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Predicting Optimal Reliable Routing Path Duration in Mobile Ad Hoc Networks using RLD Model

[1]Dr.S.R.M.Krishna, [2]Dr.R.Santosh Kumar

[1]Associate Professor, Dept of CSE, CVR College of Engineering, Hyderabad, India

[2]Associate Professor, Dept of CSE, CVR College of Engineering, Hyderabad, India

Abstract—The design parameter that majorly determines the performance of a mobile ad hoc network (MANET) is the Path duration. For instance to estimate the route expiry time in dynamic routing protocols it can be used. The Reliable Linguistic Data (RLD) model which is presented in this paper plays major role in predicting optimal secured routing path duration dynamically. The most important feature of this proposed model is that there is no unifying common model developed till now which establish relationship among node reliability, mobility, signal strength, node density, velocity of nodes and number of hops in MANET. The proposed RLD model is a unique model which predicts the optimal and secured routing paths along with it estimates routing path duration also. The accuracy of the proposed model is experimented and validated by comparing results obtained from the RLD model with existing models. By comparing the simulations results carried out in ns-2/ns-3, the accuracy of the proposed model is calculated which results better performance in terms of network parameters.

Index Terms— Mobile ad hoc networks, path estimation, reliability, Path routing duration, mobility, accuracy.

1. INTRODUCTION

Mobile Ad hock Network (MANET) is a wireless network with no fixed infrastructure. These Dynamic networks have number of real time applications like, military rescue, defense and surveillance etc. Mobility of nodes in a MANET is a reason for unpredictable topological changes which can affect the adaptability of the design and development of routing techniques. The key challenging aspects of MANETs are predicting dynamic routing, secured routing, handling dynamic traffic routing allocation (DTA) problem, utilization of nodes, optimal routing detection and various security issues etc.

In order to overcome the above list of challenges and future non predictable challenges there should be one common prototype model has to be developed to face the above challenges. So, the proposal which is presented In this paper address the above challenges. The proposed model generated optimal secured routing paths along with it measures the cost and duration of routing path dynamically time to time. The path duration plays very important role in order to maintain life time of the network secure time to time. And the path duration in the wireless network helps in the assignment of an optimum value to the route expiry time. The duration for which a route should be active in the routing table, in a on demand dynamic routing protocol.

As the routing path duration depends on various key parameters like the number of hops, throughput, reliability, number and position of relay nodes, velocity, direction of movement etc,. The determination of path duration of a selected path is very difficult due to dynamic in nature of the network.. Such a prediction is easy for GPS (Global Positioning System) based networks, but a very few wireless networks use the GPS. The recent and most popular routing protocols such as the Dynamic Source Routing (DSR) and the Adhoc On-demand Distance Vector (AODV) routing protocol, DADO do not select a path based on its expected lifetime. AODV selects the first available route where DSR selects a path which has the minimum hop count to the destination. The throughput of the MANET and performance of the routing protocols can be enhanced by incorporating the knowledge of the expected path duration.

The proposal is an analytical model combination of various parameters for estimating the path duration in a MANET. To our knowledge there is no common prototype model in the literature that includes node density, reliability and though put which can be used for estimating path duration in a MANET. Thisproposal demonstrates its feasibility under a few sensible and reasonable assumptions. The MANET is based on the principle of Least Remaining Distance (RLD). The RLD forwarding technique is similar to the shortest path forwarding in which selection of the route to a destination is based on the principle of least number of hops.

The organizations of chapters of this work are categorized as follows. Section II presents the literature survey on mobility models, particularly on Random Way Point (RWP) model. Section III presents the proposed model for optimal secured routing path duration in detail. Section IV presents experimental results. Conclusions are presented in section V.

I. LITERATURE REVIEW

The paper mainly focuses on key models to work up on determining path duration and reliability. Models are mainly categorized into four types based on its metrics. Those are Trace,, Synthetic, Stability and Mobility models[4]. Various methodologies to find stable paths in Mobile Adhoc Networks discussed in[7]. Routing protocols like unicast and multi cast routing protocols for mobile adhoc networks discussed in [8]. The node moment real time scenario prediction discussed in [9][10].

