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Analysis of Path Duration in Vehicular Ad Hoc Networks using B MFR Protocol

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Abstract

The larger and rapid changes that know all the domains in the world not excluded the transport sector. Today, the fleet is growing, the roads are becoming more dangerous by the effect of congestion and increase of collision. The intelligent transportation systems (ITS) is in effort to integrate information technology in transportation. Vehicular Ad hoc network (VANET) having vehicles as moving nodes is a subclass of MANET. It is a real time network with no central network control. For successful communication, the data from the sender should reach the destination in a timely manner. It is challenging to find and maintain optimal path between source and destination nodes, since the nodes are mobile. Path duration is an important parameter that determines the performance of a mobile ad hoc network. In this paper, we have proposed a mathematical model to estimate the path duration between source and destination node using B MFR protocol. The mathematical model is simulated and the B MFR protocol is implemented using MATLAB. The result reveals that the path duration increases as the transmission range increases and decreases as the number of hops increases in VANET.

Keywords: *Path Duration, Vehicular Ad Hoc Networks etc.*

1. Introduction

Vehicular Ad hoc network (VANET) has a significant potential to enable diverse applications associated with traffic safety, traffic emergency and infotainment. VANET represent a rapidly emerging class of mobile Ad hoc networks (MANET). They are distributed and self organizing communication network built up by moving vehicles. VANETs are infrastructure less mobile networks which has no central network control The intelligent transport system (ITS) has been working since long time to make the road safe, secure and efficient in a way to travel and transport.

In VANETs the wireless transmission range of each node will be limited and if a node desires to communicate with a node outside its transmission range, then it is possible only via neighbouring nodes. Thus in a VANET all the nodes will act itself as routers according to the situation demands and a path will be created in between the source node and destination node. Usually there may be multiple hops between the source node and destination node. In VANET, network topology is frequently changing, so finding and maintaining routes is a challenging task. Since all the nodes are mobile, there is a risk of link breakage in the network. The mobility of nodes is critical factor that affect the performance evaluation of VANETs. When a path failure occurs, the ongoing data transmission will expire and requires a new path setup. Path failure degrades routing performance and also need for new path is an overhead to the network.

Path duration can be defined as the amount of time every link of the route will be active. It is the route expiry time of a particular link. Path duration is an important parameter that determines the performance of a mobile ad hoc network. Extensive studies on path duration had been done on MANETs. It depends on certain parameters such as node density, transmission range, number of hops and velocity of nodes [3]. The author in [4] had made analysis on link stability and route life time. If there is any link breaks in the route, the whole route will expire. The link stability and route lifetime are directly proportional to each other. Knowledge of path duration can improve performance of the whole network.

In VANETs, position-based routing protocols are more suitable routing protocols and these can be used to improve the routing performance [2]. In position-based routing, the position of neighbouring nodes around the source node and position of the source node is known to every node. In these protocols, the next-hop node will be selected on the basis of maximum distance covered towards the destination within the sender's transmission range. Border-node based Most Forward progress within Radius routing (B-MFR) and Edge-node based Directional Routing (E-DIR) [5] [6] are some of the routing protocols used in VANET. We propose B-MFR protocol for our work. In B-MFR routing protocol, only the nodes presents on the border of the sender's transmission range are selected as the next-hop nodes for further packet transmission. In this paper analytical model for path duration is simulated using MATLAB. Our main contribution is the implementation of B MFR protocol using MATLAB tools.

2. Proposed work

To estimate the path duration, in our work, first we will select a region from where we can find a particular relay node. That selected node must be within the transmission region of the source node. For this purpose B MFR protocol is adopted here. It is a position based routing protocol for selecting the next hop node. The next-hop node will be selected on the basis of maximum distance covered towards the destination within the sender's transmission range. Here only the nodes presents on the border of the sender's transmission range are selected as the next-hop nodes for further packet transmission. Since the nodes on the border of the transmission range are easily available, the number of hops between source node and destination node are significantly reduced in border node based protocol. So in B MFR protocol, the number of hops will be minimum. Since we are selecting the border node only, the link distance will also be equal. There will be atleast one intermediate node in between source node and destination node if the destination is out of transmission range R_1 and within $2R_1$.

