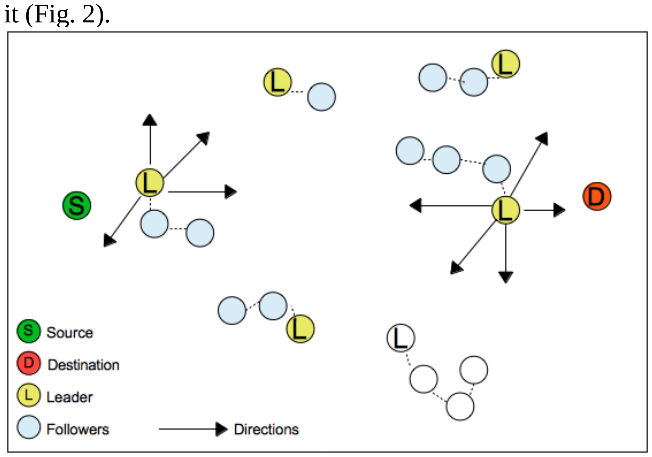

Figure 2. Movement and structure of formations of different lengths.

IV. SIMULATION

The towing group mobility model introduced in the previous section was implemented and simulated in NS-2. We used AWK scripts to analyze the trace files produced by the simulator.

A. *Simulation Environment*

In each case the network consisted of a different number of nodes roaming in a 1000 x 1000 meters square with a reflecting boundary. The NS-2.34 default settings for 802.11 legacy mode (Distributed Coordination Function DFC and 2Mbps links) are used. The transmission range is 250m. The data is generated at the source node at rate of 1 Mbps. Every packet has a size of 512 bytes. The buffer size at each node is 50 packets. Data packets are generated following a constant bit rate (CBR) process. The experiments we transmit packets from one source to one destination for 900 seconds, and measure the effective throughput with increasing mobility range and density. The other assumptions are listed below and shown in Table 1.

- The source node, S, is stationary, and is located in a specific location on the far left.
- The destination node, D, is stationary, and is located in a specific location on the far right (see Fig. 1).
- The distance between S and D is 1000 meters.
- Nodes are being generated randomly at random locations as clusters.
- The intermediate nodes are moving at a constant speed of 10m/s.
- The distribution of the intermediate nodes is divided into a number of formations with different lengths (2, 3, or 4) clustered as an initial placement, F1, F2,..Fn (Fig. 2).
- A leader, L, from each formation is automatically elected.

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 1000
Source Type	(UDP) CBR
Simulation Time	900 sec
Routing Protocol	AODV

B. *Performance Metric*

The network throughput is a metric used to calculate the amount of data transmitted from source to destination in a specific period of time (in bits per second). It can be calculated as:

$$\gamma = \frac{no.\_of\_bits\_received\_by\_node\_D}{Observation\_time} \qquad (1)$$

V. RESULTS AND ANALYSIS

The experimental results show the average throughput for the data transmitted from the source node S to the destination node D. The results are averaged over three experiments and plotted with the standard deviation shown as an error bar.

We simulated a number of groups of nodes, each with a leader (L) and one to three followers behind it. All of the followers follow their leaders' X and Y coordinates. Each leader with its followers is called a formation. Fig. 3 shows the screen shot of the node movements for a number of formations each with two followers, all simulated in NS-2 and visualized using NAM animation tool, e.g., nodes n2, n3, and n4 form a formation of 3 nodes (1 leader + 2 followers).

Figure 3. Formations of three nodes; NS2 simulation.

A. *Case 1: Different Number of Formations*

In Fig. 4, we show the performance of a MANET when a different number of formations of different lengths are used. The number of formations is varied from 6 to 10, and the length of formations is varied from 1 to 4. The graph shows that, for a given number of formations, the longer formations perform better. It should be noted that longer formations use larger number of nodes in total in the experiment: 10 formations of length 1 require only 10 nodes, while 10 formations of 4 would use the total of 40 nodes (4 leaders and 36 followers). Also, increasing the length of a formation we keep the number of leaders the same and add followers only, which may be an advantage in some applications.

