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Birth & Death Modeling of Mobility Uncertainty in Mobile Ad hoc Network

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ABSTRACT

A mobile ad hoc network (MANET) is a collection of mobile nodes, which communicate over radio. This network has an important advantage that they do not require any existing infrastructure of central administration. Thus MANET is suitable for temporary communication links. This flexibility however comes at a price of communication difficulty induced due to frequent topology changes. Here we have used two parameters-Speed and Radio range of different mobile nodes in the system for statistical modeling the uncertainty arising out of mobility of different nodes in a MANET[1][5]. To achieve this we have introduced the concept of proximity index which is a measure of the physical distance of a node within the radio range of a specific node due to the inherent uncertain characteristics of different nodes due to mobility this proximity index behaves as a statistical random variable in continuum. We proposed that this random variable follows β-distribution with suitable parameters, unknown though. On the basis of our simulation these underlying parameters have been statistically estimated to support a specific data set as available. Moreover we have investigated the relationship between the speed and radio range of a specific node under various situations for the shake of completeness. The outward mobility of a node from the radio range of a specific node has been treated as a statistical dead, whereas inward mobility from external world in the radio range of a specific node has been treated as a statistical birth. Naturally this conceptualization has induced a birth and death model of such a system prevalent in MANET. We have tried to estimate the corresponding Birth-rate and Death-rate and found encouraging results.

1 INTRODUCTION

In this paper we have taken the real world consisting of hundred mobile nodes. Having considered the frequent movement of these mobile nodes, in the first phase we have studied the relative distances of the mobile nodes present in the radio-range of the source mobile-node. This distance measure procedure is helpful for determining the shortest communication path among the mobile nodes, at a particular instance of time. In the real world simulation we also have to consider the dynamic nature of the mobile nodes. Movement of these nodes results the absence of some mobile nodes which previously in the radio range of the source; similarly it also results the presence of some nodes which were not in the radio range. So the number of measuring of relative distances changes dynamically as we have to calculate the relative distance of those nodes which are in the radio range only.

In the second phase we have considered the behavior of the mobile nodes which are incoming and outgoing from the radio range. Considering the frequent movement of all these mobile nodes we have empirically studied the nature of movement of these incoming (birth) and outgoing (death) nodes having incorporated the statistical behavior with them.

2 PROXIMITY INDEX

Proximity Index determines how a node is present in the vicinity of the source node at a certain instance of time[3]. It is represented by $\mu_s(X,t)$; where subscription "s" represents the source node and "x" represents the neighborhood node.Let, source node is indicated by S. Its Radio-Range is RR(S(t)). The neighborhood nodes[4] are $X_1, X_2,\ldots,Xn$.

Then, proximity index of node X_i :

$$\mu_s(X_i,t) = 1- [\ d\ (X_i(t),S(t))/RR(S(t))\ ]$$

for all $i = 1,2,\ldots,n$ such that $d\ (X_i(t),S(t)) \le RR(S(t)$.

As when we consider that all the nodes are in Radio-Range so, the following inequality will always hold: $0\le \mu_s (X_i,t) \le 1$. And so here the fuzzy scaling is maintained.

Now here, we can say for the source node P.I. = 1 and for the node at the perimeter of the Radio-Range of the source node P.I. =0.

3 WHY BIRTH-AND-DEATH

Nodes are eventually leave the Radio-Range because of unpredicted movement of the source node and also them. Because of such unpredicted movement of nodes if we increase Radio-Range of the source node or Speed of the other nodes in the vicinity of the source node keeping fixed the either one then how many nodes remain in the vicinity of the source node and how many will out of range? To solve such problems Birth-And-Death statistical model is necessary.

4 A MATHEMATICAL FORMULATION OF BIRTH-RATE AND DEATH-RATE

Now, in this situation we introduce jargons: **Birth & Death [2][5]**. The new coming nodes which were not previously in the Radio-Range, are the nodes whose **Birth** have been occurred. The rate of Birth is called **Birth-rate [1]**. The old nodes which were not previously out of the Radio-Range, are the nodes whose **Death** have been occurred. The rate of Death is called **Death-rate[1]**.

