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Topographical Automation of MANET using Reactive Routing Protocols

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***Abstract*--Wireless mobile ad-hoc networks (MANET) are characterized as infrastructure less networks. Topologies are formed with movement of regular nodes which has multi radio links and these regular nodes under demand behaves as backbone node (router) to forward packets across the network. These networks suffer frequent topology changes due to the dynamic stochastic process behavior of incoming nodes. Mobile ad-hoc networks lack load balancing that causes unnecessary packet loss and route break up in real-time data transmission. Area of operation, interference, and communication link range and path loss are the factors to affect the throughput of MANET. In this paper we evaluated the performance of AODV and DSR routing protocols which are enhanced by an Automation Topography, In our proposed Topographical Automation the location of incoming nodes are completely random and those will be confined themselves within a certain communication range such that the throughput is enhanced to meet better QoS level. As location of the nodes are system defined and quite automatic, nodes before being forwarded with the full assurance of successful session flows. It is often advantageous to position stable and capable relay nodes, including unmanned ground vehicles (UGVs) or unmanned aerial vehicles (UAVs), and unmanned under sea vehicles (UUVs) used by Defense to save cost as well as life.**

Keywords:
Ad hoc networks, Mobile wireless networks, QoS routing, Link survival time, Automation Topography, Mobility model.

1. INTRODUCTION:

Mobile networks can be classified into infrastructure networks and Mobile Ad Hoc Networks (MANET) according to their dependence on fixed infrastructures [2]. In an infrastructure mobile network, mobile nodes have wired access points (or base stations) within their transmission range. In contrast, Mobile Ad Hoc networks are autonomously self-organized networks without support of infrastructure. In a Mobile Ad Hoc Network, nodes move arbitrarily, therefore the network may experience rapid and unpredictable topology changes. Routing paths in MANETs potentially contain multiple hops, and every node in MANET has the responsibility to act as a router [4]. Routing in MANET has been a challenging task ever since the wireless networks came into existence. The major reason for this is the constant change in network topology because of high degree of node mobility. A number of protocols have been developed to accomplish this task.

There are various mobility models such as Random Way Point, Reference Point Group Mobility Model (RPGM), Manhattan Mobility Model, Freeway Mobility Model, Gauss Markov Mobility Model etc that have been proposed for evaluation [8, 15].

Several performance evaluation of MANET routing protocols using CBR traffic have been done by considering various parameters such as mobility, network load and pause time. We have analyzed the AODV and DSR protocol using Random Way Point model and CBR traffic sources. We investigated that DSR performs better in high mobility and average delay is better in case of AODV for increased number of nodes. Also it is investigated that AODV and DSR routing protocols under Random Way Point Mobility Model with TCP and CBR traffic sources. They concluded that AODV outperforms DSR in high load and/or high mobility situations.

In this paper, we first calculate the life time of links and of multi-link routes based on a Random Waypoint Model for mobility of hosts in the network .We show that, the life time of links and routes can be well fitted by exponential distributions, Furthermore we derive formulae for calculation of parameters such as communication link ranges, route hop counts, nodal speeds and nodal density over area of operations for networks.

2. MOBILITY MODELS USED IN MANET

MANET protocol performance may vary drastically across different mobility models [28].In the literature; there are a lot of models used, mostly in simulations. Among the common one is the Random Waypoint Model [29], which is a simple model that may be applicable to some scenarios However, this model is not sufficient to capture the more important mobility characteristics of scenarios that MANETs may develop The next section of this paper reviews the current mobility models used in the literature for simulating MANET routing protocols.

