Linear Node Movement Patterns in MANETS

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***Abstract*— MANETs are mobile, self-configuring networks of wireless mobile devices that have no fixed infrastructure configuration. Movement of the nodes affects the operation of a MANET. Because of the node movement MANETs need to rely on robust routing protocols. We focus our investigation on the impact of movement patterns on operation of a MANET. Of particular interest is linear movement patterns similar to those observed in some man-made objects. We investigate the operation of a MANET under four different linear movement patterns by simulating a MANET running the AODV routing protocol. The best results were obtained with nodes moving perpendicularly to the geographical direction of packet forwarding.**

Keywords- mobility models, MANET; M2ANET; ns-2; AODV

I. INTRODUCTION

A network which links several devices and relies on radio signal frequency is known as a wireless network. A Mobile Ad Hoc Network (MANET) is connected by radio links and consists of self-reliant mobile nodes [1]. The nodes move and operate without any central control as individual autonomous systems. They move freely in any direction and links among these devices change frequently. The dynamic movement pattern that these nodes follow influences the overall network performance. Different movement patterns can be categorized with respect to mobility models [2][3][4]. Examples of realistic models that have been suggested include obstacle mobility and pathway mobility [5]. In these models, there are pre-determined pathways and obstacles, which determine the movement of nodes and propagation of signals in a wireless network.

Linear node movement occurs in practice in man-made system. Examples of these include: movement of machines on a factory floor, bus routes following a city grid, and most interestingly some plane routes. For example, typical flight corridors for transatlantic flights show close to parallel paths of nodes (planes) as illustrated in Figure 1. In this paper, we present the results of investigation into different mobility models with practical applications for MANETs. Instead of using the most common random mobility (exemplified by setdest in ns-2) we propose moving nodes along mostly straight paths, possibly adjusting direction periodically. Such a movement pattern should be easier to realize in practice, as the nodes would be moving essentially following a predefined track, like a train moving on rails between two stations back and forth.

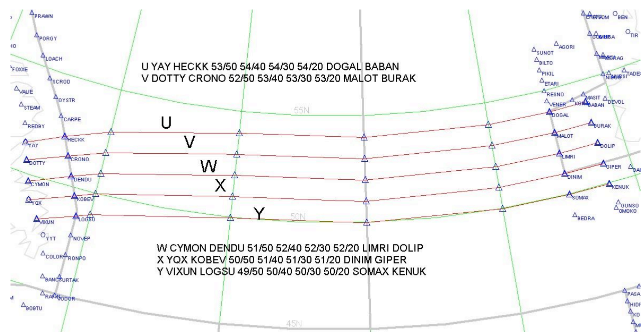

Figure 1. North Atlantic Tracks for the eastbound crossing on the evening of May 4, 2006 [6].

In Section II, we present background on MANETs and principal routing protocols. Different linear movement patterns for MANETs and simulation of these movements in ns-2 are discussed in Section III. Experiments with different linear movement patterns are in Section IV. Finally, we present the experimental results in Section V, followed by conclusion and future work.

II. STATE OF THE ART

A MANET is comprised of interconnected nodes, which make use of communication paths that are allowing multi-hop activity. They offer distinct advantages and are versatile for some particular applications and environments. There are no fixed or prerequisite base stations or infrastructures; therefore, their creation and usage is not time consuming and can occur at any given point in time and at any place. MANETs have a fault-resilient nature, given that they are not operating a single point of failure and are very flexible. The deletion and addition of new nodes, forming new links are a normal part of operation of a MANET [1][7][8]. A group of nodes can facilitate communication between distant stations forming a mobile medium, as introduced in [9]. These benefits of MANETs have resulted in many applications in hostile environments including military, police, rescue and other hostile or disorganized environments.

MANET research and deployment are aided by the fact that they use small and relatively inexpensive wireless communication devices. Simulators like ns-2 include models for wireless nodes, links and protocols and can be used for experimenting with MANETs [10]. The simulations rely on numerous parameters, which include not only the patterns of communication but also the model for mobility.

