FULL LENGTH RESEARCH ARTICLE

EFFECT OF MOBILITY MODELS ON INFRASTRUCTURE BASED WIRELESS NETWORKS

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ABSTRACT

The tremendous demand is pushing the development of wireless mobile communications faster than ever before. Handoff management has widely been recognized as one of the most important and challenging problems for a seamless access to wireless network and mobile services. Mobility Models plays an important role in handoff management. In this paper, the effect of handoff procedure on the performance of random mobile nodes in wireless networks was investigated. Mobility of node is defined by various mobility models. Evaluating mobility models within an infrastructured network gives solution to performance measures like blocking probability, dropping probability to evaluate the performance of handoff algorithm. Handoff algorithm based on Absolute and Relative Measurement was used to examine the effect of Random Walk and Gauss Markov mobility models on performance of Infrastructure based Wireless Network.

Keywords - Call blocking probability, Call dropping probability, Mobility models

INTRODUCTION

Mobile networks allow users to access services while on the move thereby giving end users freedom in terms of mobility. However, this freedom does bring uncertainties to mobile systems. Wireless networks are very popular due to their flexible nature, and the inherent possibility for wireless nodes to be mobile. Currently most wireless networks are infrastructured 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.

Infrastructure-less, or 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, but instead all nodes have the capability to forward packets for each other. Because of the special properties of ad hoc networks such as quick topology changes due to mobility of the nodes, ordinary routing protocol fails to give good performance. There are several problems with the traditional use of ad hoc networks and the scenarios where they are claimed to be useful. Infrastructured ad hoc networks (Lindgren 2002) that are intended for a different scenario than traditional ad hoc networks, namely as an extension of infrastructure wireless networks or to provide a temporary infrastructure at events where it is not desirable or possible to create an ordinary infrastructure. Multi-hop cellular networks (MCNs) (Lin & Hsu 2000) and self-organizing packet radio ad hoc networks with overlay (SOPRANO) (Zahed *et al.* 2002) are examples of such type of networks. These hybrid architectures (which combine the benefits of cellular and ad hoc wireless networks) improve the capacity of system significantly. 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. It guarantees the continuity of the wireless services when the mobile user moves across boundaries of their respective service areas.

The ad hoc mobility models are the continuous time stochastic process, which characterizes the movement of nodes in two-dimensional spaces. According to the movement pattern of each type, each node movement consists of sequence of random length interval, during which a node moves in constant speed and constant direction. The speed and direction of each node varies according to various mobility models.

Currently there are two types of mobility models used in simulation of network: Traces and Synthetic models. Traces are those mobility patterns that are observed in real life systems. Traces provide accurate information, especially when they involve a large number of participants and appropriately long observation period. In the performance evaluation of handoff algorithm for wireless networks, the handoff algorithm should be tested under realistic conditions and realistic movements of the mobile user. The Synthetic mobility models attempt to realistically represent the behaviours of mobile nodes.

Mobility Models

Mobile ad hoc networks are often studied through simulation and their performance can heavily depend on mobility model that govern the movement of node. The mobility models that represent mobile nodes whose movements are independent of each other are known as entity mobility models and the mobility models that represent mobile nodes whose movements are dependent on each other are known as group mobility models.

A mobility model should attempt to mimic the movements of real mobile node, changes in speed and direction must occur and they must occur in reasonable time slots. Random Walk Mobility Model, Random Waypoint Mobility Model, Random Direction Mobility Model, Boundless Simulation Area Mobility Model, Gauss Markov Mobility Model are some of the entity mobility models which are used in the wireless network simulation (Camp *et al.* 2002).