- *Random Waypoint Model (RWM)*

Johnson and Maltz describe the RWM [29]. It is a well designed and commonly used mobility model. It works as follows. All nodes are uniformly distributed around the simulation area at starting time. Each node then chooses arandom destination and moves there with a speed uniformlydistributed (Uniform Distribution) over [o, vmax] 0 is the initial speed when the node is stationary and vmax is the parameter used to set the maximum velocity of a particular node in the network) . Then, there is a pause time which could be selected to be 0 to give continuous motion. Thought this model is believed to be well defined, it is still insufficient to capture characteristics such as spatial dependence of movement among nodes, temporal dependence of movement of a node over time and existence of barriers obstacles constraining mobility [16]. The most common problem with simulation studies using random waypoint model is a poor choice of velocity distribution [2]

- Reference point group mobility model (RPGM)

Hong, Gerla, Pei and Chiang described another way to simulate group behavior in [3], where each node belong to a group where every node follow a logical centre (group leader) that determines the group's motion behavior. The nodes in a group are usually randomly distributed around the reference point. The different nodes use their own mobility model and are then added to the reference point which drives them in the direction of the group. At each instant, every node has a speed and direction that is derived by randomly deviating from that of the group leader.

- Freeway Mobility Model (FMM)

F.Bai, N.Sadagopan, Ashley [30] proposed this model to emulate the motion behavior of mobile nodes on a freeway. This model can be used in exchanging traffic status or tracking a vehicle on a freeway. Maps are used in this model. There are several freeways on the map and each freeway has lanes in both directions. The difference between RWM and FMM are 1) each mobile node is restricted to its lane on the freeway, 2) the velocity of the mobile node is temporally dependent on its previous velocity and 3) if two mobile nodes on the same freeway are of within the safe distance, the velocity of the following node cannot exceed the velocity of the preceding node.

- Manhattan Mobility Model (MMM)

The Manhattan mobility model is proposed to model movement in an urban area [31].In the Manhattan model, the mobile node is allowed to move along the horizontal or vertical streets on the urban map. At an intersection of a horizontal and a vertical street, the mobile node can turn left, right or go straight. The probability of moving on the same street is 0.5, the probability of turning left is 0.25 and the probability of turning right is 0.25. The velocity of a mobile node at a time slot is dependent on its velocity at the previous time slot. Also, a node's velocity is restricted by the velocity of the node preceding it on the same lane of the street. Manhattan mobility model focuses on nodes moving along horizontal or vertical streets, which is not enough to model nodes moving along non-horizontal and non-vertical streets.

- Random Gauss-Markov model (RGM)

RGM uses discrete time intervals to divide up the motion. A node's next location is predicted (or generated) by its past location and velocity. A mobile's velocity is assumed to be correlated in time and modeled by a Gauss-Markov process. Models of the RGM is described by Sanchez [33] and further developed by Liang and Haas. Markov Mobility Models are a large class of mobility models used in both cellular and ad hoc network mobility modeling. The simplest model, which is two-dimensional, assigns a probability to moving left moving right, and staying stationary.

3. PROBLEMS WITH ROUTING IN MANET

Most of the wired networks rely on the symmetric links which are always fixed. But this is not a case with ad-hoc networks as the nodes are mobile and constantly changing their position within network. For example consider a MANET(Mobile Ad-hoc Network) where node B sends a signal to node A but this does not tell anything about the quality of the connection in the reverse direction [8].

Routing Overhead: In wireless adhoc networks, nodes often change their location within network. So, some stale routes are generated in the routing table which leads to unnecessary routing overhead

Interference: This is the major problem with mobile ad-hoc networks as links come and go depending on the transmission characteristics, one transmission might interfere with another one and node might overhear transmissions of other nodes and can corrupt the total transmission.

Dynamic Topology: This is also the major problem with ad-hoc routing since the topology is not constant. In ad-hoc networks, routing tables must somehow reflect these changes in topology and routing algorithms have to be adapted. For example in a fixed network routing table updating takes place for every 30sec [8]. This updating frequency might be very low for ad-hoc networks.

4. PROBLEM DESCRIPTION

Higher degree of performance enhancement in MANET can be achieved by giving priority to the system that support partial as well as successful session flows. Implementation of an *efficient routing algorithm* and use of *topological automation* will help in finding stable routes and will give guarantee over successful data flows. Application of Load balancing, i.e., Gaussian distribution of nodes on the space with less variance results throughput enhancement in MANET.