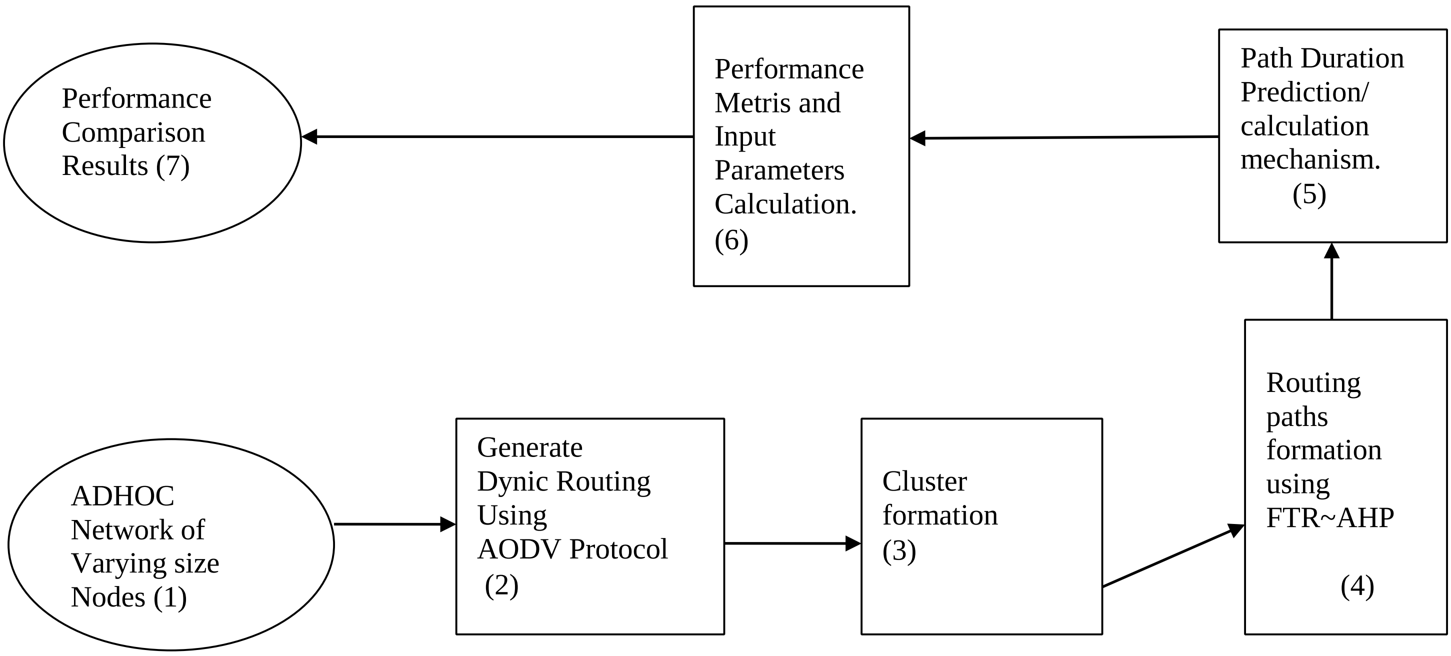
The relationship among hop count and link distance is discussed in [15]. The key assumptions made in this is the selection of relay node is function of least remaining distance [RLD} from source to destination. The relationship between RLD model bounds up on hop distance for a given Euclidean distance between nodes described in [15]. The relationship between network throughput and the average degree of the node is described in [16]. Relationship among stability and hop count based adhoc routing proposed in [17]. The relationship between link stability and routing life time discussed in [21].In order to predict the long life time routing in wireless network discussed in[18]. The relationship among link stability and routing life time analyzed [21] through various parameters. The behavior of communication link in random mobility environment, life time of the link, link change interval time, link arrival time, link availability, link persistence and link residual time discussed in [19].

