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# Analysis of Path Duration in VANETs Using B-MFR Forwarding Method

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## *Abstract*

Vehicular Ad hoc Networks (VANETs) is a network that connects multiple vehicles move in different velocities. The velocity and the direction are the main concern that affects on the route of the network. The high velocity of the vehicle is frequent cause changing in the topology of the network which turns on augmenting the probability of path failure. Therefore the path duration is used to enhance the performance of the path in the network. Many considerable studies were conducted to analyze the throughput, end to end delay and path duration to found the performance of routing protocol in the VANETs. In this paper, we present a model to estimate path duration with using border node-based most forward progress within radius (B-MFR) forwarding method. Five different scenarios for number of hopes, vehicle velocities, and direction of the vehicles are analyzed. MATLAB is used to found the analytical results. The obtained result indicates that the velocity, direction and numbers of hops effect in the average path duration and the end to end delay. Throughput is more sensitivity to the arrival rate.

**Keywords:** *VANETs, B-MFR forwarding method, Average path duration, Throughput, end to end delay.*

## 1. Introduction

Vehicle Ad hoc Networks (VANETs) is special case of Mobile Ad hoc Networks (MANETs) and real time network. VANETs are used vehicles instead of mobiles and the mobility of these vehicles is comparatively very high [1]. VANET is consisting of a Vehicle-to-Vehicle (V2V), Vehicle-to-Road side units (V2R), Vehicle-to-sensor on board (V2S) and Vehicle-to-Internet (V2I) communication system. In V2V communication, the data of the vehicle's statues is exchange between two vehicles. In V2R communication, the data about the road is exchange between the vehicles and the road side unit. In V2S communication, the data from the sensors in the vehicle are collected together and can be shared with other vehicles. In V2I communication, the vehicle is connected with the cellular base station [2]. The number of vehicles is continuously increasing, therefore the number of accidents on the road also increasing. VANETs are used to make the road more safety and comfortable [3]. Routing in the VANETs is the process of finding optimal path to forwarding the information between source and destination node. Position-base routing protocols is the one's best choice because geographic region. Forwarding the information is occurring either through direct communication or through intermediate node. The intermediate are vehicles that move in high speed in the VANETs [4]. The mobility and direction are the critical factors must be taking into account in the VANETs. The high mobility cases dynamic changes in the network topology, therefore they increase the path failure. The path between the source and the destination is frequently interrupt because the path failure. The new path must be found when one's path is interrupt [5]. The path is consisting of one or more links between pair of nodes. The



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lifetime of the path depends on the shortest link time. When one link is interrupt the path is failure. Path duration is the duration of time that all the links in the path are active. The links between the nodes are frequently failure due to high mobility of the vehicles; therefore path duration is estimation to decrease the path failure [6]. Doppler Effect is the change in the observed frequency between the source and the observed due to relative motion. The direction of intermediate nodes is found by using the Doppler Effect. When the intermediate node moves away the source, the frequency is decreases. Either when the intermediate node moves toward the source, the frequency is increased [7].

Throughput is the number of bits that send from the source to the destination and successful reach to the destination in the specific time (b/s). The vehicle density, the distance between the source and next node, and transmission probability are effects on the throughput [8].

Authors in [2] show that the analysis of path duration when the vehicles in a network are moving in a constant velocity. Intermediate nodes are direct from the source to the destination. In [8] found the throughput between two adjacent vehicles that moves in the communication range for each other, the power level for the received signal must exceed a threshold (received sensitivity). In this paper, the average path duration, end to end delay and throughput is estimation by using border-node based most forward progress within radius (B-MFR) routing protocol. The average path duration is estimated in many cases:

1. The velocities of the vehicles are constant.
2. The vehicles move on different velocities.
3. There are many paths between the source and the destination.
4. The vehicles are move on different velocities and directions.

## 2. Average path duration

Average path duration is the amount of time for which the path is active and available or till any of the link goes down. Border node-based most forward progress within radius (B-MFR) forwarding method is used to calculate the path duration. B-MFR is select the node found near the border or on the border of the transmission rang as the next hop to send the data until reach to the destination. The advantages of B-MFR are reducing the number of hops between the source and the destination; therefore reduce the probability of link failure. The disadvantages are the distance between the source vehicle and the next vehicles is long and is not suitable when there is smaller number of vehicles moving on the road.