Let $N_{X,S}(t)$={X | Such that X is the node which is in the Radio-Range of S at any instance t } i.e. $N_{X,S}(t)$ is the set of nodes which are in the Radio-Range at any instance t. And $|N_{X,S}(t)|$ is the length of $N_{X,S}(t)$ = no. of total nodes in the Radio-Range in the time instance t.

So $|\text{Death}(t)| = |N_{X,S}(t) - [N_{X,S}(t) \cap N_{X,S}(t+1)]| = |N_{X,S}(t) \cap \{N_{X,S}(t) \cap N_{X,S}(t+1)\}^C|$.

And $|\text{Birth}(t)| = |N_{X,S}(t+1) \cap \{N_{X,S}(t) \cap N_{X,S}(t+1)\}^C|$.

Now, Let Death_rate = $\mu(t)$ = (# Deaths at t) / (# total node at t – 1 in Radio Range) = (| Death (t) |) / ($|N_{X,S}(t-1)|$).

And, Birth_rate = $\lambda(t)$ = Death_rate out side the Radio Range = (| Birth(t) |) / (T - $|N_{X,S}(t-1)|$) where, T is the total no. of nodes in the world.

5 FIRST SIMULATION

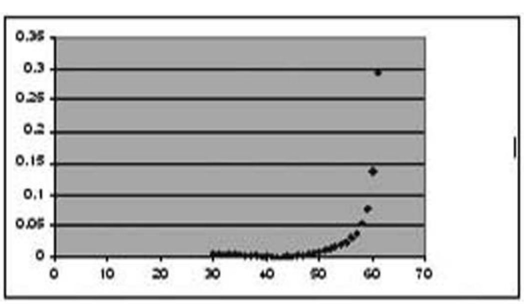
a) Under Constant Speed: Because of the special design of random function each and every node can move to k-th pixel up, down, left and right direction from its initial position when they move at k-th speed. So when nodes are moving at k units of speed two consecutive nodes can be separated with maximum distance of 2*k units at next time. And similarly which two nodes were separated with 2*k distance among themselves can be placed at m units of distance at the next instance, where m ≤ Radio-Range.

i) <u>If we gradually increase the Radio-Range then the high frequency components of **Birth_rate** is decreased.</u>

ii) <u>If we gradually increase the Radio-Range then the high frequency components of **Death_rate** is increased.</u>

iii) <u>If we gradually increase the Radio-Range then the no. of node increased</u>: This situation can only be happened when increase of Death_rate can not dominates over the decrease of Birth_rate. Here X-axis represents the Radio-Range and Y-axis represents the rate of increment of nodes.

<u>Graph:-1</u>



Here Amplitude stands for the gradually increments of the total no. of nodes while increment of the Radio-Range.

Now, this situation of the system forces us to study the nature of changing rate of the proximity indices of the nodes.

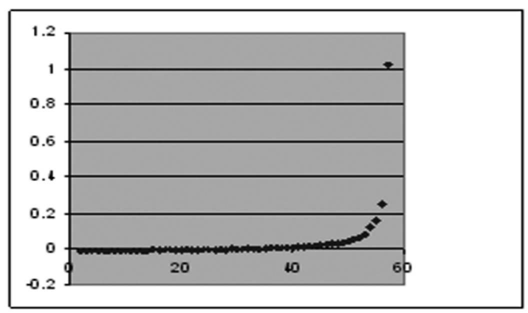
b) When Radio-Range is constant: Here all the nodes moving randomly. When speeds are high the source node actually jumps from one place to another (if we consider that negligible time is taken to move a limited distance). So almost every nodes residing inside the Radio-Range at the point of time quite naturally might not be in Radio-Range at the previous time. Because the special design of random function each and every node can move to k-th pixel up, down, left and right from its initial position when they move at k-th speed.

i) <u>If we gradually increase the speed then the high frequency components of **Birth_rate** is increased.</u>

ii) <u>If we gradually increase the speed then the high frequency components of **Death_rate** is increased.</u>

iii) <u>If we gradually increase the speed then the high frequency components of **total no. of nodes** are increased</u>: This conclusion can only be drawn when the Birth_rate dominates over the Death_rate. Here X-axis represents the Speed and Y-axis represents the No. of nodes.