Future expectations are that MANETs will be deployed in various scenarios that tend to have complex connectivity dynamics and node mobility. A good example would be a MANET on a battlefield wherein the soldiers' movement is dictated by their commander. For a citywide MANET, maps or obstacles limit the movement of the nodes. Note that mobility of the node and its properties are specific to the application in question; therefore, mobility properties that are widely varying possess the ability to greatly impact the performance of the various routing protocols. To cope with these specific requirements of MANETS, highly adaptive protocols based on flooding [11][12][13] and on dynamic routing [14][15][16] were developed. In our paper, we propose and analyze a number of variants of motion with spatial dependencies: our vertical and horizontal motions are similar to the Column Mobility Model (CMM), and square and specified area motions are similar to the Reference Point Group Mobility (RPGM) introduced in [17]. In addition to different motion types, we also investigate the relation between the direction of the motion itself and the geographical direction of the data transfer. For experiments in our research we considered using one of the two popular MANET routing protocols supported in ns-2 simulator: Dynamic Source Routing (DSR) and Ad hoc On-Demand Distance Routing (AODV). Both DSR and AODV share a similar on-demand behavior route discovery for ad hoc networks, but with different mechanics for routing. However, AODV outperforms the DSR routing protocol when simulating a large number of nodes as in our experiment [7]. This is why AODV is used in modeling MANETs in this report.

III. INVESTIGATION OF SELECTED LINEAR MOVEMENT PATTERNS

Setdest [10] is a tool built into ns-2 [10] and uses a random mobility model to generate random movements for the nodes using a pause and move strategy. In this strategy, a next movement and speed are independent of the previous move. In this paper, we investigate the MANET performance under a scenario with constrained node movement. More specifically, we investigate the node movements that are still random but confined to a single direction, a line, and are similar to some real movements. For example a rail car can move only forward and back but not sideways. We assume that the MANET is composed of many such nodes, but it is used to carry the data between two defined (and fixed) nodes. This type of a model is called Mobile Medium Ad Hoc Network (M2ANET) and is based on the concept of mobile medium introduced in [9]. The references to "vertical" and "horizontal" are based on the movement direction as observed in the ns-2 simulator on a computer screen. Horizontal corresponds to the movement of the nodes in the general geographic direction of packet forwarding, and vertical corresponds to the path perpendicular to the one defined above.

A. *Vertical motion*

In this motion, each node is initially assigned an X coordinate randomly, which stays the same during the simulation, while the Y coordinates the changes for each move. Each node is assigned a random destination located on the vertical line defined by the node X coordinate and moves to this destination at a random speed. The process is repeated until a node reaches the destination.

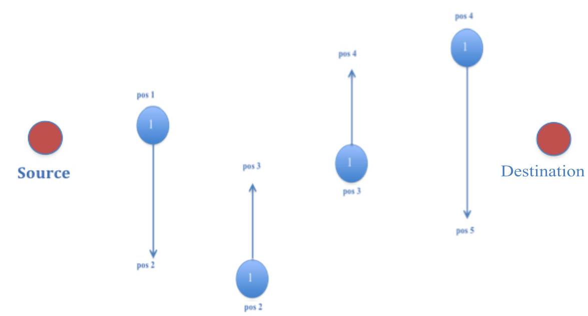

Figure 2. Vertical motion.

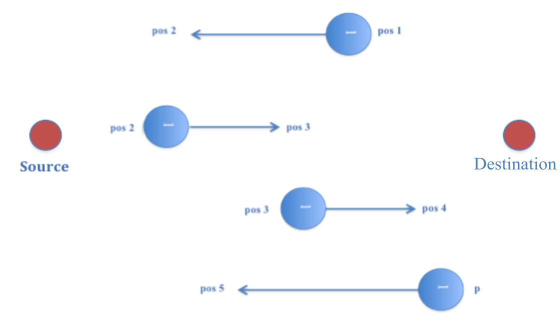

Figure 3. Horizontal motion.

B. *Horizontal motion*

This movement motion does exactly the opposite of the vertical movement. The Y's coordinate remains the same, while the X's coordinate changes for each move during the simulation time. This type of motion is similar to the movement of planes on the path shown in Figure 1, with the exception that some of the planes (if they were controlled by random number generators) would be turning back midway.

C. *Square motion*

This movement motion allows the nodes to move in a square path with different speeds for each node during the simulation time. This square path is defined to be a 100*100 square in the experimental area and is the same for each node. Each node takes a random position at first. Then it moves to the right by adding 100 to its initial position. Then it moves up by 100 from its previous position. Finally, it moves to the left by adding 100 to the previous position. A full square path is followed by each node and repeated until the end of the simulation time.