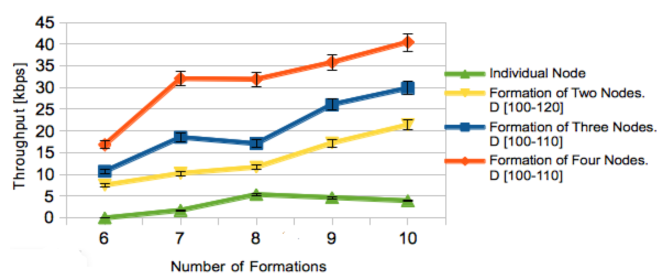

Figure 4. Throughput vs. number of formations.

B. *Case 2: Different Number of Nodes*

We tested the scenarios where a given number of mobile nodes (24, 36, 48, and 60) was equally divided into a number of formations with predetermined length (2, 3, and 4). For example, with 36 nodes we had either 18 formations of two nodes, or 12 formations of three nodes. We also show the effectiveness of increasing the default distance between the nodes in a formation in our group mobility by running two sets of experiments one with an average of 100m - 110m and the other with 150m - 210m, as illustrated in Fig. 5.

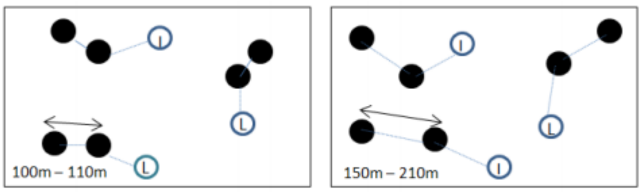

Figure 5. The distance between follower nodes

For a formation of two nodes (the leader and one follower), increasing the distance between the nodes improves the performance, but only for the cases with 36 and 48 mobile nodes (Fig. 6). Formations of three always work better when the followers keep back at a larger distance (Fig. 7). However, Fig. 8 shows the opposite: the three followers following at a short distance give slightly better throughput compared with the scenario when nodes follow at a longer distance. One could stipulate that only for short formations, the performance is improved with the increased distance between the nodes.

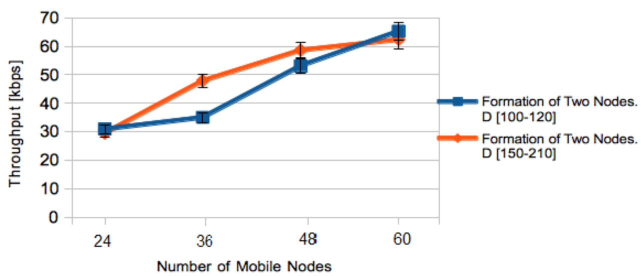

Figure 6. Throughput with length two formations.

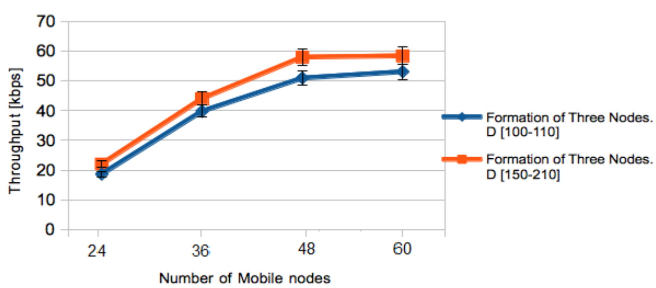

Figure 7. Throughput with length three formations.

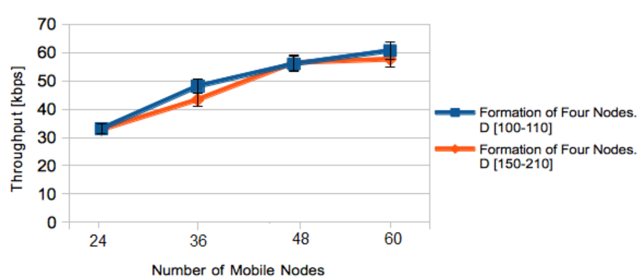

Figure 8. Throughput with length four formations.

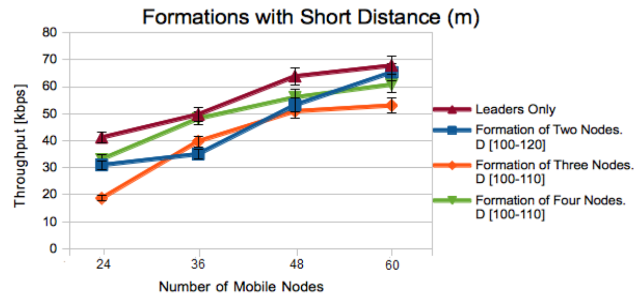

Figure 9. Throughput for short distance between the nodes for different formations.

