Heterogeneous Mobility Models Scenario:
Performance Analysis of Disaster Area for Mobile Ad Hoc Networks

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Abstract

Depicting realistically, the complex movement patterns of nodes is critical in the study of Mobile Ad hoc Networks (MANETs). As the existing mobility models cannot realistically model the identified movement patterns and characteristics in disaster area scenarios, this paper proposes a disaster area mobility model that realistically represents the movements of nodes in a disaster area scenario. This model is heterogeneous-based and pulls together the strengths of some selected homogenous mobility models. The proposed model is evaluated and compared to existing homogenous models in ns-2 simulations. Results show that the idea of heterogeneous model is a possibility, capturing realistically, the defined features of disaster scenarios and when compared to existing models, performed better.

Keywords – Mobility Model, Routing Protocol, Disaster Zone, Heterogeneous Model, Homogenous Model

1. Introduction

Disaster situations are characterized by complex and unpredictable movement patterns of nodes with heterogeneous movements and speeds. This has defined the basis for modelling ad hoc networks for disaster search and rescue which must be fully independent of the destroyed pre-installed infrastructure. MANETs, by definition, meet the requirement of being infrastructureless. In network performance evaluation, the disaster area scenario (post disaster situation) is categorized according to magnitude of the situation in terms of coverage area, volume of traffic and mobility. The choice of mobility is critical when modelling the movement patterns in a scenario for the performance evaluation of communications in a disaster area network as the results of the evaluation largely depend on the mobility model used. Existing homogenous models define single movement patterns that cannot completely and realistically depict the heterogeneous-based movements in disaster area scenarios. Mobility models for the study of a particular network must reflect complete and/or near realistic nature of the movement patterns being simulated. The main goal of this work is to study the movement patterns of nodes in a disaster area scenario, consider how these movement patterns can be modelled and propose a disaster mobility model that realistically models the movement patterns in a disaster area scenario.

The paper is organized as follows: Section 2 looks at related works published by other researchers. In section 3, we consider characteristics for mobility consideration, mobility models, performance metrics and propose a mobility model for disaster area scenario. We evaluate the simulations analysis and results in section 4 and conclude the paper pointing future research areas in section 5.

2. Related Work

Samuel C. Nelson *et al* [1] consider disaster recovery scenario and look at how to capture the movement patterns of objects in such scenarios realistically. The paper suggests that the existing homogenous mobility models for MANETs do not realistically capture the behaviour of objects in disaster area scenarios. The paper proposes a high level event and role based mobility paradigm in which objects movement patterns are caused by environmental events. Though the authours recognize that in a disaster scenario, objects take on multiple mobility patterns with respect to events, the movements in their simulations are not based on any specific mobility model while our mobility definition is based on specific mobility models.

In [2] a disaster scenario mobility model is proposed with an analysis of the characteristics of disaster area scenarios. The proposed model does not consider group mobility. We consider group mobility in our analysis. In its analysis, the paper divided a typical disaster area into different sub areas: incident site, casualties treatment area, transport zone and hospital zone. The nodes are distributed across these sub areas depending on the class of a node. The movement of a node or group of nodes is defined by the area and class the node(s) belongs.

In [3] the analyses of performance in MANETs are affected by choice of mobility model. More unpredicted pattern of a model, the more realistic it models real life patterns. Predictable homogenous models then cannot realistically depict movements in disaster scenarios.

3. Disaster Area Scenario

Disaster situations vary in scope and magnitude but have some common features. A typical disaster area has been divided into several sub areas [2]. Every member of the rescue team belongs to at least one of the sub areas. Those in transport area (including helicopters, ships and vehicles) shuttle between sub areas handling patients movements and relief materials delivery and are considered to move in tactical formation (N people carrying the wounded, N crew members in a helicopter or N ship crew members). We consider this to imply a group mobility pattern. We also note that N/n number of crew members may likely hold communication devices. We also identify that nodes are able to alternate sub areas. For example, a foot rescuer may at one point hop into a moving vehicle and at another point join another group. Looking at the different kinds and levels of movements, we identify that there are heterogeneous speeds in disaster zone. Rescuers are also ready for emergency calls (e.g. an injured rescued from the rubbles that needs more urgent and emergency attention) that is capable of changing their plan and movement. The following main characteristics are then deduced from the analysis:

- Heterogeneous movement patterns and speeds
- Group mobility pattern and movements tending to avoid obstacles
- Unpredicted movement patterns
- Nodes can join and leave the network (optional). This is a general characteristic and is optional in this study. We consider that the hospitals for this scenario are make-shift hospitals and so are covered within the disaster area scenario.