Though reactive routing protocols (Source initiated) have better routing results over the proactive (Table Driven) routing algorithms. However during real time application AODV suffers severe packet loss due to dynamic stochastic behavior of incoming mobile nodes. Communication link range and continuous change required in nodal speed are the factors that results frequent route breakup and not able to position the Unmanned vehicles (UGVs, UAVs &UUSVs) which need real time data sharing during war used by Government.

By keeping in eye, for smooth completion of session flows in hostile environment we propose an Automation Topography, i, e Gaussian distribution of nodes in space results zero packet loss. In Our proposed Topography the location of nodes being forwards are quite automatic and random but they will be coffined themselves in such a way that AODV attains its nearer global optimization routing results. This System completely aware of node distributions in the space to define a safe zone of communication of nodes(Vehicle) in war and disaster recovery to save cost as well as life.

4.1Description of reactive Routing Protocols

Reactive Routing Protocol (RRP) is a bandwidth-efficient on-demand routing protocol for MANETs. In this protocol the originator node initiates the route search process, whenever it needs to send data packets to a target node. Thus the need for a route triggers the process of route search, hence the name

Reactive Routing Protocol. RRP is intended to be implemented in the network layer of mobile nodes i.e. in the layer 3 of ISO OSI reference model. Route Discovery and Route Maintenance functions of the protocol are described next.

- ***Ad-Hoc on Demand Distance Vector (AODV)***

The Ad-hoc On-demand Distance Vector routing protocol [1,3,14] enables multi hop routing between the participating mobile nodes wishing to establish and maintain an ad-hoc network. AODV is a reactive protocol based upon the distance vector algorithm. The algorithm uses different types of messages to discover and maintain links. Whenever a node wants to try and find a route to another node it broadcasts a Route Request (RREQ) to all its neighbors. The RREQ propagates through the network until it reaches the destination or the node with a fresh enough route to the destination. Then the route is made available by uncasing a RREP back to the source.

The algorithm uses hello messages (a special RREP) that are broadcasted periodically to the immediate neighbors. These hello messages are local advertisements for the continued presence of the node, and neighbors using routes through the broadcasting node will continue to mark the routes as valid. If hello messages stop coming from a particular node, the neighbor can assume that the node has moved away and mark that link to the node as broken and notify the affected set of nodes by sending a link failure notification (a special RREP) to that set of nodes.

- ***Dynamic Source Routing (DSR)***

DSR is a reactive routing protocol i.e. determines the proper route only when packet needs to be forwarded [4,9,11]. For restricting the bandwidth, the process to find a path is only executed when a path is required by a node (On-Demand Routing). In DSR the sender (source, initiator) determines the whole path from the source to the destination node (Source-Routing) and deposits the addresses of the intermediate nodes of the route in the packets. Compared to other reactive routing protocols like ABR or SSA, DSR is beacon-less which means that there are no hello-messages used between the nodes to notify their neighbors about their presence. DSR was developed for MANETs with a small diameter between 5 and 10 hops and the nodes should only move around at a moderate speed. DSR is based on the Link-State Algorithms which mean that each node is capable to save the best way to a destination. Also if a change appears in the network topology, then the whole network will get this information by flooding. The DSR protocol is composed of two main mechanisms that work together to allow discovery and maintenance of source routes in MANET.

Route Discovery: When a source node S wishes to send a packet to the destination node D, it obtains a route to D. This is called Route Discovery. Route Discovery is used only when S attempts to send a packet to D and has no information of a route to D.

Route Maintenance: When there is a change in the network topology, the existing routes can no longer be used. In such a scenario, the source S can use an alternative route to the destination D, if it knows one, or invoke Route Discovery. This is called Route Maintenance.

