Enhancing Route lifetime in Vehicular Ad Hoc Networks Based on Skellam Distribution Model

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Abstract: the emergence of smart cities and the need to use intelligent transportation systems has led to an increased reliance on vehicle ad hoc networks (VANET). The topology of VANET is highly dynamic, which results in a short effective routing time. This paper presents a two-stage algorithm to select a route that can sustain communication between vehicles for as long as possible while taking into account the variables that affect the VANET topology. The first stage uses Skellam distribution model to assess the connectivity probability of paths in a 2d road network based on traffic-flow and the number of vehicles joining and leaving the network, accordingly, the path with the highest connectivity is chosen. In the second stage, the control packets sent only to vehicles on the selected path to detect routes between source and destination, thus reducing the overhead of control packets and increasing network stability. the algorithm adopts the principle of global evaluation to estimate the lifetime of the detected routes within the chosen path. the route with the best estimated lifetime is chosen to be the active route. in the event of route failure, the validity of the next route in lifetime is confirmed to be adopted as the alternate route. The proposed algorithm was compared with both on-demand distance vector routing protocol (AODV) protocol and the modified location-aided routing (LAR) protocol. The proposed algorithm showed greater network stability, higher performance in terms of longer lifetime route detection, less energy consumption and higher throughput.

Keywords: AODV, Route Lifetime, Skellam Distribution, Throughput, VANET.

1. Introduction

A Vehicular Ad hoc Network (VANET) is a type of network that is based in its work on the principle of Ad Hoc networks, through which vehicles try to achieve communication with each other (V2V) or with road infrastructure (V2I) [1] [2]. These networks are used in highways and city centers as well. The interest in VANET has increased in recent years as a result of developments in the fields of communications, in addition to the uses and applications of Internet, and smart devices [3] [4]. This type of network is characterized by instability in its topology, as it is in a state of continues change [5]. Whereas, while some vehicles depart the network, others join the coverage area to be a part of the network, moreover, the locations of its nodes are changed continuously [6] [7]. One of the most popular protocols used to achieve on-demand routing is the Ad-hoc On-Demand Distance Vector routing protocol (AODV), whose main activities can be summarized in two processes, namely how to discover a route, and then how to maintain it. The first process takes place when a node needs to establish a route to a specific node, as the source node broadcasts a request for a path across the network using a flood of packets until the request reaches the destination node [8] [9]. Then the latter sends a response packet to the source node. The path that the destination node packet will take toward the source node will be the reverse route. The second process, routing maintenance, begins when the active path is disconnected due to the movement of the nodes, whereby a message is sent to inform the neighboring nodes of the link disconnection, which could potentially be used to maintain the path [10]. Another commonly used on-demand routing protocol is called Location-Aided Routing (LAR) protocol [11]. This protocol is similar to AODV, but it uses local information to define two areas for connecting the destination node with the source node in order to reduce routing indirect costs. Nabil et al. [12] proposed an improvement to LAR protocol by imposing some conditions for redirecting the route request (RREQ) packets to the next node based on the assumption that both the source and the next node move in the same direction and are located in a pre-specified radius zone, as well as the period of time in which the next node will remain within the communication range. Lengliz and Slama [13] used a Route Life Time (RTL) Policy to improve AODV and DSR. The approach attempts to find the optimum distances between vehicles and the optimum speed to explore a route with the maximum life on a straight highway of two sides. The results showed that DSR outperforms AODV in network throughput. A routing protocol framework for VANET that uses inference methods such as speed, direction and vehicle location is presented in [14] [15] [16] [17]. Goswami et al., [18] presented an analytical comparison based on different QoS parameters between Destination Sequenced Distance Vector (DSDV), Dynamic Source Routing (DSR) and AODV protocols. The used parameters are throughput, packet delivery ratio (PDR), and jitter. Hassan et al. [19] introduced a comparison based on several metrics between AODV, DSDV, and ad-hoc on-demand multipath distance vector (AOMDV). The results showed that AOMDV is more suitable for use in rescue missions. Rivoirard et al. [20] performed an evaluation of two reactive protocols, AODV and DSR, and two proactive protocols, the Geographic Routing Protocol (GRP), and the Optimal Link State Routing (OLSR). The results showed that these protocols work well when there is a limited number of vehicles, but increasing them leads to more delays. As a solution to address the limited coverage problem, a set of RSUs can be deployed to improve VANET's V2I communications performance on urban roads [21]. Whereas in cities, mobile RSUs can be used as an alternative to fixed RSUs, by controlling their activation or passivation in an adaptive manner [22]. Shrestha et al. [23] combined conventional cloud and fog computing in VANET as a possible way to solve some of the problems facing such networks. The defects facing the Intelligent Transportation System (ITS) that relies mainly on VANET and IoT, the capabilities provided by the routing protocols and security that VANETs face, and the importance of interconnection and coordination between the Internet of Things and VANET is addressed in the Traffic Control Management System [24]. Whereas, Yah et al. [25] used three coefficients to optimize energy, delay, and PDR in VANET based on non-linear equations extracted from MAC protocol. Sarao [26] implemented a fuzzy inference system to improve the use of the AODV protocol in VANET. The node strength, number of hops, and maximum speed were considered as the system inputs to determine which node represented the next hop. Maan and Chaba [27] adopted a method relying on fuzzy logic for selecting head-clusters with maximum lifetime to achieve communication in 5G VANET networks. Most of the aforementioned research did not take into account the effect of vehicles density and its continuous change when choosing the communication routes. Also, most of them did not comprehensively assess the longevity of the routes from source to the destination, while some research focused on enhancing route lifetime by partitioning the path into local areas or adjacent segments, which may not lead to choosing the longest connectivity route. As a result, the number of control messages increases, which can lead to congestion in the communication channel.