Random Walk Mobility Model: Einstein first described the Random walk mobility model mathematically in 1926. Since many entities in nature move in extremely unpredictable ways, the Random Walk Mobility Model was developed to mimic this erratic movement. In this mobility model, a mobile node moves from its current location to a new location by randomly choosing a direction and speed in which to travel. Each node is assigned an initial location (x_0, y_0) and a destination is (x_1, y_1). The new speed is chosen uniformly from predefined ranges (v_0, v_1) independently of all previous destinations and speed and direction in the range (0, 2π). The nodes immediately begin traveling to the next destination without pausing. Each movement in the Random walk mobility model occurs in either a constant time interval, t or a constant distance traveled d at the end of which a new direction and speed are calculated. If a mobile node, which moves according to this model, reaches the simulation boundary, it "bounces" off the simulation border with an angle, determined by the incoming direction. The mobile node then continues along this new path. The mobile node begins its movement in the center of the simulation area. At each point the mobile node randomly chooses a direction between 0 and 2 π and a speed between 0 and 3 m/s.

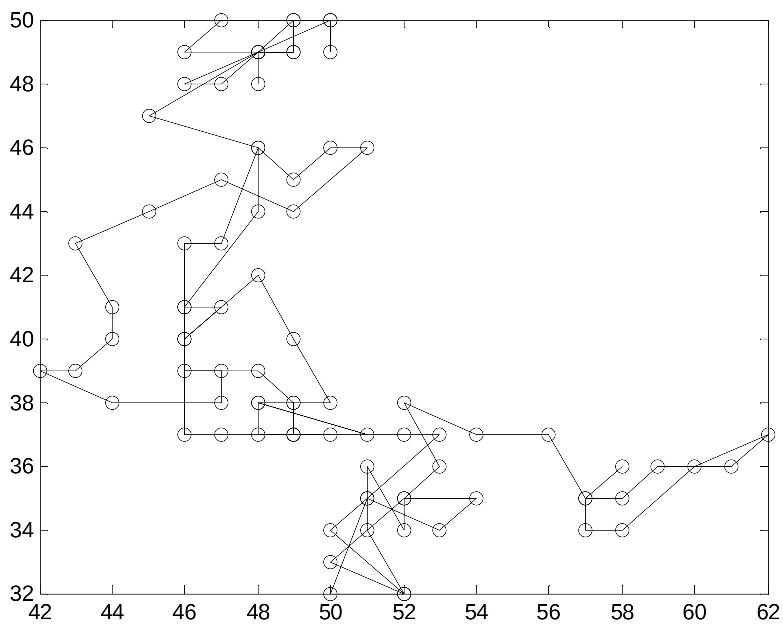

FIG. 1. TRAVELING PATTERN OF MOBILE NODE USING RANDOM WALK MOBILITY MODEL

Fig. 1 shows traveling pattern of mobile node using 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 current speed and direction of a mobile node is independent of its past speed and direction.

This characteristic can generate unrealistic movements such as sudden stops and sharp turns.

Gauss-Markov Mobility Model: The Gauss-Markov Model was originally proposed for the simulation of a PCS; however this model has been used for the simulation of an ad hoc network.

The Gauss-Markov Mobility Model was designed to adapt to different levels of randomness via one tuning parameter. Initially each mobile node is assigned a current speed and direction. At fixed intervals of time, *n*, movement occurs by updating the speed and direction of each mobile node. Specifically, the value of speed and direction at the n^{th} instant is calculated based upon the value of speed and direction at the $(n\text{-}1)^{th}$ instance and a random variable using the following equations:

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

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

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 α =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.

At each time interval the next location is calculated based on the current location, speed and direction of movement. Specifically, at time interval n, a mobile node's position is given by the equations.

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

$$y_n = y_{n-1} + s_{n-1} \sin d_{n-1} \ldots \quad (4)$$

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-1)* st time interval.

Fig. 2 illustrates an example traveling pattern of a mobile node using the 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, α = 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.

As shown in the Fig. 2 the 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.