<u>Graph:-2</u>



<u>REMARKS</u>

This Special behavior of the system forces us to study the nature of the <u>changing rate</u> of the **Proximity Indices** of the nodes in the next phase.

6 BETA (Β) DISTRIBUTION

The P.I. lies between 0 and 1. For convenience, we have scaled it by multiplying it with 100 for our calculation. The Beta distribution is one of the most flexible distributions, which only ranges from 0 to 1 and can take any shape depending upon the value of Alpha and Beta. The spectrum in this case consists of the interval (0, 1) and

$$f(x) = k(\alpha, \beta)\, x^{\alpha-1} (1-x)^{\beta-1} \text{ in } 0 < x < 1$$
$$= 0 \qquad \text{otherwise.}$$

The parameters are α (> 0), β (> 0) and a random variable is called a $\beta_1(\alpha, \beta)$ variate.

Now, $\int f(x) = k(\alpha, \beta) \int x^{\alpha-1} (1-x)^{\beta-1} dx = 1$.

<u>The equations describing the relationship between Alpha, Beta, Mean and Variance</u>:

In the Beta Distribution,

Mean (μ) = α / (α + β). ……………..(1)

Variance (σ) = α (α + 1) / (α + β) (α + β + 1)………….(2)

7 SECOND SIMULATION

a) When Radio Range is constant: Here from previous sections we have told that in case of fixed Radio-Range, the speed will be ranges from 2 to 60 gives the better result. So here we consider the range of speed 2 to 60 and the value of Radio-Range 40.

i) <u>If we gradually increase the speed then the movement of **Alpha** with **Beta**</u> : If we gradually increase the speed then alpha and beta oscillates with smaller range.

Since, we have already calculated from equations (1) and (2) that,

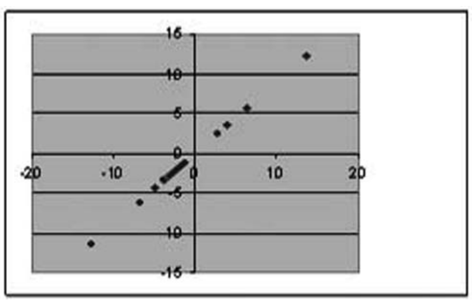
$\alpha = \mu (\mu - \sigma) / (\sigma - \mu^2)$. ……….(3)

$\beta = (1 - \mu) (\mu - \sigma) / (\sigma - \mu^2)$. ……(4)

Hence, $\beta / \alpha = (1 - \mu) / \mu$. ……….(5)

As, $0 \le \mu \le 1$, So $(1 - \mu)$ is always positive and so β / α is always positive and β and α always have the same sign. So whenever we plot them the curve always be in 1st and 3rd quadrant. Here X-axis represents the **Alpha** and Y-axis represents the **Beta**.

<u>Graph:-3</u>



Under fixed Radio Range (40) Alpha varies with Beta.

ii) <u>If we gradually increase the speed then the high frequency components of **Mean** is increased.</u>

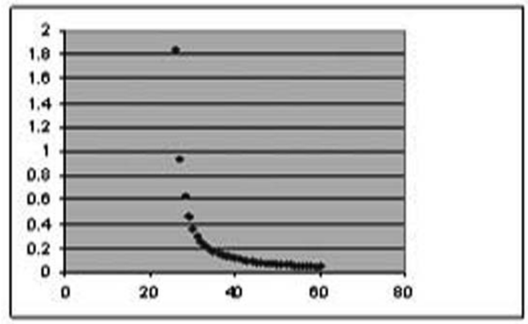
iii) <u>If we gradually increase the speed then the high frequency components of **Variance** is increased</u>

iv) <u>If we gradually increase the speed then the high frequency components of **Alpha** is decreased</u>: From the formula we have,

$\alpha = \mu (\mu - \sigma) / (\sigma - \mu^2)$.