This paper examined the effect of the Skellam distribution on the density of vehicle within a two-dimensional road network covering the communication between the source and destination vehicle by calculating the connectivity probability depending on the expected number of vehicles joining and leaving the roads in this area. Based on this, the possible routes within the path with the best connectivity are explored, after which the lifetime of the routes is calculated to choose the one with the longest lifetime.

The remainder of this paper is organized as follows; Section 2 provides an explanation of the Skellam distribution and how it can be used as a system model in calculating the connectivity probability. It also introduces the details of the proposed algorithm. The simulation results and comparison are presented in section 3. While section 4 includes the conclusions drawn from this work.

2. System model and Route Selection Algorithm

This section introduces the Skellam distribution model to find vehicle connectivity probability. Skellam distribution, is the difference between two independent random variables ($\lambda_1(t)$ - $\lambda_2(t)$). These two variables are Poisson distributed in different expected densities. In Poisson distribution, if λ is the vehicle density per kilometer on road with length L, then the probability of having α vehicles on this road is [16]:

$$p(\alpha,\lambda L)=\begin{cases}\frac{(\lambda L)^{\alpha}}{\alpha!}e^{-\lambda L}, & \alpha\geq 0\\ 0 & otherwise\end{cases} \quad (1)$$

In a VANET that covers a 2D road network, many communication methods can be established between the source vehicle S and the destination vehicle D. The dynamic movement in the VANET topology makes vehicle density unstable which affects the life of any route and may cause communication continuity issues. Suppose that at a given moment, the density of vehicles joining the coverage area on a particular road between the two vehicles *S* and *D* is λ_1, the density of vehicles leaving this area is λ_2, and the distance between the two vehicles on this road is χ with a communication range of *R*, the probability of having α number of vehicles within the communication range can be expressed by

$$p(\alpha;\lambda_1,\lambda_2)=f\big((\lambda_1-\lambda_2)\chi/R\big)$$

In the event that α = 1, then *p* will give the probability of having at least one vehicle covering the communication in a portion of a road of length *R*. This value represents the connectivity probability and can be calculated based on Skellam distribution as follows

$$p(\alpha;\lambda_1,\lambda_2)=e^{-((\lambda_1+\lambda_2)\chi/R)}\left(\frac{\lambda_1}{\lambda_2}\right)^{\alpha/2}\mathrm{I}_{|\alpha|}\left(2\chi\sqrt{\lambda_1\lambda_2}/R\right) \quad (2)$$

where $\mathrm{I}_{|k|}$ is the modified Bessel function of first kind [28] and defined as

$$\mathrm{I}_{|\alpha|}\left(2\chi\sqrt{\lambda_1\lambda_2}/R\right)=\sum_{n=0}^{\infty}\frac{(\chi\sqrt{\lambda_1\lambda_2}/R)^{2n+\alpha}}{n!(n+\alpha)!}$$

This mathematical model of Equation (2) can provide the basis for an optimization algorithm for long-lifetime route selection.