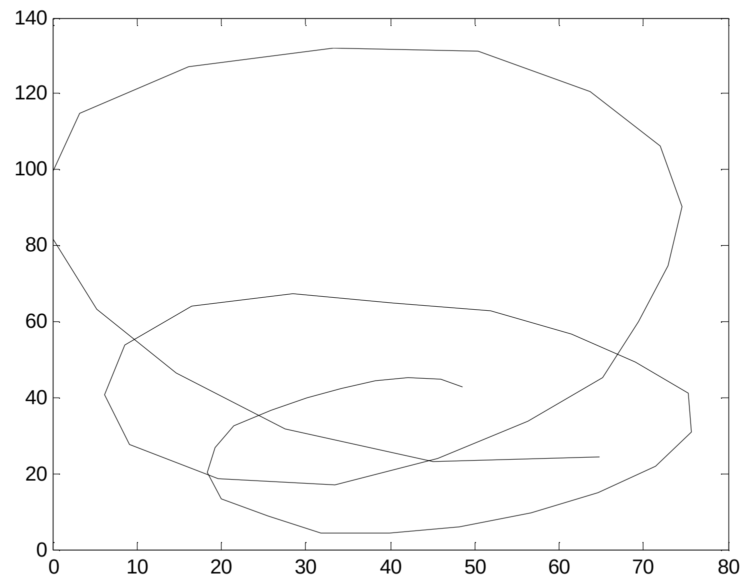

FIG. 2 TRAVELING PATTERN OF MOBILE NODE USING GAUSS MARKOV MOBILITY MODEL

Handoff Algorithm: Handoff algorithm used here is based on Absolute and Relative measurements. This is an extended analysis for the handoffs based on the relative signal strength measurements.

The absolute signal strength is the averaged value of received signal level from current serving access point (AP) measured by mobile device. This value has to be below a fixed threshold to initiate a handoff. In this way the mobile device should be assigned to a new AP. If the absolute signal strength from the old AP drops below the threshold and the relative signal strength between the new and old access point reaches the hysteresis level. Figure 3 shows two cell model showing Handoff and RSS.

In the network two APs 'A' and 'B' separated by 'D' meters, with a mobile moving at a constant speed along the straight line between them. The signal strength received at the mobile unit from each AP, which is measured in dB, is a sum of two terms, one due to path loss and other due to shadow fading.

Therefore signals received from APs A and B namely $a(d)$ and $b(d)$ when mobile is at a distance d from A is

$$a(d) = k_1 - k_2 \log(d) + u(d) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$b(d) = k_1 - k_2 \log(D - d) + v(d) \ldots\ldots\ldots\ldots (6)$$

$$d \in (0, D)$$

k_1 and k_2 are parameters for path loss shadow fading processes $\{u(d)\}$ and $\{v(d)\}$ are zero mean stationary Gaussian processes, independent of each other.

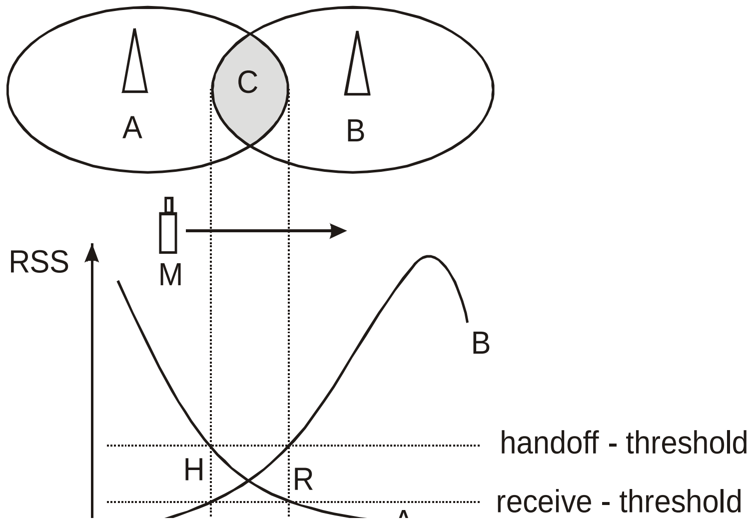

FIG. 2 TWO CELL MODEL

We have used FIFO, which is prioritized call handling scheme in which handoff request will be filed in the queue with first in first out strategy if the target access point has no free channel**.** The FIFO queuing scheme can be approximated by $M/M/c$ queue with non-homogenous arrival rates. Until all channels are occupied, the arrival rate is the sum of new calls and handoff calls. Once all the channels are busy, only handoff calls are queued. Packet blocking probability of originating call is simply given by the probability of number of nodes in the system being equal to or more than the number of channels, *c.*