So whenever the value of σ will high the value of α will be low.

<u>Graph:-4</u>



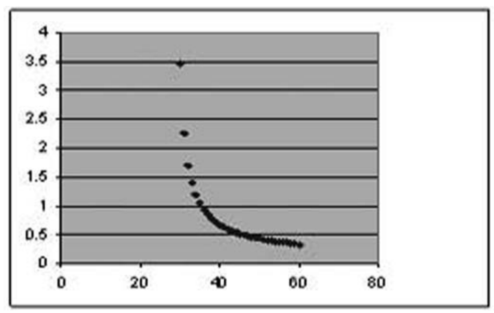
Under fixed Radio Range (40) Alpha varies with Speed. Here X-axis represents the **Speed** and Y-axis represents the **Alpha**.

v) <u>If we gradually increase the speed then the high frequency components of **Beta** is decreased</u>: From the formula we have,

$\beta = (1 - \mu) (\mu - \sigma) / (\sigma - \mu^2)$.

So whenever the value of σ will high the value of β will be low. . Here X-axis represents the **Speed** and Y-axis represents the **Beta**.

<u>Graph:-5</u>



Under fixed Radio Range (40) Beta varies with Speed.

<u>RELATIONSHIP BETWEEN REAL WORLD (SPEED) AND VIRTUAL WORLD PARAMETERS (ALPHA, BETA) :</u>
With values obtained from Graph-4 and Graph-5 we have calculated the following functions by Lagrangian Interpolating Formula: According to Lagrangian Formula a function Φ(x) is defined as follows:

$$\Phi(x) = \sum_{i=0}^{n} (\psi(x).y_i) / ((x-x_i).\psi(x_i))$$

………………………..(A)

Where x_i, y_i are discreet points and

$$\psi (x) = \prod_{i=0}^{n} (x - x_i)$$

With the formula (A) we have formulated Mean as,

$$\mu\,(Sp) = \prod_{i=20}^{60} (Sp - RRi) * m_i \quad \text{...........(B)}$$

$$\sigma\,(Sp) = \prod_{i=20}^{60} (Sp - RRi) * v_i \quad \text{............(C)}$$

Here Sp denotes the Speed. RRi denotes the Radio-Ranges. m and v denotes mean and variance. We can formulate alpha and beta in terms of speed now:

$$\alpha = \mu(Sp)\,(\,\mu(Sp) - \sigma(Sp)\,) / (\sigma(Sp) - (\mu(Sp))^2\,).$$

$$\beta = (1 - \mu(Sp)\,)\,(\,\mu(Sp) - \sigma(Sp)\,) / (\sigma(Sp) - (\mu(Sp))^2\,).$$

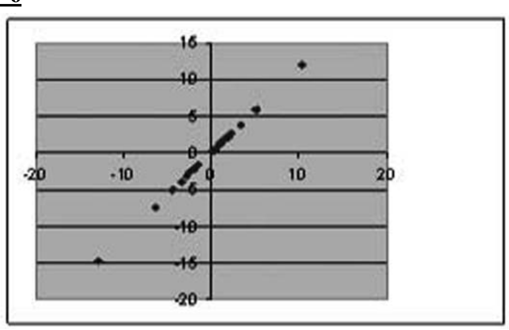
Thus the virtual world parameters are defined in terms of real world parameters.

b) When Speed is constant: Here from previous sections we have told that in case of fixed Speed, the Radio-Range will be ranges from 20 to 40 give the better result. So here we consider the range of speed 20 to 40 and the value of speed 10.

i) <u>If we gradually increase the Radio-Range then the movement of **Alpha** with **Beta**</u> : If we gradually increase the speed then alpha and beta oscillates with smaller range.

