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ANALYTICAL MODEL FOR PERFORMANCE EVALUATION OF AD HOC WIRELESS NETWORKS

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Abstract

Ad hoc networks, a subset of wireless networks, allow the formation of a wireless network without the need for access point. All participating users in an ad hoc network agree to accept and forward messages, to and from each other. Wireless networks have the ability to form anywhere, at any time, when two or more wireless users are willing to communicate with each other. Mobility management with reference to handoff management has widely been recognized as one of the most important and challenging issue in ad hoc network. Various mobility models are used to define mobility of nodes. Evaluating mobility models within an ad hoc network gives solution to find out performance measures like handoff probability, dropping probability etc. In the present paper we present the analytical model for simulation to analyze performance of ad hoc network. Performance measures are the packet blocking probability and packet dropping probability.

Keywords - *Blocking Probability, Dropping Probability, Mobility Models*

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1. INTRODUCTION

Mobile networks allow users to communicate with each other while moving and give end users freedom in terms of mobility. But this freedom brings uncertainties to mobile systems. Wireless networks are widespread due to their flexible nature, and the possibility for wireless nodes to be mobile. Currently most wireless networks are infrastructure networks, where all communications go through an access point (AP) that acts as a gateway between the wired and wireless domains. To accommodate mobility, hand-over can be performed between two access points as the wireless station moves from the coverage area of one access point to another, enabling the communication to seamlessly continue.

Ad hoc networks have gained a lot of interest in the research community. In ad hoc networks there are no fixed routers or base stations. All nodes have the capability to forward packets to each other. Handoff is the essential component for dealing with the mobility of end users. Handoff can be defined as opportunistic switching of mobile user’s connections as they move and change their attachment points to the network.

The ad hoc mobility models are characterized by continuous time stochastic process. They define the movement of nodes in two-dimensional spaces. There is a different kind of movement pattern for each type of mobility model. The movement pattern of each node contains sequence of random length interval. In this interval it is assumed that node moves with constant speed and along constant direction.

As synthetic mobility models represent the behaviors of mobile nodes in realistic manner they are used in the performance evaluation of handoff algorithm for wireless networks.

2. MOBILITY MODELS

Performance of mobile ad hoc networks depends on mobility model and it is studied through simulation. There are two types of mobility models namely entity mobility models and group mobility models. In entity mobility models, movement of node does not depend upon movement of another node whereas in group mobility models, node movement is dependent on each other.

A mobility model should be able to imitate real mobile node’s movements. Similar to real mobile node, mobility model should change its speed and direction and this change must occur in reasonable time slot. Examples of mobility models used in simulation of ad hoc networks are Random Walk Mobility Model, Random Direction Mobility Model, Random Waypoint Mobility Model and Gauss Markov Mobility [1][2].

2.1 Random Walk Mobility Model

Random walk mobility model was mathematically described by Einstein in 1926. Numerous entities in nature move in very unpredictable ways. The Random Walk Mobility Model was developed to mimic this erratic movement. In Random walk mobility model, a mobile node randomly chooses direction and speed and moves from its present location to a new location. Each node is assigned an initial location (x, y) and a destination is (x_1, y_1). From predefined ranges of velocity defined as (v_0, v_1), the new speed is chosen uniformly by the node. The new direction is also selected by the node in the range of (0, 2π).

In this model the nodes instantaneously start traveling to the next location without taking any pause. Every movement in the Random walk mobility model takes place in either a constant distance traveled d or a constant time interval t. After that a new direction and speed are calculated. If mobile node touches the boundary, it bounces off the border of simulation area. The mobile node then carries on along this new path. The mobile node starts its movement in the center of the simulation area. At each point the mobile node randomly chooses a direction and speed.Figure 1shows flowchart of Random walk mobility model. It has been observed that Random walk mobility model has memory less mobility pattern, because it retains no knowledge concerning its past locations and speed values.

The present direction and speed of a mobile node is not dependent upon its past direction and speed. Due to this, an unrealistic movement such as sudden stops and sharp turns generates.