D. Specified area motion

This movement motion keeps the nodes moving randomly based on values generated the Java Math library function Math.random() in a specified area (200*200 in our experiment). Each node has an initial random position at the start of the simulation. Then each node moves to a new randomly assigned position but does not go beyond 200*200 from the node's first initial position during the simulation time. (The displacement along each axis is calculated mod 200).

E. Simulation environment

The simulation time for our experiment is set to be 1000 sec in a topology of size 1000m * 1000m. We tested different node density starting from 5 nodes up to 100 nodes, which includes the two stationary nodes. We run the simulation 10 times for each node density and then we calculate the average of these runs. Node transmissions are simulated using the 802.11 ns-2 model, and the packets are forwarded using the AODV protocol.

For comparison, we also simulated random motion using the standard ns-2 setdest utility. For performance evaluation, since we always have the same number of packets sent, we only need to quantify packets that are received at the destination node. This is the same as using the packet delivery as a main performance metric in the experiment.

IV. EXPERIMENTAL RESULTS

A. Base case scenario with setdest results

The base case scenario in our experiment used the setdest utility to generate random movements for the nodes. The experiment for this movement was run 10 times for each node density and the average of packet delivery was calculated. In Figure 2, the three curves represent the number of packets received at three different speeds. The graph shows that at high densities the number of packets received at the destination node decreases as the maximum speed increases from 25, 50 to 500 m/s. This result is based on the random movement generated from setdest in ns-2.

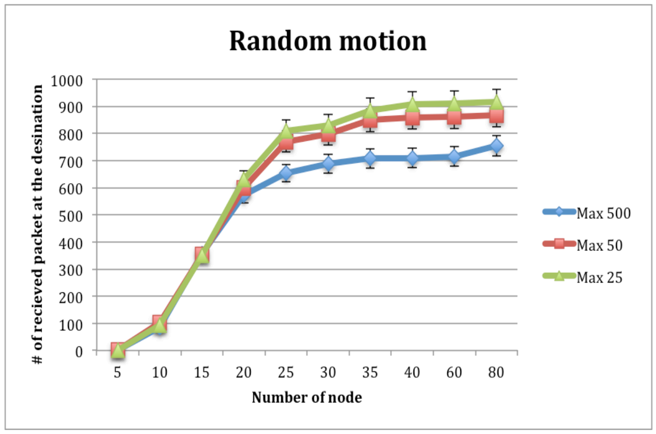

Figure 4. Random motion results.

B. Vertical motion result

In this scenario, where the nodes are moving only up and down (i.e., perpendicular to the geographical direction between the source and destination) during the simulation with random speeds, we observe the average packets received at the destination node density during 10 experiments. Figures 5 and 6 illustrate the comparison of different motions in low and high average speed. The graphs show that the number of received packets increases with the increase in number of mobile nodes (which increase node density), up to a point when certain number of nodes is reached (35 in our experiments). At this point the node density is no longer the primary factor in delivery of packets. After this node density is reached, the node speed becomes the primary deciding factor in how many packets are delivered.

C. Horizontal motion result

The horizontal motion, as explained before, allows the nodes to move only in the direction of (i.e., defined by a line between) the two stationary nodes, which is in the horizontal motion experiment would be right and left. In this experiment, we also run the simulation 10 times for each node density, and calculated the average of packets received. As illustrated in Figures 5 and 6, the overall trends are similar to the vertical motion, except that the vertical motion reaches a higher packet delivery, which is particularly pronounced at high node speeds. A closer inspection of the simulation runs revealed that in case of horizontal motion some mobile nodes had their initial random position assigned too far from the two stationary nodes that these nodes were out of range to deliver the cbr packets.

For both motions that we create, Figure 5 shows no difference for the delivery rate at lower speed, whereas with the higher speed, we can see from Figure 6 that vertical motion has a better performance based on the packet delivery.

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D. Square path motion result

In the square path, we combined the vertical and horizontal motions into one set of moves and we limited the extent of movement to a square path. Therefore, each node moves only 100*100 from its initially random position and this would have an impact on the network connectivity at low node densities. Indeed, the observed performance (Figures 5 and 6) was lower than horizontal and vertical motion at lower node densities, and similar to these two at higher node densities.