Once the next hop node is selected, data from the source node will be send to destination node. The destination node may be outside the transmission range of the sender. Poission distribution method is used to develop a mathematical model to estimate the path duration in VANETs. Here we adopt the traditional traffic flow principle to describe the vehicular environment. All the vehicles have same speed and link distance. For practical implementation all vehicles should have GPS receivers, digital maps and sensors.

3. Analytical Path duration Estimation

The main goal is to derive mathematical expression for path duration. Since the path duration is a design parameter that depends on certain other parameters such as the node density, transmission range, number of hops and velocity of nodes, we should calculate these parameters to obtain the path duration. First we find the area of the border region to find the next hope node as follows:

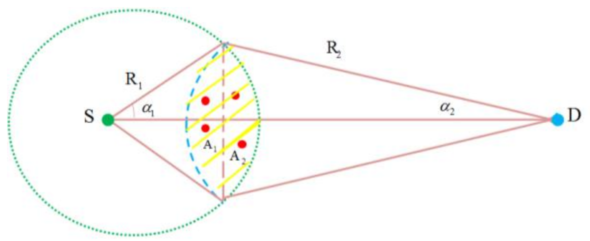
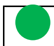
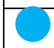


Fig.1 Area of selected region (A_s=A_1+A_2)

	Source node S_n
	Destination node D_n
R_1	Radius of source node
R_2	Radius of destination node
α_1	Angle between R_1 and SD
α_2	Angle between R_2 and SD
(A_s=A_1+A_2)	Selected region

To reduce the number of hop counts between source and destination , the node closer to the border or on the border line has to be selected. This node will cover maximum distance towards destination. But it may not be possible to find a even a single node at the extreme end of the transmission range. Therefore we select a region A_s around the extreme end of the transmission range towards destination. The border region (A_s=A_1+A_2) shown in Fig.1.

The transmission range of the source is shown by the circle in Fig.1. Selected region A_s is divided into A_1 and A_2. The border node can be chosen either from A_1 or A_2, accounting the closest one to the border line of senders transmission range. The area A_s can be calculated as:

$$(A_s=A_1+A_2) \tag{1}$$

Where

$$A_1 = R_1^{\,2}.\alpha_1 - \frac{R_1^{\,2}.\sin(2\alpha_1)}{2}$$

$$A_2 = R_2^{\,2}.\alpha_2 - \frac{R_2^{\,2}.\sin(2\alpha_2)}{2}$$

From Fig.1. $\alpha_1 = 45^0$ (SD is the bisector of the angle). Therefore the area of the shaded region, A_S is

$$A_S = \frac{w}{2} R_1^{\,2}\left[\frac{\pi-2}{4}\right] + R_2^{\,2}\left[\alpha_2 - \frac{\sin(2\alpha_2)}{2}\right] \tag{2}$$

So we can say that the shaded region is formed by two arcs, one with radius R_1 and other with radius R_2. The value of α_2 depends on transmission range R_1 and distance between source and destination.

Probability of finding nodes in the selected area is first step for the analysis of path duration. We have to find atleast one node in the selected region. Here we assume the nodes are two dimensionally Poission distributed over the network with node density ω. Then the number of nodes in the selected region is calculated as:

Number of nodes= $\omega \times$ Area of the selected region

If X is the random variable representing the number of nodes in the shaded region A_s, then the probability that number of nodes X located in the shaded region can be calculated as:

$$P(X=x)=\frac{(\omega A_S)^x.e^{-\omega A_S}}{x!}, x=0,1,2,3,...... \quad (3)$$

The probability of selecting *n* nodes out of *x* nodes is given by

$$P(Y=n)=\binom{x}{n}(p)^n(1-p)^{x-n} \quad (4)$$

If a node present in the selected region, only two possibilities are there: one is selecting the node P_s, and other is not selecting the node $q=1-P_s$. Therefore, probability of occurring both the cases is equal i.e. $P_s= q=1/2$

