Analysis of Adaptability of Mobility Models for AANETs

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Abstract- The designing of Airborne Ad-Hoc Networks (AANETs) mainly depends on mobility models. The mobility models must be able to capture the realistic behaviour of AANETs. In this paper, a detailed analysis of different mobility models for the airborne environment has been provided. This analysis is done on the basis of their adaptability and ability to capture the realistic behaviour of high-speed aircraft.

Keywords – AANET, realistic behaviour, adaptability

I. Introduction

Communication among aircraft is one of the critical issues for their coordination, data sharing in real time & success of any mission if they are being implemented in the battlefield. The previous researchers have found that implementation of AANET is comparatively more challenging than typical MANET & VANET. The main cause behind this is high mobility, high safety requirements & limited bandwidth. Due to these properties, existing protocols which are developed for traditional MANETs will not perform as good in AANETs [1].

From the previous research in the field of AANETs, it is observed that there is a need to select a proper mobility model to represent the aircraft movements in a more realistic manner. The mobility models are a basic need for any simulation work. These are designed for typical MANETs [2] [3]. As the mobility of Aircraft is very different, hence these existing models may not be able to emulate these networks. As the performance of any protocol depends on any mobility model used to a large extent, hence if we use these already existing mobility models for highly dynamic networks then the evaluation results may be misleading to the wrong conclusion. So, there is a need to investigate the mobility models for airborne networks. This paper provides a survey of AANET mobility models.
The rest of the paper is organized as follows. Section II explains the need for mobility model for AANET. Various mobility models are discussed in section III. Concluding remarks are given in section IV.

II. The Need For Mobility Model For AANET

Mobility models define the movement patterns of mobile nodes. These are used to provide statistical analysis of the routing protocols using various performance measures like throughput, packet delivery ratio, overhead, and delay. Already existing memory less synthetic random models [3] are used at a large scale because the cost of testing's in the real field are much higher & restricted to particular design limits. These random mobility models abstract some key statistical features using which those rich mobility entities can be generated for testing the performance of any routing protocol.

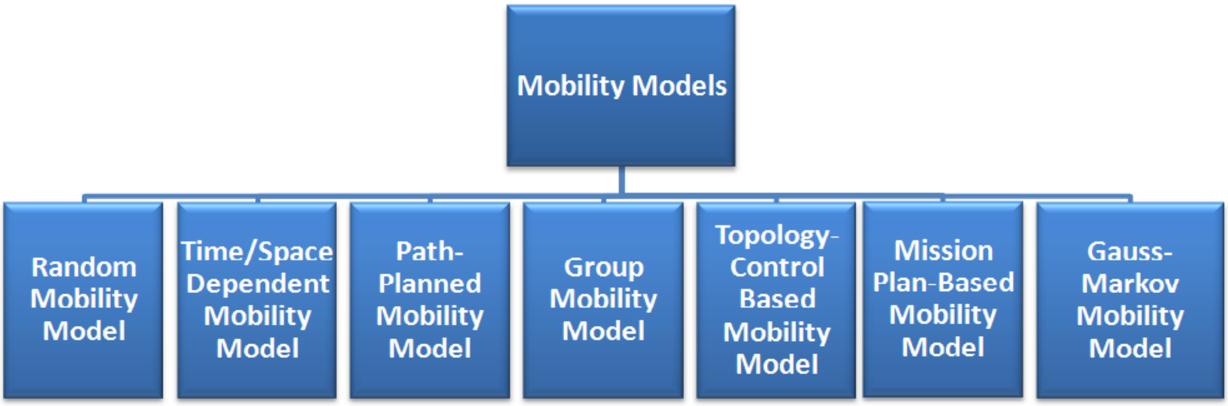

Figure 1. Various Mobility Models in AANETs

IV. MOBILITY MODELS FOR AANETS

AANETs have unique properties like rapid topology changes due to higher mobility, limited bandwidth, and transmission range and variable link quality due to variations in distances among nodes [4]. The movement of nodes in AANETs can only be implemented in a realistic way if the mobility model is able to decide new speed and direction of movement of aircraft w.r.t. previous speed and direction (or position) vectors. Hence, the mobility model must be memory based. Basically, mobility models can have the following categories [4] [5] [6] [7] [8]:-