The model presented in this paper is designed by considering following classification metric based parameters. The classified metrics were Node based metrics, Communication based metrics, Mobility based metrics, link based metrics and Stability based metrics. Relative velocity of nodes, Transmission range, No of Hops and node density comes under communication ased metrics. End-to End delay, Euclidiandistance, throughput, packet delivery ratio comes under Node metrics. Link life time, new link arrival time, link change interval time, link persistence, link availability and link residual time comes under link based metrics. Residual life time of the link comes under stability based metrics.[3][11][12]. Even though various preexisting models like RWP, RPG, Analytic Estimation models[ ] are to find the path duration in MANET but all are limited to specific classification designed with limited parameters and there is no interconnectivity parameter oriented analytical study.. There is no common prototype which generates unique secured routing with long life. So, the model which is proposed in this paper overcomes all the limitations of existing models and gives a network model which secures the routing paths with maximum life time.

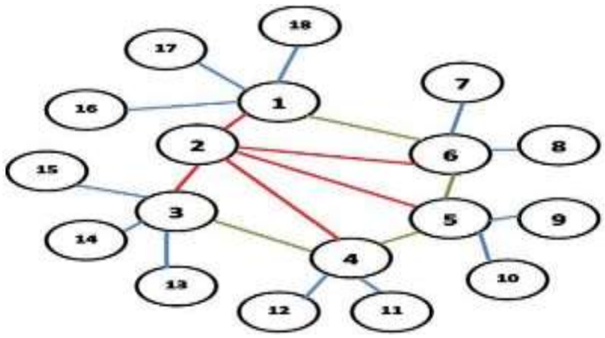
Another specialty of the model presented in this paper is useful rating of the model in high in all circumstances. This model will overcome network failures and reforms the network in optimal duration and it also overcomes Dynamic traffic routing problem(DTA)[20-24], edge effect phenomena while network formation [21], This model also suggest that when network reformation taken place the shortest path is not the best optimal routing path when duration of path is taken into account.

II. PROPOSED MODEL

In this Section how the flow of proposed model taken place from Input to Out Put Generation described briefly.



In the proposed model using Integer linear programming (ILP) with Fuzzy rough sets[50- my Ph.D. thesis] uses mesh topology used to determine the optimal reliable routing paths from the Network and wireless networks are static network at a particular instant of duration. Topology can be predicted at a particular instance based on various mobility models with the help of mobility metric parameters.



M
N

Fig 1: Network to implement ILP Model

The above model follows network with mesh topology where Master cluster head (M) and Network node (N) are classified and identified with the following objective function.

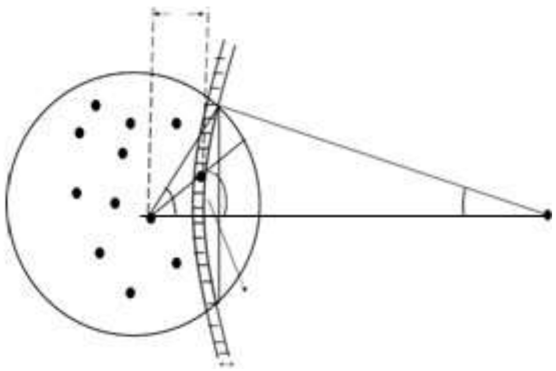
The objective function in determine optimal reliable routing paths using ILP model as follows

$$MIN:\left(\sum_{i=0}^{N}\sum_{j=1}^{N} aij\,P_{i,j} + \sum_{j=1}^{N} wjrj + \sum_{j=1}^{N} wjKj + \sum_{j=1}^{N}\sum_{k=1}^{N} bjk\ Qjk + \sum_{i=0}^{N} Ri \right) + \mathbf{MAX}\ \sum_{i=0}^{N} WD)$$

The above objective function results optimal routing paths under various constraints [55- ILP Paper ref].

Method for predicting Optimal Reliable routing path duration:

Once clusters are formed optimal reliable routing path and its duration determined through the following Graphical Model representation:



The set of all parameters to evaluate various metrics in order to predict the optimal secured routing path duration is listed below

1. Battery Power Consumption
2. Signal Strength
3. Residual Energy
4. Throughput
5. Trustworthiness of Nodes
6. Average Mobility
7. Dynamic Node Speed
8. Node Distance ref[srmk paper]

in which the topological changes can be predicted from that instant to the next instant based on the assumed mobility model. Consistent with the literature, let us use the RLD forwarding process as an approximation to shortest path based forwarding. As there could be many paths between the source and the destination, analysis of the duration of all these paths is not feasible.