### 2.1 Model of the system performance

In this section we illustrate the main parameters that effect in the path duration between two vehicles.

Distance between the source and the destination:

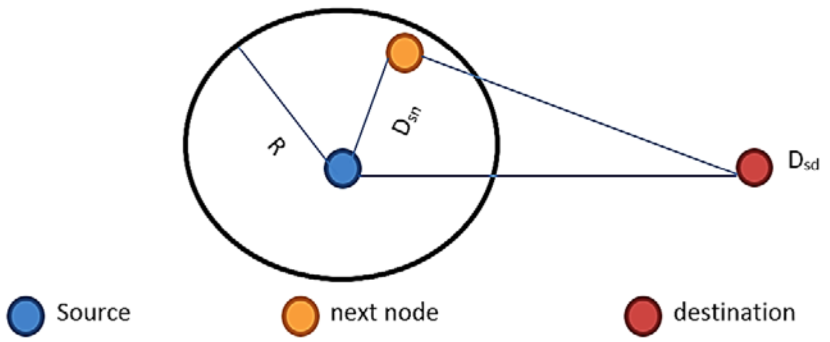


**Figure 1:** Distance between the source and next node, distance between the source and the destination.

Distance between the source node and the next- hop node (border node) and between the source node and the destination, respectively, as shown in Fig.1, may be given as:

$$D_{sn} = \frac{n \times R}{n+1} \quad (1.a)$$

$$D_{sd} = D_{sn} \times h \quad (1.b)$$

where, n is the number of vehicles in the transmission range, Ris the transmission range of the node, and h is the hops between the source and the destination.

**Velocity of nodes (vehicles)**

Assume the $v_1$ is the velocity of the source and the next hop node moves on ($v_2$) velocity. The relative velocity between two vehicles is given by:

$$v_r = \sqrt{{v_1}^2 + {v_2}^2 - 2 \times v_1 \times v_2 cos\alpha} \qquad \alpha = 0 \text{ to } \pi/2 \quad (2)$$

When, $v_1$=$v_1$=v (i.e. the vehicles moves on constant velocity), then:

$$V_r = V \times \sqrt{2(1 - cos\alpha)} \quad (3)$$

Also, the link duration is defined as the amount of time for which two nodes are connected directly, without any intermediate node and found in the transmission range and it is part of the route. Link duration is calculated in:

$$T = \frac{D_{sn}}{Vr} \quad (4)$$

The probability distributed function (pdf) for T is:

When $V_1$=$V_2$=V

$$f_T(T) = \int_0^V D_{sn} \times [\frac{2}{\sqrt{4V^2 - V_r^2}} \times \frac{1}{\pi}]\, dV_r \quad (5\text{-a})$$



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When the velocity of vehicles are different, then

$$f_T(T) = \int_0^{V_r} D_{sn} \times [\frac{2}{\sqrt{4V^2-V_r^2}} \times \frac{1}{\pi}]\, dV_r \qquad (5\text{-b})$$

Another parameter that used to describe the performance of the network is the path duration. It may be given as the following when the vehicles move in constant velocity:

$$F\,(T_{path}) = h\times f_T(T) \times [1-\int_{T=0}^{\infty} f_T(T)\, dT]^{h-1} \qquad (6\text{-a})$$

when the velocity of vehicles are different, then

$$F\,(T_{path}) = \sum_{i=1}^{h} f_{T_i}\,(T_i) \times \prod_{i=1}^{h-1}[1 - \int_{T=0}^{\infty} f_{T_i}(T_i)\, dT_i] \qquad (6\text{-b})$$

where h Expected hop from the source to the destination

End-to-End delay is the time taken to reach data from the source to the destination, is given by

$$D = \sum_{i=1}^{h} T_i + (i\text{-}1)\, P \qquad (7)$$

where P Processing time that take in each intermediate node.