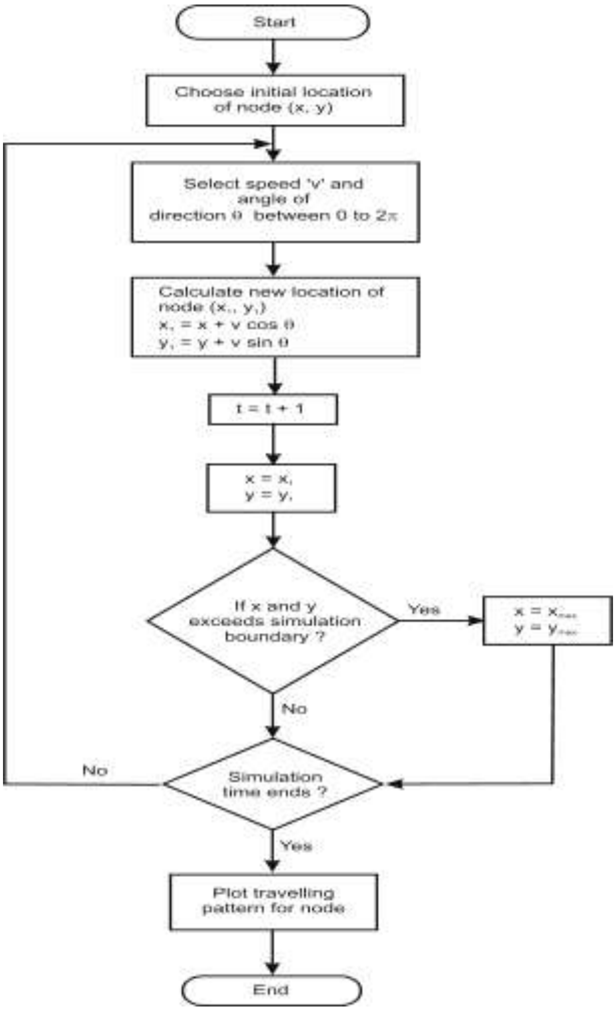

Fig 1: Flowchart of Random walk mobility model

2.2 Random Waypoint Mobility Model

The pause time is included when changes in direction and changes in speed takes place for Random waypoint mobility model. Node stays at particular location for certain amount of time which is termed as pause time.

Once this pause time expires, the mobile node chooses another random destination in the simulation area. At the same time it chooses a new speed that is uniformly distributed between $(Minspeed, Maxspeed)$.

With newly chosen speeds mobile node moves towards selected destination. When it reaches the destination, it pauses for specified amount of time and after that it starts moving again towards new destination.

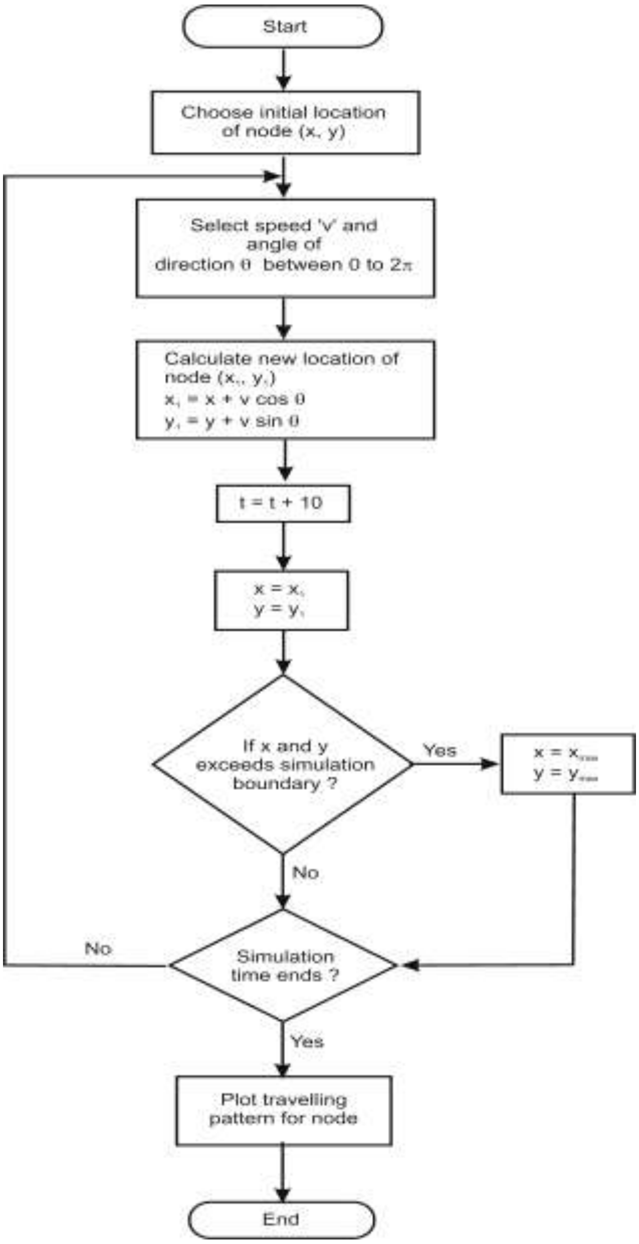

Fig 2: shows the flow chart for Random Waypoint Mobility Model.