Given that the behavior of "on demand" routing protocols is closely associated with the shortest path, the analysis of average path duration based on shortest path principle is appropriate and meaningful.

A. Proposed Model

In the proposed model, it is assumed that the locations of the nodes are determined by a spatial point process with the

property that the number of nodes in a two-dimensional or three-dimensional region is Poisson distributed with parameter β[15], [19]. Fig. 1 describes the model and Table I describes the notation followed in the analysis. The notation used for the random variables (RVs) used in the model is described in Table II.

B. RLD and Shortest Path

In RLD forwarding, among all the available forwarding (or relay) nodes, the node which has the minimum distance to the destination is selected as relay node [15]. This behavior is similar to shortest path because shortest path attempts to reach the destination with the least number of hops, which is possible only when the node with minimum remaining distance to destination is selected as a relay node.

TABLE I

Notation Followed In The Analytical Model

Variable	Description
d	Distance between the source(M) and the destination(N)
a	Distance between the relay node(E) and N
p	A point of intersection between the two circles; one drawn at M with radius x and other drawn with radius y
b	Distance between M and N
t	Transmission range of a node in the MANET
α	Angle between the two straight lines ME and MN
i*int(a)*	Area of intersection between two circles ,one drawn at M with radius x and the other drawn at N with radius y
Δa	Width of the strip shown with stripes in fig. 1; The strip is formed by two arcs drawn from D with radius a anda+Δa respectively.
i*arc*(a,Δa)	Area of the strip described above
α	Parameter of Poisson distribution representing node density

TABLE II

Random Variables Used In The Analytical Model And Their Notation

RV	Represents	PDF
A	Distance between the relay and destination nodes	$f_A(a)$

C	Distance between per hope made by the relay node	f_C(c)
N	Distance that need to be travelled by the relay node	f_N(n)
	to get out of source node's transmission range	
St	Relative velocity between any two nodes	$fS_t(s_t)$
U	Number of hopes	NA
Q	Link Duration	f_Q(q)
Qpath	Path duration	*f*Qpath(qpath)

C. Link Residual Life

Link residual life is stated as the time during which a link will be active once it becomes a part of a path. A link between two mobile nodes will be active as long as they are in the transmission range of each other. Link residual life (q) can be expressed as the ratio (1)

$$\boxed{q = \frac{n}{\mathrm{St}}}$$

Where *n* is the distance that the neighbor (relay) node needs to travel to get out of the transmission range of its neighbor and $S_t$is the relative velocity between the two neighbors. In order to find the distribution of link residual life, the distributions of *N* and S_t need to be known. From the following subsections, the PDF for the path Duration Q_{path} and its expected value are derived using Fundamental principles. In this analysis, the neighbors that do not fall in the path towards the destination are ignored and only those nodes which are on the path to destinationare considered.

D. Link Distances

Starting with the link distance, this is dependent on the underlying routing protocol used in the MANET. Since most on demand routing protocols such as DSR andAODV are based on the principle of shortest path, link distances can be analyzed based on the same principle. Shortest path is achieved in RLD forwarding method by the selection of a relay node with leastdistance to the destination.

According to the RLD principle, the source node selects a node located at a distance *x* from the destination if it cannot find any other node within $i_{int}(a)$and there is at least one node within the stripe $i_{arc}(a, a)$, then the corresponding probability of random variable *A*is given by

$P(a \le A \le a + \mathrm{Aa})$

$= Pr(no\ nodes\ in\ i_{int}(a))$

$$\times Pr(at\ least\ one\ node\ in\ i_{arc}(a, \mathrm{Aa}))$$

$$= e{-}\beta i\,int(a)(1 - e{-}\beta i\,arc(a,\mathrm{Aa})), d - t \le a \le l. \qquad (2)$$

Note that $i_{int}(a)$ and $i_{arc}(a, a)$ represent segments or areas in which the source nodes looks for a relay node.

The division $i_{int}(a)$ into two ($B_1$and B_2) segments makes it easier to compute its area.