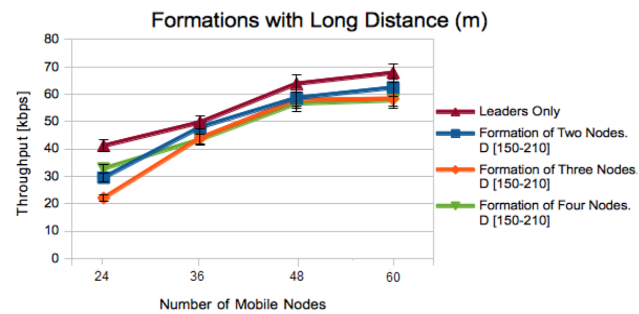

Figure 10. Throughput for long distance between the nodes nodes for different formations.

In all the comparisons, the formation of one node (the leader only) consistently gave the best throughput (Figs. 9 and 10).

For all other cases, if we set the distance separating the nodes in the towing formation to be large and analyze the role of the formation size, we see consistent results for all the cases with a larger distance between the nodes in a formation: for the cases with following distance in the 150-210m range we notice the shorter the formation the better the throughput for all experiments except for the case with the smallest number of nodes (24 in Fig. 10). We also noticed that there was no performance difference when formations of three or four nodes were used in the experiments with 36 and more nodes (Fig. 10).

For all the cases where the distance separating the nodes in the towing formation is small, the preference for any particular length of the formation is not so clear cut. Moving nodes individually (formation of one) is still always the best, formation of four is always significantly better than the formation of three, and the relative performance of the formation of two varies and seems to depend on the number of nodes.

VI. Conclusion and Future Work

In this paper, we presented a group mobility mode for moving mobile nodes in formations. All the available nodes in a network are divided into groups and each group forms a formation and moves independently form the others. We proposed a mobility model for moving the nodes in a formation called “towing”. In the towing formation model

Copyright (c) IARIA, 2013. ISBN: 978-1-61208-284-4

one of the nodes within a formation acts as a leader, with the other nodes, now called followers, trailing closely.

The towing formation model was tested by simulation. We used the recorded throughput for the CBR traffic between designated nodes as the main performance metric. We observed that the larger the total number of mobile nodes the better the throughput. Also, the larger the number of formations, the higher the throughput. Consequently, for a given total number of nodes, using shorter formations results in more formations being created, and leads to a better performance (observed at larger distances separating the nodes in a formation). In the case of a fixed total number of mobile nodes, increasing the number of formations by shortening the formations all the way to only one node, i.e., moving nodes individually always gives the best performance. For short formations, increasing the distance between the followers improves the performance.

It should be noted that the fact that the best throughput was recorded when moving nodes individually does not negate the results of this research. As stated in Section I, using the towing formation implies having two types of nodes: the leaders and the followers. For example, when the number of available leaders is limited, one can still improve the performance of a MANET by increasing the number of followers. As a part of future work, we would like to benefits of adding more nodes to a network and the tradeoffs between adding the leaders and the followers. We would like to investigate forming formations automatically from nodes that are not prearranged into clusters. The (direction of) movement of the towing formations could be optimized to take a maximum advantage of the guaranteed connectivity between the nodes within the cluster to extend the coverage area to the maximum. The random movement in free space could be replaced with a more realistic model based on the actual maps and street layout.

ACKNOWLEDGMENT

We would like to thank the Ministry of Higher Education of Saudi Arabia including the Saudi Cultural Bureau in Canada for their support.

REFERENCES

[1] M. K. J. Kumar and R.S. Rajesh, “Performance analysis of MANET routing protocols in different mobility models,” IJCSNS International Journal of Computer Science and Network Security, vol. 9, no. 2, Feb 2009, pp. 22-29.

[2] C. M. Cordeiro and D. P. Agrawal, “Mobile ad hoc networking,” in Tutorial/Short Course in 20th Brazilian Symposium on Computer Networks, May 2002, pp. 125-186.