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It has been noted that the movement pattern of an MN using the Random Waypoint Mobility Model is similar to the Random Walk Mobility Model if pause time is zero and $(v_0, v_1) = (Minspeed, Maxspeed)$.

2.3 Gauss-Markov Mobility Model

In Gauss Markov mobility model a tuning parameter is used. With this tuning parameter randomness in speed of node and direction of motion of node is obtained.

At the beginning of simulation, each mobile node is assigned a particular speed and direction.

The speed and direction of mobile node is updated at fixed intervals of time and movement of node takes place.

Based upon the value of speed and direction at the $(n\text{-}1)^{th}$ instance the value of speed and direction at the n^{th} instant is calculated. For this the following equations are used

$$s_n = \alpha s_{n-1} + (1-\alpha)\bar{s} + \sqrt{(1-\alpha^2)}\, s_{x_{n-1}} \text{ …….. (1)}$$

$$d_n = \alpha\ d_{n-1} + (1-\alpha)\ \bar{d} + \sqrt{(1-\alpha^2)}\, d_{x_{n-1}} \text{ … (2)}$$

Where s_n and d_n are the new speed and direction of the mobile node at time interval n; α, where $0 \leq \alpha \leq 1$ is the tuning parameter used to vary the randomness, s and d are the constants representing the mean value of speed and direction as n and $s_{x_{n-1}}$ and $d_{x_{n-1}}$ are random variables from Gaussian distribution. Totally random values (or Brownian motion) are obtained by varying the value of $\alpha = 0$ and linear motion is obtained by setting $\alpha = 1$. Intermediate levels of randomness are obtained by varying value of α between 0 and 1.

A mobile node's new position at time interval n is given by the following equations.

$$x_n = x_{n-1} + s_{n-1}\cos d_{n-1} \text{ ………… (3)}$$

$$y_n = y_{n-1} + s_{n-1}\sin d_{n-1} \text{ …………... (4)}$$

Where (x_n, y_n) and (x_{n-1}, y_{n-1}) are the x and y co-ordinates of the mobile nodes position at the n^{th} and $(n\text{-}1)^{st}$ time interval.

Figure 3 shows the flowchart for Gauss-Markov Mobility Model. The mobile node begins its movement at any random location in simulation area and moves for 500 sec.

For simulation, n is selected as 1 second, $\alpha = 0.75$, $s_{x_{n-1}}$ and $d_{x_{n-1}}$ are chosen from a random Gaussian distribution with mean equal to zero and standard deviation equal to one.

The value of $\bar{s}$ is fixed at 3m/s. The value of $\bar{d}$ is 90 degrees initially but changes over time according to the edge proximity of the node.

It has been observed that Gauss-Markov Mobility Model can eliminate the sudden stops and sharp turns encountered in the Random Walk Mobility Model by allowing past velocities and past directions to influence future velocities and future directions respectively.