Doppler-Effect is the change in the frequency. If the observer moves toward the source then the frequency is increased, else if the observer moves away from the source then the frequency is decreased. These two cases are illustrated as follows:

1. The source and the next vehicle at the same direction:

$$F = \frac{c-v_s}{c-v_n} Fs \qquad (8\text{-a})$$

2. The next vehicle is move toward source:

$$F = \frac{c+v_s}{c-v_n} Fs \qquad (8\text{-b})$$

Where C sound velocity, Fs frequency of the source, Vn velocity of the next hop, Vs velocity of the source. Throughput is the number of bits that send from the source to the destination and successful reach to the destination in the specific time [8]. The throughput from the source to the destination is given by

$$Th = pt\,(1\text{-}e^{-wR_c})(1\text{-}pt)\times \frac{\prod_{h=1}^{\infty}[(1-pt)+(pt\,\sum_{n=0}^{h-1}\frac{(w\,R_f)^n}{n!}e^{-wR_f})]^2}{(1-pt)+pte^{-wR_f}} \qquad (9)$$

where pt transmission probability, w Vehicle density, $R_c$ communication range is the distance from a given transmitting vehicle to the received vehicle, k number of hops.

$$R_f = R_c\, \beta^{1/\alpha} \qquad \beta = 4 \qquad \alpha = 4$$



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## 3. Simulation and Results

This section shows the results from the model illustrated in Section 2.1. The parameters values are adopted in this evaluation are that used by [2, 9]; the transmission range (R) = 100 m, vehicles density= 30 vehicles/m, frequency=500 Hz. The average path duration and end to end delay for multi different cases:

**Case 1:** Average path duration when number of hops = 1-10 and the vehicles moves at a constant velocity.

Figure 2 (a) shows the network between the source and the destination. The blocks represent the vehicles in the network and the numbers inside the blocks are the vehicle's velocity. The source can be connected with the destination throw multi hops from 1 to 10. The considered velocities of the vehicles are: 40 km/h, 50 km/h, 70 km/h, or 120 km/h, respectively. The source can be connected directory with the destination, i.e. one hop, or the source can be connected with the vehicles found in the border or near the border of the source's transmission rang. In all cases the border vehicle is the first next hop and this vehicle connected to the destination in case of two hops, or to another one through another node, and so on. The edge's number at the figure is the time to send data between vehicles that connected in this edge. The average path duration may be found in the simulation when the hops are either 1, 2… or 10.