Now, probability of selecting exactly *n* nodes in the given border region is

$$P(n)=\sum_{x=n}^{\infty}\binom{x}{n}p_s{}^n(1-p_s)^{x-n}.\frac{(\omega A_S)^x.e^{-\omega A_S}}{x!}$$
$$=\frac{(\omega A_S p_s)^n.e^{-\omega A_S}}{n!} \quad (5)$$

Let the value of $P_s= 1/2$, then

$$P(n)=\frac{\left(\frac{w}{2}\left\{R_1{}^2\left[\frac{\pi-2}{4}\right]+R_2{}^2\left[\alpha_2-\frac{\sin(2\alpha_2)}{2}\right]\right\}\right)^n}{n!}\times e^{-\left(\frac{w}{2}\left\{R_1{}^2\left[\frac{\pi-2}{4}\right]+R_2{}^2\left[\alpha_2-\frac{\sin(2\alpha_2)}{2}\right]\right\}\right)} \quad (6)$$

Now, the probability for selecting at least *n* nodes in the shaded region is

$$P(n)=1-\sum_{i=0}^{n-1}\frac{\left(\frac{w}{2}\left\{R_1{}^2\left[\frac{\pi-2}{4}\right]+R_2{}^2\left[\alpha_2-\frac{\sin(2\alpha_2)}{2}\right]\right\}\right)^i}{i!}\times e^{-\left(\frac{w}{2}\left\{R_1{}^2\left[\frac{\pi-2}{4}\right]+R_2{}^2\left[\alpha_2-\frac{\sin(2\alpha_2)}{2}\right]\right\}\right)} \quad (7)$$

From the equation (7), we can obtain the probability of having at least one node within the border region as

$$P=1-p(X=0)$$
$$=1-e^{-\left(\frac{w}{2}\left\{R_1{}^2\left[\frac{\pi-2}{4}\right]+R_2{}^2\left[\alpha_2-\frac{\sin(2\alpha_2)}{2}\right]\right\}\right)} \quad (8)$$

To find the average number of hops between source and destination node, we assume that average distance covered by each hop will be equal. That is the link distance of every hope will be the same. To decrease the chance of link breakage we have keep the number of hopes as minimum as possible. The probability density function of the link distance, L_1 between source and next-hop node is defined as [5]

$$f(L_1)=2\pi\omega L_1.e^{-\pi\omega L_1^2} \quad (9)$$

Distance between two nodes, which provide a link to a route can be defined as the link distance. Link distance depends on the protocol which is used in the VANETs. Link distance will increase if we choose the border node of the transmission range as a next-hop node [6].

The probability of one-hop count can be calculated as follows:

$$P(1)=\int_0^{R_1} f(L_1)dL_1$$
$$=1-e^{-\pi\omega R_1^2} \quad (10)$$

The number of hops between source and destination node will vary accordingly with the distance of destionation from source. It may become 2,3or more. The probability of a two-hop counts [8] can be calculated as follows:

$$P(2) = \int_{R_1}^{2R_1} 2\pi\omega L_1.e^{-\pi\omega L_1^2} dL_1 \times \left[1 - e^{\frac{-\omega}{2}.A_S}\right]$$

$$= \left[e^{-\pi\omega R_1^2} - e^{-4\pi\omega R_1^2}\right] \times \left[1 - e^{\frac{-\omega}{2}.A_S}\right] \tag{11}$$

Similarly, for three-hop count is

$$P(3) = \left[e^{-4\pi\omega R_1^2} - e^{-9\pi\omega R_1^2}\right] \times \left[1 - e^{\frac{-\omega}{2}.A_S}\right]^2 \tag{12}$$

For k hop counts, probability can be defined as

$$P(k) = \left[e^{-(k-1)^2\pi\omega R_1^2} - e^{-k^2\pi\omega R_1^2}\right] \times \left[1 - e^{\frac{-\omega}{2}.A_S}\right]^{k-1} \tag{13}$$

Now we have to find the expected number of hops E_{NH} between source and destination node. Using equations (9), (10), (11) and (12) E_{NH} can be calculated as:

$$E_{NH} = \sum_{NH=1}^{k} NHP(NH) \tag{14}$$

$$= P(1) + 2P(2) + 3P(3) + ... + kP(k)$$

$$= \sum_{NH=1}^{k} NH\left[e^{-(NH-1)^2\pi\omega T^2} - e^{-(NH)^2\pi\omega T^2}\right] \times \left[1 - e^{-\left(\frac{w}{2}\left\{R_1^2\left[\frac{\pi-2}{4}\right] + R_2^2\left[\alpha_2 - \frac{\sin(2\alpha_2)}{2}\right]\right\}\right)}\right]^{NH-1} \tag{15}$$

where T is the link duration.