4.2 SURVIVAL time of links and routes

In [7] and [8], we have examined the behavior of link and route lifetimes by focusing on breakups that are induced by nodal mobility. Assuming a random waypoint mobility model (with relatively low values assumed for the times spent by nodes in pausing at the area boundary), we have shown that the distribution of the route survival time due to mobility L_m is well approximated by an exponential distribution. It is thus written as

(1) $$P(L_m \le t) = 1 - e^{-\kappa t} \quad (t \ge 0)$$

where κ is a constant that is determined by the mobility pattern of the nodes. We have shown the parameter of the underlying link lifetime distribution to be well approximated by setting $K=(V_1+V_2)\mu t/2r$, where $\underline{\mu}$ is a parameter determined by the mobility pattern (see [7]), r denoted the link's communications range, and $\underline{v_1}$ and $\underline{v_2}$ represent the speeds of the underlying link's end nodes; so that we have

(2) $$P(L_m \le t) = 1 - e^{-\frac{\mu(v_1+v_2)t}{2r}} \quad (t \ge 0)$$

To represent link failure events, we assume the following model. A link breakup can be induced by either one of the following two factors: (1) Nodal mobility that sets the link's end nodes to be at a distance that exceeds the threshold level r, and thus making communication ineffective at the desired bit error rate level. (2) Link outages that occur when the nodes are located within the designated communications range (r). Such outages can be caused by noise and interference processes, as well as the mobile character of the end nodes. For mathematical simplicity, we assume the link's time-to-fade (T_f) that represents the above mentioned second factor to also follow an exponential distribution, we have:

(3) $$P(T_f > t) = e^{-\mu_f t} = e^{-\frac{t}{\bar{T}_f}} \quad (t \ge 0),$$

Where $\bar{T}_f = \frac{1}{\mu_f} > 0$, denotes the average time to such an outage occurrence. For illustrative purposes, assume the above mentioned two lifetime periods to be statistically independent (for scenarios under which link breakup events caused by nodal mobility are approximately independent of outage causing fading phenomena). In this case, when we combine these components, the link life time ($\underline{L_l}$) is characterized by the following exponential distribution:

(4)
$$P(L_l \ge t) = P(L_m > t) = e^{-\kappa t} e^{-\mu_f t} = e^{-(\kappa+\mu_f)t} = e^{-\left(\frac{\mu(v_1+v_2)}{2r}+\frac{1}{\bar{T}_f}\right)t} \quad (t \ge 0)$$

To confirm this modeling approach, we have run a simulation of an ad hoc network over an operational area of size 1000 x 1000m. We have varied speed of the mobiles in the range of v = 2, 4, 6 and 8 m/s. The maximum (link) communication range level is r = 400m. Nodes have been assumed to move in accordance with random way-point mobility model [9] with a pause time set equal to zero; no multi-path fading factors are included.

Results for the link survival time distribution, for each prescribed speed value, are displayed in Fig. 1. The solid line curves are based on simulation results while the dashed line curves use the analytical computation described by Eq. (4). Noting the graphs to be plotted in a log–normal scale, we observe that the depicted simulation based linear curve confirms good fit with an exponential distribution. We have calculated the parameter μ used in the analytical expression by fitting the latter with the curve obtained by simulation for the v = 4 m/s case; we obtained it to be given by μ = 0.815. We have subsequently used the latter parameter for drawing the analytically computed distributions for all other speed levels, confirming, as shown in Fig 1, a good fit for all cases.

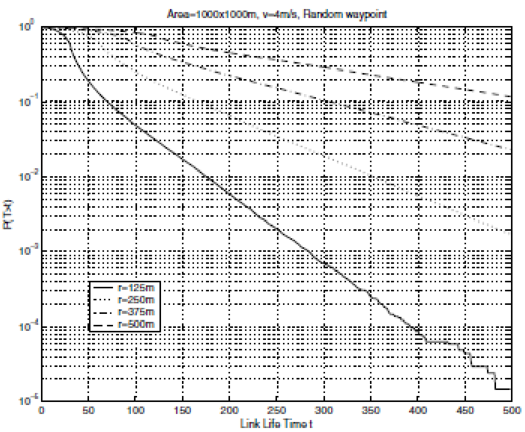

Fig. 1. Link survival time for different node speeds

We have also showed in[7] that a good approximation for the survival time of a flow's route, for the random mobility model under consideration, is obtained by assuming the variables representing the lifetimes of the links that make the route to be statistically independent. Consequently, noting that a route will break as soon as one of its links fails, the distribution of the survival time of a route whose path length is π can be calculated as