These characteristics must be considered when designing a mobility model for the study of a disaster area scenario mobile ad hoc network. The Haiti earthquake of January 2010 is a typical example of a disaster scenario. We observed how groups of rescuers worked from ground, air and sea depicting some of the characteristics listed here.

3.1 Mobility Models

Several mobility models have been developed and are used in the performance evaluation of mobile ad hoc networks. These can be classified into homogeneous and heterogeneous models.

3.1.1 Homogeneous Mobility Models:

Homogeneous models depict single movement patterns. Models considered here include Random Waypoint (RWP), Gauss Markov (GMM), Manhattan Grid (MGM) and Reference Point Group (RPGM) mobility models. Basically nodes wait for a pause time and then moves to a randomly chosen location at a speed chosen from the range [Vmin, Vmax]. In our implementation of RWP, a long enough initial simulation period is discarded, minimum speed Vmin > 0 and maximum pause time Pmax < ∞ to mitigate the unwanted assumptions raised in [4] and [5] analysis. GMM models movement of nodes where the node's next (future) position and speed are likely to be correlated with its former and current position and speed. The model adapts to different levels of randomness –complete random or linear motion. MGM defines movements on predefined paths. It uses a grid road topology and selects nodes movements (in terms of direction) based on probabilistic approach. In RPGM nodes move in groups and every group has a logical centre whose motion detects the speed and direction of movement of the group's corresponding mobile nodes. Though with varied levels of randomness defined, these homogeneous models on their own do not depict the whole movement patterns of a disaster area including group mobility.

3.1.2 Heterogeneous Mobility Models

The proposed disaster mobility model is a combination of entity and group mobility models (depicting varied movement patterns) in that it pulls together the strengths of other mobility models. Heterogeneous mobility can be achieved in two ways as considered below:

– Heterogeneous Mobility Model 1 (Het1): This is based on the BonnMotion ChainScenario model [6]. In this model each mobile node observes movement patterns defined in all constituent models. Het1 comprises of RWP, GMM and MGM and each node in the model moves in patterns defined by all three models such that nodes final position of the $(n\text{-}i)^{th}$ scenario is linked to the initial position of the n^{th} scenario, and so on. RPGM is not included in Het1because the BonnMotion ChainScenario model does not support the implementation of RPGM. **Heterogeneous Mobility Model 2 (Het2):** Het2 defines a situation where each constituent model depicts movement for one-third of the overall considered number of nodes. RWP depicts movements for nodes 0 – 9, GMM 10 – 19 and RPGM 20 – 29. This model does not generate a scenario file but in this implementation, each of the scenario files that make up the model is defined separately and linked from the tcl file to run the simulation.

3.2 Performance Metrics

The following mobility metrics are used to analyze our first simulation (simulation 1). All the metrics, except relative mobility speed, depend on transmission range.

Mobility Metrics

- **Relative Mobility Speed (RMS)**

This metric is used in [2] to express the average relative speed between all the considered nodes in a network. It is a function of the relative motion of all nodes in a scenario. This metric is calculated with the following formula adapted from [7].

$$M = \frac{1}{|x,\ y|} \sum_{x,y} M_{xy} = \frac{2}{n(n-1)} \sum_{x=1}^{n} \sum_{y=x+1}^{n} M_{xy} \qquad (1)$$

Where M is the average of M_{xy} over all node pairs in a particular scenario, M_{xy} is the relative mobility between the node pair $(x,\ y)$ and n is the number of nodes in the scenario and $|x,\ y|$ the distinct number of node pairs.

- **Average Link Duration (ALD) and Average Node Degree (AND)**

ALD measures the average link duration for links that go up after the start of simulation and go down before the end of simulation while AND is number of neighbour nodes.