- **Random Mobility Models:** These are the simplest mobility models used for research in MANETs. In these models, the mobile nodes can move without restrictions in any direction. The next direction, speed, and destination are all chosen independently of others nodes and randomly. In this category, there is Random Walk (RW), Random Direction and Random Waypoint mobility models. Another mobility model in this category is the Manhattan Grid (MG) [9].
- **Time/Space Dependent Mobility Models:** These mobility models are able to avoid sharp changes in direction and speed of nodes. Different mathematical equations can be derived to represent a smooth change of motion. The Gauss-Markov Mobility model (GMMM) [10] and the Boundless Simulation Area (BSA) [11] are the examples of this kind. In these mobility models, new speed and directions of movement of nodes will be based on earlier speed and directions of that node. In Smooth Turn (ST) mobility model [12] the mobile node movement is curved. A point is chosen in space and then rotates around it until another turning point is selected by UAV.
- **Path-Planned Mobility Models:** Here, UAV's follow a predefined route until they reach to the last point of it. Then shift to another path or may follow the same path again. Semi-Random Circular Movement (SRCM) [11] mobility model provides the curved path scenario of UAVs. Paparazzi mobility model (PPRZM) [12] is established on the matching of movement patterns: stay-at, Eight, Oval, Scan, and waypoint. A UAV may choose any pattern and a random velocity.
- **Group Mobility Models:** In these models, all the mobile nodes have a spatial constraint. The Reference point Group Mobility Model (RPGM) [13] represents the random movement of the different mobile nodes around any reference point. The nodes move according to simple RWP model in a defined area.
- **Topology-Control Based Mobility Model:** Sometimes, there is a need to continuously satisfy certain mission or network constraints. Because of this, the mobility model needs to provide the real-time controlling of any topology changes. The Distributed Pheromone Repel (DPR) mobility model [7] is that kind of mobility model. This model can be employed for search missions and reconnaissance. Each node maintains its own pheromone map. The Self-Deploy point Coverage (SDPC) model has been proposed in [14] which is suitable for disaster management.
- **Mission Plan-Based Mobility Model:** Here, a predefined flight plan is used by the aircraft to go ahead. The aircraft follows the defined path every time [15]. After expiry of time, the mobility plans are updated. The mission of each aircraft is designated arbitrarily while flight time and rate are defined. In case of completion of any mission by an aircraft before the flight time ends, it commences a new trip with different direction and continues its flying.
- **Gauss-Markov Random Mobility model:** This model has the property of temporal correlation. Due to this, the current state (either velocity or direction of movement) of the node depends on the previous state. Hence, it is able to avoid sharp motion changes as was in random mobility models like a random walk, random waypoint, and random direction. This model keeps the memory of motion to overcome sharp changes, so also known as memory based mobility models [10][15][16]. In Basic 2-D model, every mobile node is initialized with a speed and direction vector along with average speed and direction. After a defined period of time (called time step), these speed and direction vectors are recalculated for every node which will be remaining same up to the next time step. This way, updated speed, and direction are calculated again and again for the whole simulation time.

In the Gauss Markov Mobility model, there is one major factor known as the tuning parameter and represented as alpha (α). This parameter defines the amount of randomness and memory to be used for the particular implementation. The dynamics of the model are also affected by time step and values of average speed and direction etc. To model the movement of aircraft, the following equations are followed:

$$S_n = \alpha S_{n-1} + (1-\alpha)\overline{s} + \sqrt{(1-\alpha^2)} S_{x_{n-1}}$$

$$d_n = \alpha d_{n-1} + (1-\alpha)\overline{d} + \sqrt{(1-\alpha^2)} d_{x_{n-1}}$$

If α is made equal to 0, then it becomes a memory-less model and the next speed and direction parameters will be based on the average speed and direction variables and Gaussian random variables.

$$S_n = \overline{s} + S_{x_{n-1}}$$

$$d_n = \overline{d} + d_{x_{n-1}}$$

If α is made equal to 1, there will be no randomness and every movement will become predictable. It means the next speed and directions values will remain the same as previous values. So it is required to define the values in the range between 0 and 1. In addition to this, the behavior of this model is also affected by time step, mean speed, mean direction and standard deviation for Gaussian distribution [16].

To model the aircraft flight more accurately, velocity variable has to be combined with direction and pitch variables [17]. So, for 3-D representation, a third variable called pitch is added to the 2-Dimensional model. Now, there are three equations to represent the 3-dimensional movement of aircraft.

$$S_n = \alpha S_{n-1} + (1-\alpha)\overline{s} + \sqrt{(1-\alpha^2)} S_{x_{n-1}}$$

$$d_n = \alpha d_{n-1} + (1-\alpha)\overline{d} + \sqrt{(1-\alpha^2)} d_{x_{n-1}}$$

$$p_n = \alpha p_{n-1} + (1-\alpha)\overline{p} + \sqrt{(1-\alpha^2)} p_{x_{n-1}}$$

These three variables are required to find out 1new velocity vector. This information has to be sent to ns-3 constant velocity helper which will calculate the new node position.

Table -1 A Comparative Analysis of Mobility Models In Terms of Adaptability

Mobility Model	**Parameters**		
	Basic Description	**Adaptability for AANET**	**Applications**
Gauss Markov	Selection of speed and direction is memory-based	Pitch co-ordinates can be used to extend from 2-D to 3-D for AANETs	MANET(2-D) Airborne networks (3-D)
Three-Way Random	Mobility pattern is based on the Markov chain.	The turning radius can be made constant while boundary movements are identical to Gauss Markov	Reconnaissance
Smooth Turn	Able to reproduce aircraft movement patterns.	To allow more turns turning radii is selected randomly	Military investigations and patrolling.
Pheromone Repel	Different nodes peruse according to the smell of the particular location	Better coverage than Three-Way random mobility model	To anticipate the possibility of congestion in any area.
Flight -Plan-Based	Aircraft trajectories are predefined	Whenever required predefined flight plan can be changed.	Commercial flights, as a backbone for airborne networks
Semi-Random Circular Movement(SRCM)	Provides circular advances in node position w.r.t. any fixed target but with varying radii.	Highly able to implement smooth turns during aircraft trajectories.	Search and Rescue Operations
RW, RWP, and RD	The direction of movement of a node is randomly decided	Only high mobility of aircraft can be configured but neglects many realistic airborne environment features	MANETs and VANETs

Table 1 shows that the selection of mobility models is based on their application requirements and their ability to capture the aircraft realistic movements.

IV.CONCLUSION

This paper presents an analysis of various mobility models on the basis of their adaptability with the realistic mobility scenario of AANET. This analysis can be highly advantageous in future researches to decide which mobility model will be suitable for any particular application of AANETs.

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