(5)

$$P(L_{\pi} > t) = e^{-\frac{\mu(v_0+2v_1+2v_2+\dots\dots+2v_{\pi-1}+v_\pi)t}{2r}} \quad (t \geq 0)$$

$$P(L_{\pi} > t) = e^{-\frac{\mu(v_0+2v_1+2v_2+\dots\dots+2v_{\pi-1}+v_\pi)t}{2r}} \quad (t \geq 0)$$

When we include link fading effects, we have:

(6) $$P(L \geq t) = e^{-\left(\frac{\mu(v_0+2v_1+2v_2+\dots\dots+2v_{\pi-1}+v_\pi)}{2r}+\frac{\pi}{T_f}\right)t} \quad (t \geq 0)$$

For aid in the operation of the routing scheme to be introduced in a later section, we denote the path mobility weight for a given route as,
$w=(v_0+2v_1+2v_2+\dots+2v_{\pi-1}+v_\pi)/2$. We let $W=W(\Pi,v)$ represent a random variable whose distribution is equal to that of the mobility weight of the path selected for a flow upon its admission to the network. Given a route whose hop-length Π is equal to π and whose mobility weight is equal to $W=W(\pi,v)=w$, we write:

(7) $$P(L \geq t) = e^{-\left(\frac{\mu w}{r}+\frac{\pi}{T_f}\right)t} = e^{-Kt} \quad (t \geq 0)$$

Where,

$$K = K(W,\Pi) = \frac{\mu w}{r} + \frac{\Pi}{T_f}$$

so that K^{-1} denotes the route's average lifetime to breakup.

4.2. Automation Topography.

Though performance of a mobile ad hoc wireless network is impacted by the dynamic stochastic process characteristics of its underlying links (and the associated noise interferences, data rates, ranges, communications capacity levels), nodes (e.g., their mobility patterns and resource states), the underlying graph connectivity of the network topology, and the application induced traffic loading processes and their required quality of service (QoS) objectives.

In this thesis, we proposed an *automation topology* by considering AODV as our routing protocol for forwarding packets. However our objective of topology automation is to achieve a good put model for MANETs i.e. position of mobile nodes are automatically defined by the system before they entry into this *safe network zone.*

In *Automation Topology,* nodes are free to move randomly in all direction but those will be confined themselves within a certain communication range such that the throughput is enhanced and it has an approach towards systems robust throughput.

In a hostile environment, like Un Manned Under Sea Vehicle (USV), Un Manned Air Vehicle (UAV) used by Defense to track the terrorist. Our proposed automation topology will best fit to recover the vehicle involved in war and assure good coordination between them. The use of *topological automation* will help Government not only in saving money but also in safe travel of Very Important Person from one place to another.

6. SIMULATIONS AND RESULTS

We conducted performance evaluation using the ns-2 simulator [15] over an operations area of size 1000m × *10*00m, and a maximum communications range level in the range of r = 125m to r = 500m. Each node starts moving at random speed from its initial position to a random target position selected from within the simulation area. The speed is uniformly distributed from (0 to V_{max}], where V_{max} is the maximum speed of the simulation. When a node reaches the target position, it waits for a pause time period, and then selects another random target location and moves again. We have varied speed of the mobiles in the range of 2, 4, 6 and 10*m/s*. Nodes have been assumed to move in accordance with a Random Waypoint mobility model with a pause time equal to zero (high mobility) environment. We show the survivor function (i.e., the probability that a link lifetime is longer than value t, over a range of t values).