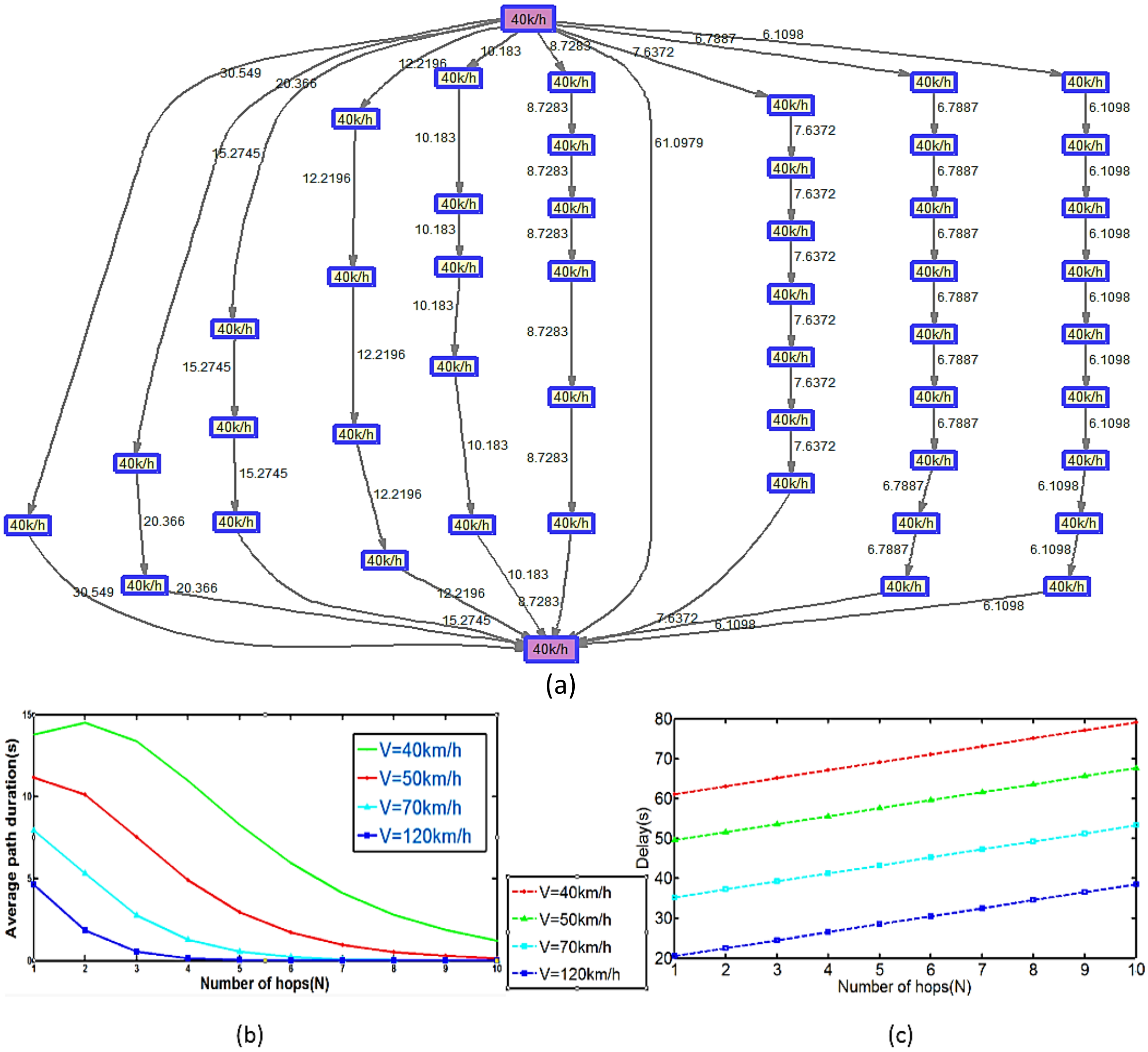



**Figure 2:** (a) network connection between source and destination. (b) Average path duration versus number of hops. (c) Delay versus number of hops.

Figure 2 (b) shows the average path duration as a function of the number of hops. The velocity of the vehicles is: 40 km/h, 50km/h, 70km/h, or 120km/h, respectively. When number of hops increases the average path duration decreases. This due to the probability of link failure increases and the availability of the path decreases. The velocity also effect in the average path duration, when increasing the velocity decreasing path duration and vice versa. Figure 2 (c) shows the delay to send the packet from the source to the destination. When number of hops increases the time required to reach the data to the destination increases. When the velocity of the vehicles increases the delay decreases. When the vehicle's velocity in the network is 40km/h will take long time to reach the data to the destination compared to the case when the vehicle's velocity is 70km/h.

**Case 2:** Average path duration when number of hops = 1-10 and each transmission range consists of three vehicles on the border that moves on different velocities.

When the transmission range of each node found in the path from the source to the destination is consists of three vehicles in the border of the transmission range moves in different velocity as shown in the Figuare.3 (a). The transmission range of the source is consists of the three vehicles in the different velocity, which are found on the border or near the border of the transmission range towards the destination. These vehicles as represent as the next hop node to the source. Velocities of the vehicles, for example, are (40km/h, 20km/h, and 70 km/h) and the source's velocity is (60 km/h). with selecting the fastest vehicle as a next hop node to receive the data from the source and send the data either direct to the destination (i.e. two hops), or to the fastest vehicle found in the on the border or near the border of the transmission of the next hop node and then to the destination (i.e. three hops), and so on to 10 hops. The average path duration of this network may be found when selecting the fastest velocity from the vehicles found in the border of the transmission range, or slowest vehicles, respectively, are shown in the Figuare.3 (b).This results show that the average path duration decreases with increasing number of the hops. This is due to increasing of the probability of the link failure. Velocities of the vehicles also effect on the average path duration, when the velocity increases the average path decreases. Figure 3 (c) shows the delay as a function to the number of hops. The delay increases with increasing the number of hops because increasing the accumulative time taken in each hop and in the processing in each vehicle.