Protocol Performance Metrics

- **Throughput, Average End-End Delay and Average Number of Nodes relaying Packets**

Throughput of receiving bits is the cumulative number of bits received at destinations per total simulation time (bits/TIL). Average End-to-end delay is the average total time lapse between times of sent and receipt of a packet. Average number of nodes receiving and forwarding packets is the average intermediate nodes for the whole network including those receiving and forwarding packets.

4. Simulation Analysis

Two sets of simulations with various scenarios each are presented. Simulation 1 is a mobility comparison and analysis of four mobility models with Het1 mobility model. Simulation 2 is a performance comparison of five mobility models including Het1 and Het2. All scenario traces in simulation 1 are generated under the same condition. The same parameters for individual models are also replicated in Het1 which is a combination of three models.

Parameter	**Value**	
	Common Metrics	
Het1	rwp, gmkv and man	
Het2	rwp, gmkv and rpg	
Packet size	192	
Protocol	AODV	
Number of runs	10	
Maximum speed	10 (m/s)	
Simulation	**Simulation 1**	**Simulation 2**
Area	750 X 500 (m)	750 X 500 (m)
Number of nodes	60	30
Duration	3000 (sec)	1000 (sec)
Mobility model	rwp, man, rpg, gmkv and Het1	rwp, rpg, gmkv, Het1 and Het2
Transmission Range	50, 75, 100, 125, 150	
Traffic, Max connections		CBR, 30
Rate, Interval		4 pkt/sec, 0.25

Table 1: Simulation Parameters

Simulation 2 is modelled according to the scale of the Haiti earthquake of January 2010. The quake epicentre was reported [8] to be Léogâne, 25 kilometres from Port-au-Prince the Capital city. The disaster area required to be covered by rescue workers is a rectangle (of approximately 25km X 13.5km). About 2000 rescuers are reported [8] to have taken part in the emergency rescue. The importance of this analysis is to have a clue of the disaster scenario area, node density and be able to replicate same in this simulation. In a rescue mission, it is obvious that not all rescue workers have communications device. If we assume that half of the rescue workers have devices in this case, it follows that about 1000 nodes are distributed in an area of about 25km X 13.5km. Scaling this to maintain the same node density will result in a scenario of about 30 nodes in an area of 750m X 400m.

4.1 Result Analysis

To analyze the impact of the models on the link/mobility based metrics, we calculate the metrics for transmission ranges 50m to 150m (step 25) for all the mobility models.