[3] D. Goldenberg, J. Lin, A. S. Morse, B. Rosen, and Y. R. Yang, “Towards Mobility as a Network Control Primitive,” in Proc. of the 5th ACM MobiHoc, 2004, pp. 163-174.

[4] 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.

[5] X. Chen, Z. Jiang, and J. Wu, “Mobility control schemes with quick convergence in wireless sensor networks,” Parallel and Distributed Processing, IEEE International Symposium on, April 2008, pp. 1-7, doi: 10.1109/IPDPS.2008.4536119.

[6] J. Wu and F. Dai, “Mobility control and its applications in mobile ad hoc networks,” Network, IEEE , vol.18, no.4, July-Aug. 2004, pp. 30- 35, doi: 10.1109/MNET.2004.1316759.

[7] F. Bai and A. Helmy, A Survey of Mobility Modeling and Analysis in Wireless Ad Hoc Networks, A Survey of Mobility Models in Wireless Adhoc Networks, Kluwer academic Publishers, University of Southern California, U.S.A., pp. 2-32, 2004.

[8] A. Jadbabaie, L. Jie, and A.S. Morse, “Coordination of groups of mobile autonomous agents using nearest neighbor rules,” Automatic Control, IEEE Transactions on , vol. 48, no. 6, June 2003, pp. 988-1001, doi: 10.1109/TAC.2003.812781

[9] X. Hong, M. Gerla, G. Pei, and C.-C. Chiang, “A Group Mobility Model for Ad Hoc Wireless Networks,” Proc. ACM Int'.l Workshop Modeling, Analysis, and Simulation of Wireless and Mobile Systems (MSWiM), 1999, pp. 53-60.

[10] J. Hortelano, M. Nacher, J.-C. Cano, C. Calafate, and P. Manzoni. “Evaluating the goodness of MANETs performance results obtained with the ns-2 simulator,” in NSTools'07, Nantes, France, 2007, pp. 1-7.

[11] S. Gunasekaran and N. Nagarajan, “An Improved Realistic Group Mobility Model for MANET Based On Unified Relationship Matrix,” Advance Computing Conference, 2009. IACC 2009. IEEE International, March 2009, pp. 1270-1274, doi: 10.1109/IADCC.2009.480919.

[12] B. Malarkodi, P. Gopal, and B. Venkataramani, “Performance Evaluation of Adhoc Networks with Different Multicast Routing Protocols and Mobility Models,” Advances in Recent Technologies in Communication and Computing, 2009. ARTCom '09. International Conference on, Oct. 2009, pp. 81-84, doi:10.1109/ARTCom.2009.29.

[13] K. Blakely and B. Lowekamp, “A structured group mobility model for the simulation of mobile ad hoc networks,” in Int. Conf. Mob.Comp. Netw., Proc. 2nd Int. Worksh. Mob. Manag. Wirel. Acc. Protoc., Philadelphia, USA, 2004, pp. 111–118.

[14] D. O. Jorg, “Performance comparison of MANET routing Protocols in different network”, Institute of Computer Science and Applied Mathematics, Computer Networks and Distributed Systems, University of Berne, Switzerland, Computer Science Project Report, February 2004.

[15] H. A. Lagar-Cavilla, G. Baron, T. E. Hart, L. Litty and E. de Lara, “On the robustness of simple indoor MANET simulation models,” Ad hoc & sensor wireless networks, 2007, pp. 321-354.

[16] H. Akcan, V. Kriakov, H. Bronnimann and A. Delis, “GPS-Free Node Localization in Mobile Wireless Sensor Networks,” Proc. Fifth Int'.l ACM Workshop Data Eng. for Wireless and Mobile Access (MobiDE ',06), June 2006, pp. 35-42.

[17] L.A. Latiff and N. Fisal, “Routing Protocols in Wireless Mobile Ad Hoc Network” - a review, Communications, The 9th Asia-Pacific Conference on, 2003, pp. 600- 604.

[18] E. Royer and C. Toh, “A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks”. IEEE Personal Communications 6 (2), April 1999, pp. 46–55.

[19] C. E. Perkins, Ad Hoc Networking, New York, Addison-Wesley, 2001.

[20] T. Issariyakul and E. Hossain, Introduction to Network Simulator NS2, Springer, 2009.

[21] N. Friedman, The Naval Institute Guide to World Naval Weapon Systems, Naval Institute Press, 2006