In this section the proposed algorithm for finding and selecting the route with the best expected lifetime is explained. The algorithm works in two stages. The first stage involves calculating the connectivity probability based on the Skellam distribution of potential road paths, while the second stage involves finding the route that is expected to have the longest lifetime out of the routes likely to be found within the boundaries of the road path that has the best connectivity probability. The proposed algorithm is called only when there is a need to establish a communication route and, therefore, the proposed protocol is of reactive type.

2.1 First stage

For the first stage, suppose that there are *M*-road paths between the S and D vehicles. In order to calculate the connectivity probability for each of these paths, three values must be determined, namely the density of joined vehicles λ_1, the density of the leaving vehicles λ_2, and the path length χ_i between S and D.

To simplify the simulation, a linear relationship between vehicle velocity and vehicle density has been considered. So, if *q* represents vehicle flow rate (vehicle / hour), and *v* is the average vehicles speed, then vehicle density can be determined by:

$$\lambda = q\ /\ v \text{ (vehicle/km)} \quad (3)$$

The hypothesis considered in this work is that the road vehicle flow is according to Poisson distribution model, the direction and speed of the vehicles are normally distributed with zero acceleration, and the locations of vehicles within the study area are known. The number of vehicles that will join and which will depart the communication area between S and D during a certain period of time can be determined by calculating the distance separating each vehicle tends to join or leave from this area, which depends on the vehicle's location, speed, direction as well as the communication radius *R*. If this distance is less than or equal *R*, and the vehicle was outside the boundaries of the concerned area, then the vehicle is considered to have joined, but if it becomes outside the boundaries of this area by a distance greater than *R* and that it was within the area, it will be considered to have left. The term joining the area means that the distance between the vehicle that intends to enter the area with any vehicle located within the communication area is less or equal to *R*. And the vehicle's departure from this area is when the closest distance to this vehicle is more than *R* from any vehicle within this area. Therefore, the probability of a vehicle joining the region can be expressed by

$$p_{join}(d) = \begin{cases} 1 & if\ d \le R \\ 0 & if\ d > R \end{cases} \quad (4)$$

While the probability that a vehicle will depart is expressed by:

$$p_{depart}(d) = \begin{cases} 1 & if\ d > R \\ 0 & if\ d \le R \end{cases} \quad (5)$$

To calculate *d*, let's consider the case shown in Figure 1, where vehicle *i* travels at speed v_i in the direction dr_i, vehicle *j* travels at speed v_j in the direction dr_j, and (x_i, y_i), (x_j, y_j) are geometric coordinates of vehicle *i* and *j* respectively. Then the distance d_{ij} between the two vehicles after *t* time units can be calculated according to Pythagorean equation of right triangle:

$$d_{ij}^2 = [(x_i + dr_i\, v_i\, t) - x_j]^2 + [y_i - (y_j + dr_j\, v_j\, t)]^2 \quad (6)$$

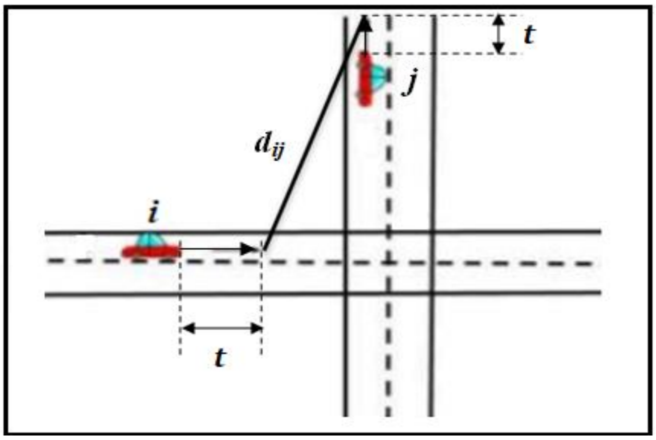


Figure 1. Distance between two vehicles after t time

The direction *dr* is assumed to be a two-value variable (-1 and 1) as shown in Table 1.