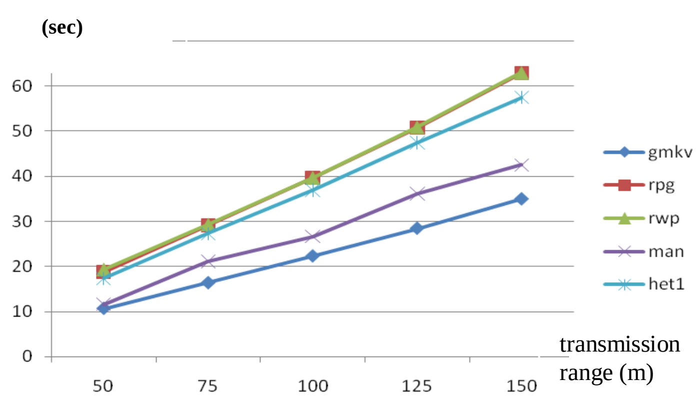

Figure 1: Average link duration distribution

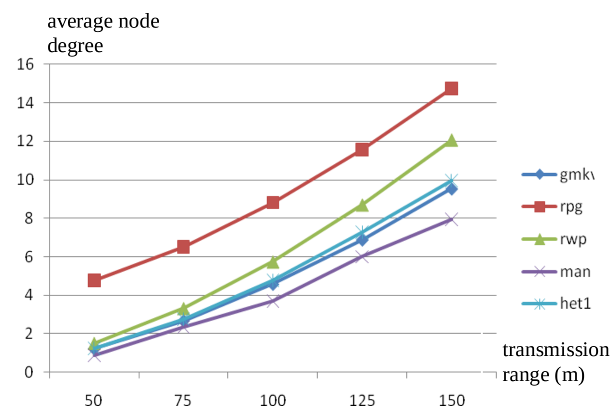

Figure 2: Average node degree distribution

Results show a high RMS value for Het1 because of its normalized transition for all nodes –relations of nodes' final position of current scenario and nodes' initial position of next scenario. This is an indication that destinations are reached faster with Het1. Also GMM generated the highest number of links but these links do not last long (fig 1). The movement pattern defined by GMM is highly erratic which also results in low connectivity. Het1 has a high level of link duration as a result of nodes being able to change movement patterns for different conditions. High level of link duration is an indication of more stable and reliable communications. RWP and RPGM have higher link duration than Het1 but Het1 has higher level of connectivity (as range increases). RPGM understandably has the largest average node degree owing to the inter/intra node relationship. Communication is sustained longer as transmission range increases (fig 2) with Het1 outperforming GMM and MGM.

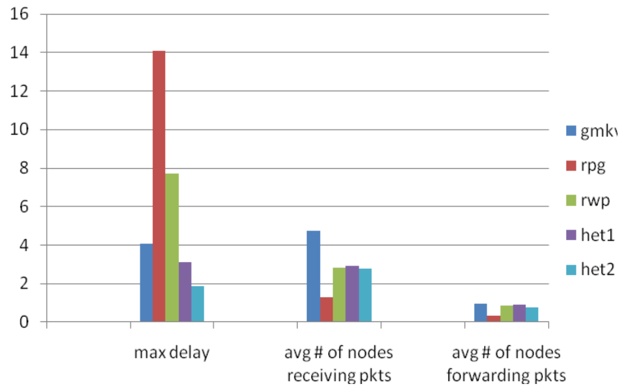

Figure 3: Maximum Delay (sec), Avg number of nodes forwarding and receiving packets

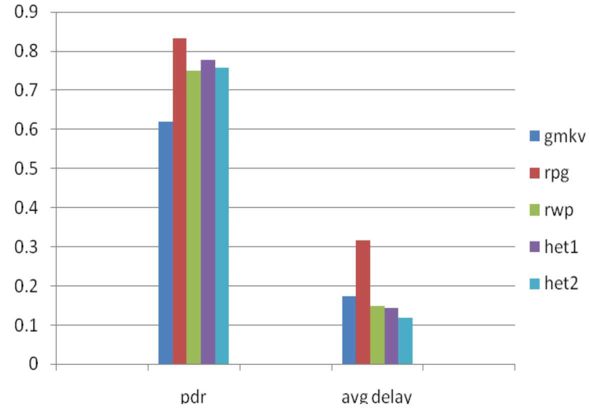

Figure 4: Avg Delay (sec) and Packet Delivery Ratio (PDR) distribution

Simulation 2 analysis concentrates on comparing Het1 and Het2 to see which method of heterogeneous model best serves our purpose. The high random and dynamic nature of GMM explains why it has the lowest PDR value despite generating and forwarding the largest number of packets (fig 3). Het2 high PDR performance (fig 4) despite its low number of forwarding nodes (fig 3) and generating lesser packets than GMM is an indication of its reliability. High number of nodes forwarding packets is an indication of high number of hops (i.e. longer routes) to destinations. Again, high transmission range reduces the number of forwarding nodes. Results show an inconsistent increase of delay with increase in throughput for all other models except Het2. Het2 outperformed all the other models and followed by Het1. After a major delay fluctuation in Het2, delay level stabilizes as throughput increases. This can ascertain communication quality of a network. High delay level leads to congestion and packet loss.

5 Conclusion and Future Work

The simulation results have shown the unsuitability of single mobility models as compared to heterogeneous models in modelling g disaster area MANETs. Homogenous models that define fixed movement patterns yield misleading results when used to analyze disaster scenarios where movement patterns are heterogeneous. In disaster scenarios, rescuers can at one point walk on the road and at another hop into a moving vehicle or join other groups. The underlying movements are heterogeneous and can only be defined by heterogeneous models. Heterogeneous models provide results that are averages of the component models. These results are clearly distinctive of those produced by homogenous models and in most cases outstanding. We have shown that Heterogeneous mobility model approach is a feasibility and shows more realistic modelling of movement patterns for disaster area scenarios. This work has opened door for more heterogeneous mobility research.

As a future work we seek ways of improving the study of heterogeneous mobility model.

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