It is assumed that the source node gets to know the distances, in terms of hops, of the relay nodes using the standard routing protocols. If the PDF of *A*is represented as $f_a(a)$, then, (2) can be represented as:

$1 - e{-}\beta iint(a,\Delta a0)$

$e{-}\beta iint(a)$ ( )

$(a)\Delta a = f(x) = \{$ $(d - t \leq a \leq d,$ (3)

fa

$elsewhere.$

0;

From Fig. 1, $i_{int}(a)$ and $i_{arc}(a,\Delta a)$can be computed as follows:

$I_{int}(a) = B_1 + B_2$

$$= t^2[\alpha 1 - \frac{\sin 2\alpha 1}{2}] + a^2[\alpha_2 - \frac{\sin 2\alpha 2}{2}], \qquad (4)$$

$iarc(a,\Delta a)$

=area of the inner arc of width Δa

$-[\frac{2\alpha 2}{2\pi}][\pi(a+\Delta a)^2 - \pi a^2]$

$=\alpha_2[2a + \Delta a]\Delta a$ and

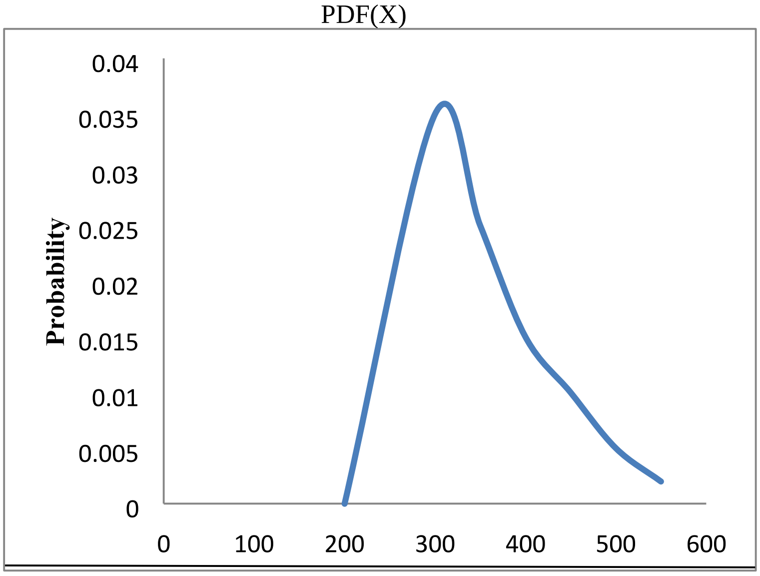
$\approx \alpha 22a\Delta a$

$$\approx \cos^{-1}[\frac{a^2+d^2-t^2}{2ad}][2a]\Delta a \qquad (5)$$

Where α_1 and α_2 are defined as : $\alpha_1 = \cos^{-1}[(d^2 + t^2 - a^2)/2dt]$ and

$\alpha_2 = \cos^{-1}[(a^2 + t^2 - d^2)/2at$ (6)

PDF(X)



Distance from the Destination

Fig2. Probability density function of the random variable

Fig. 2. Probability density function of the random variable A (distance between the relay and destination nodes) plotted with parameters d is 500 m and *t is* 250 m.

The above figure describes how Probability Density Function varies when we take range from 200m to 500m among mobility of nodes in a Mobile Adhoc Network.

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Details of these derivations are given in Appendix A. Using simple calculus, the PDF of Acan be approximated as below:

$$fA(a) \approx 2\beta\alpha 2xe{-}\beta aint(x). \qquad (7)$$

This approximation results in simplification of the analysis. As an example, $f_A(a)$ when d500m, and t250m is shown in Fig. 2. From $f_A(a)$, the expected distance from the relay node to the destination node can be computed as,

$$E[A]=\int_{d-t}^{d} a f A(a) da. \quad (8)$$

From Fig. 1,we get,

$$c=d-a\cos\alpha 2. \quad (9)$$

Substituting the value of $\cos\alpha$ from (6), we get,

$$c=d-\frac{(a^2+d^2-t^2)}{2ad}, \quad (10)$$

This leads to

$$a^2=d^2+t^2-2dc. \quad (11)$$

Therefore a and c can be expressed as:

$$a=\sqrt{d^2+t^2-2dc}=g^{-1}(c), \text{ and,}$$

$$c=\sqrt{\frac{d^2+t^2-a^2}{2d}} \quad (12)$$

In order to estimate the remaining distance d – c, we need to know the distribution of C. The rest of this subsection deals with the derivation of $f_c(c)$ from $f_c(c)$.