Table 1. Direction Values.

dr	Direction of movement	Value
EW	from east to west	1
WE	from west to east	-1
SN	from south to north	1
NS	from north to south	-1

Depending on the Skellam distribution given in Equation (2), the connectivity probability is calculated for each of the *M*-road paths. Among them, the path with the best probability will be chosen for the purpose of its adoption in determining communication routes in the next stage of the algorithm. The rest of the *M*-road paths will be neglected as it is unlikely that they will be able to achieve communication.

2.2 Second stage

In the second stage, vehicle *S* sends a request packet exclusively for vehicles within the path chosen by Stage 1 to search for a suitable route to vehicle *D*. This stage attempts to utilize the control packets to discover possible routes that can be established between vehicles *S* and *D* , bearing in mind that any of these routes must be within the allowed TTL. Note that when setting the TTL value, it should not be too low, which leads to the packets being dropped early, that is, before they reach a suitable distance, and at the same time it should not be too large, which leads to saturation in the channel [29]. After that, the estimated lifetime of the discovered routes is calculated and arranged in descending order, so that each route is given a specific rank according to its estimated lifetime. Each vehicle falls within these routes stores information in a table that includes the route rank, the vehicle that precedes it and the vehicle that follows it for each of the determined route. Then, the route with the best longevity is chosen as the current active route between vehicle *S* and *D*.

To cover V2I communications as well as V2V, a number of RSUs have been deployed in various locations. In this stage, it is assumed that *i* and *j* are two successive vehicles located in the path chosen by Stage1 and they are within the radius of the transmission coverage area, these two vehicles are assumed to be linked by a hypothetical segment *k*, and *K* is the total number of linked segments in each of the determined routes. In a multi-hop route, the smallest link segment time determines the lifetime of the route. The steps of the second stage of the proposed algorithm are as follows:

1. The source vehicle *S* broadcasts a route request to neighbor vehicles.
2. Only vehicles present in the chosen path respond to identifying possible routes to the destination vehicle.
3. All the detected routes between *S* and *D* should not exceed the permissible TTL.
4. For each route(*n*), (*n*=1, …, *N*), where *N* is the number of the detected routes, do steps 5-8
5. For each $segment_k(n)$, (k=1, …, $K(n)$) do steps 6-8
6. Calculate the estimated communication lifetime of the $segment_k$ (*ELTS*)
7. Store *ELTS* value in a vector *T*(*n*)
   $$T(n) = \{ELTS_1, ELTS_2, \ldots, ELTS_k\}$$
8. Determine the estimated lifetime of the route (*ELTR*)
   $$ELTR(n) = min(T(n)) \quad (7)$$
9. Sort the N routes in descending order according to their *ELTR* values. In the event of a tie, and to reduces the routing overhead, the route with the fewest number of hops (NoH) takes precedence.
10. Rank each route according to its sequence order from N to 1.
11. Select the route with highest rank as the best estimated lifetime (*BELT*) route. This can also be expressed by
    $$\begin{aligned} BELT &= Route(\max(\min(T(n)))) \\ &= Route(\max(ELTR(n))) \\ &= Route(Rank == N) \end{aligned} \quad (8)$$

The ratio of the BELT value with respect to the ELTR value of the other detected routes represents an indicator to measure the amount of improvement in route lifetime (ImLT) and is calculated as follows:

$$ImLT(n) = BELT/\ ELTR(n),\ for\ ELTR(n) \neq 0 \quad (9)$$

It is assumed that the movement of vehicles can be either in the same direction or in different directions, and that the roads on which they drive may be in parallel or perpendicular to each other. It is also assumed that there were no obstacles between these roads.

Equation (6) can be applied to calculate the value of *ELTS* of any segment *k* by considering $d_{i,j} = R$, which yields:

$$R^2 = [(x_i + dr_i\, v_i\, t) - x_j]^2 + [y_i - (y_j + dr_j\, v_j\, t)]^2$$

$$(v_i^2 + v_j^2)\, t^2 + 2t\, [dr_i\, v_i\, (x_i - x_j) - dr_j\, v_j (y_i - y_j)] + [(x_i - x_j)^2 + (y_i - y_j)^2 - R^2] = 0 \quad (10)$$

The *ELTS* value can be determined by solving Equation (10) for *t* using the quadratic formula, and considering the following rules:

1. Since the time is obviously positive, *ELTS* = the positive root of *t*, while the negative root is rejected.
2. For the case of two vehicles *i* and *j* move in the same direction with $v_i = v_j$, then *ELTS* = ∞.
3. The RSUs are assumed to be stationary, and their velocity is equal to zero.