The node **velocity** and direction of nodes are two parameters that are necessary for path duration calculation. Here we assume that the nodes are omni directional. But node velocity has to be calculated. The relative velocity between nodes is inversely proportional to the link duration. The relative velocity of the source node and next-hop node should be known to determine the expected link duration. Let V_1 V_2, V_R be the velocity of source node, next hop node and relative velocity respectively. Then relative velocity V_R is given by,

$$V_R = \sqrt{V_1^2 + V_2^2 - 2V_1V_2\cos\phi} \tag{16}$$

Here we assume that all nodes have same velocity, then $V=V_1=V_2$.so the relative velocity V_R is given by,

$$V_R = V.\sqrt{2(1-\cos\phi)}$$

Since the next hop move only towards the destination to maintain the link between nodes, the value of ϕ vary from $\left(0-\frac{\pi}{2}\right)$. We assume that angle is uniformly distributed between $\left(0,\frac{\pi}{2}\right)$ and pdf of $f_\phi(\phi)$ is $\frac{2}{\pi}$.The pdf of V_R, $f_{V_R}(V_R)$ can be expressed as

$$f_{V_R}(V_R) = \frac{1}{\sqrt{1-\sin^2\frac{\phi}{2}}}\frac{1}{\pi}$$

$$= \sqrt{\frac{4V^2 - V_r}{V}} \cdot \frac{2}{\pi} \qquad (17)$$

Link duration is another important parameter regarding path duration. Link duration is the amount of time for which the direct link between two nodes within the transmission range is active and it is a part of the route. There must be atleast a single node in transmission range of the source node. For this paper we use B MFR Protocol for next node selection. The velocity of all the nodes in network is assumed to be equal . Hence there will always be a link between the source node and border node. Let *L* is the distance between source and next-hop node within radius R_1, then the expected value of *L* [9][10] can be computed as

$$E_L = \frac{nR_1}{n+1} \qquad (18)$$

Then the link duration T can be expressed as

$$T = \frac{E_L}{V_R}$$
$$= \frac{1}{V_R} \frac{nR_1}{(n+1)} \qquad (19)$$

The pdf of T, $f_T(T)$ is given by

$$f_T(T) = \int_0^V V_R \, fd_{VR}(V_R T, V) dv$$
$$= \int_0^V [E_L] \left[\frac{2}{\sqrt{4V^2 - V_R^{\ 2}}} \cdot \frac{2}{\pi} \right] dV_R \qquad (20)$$

Path duration can be derived from the *pdf* of the link duration. Let $T_1, T_2, T_3 ......T_{ENH}$ denotes the link duration of $1, 2, 3......E_{NH}$ hops respectively. E_{NH} is the average number of hops required to reach the destination as estimated in equation (13), therefore, the path duration can be expressed as:

$$T_{PATH} = MIN(T_1, T_2, T_3......T_{ENH}) \qquad (21)$$

By using Baye's theorem [11], the probability density function T_{PATH} is given by:

$$f\left(T_{PATH}\right) = E_{NH}.E_L.C_T^{\ E_{NH}-1} \qquad (22)$$

where T represents the link duration and C_T is the complementary cdf of T.

$$f\left(T_{PATH}\right) = E_{NH} \cdot f_T(T). \left[1 - \int_{T=0}^{\infty} f_T(T) dT \right]^{E_{NH}-1} \qquad (23)$$

Therefore, the average path duration can be estimated as

$$E_{T_{PATH}} = \int_0^{\phi} T_{PATH} . f\left(T_{PATH}\right) dT_{PATH}$$
$$= \int_0^{\phi} T_{PATH} . E_{NH} \cdot f_T(T). \left[1 - \int_{T=0}^{\infty} f_T(T) dT \right]^{E_{NH}-1} dT_{PATH} \qquad (24)$$

4. MATLAB Simulations

The mathematical model obtained for path duration estimation has been simulated using MATLAB. To estimate the path duration of the route in VANETs, use of the suitable routing protocol is also a critical factor. In this paper we adopted the B MFR protocol to select the next hope node. Using the MATLAB tools the B MFR protocol has been implemented. Next hop node is selected from the border to send data from source to destination (Fig.2.) By using B MFR protocol, the number of hops required will be minimum.