We begin with the basic step involving change of variables,

i.e.,

$$F_c(c) = f_a(g^{-1}(c))\left|\frac{dg^{-1}(a)}{da}\right| \quad (13)$$

$$\frac{dg^{-1}(a)}{da}-\frac{d}{\sqrt{d^2+t^2-2dc}} \quad (14)$$

Since,d and t are constants with respect to a,we get, $da = \frac{-d}{\sqrt{d^2+t^2-2dc}}dc$. (15)

From the expression for ain (11) we get,

$$\Delta a=\frac{-d}{\sqrt{d^2+t^2-2dc}}\Delta a \quad (16)$$

Both α_1 and α_2 also need to expressed in terms of c. From (6), α_1 and α_2 can be expresses in terms of c as: $\alpha_1(c) = \cos^{-1}(\frac{c}{t})$ and

$$\alpha_2(c)=\cos^{-1}(\frac{d-c}{\sqrt{d^2+t^2-2dc}}) \quad (17)$$

Finally,$i_{int}(a,\Delta a)$ needs to be expressed in terms of c.This is done as follows:

$$\text{iint}(c) = t^2\left[\alpha 1(c) - \frac{\sin 2\alpha 1\,(c)}{2}\right]$$

$$+(d^2 + t^2 - 2dc)\left[\alpha 2(c) - \frac{\sin 2\alpha 2\,(c)}{2}\right]$$

$$= t^2\left[\cos^{-1}\left(\frac{c}{t}\right) - \frac{c\sqrt{a^2-b^2}}{t}\right]$$
$$+(d^2 + t^2 - 2dc)$$
$$\times\left[\cos^{-1}\left(\frac{d-c}{\sqrt{d^2+t^2-2dc}}\right) - \sqrt{\frac{t^2-c^2}{d^2+t^2-2dc}}\right] \qquad (18)$$

Now, $_a(g^{-1}(z))$ when expressed in terms of c results in the

Following:

$$f_a(g^{-1}(z)) = 2\beta\ \alpha_1(c)\ g^{-1}(z)e^{-\beta \text{iint}(c)} \qquad (19)$$

By substituting the expression for $\left|\frac{dg^{-1}(a)}{da}\right|$ and $f_a(g^{-1}(z))$ into (13),we obtain,

$$f_c(c) = 2d\beta\ \alpha 2(c)e^{-\beta \text{iint}(c)} \qquad (20)$$

Once $f_c(c)$ is known,the expected value of this length is Calculated by,

$$E[C] = \int_0^r c f c(c)dc. \qquad (21)$$

E. Relative Velocity

In order to find the PDF corresponding to the relative velocity, The source node M is assumed to be fixed and the relative movement of the relay node with respect to M is considered.

Relative velocity between the source and relay nodes is given by,

$$S_t = \sqrt{s1^2 + s2^2 - 2s1s2 \cos \gamma} \qquad (22)$$

Where γ is the angle between the velocity vectors s_1,s_2.

Assuming that all nodes move with an average (constant)

Velocity, we can write $s_1 = s_2 = s$, Hence s_t can be expressed as follows, s_t

$$= s\sqrt{2 - 2\cos\gamma} = 2s\sin\frac{\gamma}{2} \qquad (23)$$

Where, γ is a random variable whose range is (0,2π).The relay node may move either towards the source node or away from the source node with equal probability (0.5).the link between the source node and relay node breaks when the relay node moves in the direction away from the source node. It is sufficient if node movement $\frac{\gamma}{2}$ away from the source ad the relay node to break. Since γ varies within (0,2π) with uniform probability. can be assumed to vary with uniform probability between (0,π),the pdf of $f_{a/2}$ is given by, $(\frac{\gamma}{2})$

$$f_{a/2}\left(\frac{\gamma}{2}\right) = \frac{1}{\pi} \qquad (24)$$

From (23),the pdf of S_t,$f\,S_t(S_t)$ is expressed as,

$$f\,S_t(S_t) = \frac{1}{\sqrt{4s^2 - st^2}}\frac{1}{\pi} \qquad (25)$$

F.Link Residual Life

Link residual life k is given by,

$$K = \frac{n}{St}$$

Where n=t-c,which is the straight line distance that the relay node needs to travel to get out of the transmission range of M.Hencef_m(k) is given by,

$$f_m(k) = \int_0^{Smax} St f Ns, (Stk, St) dSt$$

$$= \int_0^{Smax} [f N(n)]n = Stk\left[\frac{1}{\sqrt{4s^2 - st^2}}\frac{1}{\pi}\right] dSt \qquad (26)$$