If the target access point has no available bandwidth to serve a new request for call, queuing the handoff request is possible. When an ongoing call is finished, the occupied bandwidth will be released. In this model line up method has been used for handoff requests. If all channels of an access point are blocked, the handoff requests to that service area are queued according first come first serve basis. If the channel is released when queue for handoff request is not empty, the channel is assigned to request on the top of the queue.

If there has no enough bandwidth in service area, source node's request is blocked. After request of sending a data packet is accepted, The RSS level of mobile node is monitored continuously. When RSS level is lower than handoff threshold level, a handoff request is proposed to the target service area where the mobile node is heading. If there has free bandwidth, the highest priority handoff request gets the channel. But if the RSS is less than receive threshold the ongoing call is forcefully terminated; this situation is called as call dropping.

Network Model for infrastructure based Network: We have used network model given by Ruay-Shiung & Shing-Jiuan (2004). The total area is partitioned into 25 service areas as shown in the Fig. 4. Each service area is having one Access Point (AP). We assume the top service areas (areas 21, 22, 23, 24, 25) and bottom service areas (areas 1, 2, 3, 4, 5) are connected. That is if node comes out of service area 21 from top, it will come into a service area 1. Analogously we assume the left side service areas (1, 6, 11, 16, 21) and right service areas (areas 5, 10, 15, 20, 25) are connected too. Fig. 5 shows the concept of handoff threshold and receive threshold setting. Assume that access point of each service area is at the center of square. We set the receive threshold about half of the diagonal length in order to cover that particular service area. The handoff threshold can be set at any distance between access points to receive threshold. The area between handoff- threshold and receive- threshold is called handoff area (the shaded area in the Fig. 5).

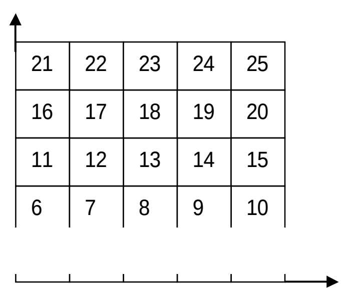

FIG. 4. SIMULATED WIRELESS NETWORK

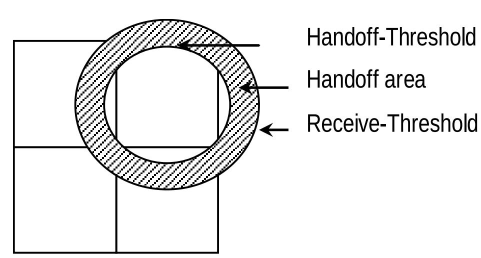

FIG. 5. HANDOFF THRESHOLD AND RECEIVE THRESHOLD

Traffic model: The traffic model, which is used in simulation, is based on "Xie and Kukek's" (Pollini 1996) one and two dimensional traffic model. This model assumes uniformly distributed mobile nodes throughout an area and that a node is equally likely to move in any direction with respect to area border. From this assumption arrival rate of handoff is:

$$\lambda_H = E[c]\mu_c - dwell \ldots \qquad (7)$$

Here $E[c]$ is the average number of calls in the transmission range of the node and $\mu_c - dwell$ is the outgoing rate of calls from transmission range of node.