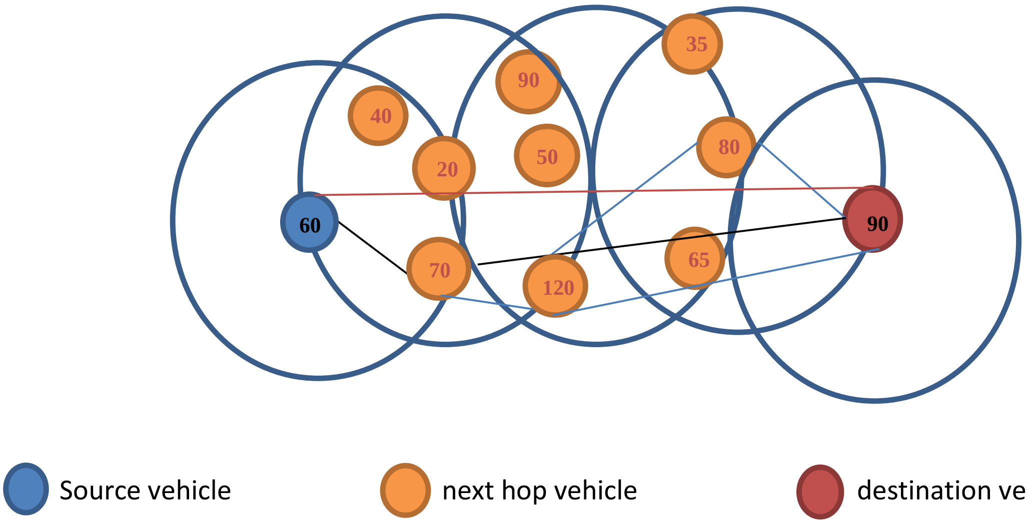



**Figure 3:** (a) connection between the source and the destination when the fastest vehicle's velocity as a next hop node is selected.

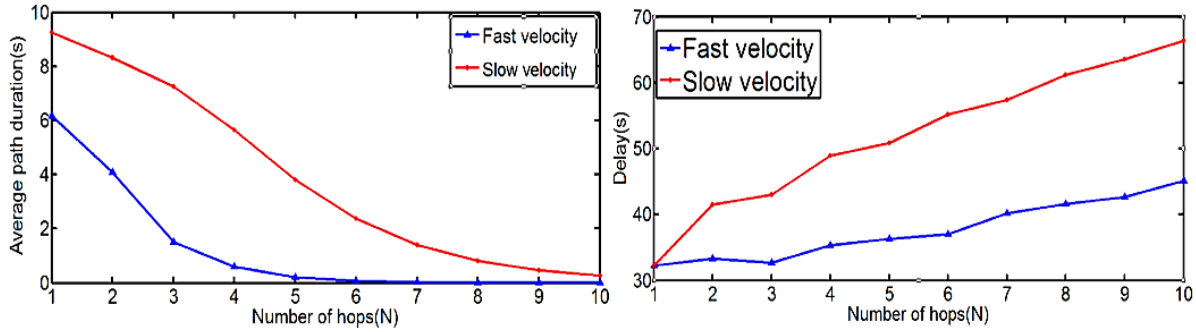



**Figure 3:** (b) Average path duration versus number of hops. (c) Delay versus number of hops

**Case 3:** Average path duration when number of hops = 1 -10 and there are seven available paths between the source and the destination. Selecting the shortest path is based on using dijkstra algorithm.

Dijkstra algorithm is the algorithm that used to select the shortest path between two nodes in the network using graph mode that content nodes and edges. In this algorithm assigned zero to the source node and infinity to the others nodes. It starts from the source and selects the minimum link's value and update the cost of the node that found in the second party for this link. The new cost to this node is found by adding the cost for the source node and the link's value. This process is continuing until reach to the destination and the shortest path is found [10].

There are seven available paths between the source and the destination, as shown in the Figure 4 (a). The paths are different from each other in the hops and velocities of the vehicles.