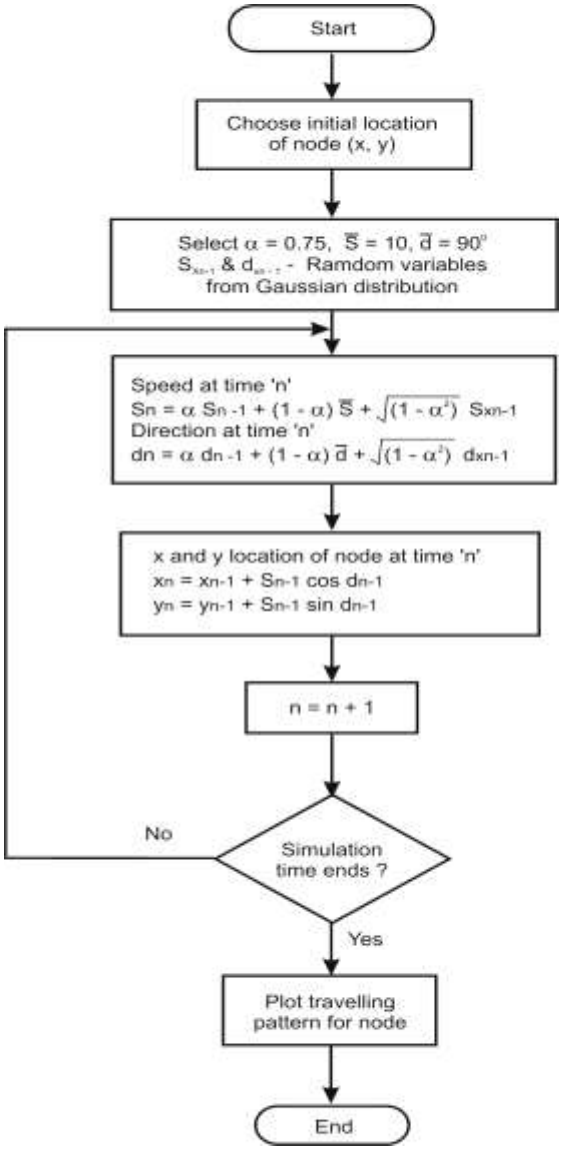

Fig 3: Flowchart of Gauss Markov mobility model

3. ANALYTICAL MODEL

Analytical model which has been developed for infrastructure-less mobile Ad hoc networks uses handoff schemes in single traffic systems. We have assumed that a system has more than one service areas, with each having S channels. The channel holding time has an exponential distribution with mean rate μ. Both originating packets and handoff packets are generated in a service area according to

Poisson processes, with mean rates λ_0 and λ_H , respectively. We focus our attention on a single service area.
In this scheme, all *S* channels are shared by both originating and handoff request packets. The system model is shown in Figure 4.

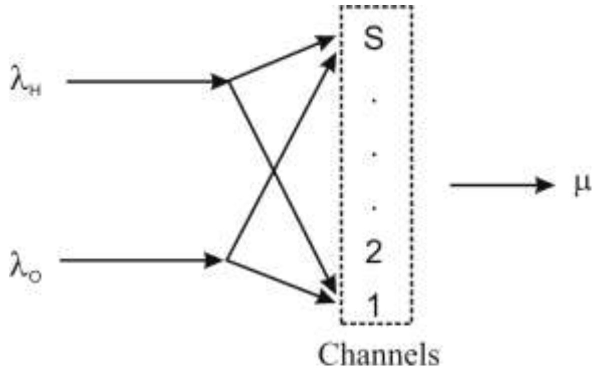

Fig 4: A generic system model for handoff

With the blocking packet cleared policy, we can describe the behavior of a service area as (S+1) states Markov process. Each state is labeled by integer $i(i = 0,1,\ldots\ldots, S)$, representing the number of channels in use. The state transition diagram is shown in Figure 5. The system model is modeled by a typical M/M/S/S queuing model.

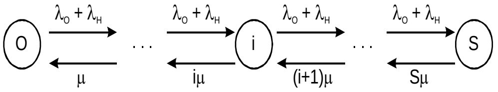

Fig 5: State transition diagrams for Figure 4

Let $P(i)$ be the probability that the system is in state i . The probabilities $P(i)$ can be determined in the usual way for birth-death processes. From Figure 5 the state equilibrium equation is

$$p(i) = \frac{\lambda_0 + \lambda_H}{i\mu} p(i-1),$$
$$0 \le i \le S \text{ …………………………….. } (1)$$

Using the above equation recursively, along with the normalized condition

$$\sum_{i=0}^{S} p(i) = 1 \text{ ……………………….…… } (2)$$

The steady state probability $p(i)$ is found as follows:

$$p(i) = \frac{(\lambda_0 + \lambda_H)^i}{i!\mu^i} p(0),$$
$$0 \le i \le S \text{ …………………………….. } (3)$$

Where

$$p(0) = \frac{1}{\sum_{i=0}^{S} \frac{(\lambda_0 + \lambda_H)^i}{i!\mu^i}} \text{ ……………… } (4)$$

The blocking probability p_b for an ongoing packet is

$$p_b = p(S) = \frac{\frac{(\lambda_0 + \lambda_H)^S}{S!\mu^S}}{\sum_{i=0}^{S} \frac{(\lambda_0 + \lambda_H)^i}{i!\mu^i}} \text{ ……………. } (5)$$

Let $P(h)$ be the probability that the system is in handoff state h . λ_H is the arrival rate of handoff packets.