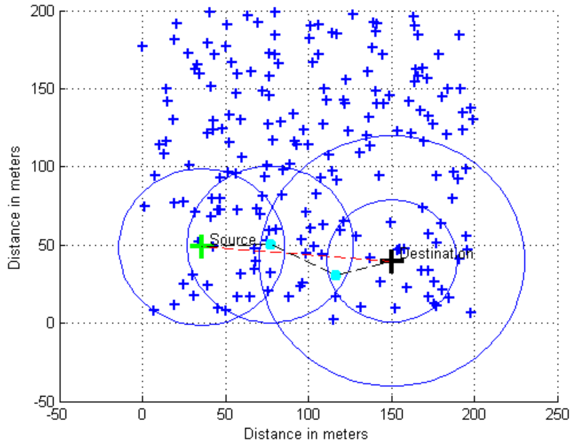


Fig.2 B MFR protocol simulation

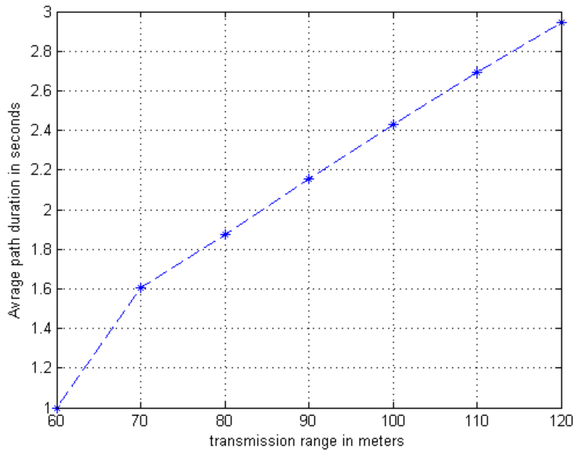


Fig.3 (a) Average path duration Vs Transmission range

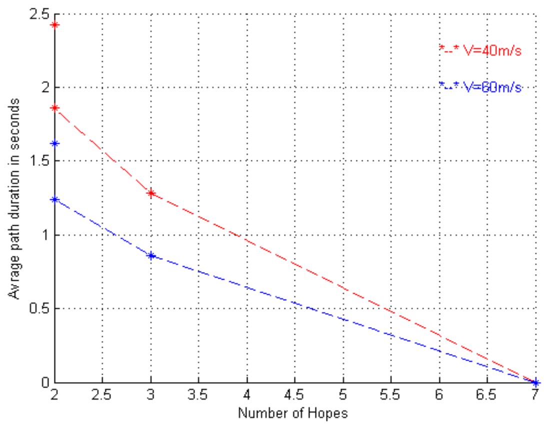


Fig.3 (b) Average path duration Vs Number of hops

Fig.3 (a) shows the plot of path duration Vs transmission range. It shows clearly that the average path duration increases as the transmission range increases. When the transmission range is maximum, the probability of finding the next hop node on or close to the border of sender's transmission range is also maximum.

Path duration Vs number of hops is shown in Fig.3 (b). Here the transmission range is kept constant. As the number of hops increase, the average path duration decreases for a fixed number of nodes and fixed area. Fig.3(b) also reveals that the path duration will higher for nodes with low relative velocity and for high velocity nodes ,the path duration will be small.

Conclusion

In our work, we have proposed an analytical estimation using B MFR protocol. The mathematical model are verified using MATLAB simulations. The position based routing protocol (B MFR) is also implemented using MATLAB. Simulation result concluded that the path duration will be higher for nodes with low relative velocity. When the transmission range is higher, the path duration also will be higher. Thus path duration estimation will help for successful communication and reduce the chance of path failure.

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