Path 1: 60 km/h - 80 km/h -70 km/h - 50 km/h - 80 km/h

Path 2: 60 km/h - 80 km/h - 70 km/h - 80 km/h

Path 3: 60 km/h - 90 km/h - 70 km/h - 50 km/h - 80 km/h

Path 4: 60 km/h - 90 km/h - 70 km/h - 80 km/h

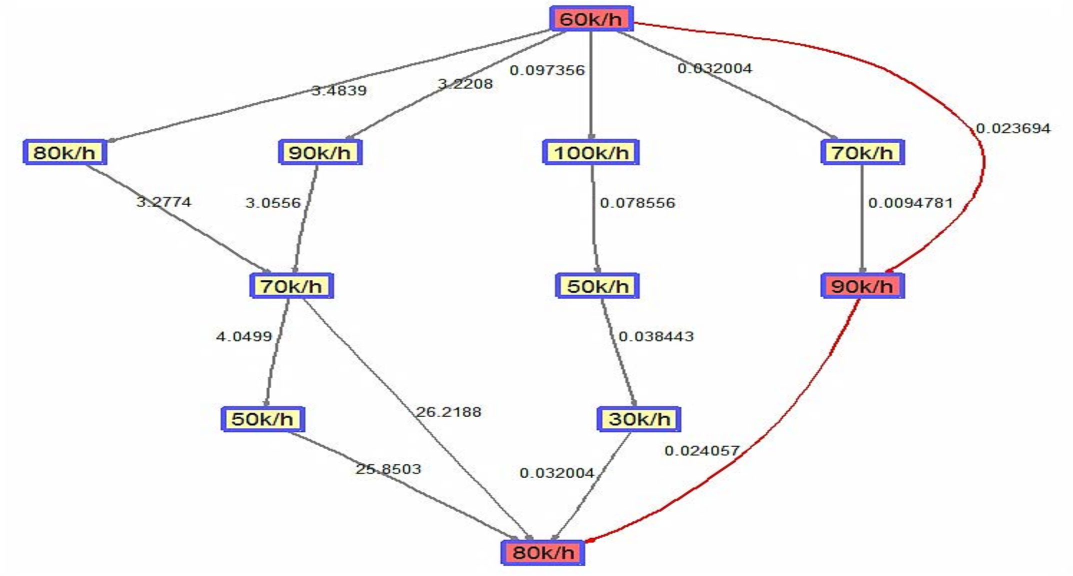
Path 5: 60 km/h - 100 km/h - 50 km/h - 30 km/h - 80 km/h

Path 6: 60 km/h - 70 km/h - 90 km/h - 80 km/h

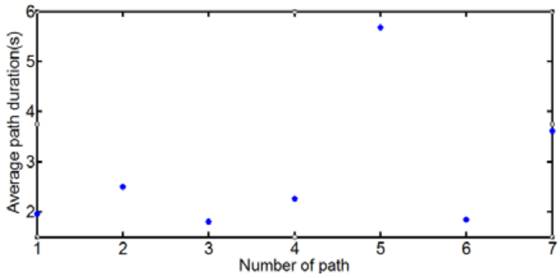
Path 7: 60 km/h – 90 km/h – 80 km/h

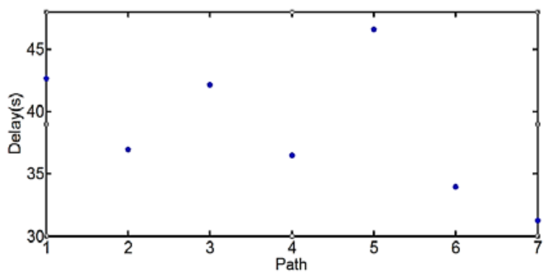
The red path is the path that selected by using dijkstra algorithm as a shortest path, there is path 7.

Fig.4 (b) shows the average path duration for each path in the network, as shown path 6 is the path has less available time. Fig.4 (c) shows the delay for each path in the network. The path 7 is the path takes less time to reach the data to the destination and this is symmetric with dijkstra algorithm.




(a)




(b) (c)

**Figure 4:** (a) network with multi paths and hops, (b) Average path duration for each path, (c) Delay respect to path.

**Case 4:** Average path duration when number of hops = 1-10 and the intermediate vehicles move in different velocities and the directions is in the line of side between the source and the destination.

Figure 5 shows the connection between the source and the destination. The intermediate vehicles move in different velocities and directions. The source searches for the next node from the vehicles found in the border of the transmission rang. The next node must satisfy two conditions:

1. Moves away from the source but moves towards the destination.

2. Moves in the fastest velocity (comparatively).

The process is continuing until reaching the destination.