G. Path Duration

Path duration (q_{path}) is derived from the PDF of the link residual life. If the number of hopes needed to reach the destination is h, then q_{path} can be written as

qpath = min(q1, q2, q3, q4,….Qh) ,(27)

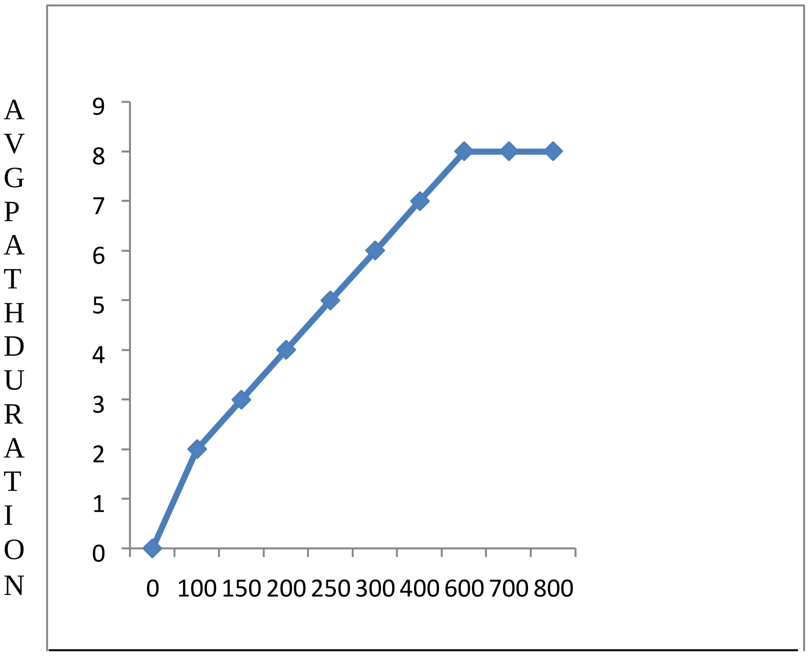
where k_i is the residual time corresponding to i^{th} link.

Using Bayer's Theorem [15] and chapter 6 in [22], the PDF of q_{path} can be Expressed as:

$$fQ_{path}(q_{path}) = h\, fQ_{path}(q_{path})(CQ_{path})^{h-1} \tag{28}$$

whereCQ_{path} = 1- fQ_{path} is the complementary cumulative distribution function(CDF) of Q_{path} and FQ_{path}represents the CDF. Average path duration is given by,

$$E[Q_{path}] = \int_0^{\gamma} qpath\, f Qpath(qpath)\, dqpath \tag{29}$$



Network transmission Range

Fig .3. Path Duration Estimation for the Network

Fig. 3 describes the plot between transmission range and average path duration. This graph suggests that avg path duration increases linearly with transmission range increasement. If the transmission range going high, then the probability of a relay node's location being well within the circle of transmission range, is higher. This gives greater room for mobility of the relay node, there by resulting in higher path duration.

RESULTS & CONCLUSION

The results presented in this paper demonstrate that average path duration in a MANET is predictable for the shortest routing path analytically. Prediction of average routing path duration is highly useful and can be used as a parameter to optimize routing expiry time, routing formation time of routing protocol. The model also provides an insight into the impact of mobility on routing protocols. It enhances the performance of routing path prediction in secured and optimal mode.

Future work can focus on mobility model dependent factors and parameters that contribute to average path duration. The complexity in computing average path duration also can be reduced so that it will be useful for networks with resource constraints. The presented model can also be optimized or verified with Boolean models, Meta and non Meta heuristic models in the process of MANET functionality.

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