As, from (3) and (4) we have $0 \le \mu \le 1$, So $(1 - \mu)$ is always positive and so β / α is always positive and β and α always have the same sign. So whenever we plot them the curve always be in 1st and 3rd quadrant. So the tendency of each node will be going nearer to the perimeter of the Radio-Range. So the P.I. of each node will tend to 0. Here X-axis represents the **Alpha** and Y-axis represents the **Beta**.

<u>Graph:-6</u>



Under fixed Speed (10) Alpha varies with Beta.

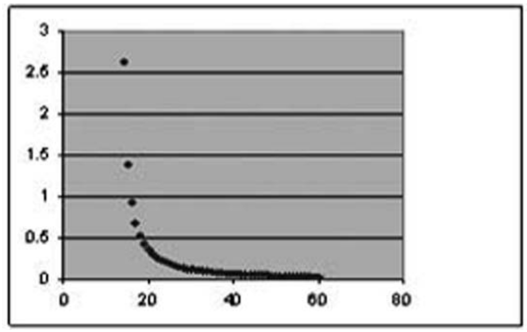
ii) <u>If we gradually increase the Radio-Range then the high frequency components of **Mean** is decreased</u>.

iii) <u>If we gradually increase the Radio-Range then the high frequency components of **Variance** is decreased</u>.

iv) <u>If we gradually increase the Radio-Range then the high frequency components of **Alpha** is decreased</u>: From the formula we have,

$\alpha = \mu\,(\,\mu - \sigma\,) / (\sigma - \mu^2\,)$. So whenever the value of σ will high the value of α will be low.

<u>Graph:-7</u>



Under fixed Speed (10) Alpha varies with Radio Range. Here X-axis represents the **Speed** and Y-axis represents the **Alpha**.

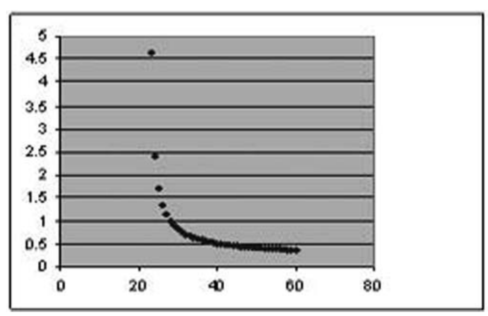
v) <u>If we gradually increase the Radio-Range then the high frequency components of **Beta** is decreased</u>: From the formula we have,

$\beta = (1 - \mu)\,(\,\mu - \sigma\,) / (\sigma - \mu^2\,)$. So whenever the value of σ will high the value of β will be low. . Here X-axis represents the **Speed** and Y-axis represents the **Beta**.

Under fixed Speed (10) Beta varies with Radio Range.

<u>RELATIONSHIP BETWEEN REAL WORLD (RADIO-RANGE) AND VIRTUAL WORLD PARAMETERS (ALPHA, BETA) :</u> With values obtained from Graph-7 and Graph-8 we have calculated the following functions by Lagrangian Interpolating Formula:

<u>Graph:-8</u>



With the formula (A) we have formulated Mean as,

$$\mu\,(RR) = \prod_{i=20}^{60} (RR - Spi) * m_i \quad \text{...........(B)}$$

$$\sigma\,(RR) = \prod_{i=20}^{60} (RR - Spi) * v_i \quad \text{...........(C)}$$

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Here RR denotes the Radio-Range. Sp denotes the Speeds. m and v denotes mean and variance. We can formulate alpha and beta in terms of Radio-Range now:

$$\alpha = \mu(RR) (\mu(RR) - \sigma(RR)) / (\sigma(RR) – (\mu(RR))^2).$$

$$\beta = (1 - \mu(RR)) (\mu(RR) - \sigma(RR)) / (\sigma(RR) – (\mu(RR))^2).$$

Thus the virtual world parameters are defined in terms of real world parameters.

8 CONCLUTION

Here if we choose the Radio-Range within 30 to 60 or Speed 2mbps to 60pbps of mobile nodes keeping fixed either, we can remove the uncertainty of the mobile nodes in a MANET.

Thus we can get a suitable communication link over a set of mobile nodes which have unpredicted movement in their nature.

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