The probabilities $P(h)$ can be determined for birth-death processes.

$$p(h) = \frac{\lambda_H}{h\mu} p(h-1), \quad 0 \le h \le S \text{ ……….. …. } (6)$$

Using the above equation recursively, along with the normalized condition

$$\sum_{i=0}^{S} p(h) = 1 \text{ …………………………….… } (7)$$

The steady state probability of handoff packets $p(h)$ is found as follows:

$$p(h) = \frac{(\lambda_h)^h}{h!\mu^h} p(0),$$
$$0 \le h \le S \text{ …………………………… } (8)$$

Where

$$p(0) = \frac{1}{\sum_{h=0}^{S} \frac{(\lambda_H)^h}{h!\mu^h}} \text{ …………………… } (9)$$

The dropping probability p_d for an ongoing handoff packet is

$$p_d = p(S) = \frac{\frac{(\lambda_H)^S}{S!\mu^S}}{\sum_{i=0}^{S} \frac{(\lambda_H)^h}{h!\mu^h}} \text{ ………………… } (10)$$

To calculate the packet dropout probability, handoff probability [3], it has been considered that mobile nodes are moving in the deployment region with Random walk, Random waypoint and Gauss Markov mobility models.

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4. RESULTS OF ANALYTICAL MODEL

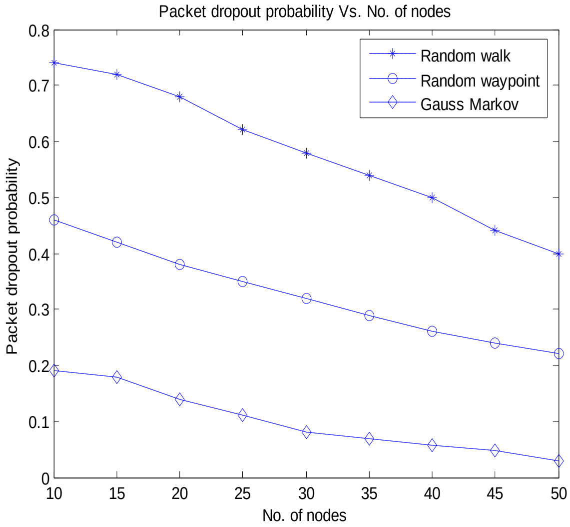

Fig 5: Packet dropping probability Vs. Number of nodes

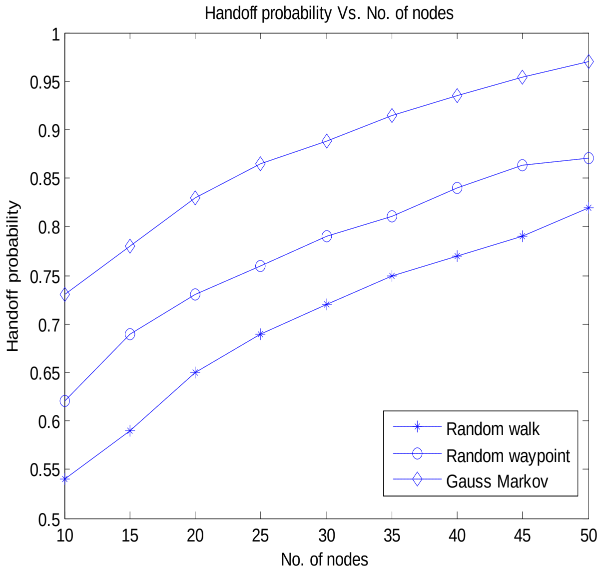

Fig 6: Handoff Probability Vs. Number of nodes

Figures 5 shows plot for dropping probability of packets and Figure 6 shows handoff probability of packet incorporating mobility models.

5. CONCLUSION

Packet dropping probability decreases with increasing number of nodes for Random walk, Random waypoint and Gauss Markov mobility models. Dropping probability is greater with Random walk mobility model and low with Gauss Markov mobility model. For Random walk, Random waypoint as well as Gauss Markov mobility models handoff probability increases with increasing number of nodes. Handoff probability is greater with Gauss Markov mobility model as compared to remaining two mobility models.

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