The second stage of the proposed algorithm is also responsible for maintaining communication in the event of a route breakdown, in which the vehicle where the break occurred will search its table for the next ordered rank-route. If it is present, it will verify its validity and then send a control message to the next vehicle in the new route, informing it to adopt this route, otherwise, a message will be sent to the precursor vehicle informing it of the failure of the current route, so that this vehicle in turn will search for the route that carries the next rank-route, and so on.

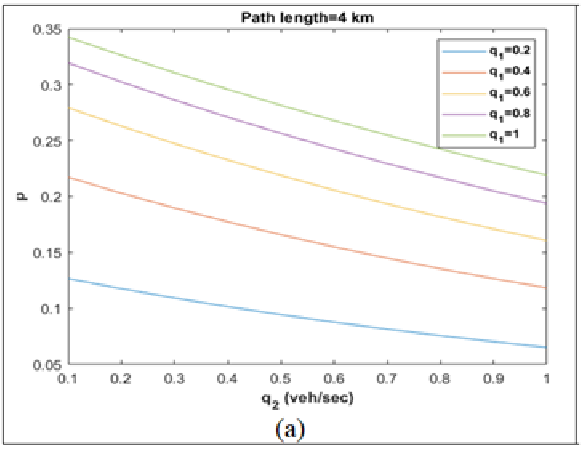
3. Simulation Results

The simulation is based on a road network over a total area of 4 km^2 in which a number of vehicles travel at different speeds and directions distributed normally, and that the distribution of the traffic-flow for these vehicles is according to Poisson distribution. The simulation also considers that due to the movement of vehicles in VANET, during each time period a number of vehicles join the network and some leave with an incidence rate dependent on the Skellam distribution, as well as a number of RSUs added and distributed across roads in different locations. Results were extracted using MATLAB using the simulation parameters illustrated in Table 2.

Table 2. Simulation Parameter Values

Parameter	Value
Simulation area (m^2)	2000×2000
Number of vehicles	30 – 80
Number of RSU	10
Transmission range (m)	300
Vehicle speed range (km/hr)	40 – 100
Packet rate (packets/sec)	10
Packet size (bit)	512

Initially, the effect of Skellam distribution on connectivity probability is evaluated by adopting different path lengths with several join and departure rates, and different velocity rates as well. Figure 2.a illustrates the connectivity probability for a 4 km path with different values of vehicle join rates q1 versus departure rate q2 (veh/sec).



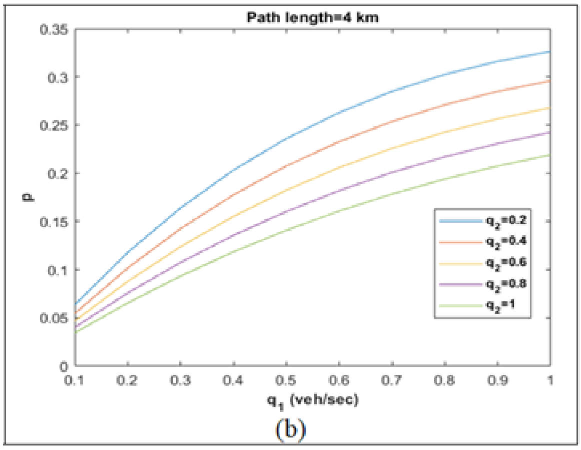
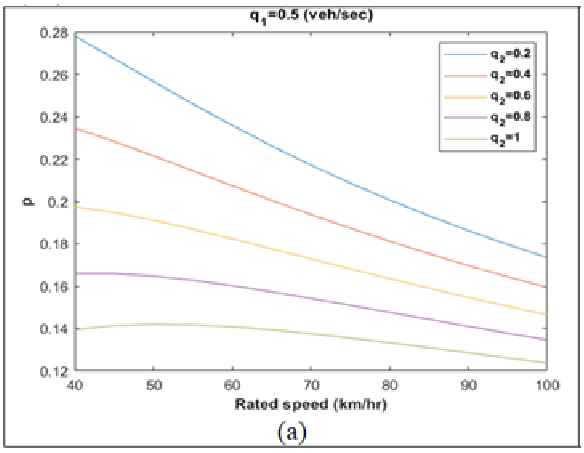


Figure 2 (a,b). Skellam connectivity probability

Whereas Figure 2.b shows the connectivity probability of different values of the departure rates q_2 versus the joining rate q_1 for the same path length. It is clear from Figure 2 that for a high vehicle joining rate the connectivity probability increases, correspondingly, the higher the rate of departing vehicles, the lower the connectivity probability.