Transmission Model: The transmission model, which has been adopted here, is Two Ray Ground (TRG) model. TRG is based on free space propagation model. The simulator calculates the Received Signal Strength (RSS) for every transmission between two nodes with free space propagation model. (Gregory 1996). Free space propagation model assumes only direct path between transmitter t and receiver r. Certainly the receiving power P_{wr} is independent on transmitter power P_t. Other parameters which are involved to compute P_{wr} are the wavelength λ, the gain of the transmitting and receiving antenna (G_t, G_r), the distance between the two communicating nodes and introduced system loss component L. The only parameter that is not system wide constant is the distance between the sender and receiver. Furthermore, the receiving and carrier sense thresholds are kept constant throughout the simulation. Equation 8 shows the particular algorithm used in free space model.

$$P_{wr-FS(d)} = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L} \ldots \qquad (8)$$

Two Ray Ground Model: TRG (Two Ray Ground Model) is a model that improves the principle of functioning of free space. The only real parameter is the node's distance *d*. Two additional system constraint parameters are introduced in the formula. Specifically h_t and h_r are the heights of antennas.

The signal propagation model concerned keeps into account both the direct path between source and receiver and the ground reflection path. Hence, the additional feature of TRG is that ground reflection negatively affects the receiving power due to multi-path effect for nodes within certain threshold distance $d_{thresh} = {4\pi h_t h_r}/{\lambda}$ the model behaves as free space.

In contrast when nodes are far apart from each other for more than this threshold distance, then receiving signal strength (*RSS*) is inversely proportional to d^4. Evidently, this restriction strongly affects the power of a signal when the distance is relevant. The assumption makes the power prediction to more realistically resemble the real world situations. Specifically the formalization of TRG resides in equation 9 for each *d* over threshold $\frac{d_{thresh}}{d} < 1$.

$$P_{wr-TRG}(d) = \begin{cases} P_{wr-FS}(d) \ldots\ldots\ldots for \ldots\ldots d < d_{thresh}. \\ P_{wr-FS}(d)(\frac{d_{thresh}}{d})^2 \ldots\ldots\ldots \geq d_{thresh} \end{cases} \ldots\ldots\ldots(9)$$

$P_{wr-TRG}(d)$ is the received signal strength (*RSS*) of mobile node. We monitor the user's location and *RSS* at every second.

PERFORMANCE MEASURES

Blocking Probability (P_b): When a new call requests for service, its request may either grant or denied. The denial of request is due to unavailability of enough bandwidth in service area. This denial of request is called as call blocking and its probability is known as call blocking probability.

Dropping probability (P_d): If the RSS of mobile node is less than receive threshold the ongoing call is forcefully terminated which causes failure to get a successful handoff in the path; this forces the network to drop the call. The probability of such event is known as call dropping probability.

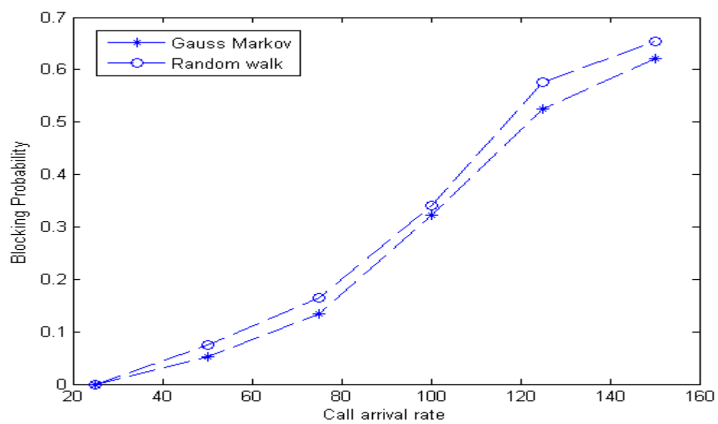

FIG. 6 BLOCKING PROBABILITY OF NEW CALLS VERSES CALL ARRIVAL RATE INCORPORATING GAUSS MARKOV AND RANDOM WALK MOBILITY MODELS

Handoff dropping probability: The handoff call is dropped if the *RSS* of mobile node is less than handoff threshold but it does not get channel available for continuation of call. This probability is called as handoff dropping probability.