The Fig 2 presents the average network throughput versus pause time from the simulation of the AODV protocol at 10m/s average speed. The network throughput is the sum of all application bytes delivered to all of the sources during the simulation trial divided by the simulation time. The Fig 3 presents the average network throughput versus pause time from the simulation of the DSR protocol at 10m/s average speed. Average network throughput of AODV and DSR with

50 sources increases with pause time. A comparison of the two protocols with 50 active sources is presented in Figure 4.
It is clearer here that AODV had the best performance at shorter pause times and DSR had the best at longer pause times. We examined the routing overhead incurred by each protocol during the trials. The size of the routing packets is also very important as it has a direct impact on data throughput. However, many small packets incur a certain penalty in additional MAC headers and RTS/CTS exchanges of the MAC layer. During the simulation we counted the number of routing protocol initiated data packets at each node. To normalize the data we counted each instance that a routing packet is forwarded from one node to another as an individual packet. Figure 8-8 presents the comparison of the three protocols. AODV and DSR are on-demand protocols and exhibit characteristics of efficient routing at lower traffic and source densities and increased routing overhead with additional sources. DSR has the lowest number of routing packets at all pause times than AODV.

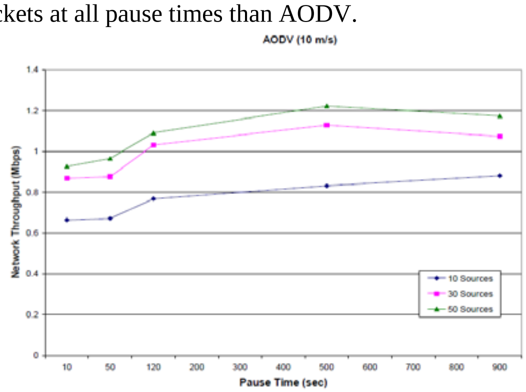

Fig. 2. AODV avg. network throughput (50-node, 1Mbps links)

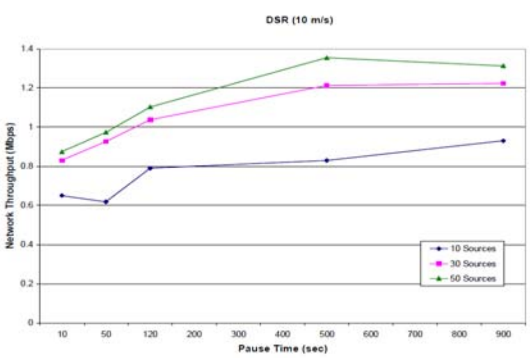

Fig. 3. DSR avg. network throughput (50-node, 1Mbps links)

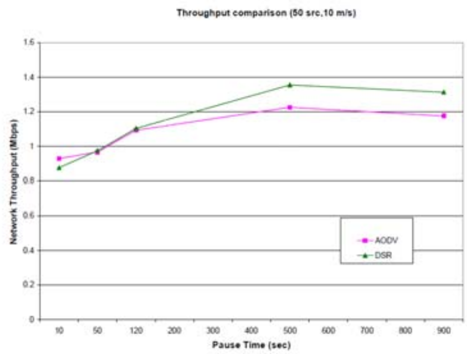

Fig. 4. Comparison of 50 source throughput (50-node, 1Mbps links)

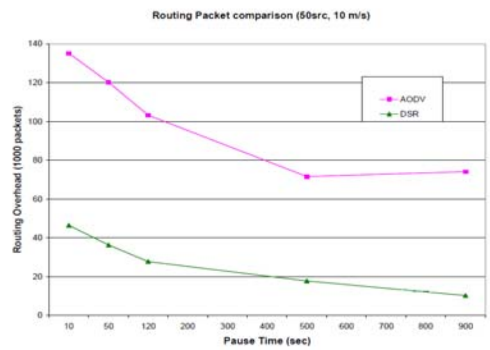

Fig. 5. Comparison of routing packet overhead (50-node, 1Mbps links)

6. CONCLUSIONS

This Paper presents an overview of mobility models and determination of link life times is essential when there is demand on real time packet transmission. In our case the AODV is a better choice for ADHOC network establishment but implementation of Automation Topography by using AODV routing protocol define a self configuring autonomous system that will provide safe zone for communication and there will be no chance of root breakup in any circumstances. It will be useful in applications for emergency services, battle field communications, conferencing and community based networking.
We plan to port other MANET routing protocols to this system in order to compare them within our platform and show our results with these, obtained through simulations. Finally, we proposed the use of Automation Topography as a tool to deploy random and mobile nodes in MANET without disturbing the conventional routing protocols.