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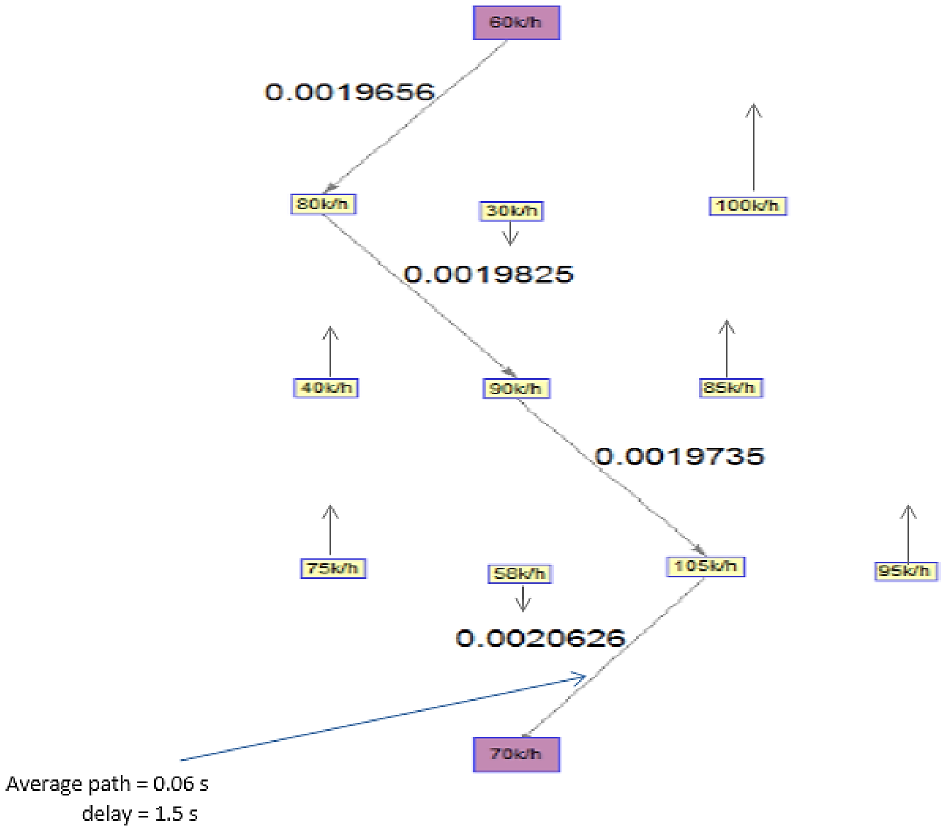
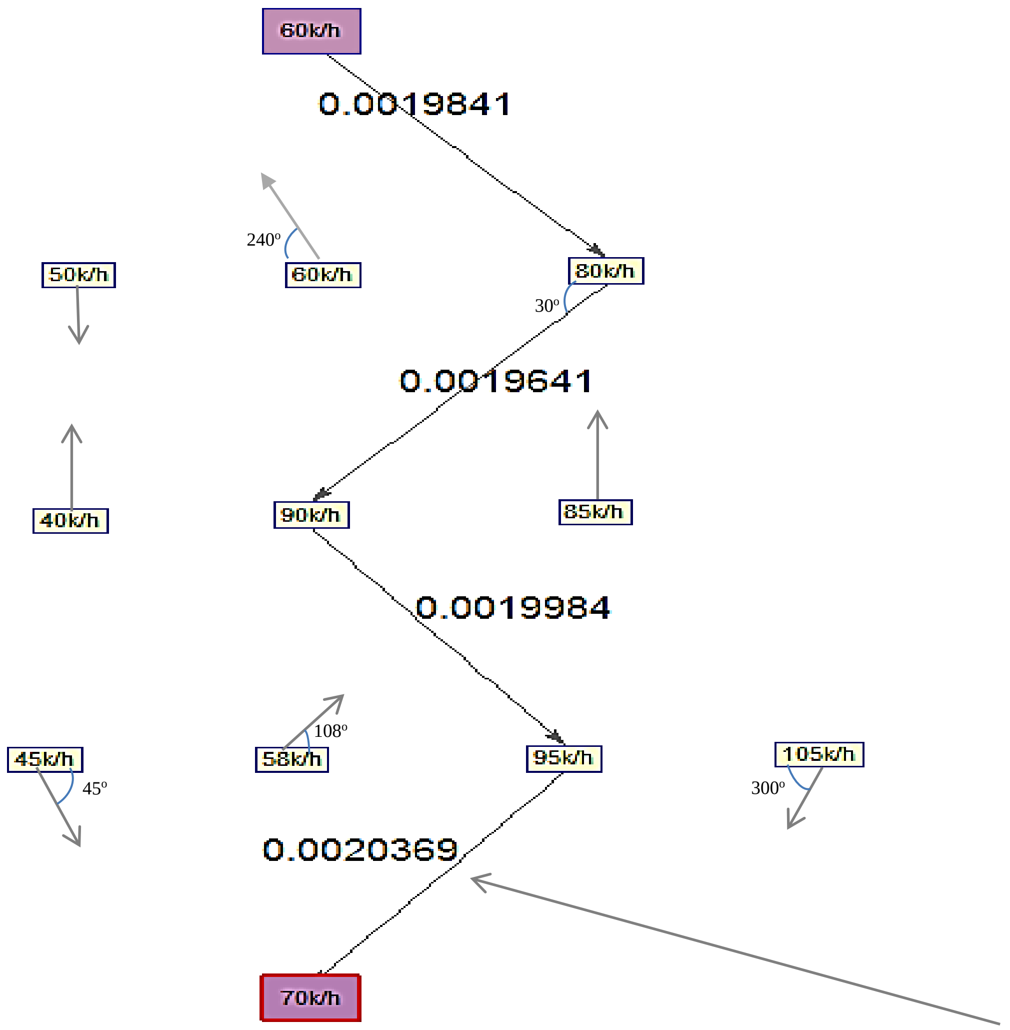