E. Specified area motion result

Specified area motion keeps the nodes move randomly but in limited square shaped area, which is in our experiment 200m * 200m from the topology size 1000m *1000m. With the specified area motion, the nodes are also moving in a confined area. Despite the randomness of the movement, the observed performance is the worse of the four movement types investigated in this paper.

F. Comparing four different motions

At both high and low speeds the specified area motion type delivers the least number of packets and vertical motion delivers the most. Square motion is more reliable at high speeds than horizontal motion, but less reliable at low speeds. This is because square motion performs both vertical and horizontal motion and at lower speeds suffers loss of connectivity during the horizontal motion and vertical motions that occur while out of range. For all motions at high node density, movement speed becomes the primary factor in reliability and with a fewer packet delivered at high speed.

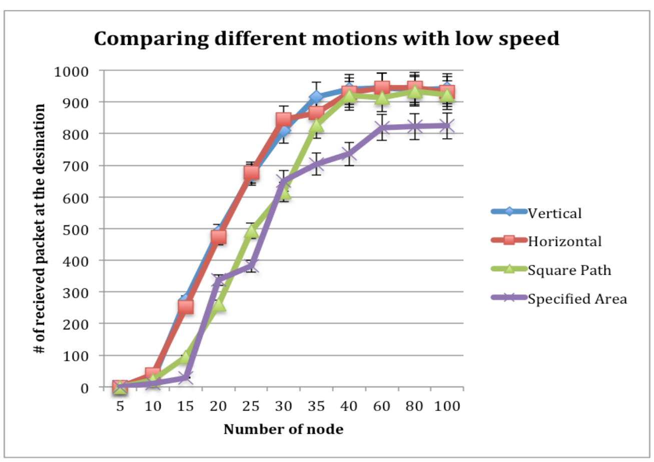

Figure 5. Comparing different motions with low speed.

From our experiment, we notice that when there is no motion among the nodes then, depending on the initial positions of the nodes, either zero percent (no path from source to destination expect) or 100 percent (path exists) of the packets will be delivered. In this case, the possibility of receiving all the packets rises with increased node density. As soon as the nodes start to move, the packet delivery starts to decrease. When we have the nodes distributed randomly in our experiment topology, there are no packets received when we have very low node density. Once we have 20 or more nodes distributed randomly, there will be either zero or 100 percent of the packets received. The higher the node density, the better are the chances of having the packets delivered.

V. CONCLUSION AND FUTUR WORK

In this paper, we presented four different node movement patterns for use in MANETs. They include: the horizontal movement in which the nodes move in the geographical direction of forwarding packets, the vertical movement (perpendicular to the above), the movement in a square paths, and the movement in a specified area. We observed that the movement of the nodes affects the performance of packet delivery in the simulated MANET.

As expected, we observed that the speed of the movement affects the performance of the MANET in all movement types. More packets are dropped with larger maximum speeds at higher node densities. For example, for the horizontal motion the average packet delivery in the simulation with 40 nodes was 93% at low speed and only 80% at high speed. Our experiments show that the vertical motion (i.e., motion perpendicular to the direction of forwarding packets) is better than the horizontal motion (i.e., motion in the direction of forwarding packets) at a given node density. For example, in experiments at high speed, 89% of packets are delivered in a network with vertical node movements vs. 80% in case of the horizontal movement (both in the simulation of a network with n=40 nodes). The horizontal motion causes the most displacement for the node relative to the source and destination nodes. Once the nodes are out of range by horizontal motion, they continue to be out of range and do not forward data.

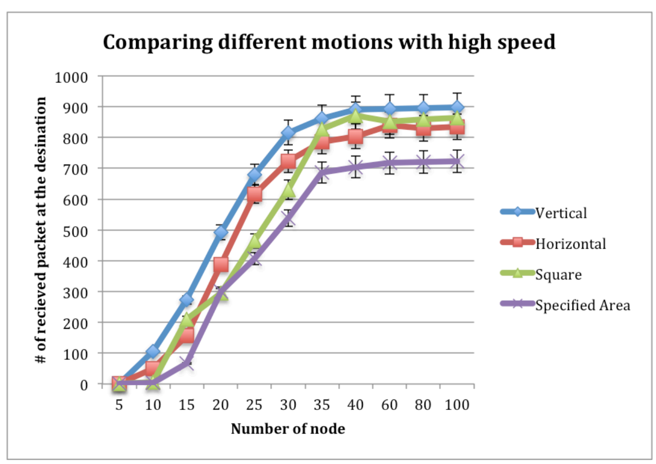

Figure 6. Comparing different motions with high speed.