Results of Simulation Model incorporating mobility models
The Fig. 6 shows that for both Random walk and Gauss Markov model, the blocking probability of new calls increases with increasing call arrival rate.

Fig. 8 shows the results of simulation carried out to observe the performance of Random walk and Gauss Markov model on dropping probability verses call arrival rate. Dropping probability increases with increasing call arrival rate.

The same figure shows the effect of call arrival rate on dropping probability of handoff calls. For lower data rate the dropping probability of handoff call is greater and as call arrival rate increases the dropping probability decreases for both mobility models.

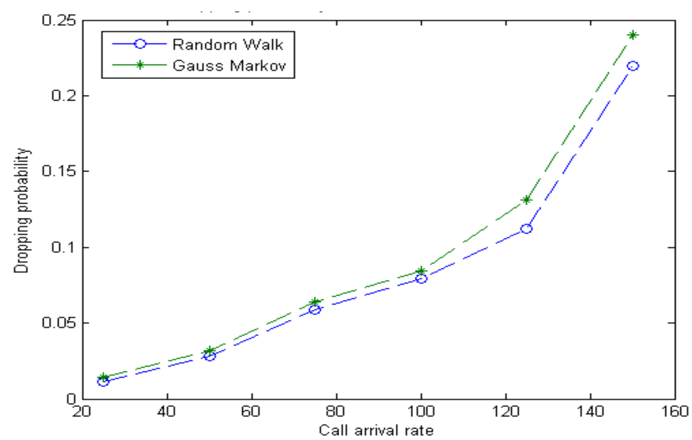

FIG. 7 DROPPING PROBABILITY OF NEW CALLS VERSES CALL ARRIVAL RATE INCORPORATING GAUSS MARKOV AND RANDOM WALK MOBILITY MODELS

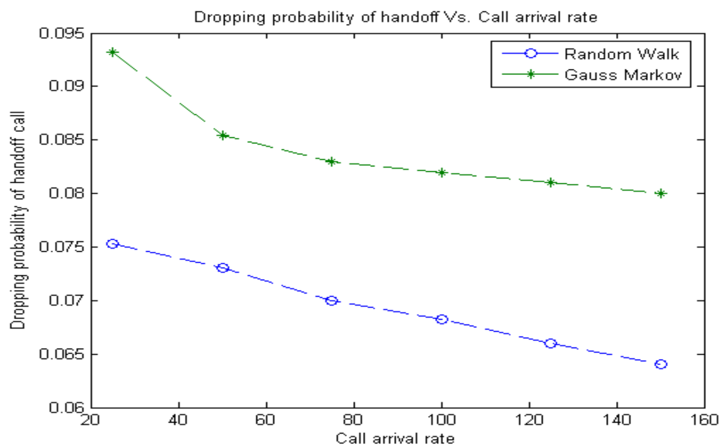

FIG. 8 DROPPING PROBABILITY OF HANDOFF CALLS VERSES CALL ARRIVAL RATE INCORPORATING GAUSS MARKOV AND RANDOM WALK MOBILITY MODELS

In conclusion, the absolute relative measurement based handoff algorithm is used to observe the performance of infrastructure based ad network. The results of simulation model incorporated the Random walk and Gauss Markov mobility models to find blocking probability of new call verses call arrival rate. For call arrival rate, from 20 to 160 blocking probability with Random walk mobility model is slightly higher than with Gauss Markov model. The paper also demonstrated simulation model in which Random walk and Gauss Markov mobility models are used to find dropping probability of new call verses call arrival rate. For call arrival rate, from 20 to 160 dropping probability with Gauss Markov model is slightly higher than with Random walk mobility model.

Random walk and Gauss Markov mobility models shows the dropping probability of handoff calls verses call arrival rate where it shows that dropping probability for Gauss Markov model is greater than Random walk. For lower data rate, the dropping probability of handoff call is greater, and as call arrival rate increases the dropping probability decreases for both mobility models. This is because for higher traffic, only handoff calls are accepted and the number of new calls accepted by network are less.

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