**Figure 5:** Network between the source and the destination and intermediate nodes.

Case 5: Average path duration when number of hops = 1-10 and the intermediate vehicles moves in different velocity and the direction is not in the line of side between the source and the destination (i.e. moves in an angle).

The intermediate vehicles moves in different velocities and some vehicles move in an angle not in the line of side, as shown in the Figure.6. The conditions that are illustrated for case 4 must be also satisfied in this network.




Average path = 0.05 s

Delay = 1.5 s

**Figure 6:** Network between the source and the destination and intermediate node

As shown in Figure.7, the throughput reaches the maximum at a certain value of the transmission probability. The vehicle density (Arrival rate) and average distance are affected on the throughput

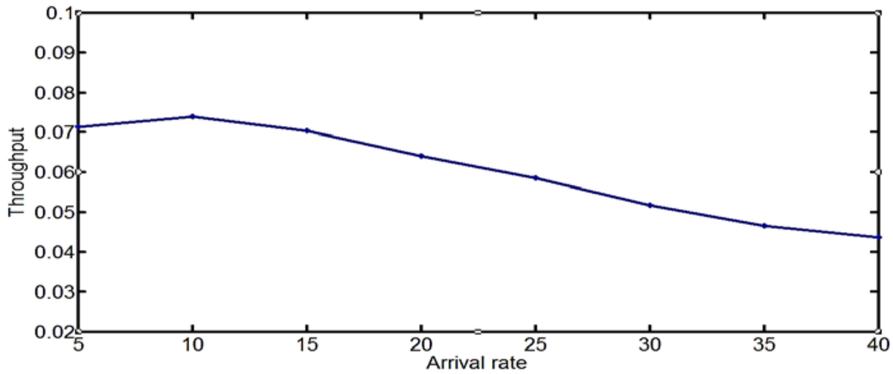



**Figure 7:** Throughput as a function to the arrival rate

## CONCLUSION

The paper is conducted to present a model to estimate the average path duration, throughput and delay for multi cases for the VANETs network. The results show that the average path duration decreases when the velocity of the vehicles and number of hops increase. Direction of the vehicles also effect on the average path duration. Throughput is more sensitivity to the increasing in the arrival rate. End to end delay increases as the number of hops increases, but it decreases when the velocity of the vehicles increases.

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