Based on our results, we suggest further testing of all the movements with changing multiple parameters, such as increasing or lowering the experimental area, changing the size of the specified area size in one of the movement models, changing the routing protocols, varying speed, and node density, etc. Furthermore, other movement patterns can be investigated in simulation and in an actual physical MANET experiments. It would also be of interest to model the movement of all transatlantic flights over the North Atlantic and see if a MANET network could be established if all the planes were equipped with suitable transceivers.

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REFERENCES

[1] S. Basagni, M. Conti, S. Giordano and I. Stojmenovic (Ed.). Mobile Ad Hoc Networking. IEEE/Wiley Press, 2004.

[2] F. Bei, and A. Helmy, "*A survey of mobility models in wireless Ad hoc Networks*. California: University of California", USA, 2004.

[3] M. Dorigo, V. Maniezzo, and A. Colorni, "The Ant System: Optimization by a colony of cooperating agents", *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on,* 26 (1), 1996, pp. 29-41.

[4] A. B. McDonald and T. F. Znati, "A mobility-based framework for adaptive clustering in wireless ad hoc networks", IEEE Journal on Selected Areas in Communications, Vol 17, No. 8, Aug 1999, pp. 1466-1487.

[5] D. P. Agrawal and Q. A. Zeng, Introduction to wireless and mobile systems, third edition. Thomson Engineering, 2011.

[6] North Atlantic Tracks. (2012, October 18). *In Wikipedia, The Free Encyclopedia.* Retrieved 06:36, June 5, 2013, from http://en.wikipedia.org/w/index.php?title=North_Atlantic_Tracks&oldid=518517067.

[7] M. R. Pearlman and Z. J. Hass, "Determining the optimal configuration for the zone routing protocol," IEEE Journal on Selected Areas in Communications, vol. 17, no. 8, pp. 1395-1414, Aug. 1999.

[8] S.Sarkar, T.G.Basavaraju et al,"Ad hoc Mobile Wireless Networks, Principles, Protocols and Applications", Auerbach Publications - 2008.

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

[10] T. Issariyakul and E. Hossain, "Introduction to Network Simulator NS2 ", Springer, ISBN: 978-0-387-71759-3, 2009

[11] S. Pleisch, M. Balakrishnan, K. Birman, R. van Renesse, "MISTRAL: Efficient Flooding in Mobile Networks", Proc. ACM MobiHoc, pp. 1–12, 2006.

[12] P. Chan, and Y. Dong,, "Performance Evaluation on URL Distribution using Flooding in Mobile Ad Hoc Networks (MANETs)", *Southeast Conference, Kennesaw*, Kennesaw, GA, USA, 2005, pp. 70-80

[13] S. Murthy, and J.J Garcia-Luna-Aceves, "An efficient routing protocol for wireless networks", ACM Mobile Networks and Applications Journal, Special issue on Routing in Mobile Communication Networks, 1996, pp. 183-197.

[14] G. Di Caro and M. Dorigo "Mobile agents for adaptive routing," System Sciences, Proceedings of the Thirty-First Hawaii International Conference on, Volume: 7 , 6-9 Jan 1998 Page(s): 74 -83.

[15] V. Park and M.S. Corson, "A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks," Proc. IEEE INFOCOM '97 (April 1997),.pp. 1405-1413.

[16] C. E. Perkins and P. Bhagwat "Highly dynamic destination sequenced distance vector routing (DSDV) for mobile computers" SIGCOMM '94—Computer Communications Review, 24(4):234–244, 1994.

[17] N. Aschenbruck, E. G. Padilla, and P. Martini, "A survey on mobility models for performance analysis in tactical mobile networks", Journal of Telecommunications and Information Technology, vol.2, 2008, pp. 54-61.

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