REFERENCES

[1]. C.E. Perkins, E.M. Royer, Ad hoc on-demand distance vector routing, in: Proceedings of the 2nd IEEE Workshop on mobile Computing Systems and Applications, WMCSA'99, February 1999, New Orleans, pp. 90–100.

[2]. D.B. Johnson and D.A. Maltz, Dynamic source routing in ad hoc wireless networks, *Mobile Computing*, Kluwer Academic Publishers (1996) pp. 153–181.

[3]. Z. Ye, S.V. Krishnamurthy, S.K. Tripathi, Effects of multipath routing on TCP performance in ad hoc networks, in: Proceedings of Global Telecommunications Conference, GLOBECOM'04. IEEE, vol. 6, November 2004, Dallas, pp. 4125–4131.

[4]. Y.C. Hu, D.B. Johnson, Exploiting congestion information in network and higher layer protocols in multihop wireless ad hoc networks, in: Proceedings of 24th International Conference on Distributed Computing Systems, March 2004, Tokyo, Japan, 2004, pp. 301–310.

[5]. K. Fall, A delay-tolerant network architecture for challenged internets, in: Proceedings of the 2003 Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications, 2003, Karlsruhe, Germany, pp. 27–34.

[6]. J. Burgess, B. Gallagher, D. Jensen, B. Levine, Maxprop: routing for vehicle-based disruption-tolerant networks, in: Proceedings of INFOCOM 2006, 25th IEEE International Conference on Computer Communications, April 2006, Barcelona, Spain, pp. 1–11.

[7]. R. Zhang, I. Rubin, Mobility induced stable throughput behavior in mobile ad hoc networks, in: Proceedings of IEEE 60th Vehicular Technology Conference, 2004. VTC2004-Fall, vol. 4, 2004, Los Angeles, pp. 2708–2711.

[8]. R. Zhang, I. Rubin, Stable flow admission and routing for mobile ad hoc networks, in: Proceedings of Military Communications Conference (Milcom), October 2006, Washington DC.

[9]. D.B. Johnson, Routing in ad hoc network of mobile hosts, in: Proceedings of the IEEE Workshop on Mobile Computing Systems and Applications, December 1994, pp. 158–163, Santa Cruz.

[10]. I. Rubin, R. Zhang, H. Ju, Topological performance of mobile backbone based wireless ad hoc network with unmanned vehicles, in: Proceedings of IEEE Wireless Communications and Networking Conference, WCNC'03, vol. 3, 2003, New Orleans, pp. 1498–1503.

[11]. I. Rubin, A. Behead, H. Ju, R. Zhang, X. Huang, Y. Liu, R. Khalaf, Ad hoc wireless networks with mobile backbones, in: Proceedings of the 15th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), vol. 1, September 2004, Barcelona, Spain, pp. 566–573.

[12]. X. Huang, I. Rubin, H. Ju, A mobile backbone network routing protocol with flow control, in: Proceedings of Military Communications Conference (MILCOM), vol. 2, 2004, pp. 1086–1092.

[13]. H. Ju, I. Rubin, Backbone topology synthesis for multi-radio meshed wireless LANs, in: Proceedings IEEE INFOCOM 2006 Conference, April 2006, Barcelona, Spain.

[14]. J. Hsu, I. Rubin, Performance analysis of multi-rate capable random access MAC protocols in wireless multi-hop networks, in: Proceedings IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'06), September 2006, Helsinki, Finland.

[15]. NS-2, The ns Manual (formally known as NS Documentation) available at http: //www. isi.edu/*nsnam/ns/doc.*