The effect of vehicle velocity rate on the connectivity probability according to Skellam distribution is illustrated in Figure 3. It is found that increasing the velocity rate leads to a decrease in the connectivity probability. And this value decreases as the amount of departure rate q2 increases as shown in Figure 3.a. Whereas, the effect of increasing the joining rate of q1 is directly proportional to the connectivity probability as shown in Figure 3.b.



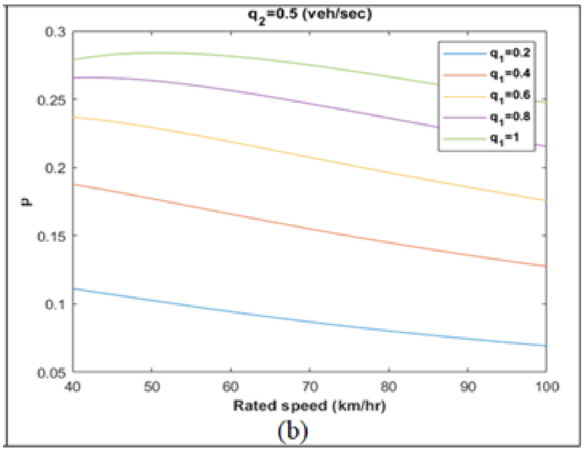


Figure 3 (a,b). Effect of rated speed on connectivity probability

In this work, the Skellam distribution was applied by proposing several scenarios that involved different numbers of vehicles traveling in different directions on a two-dimensional road network with varying traffic-flow and vehicle densities, during which two vehicles were randomly selected, one as a source and the other as a destination. Then, the path with the highest Skellam connectivity probability is selected to be adopted while ignoring the others. After that the vehicles that fall within the coverage area of the chosen path are determined in order to calculate the possible routes between the source and destination vehicles.

Figure 4 illustrates one of the adopted scenarios, where Vehicle No. 5 is assumed to be the source while the destination is Vehicle No. 35. In this figure, path-1 (green) is one of the two possible paths between source and destination, and path-2 (yellow) is the other, while gray-shaded areas are shared between them, each with a length of 2 km. The vehicle density in these two paths is approximately 15.5 and 10.5 veh/km, respectively.

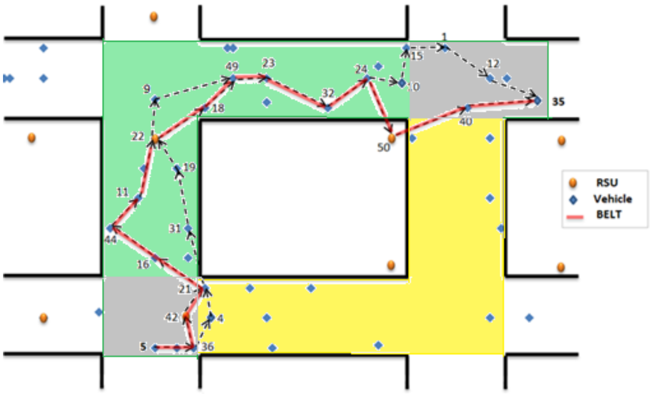


Figure 4. Paths between source vehicle No. (5) and destination vehicle No. (35)

The connectivity probability for these two paths is calculated according to Skellam distribution for different values of α as shown in Figure 5, whereby it is found that the sum of the connectivity probability of path-1 is about 0.4471, while for path-2 it is about 0.3286 (the sum of probabilities for α = 1, 2, …, etc.). It turns out that path-1 has the highest probability, therefore, in the next stage, only possible routes within this path will be searched. This will reduce the number of control packets during the routes discovery process, and as a result reduce network congestion.

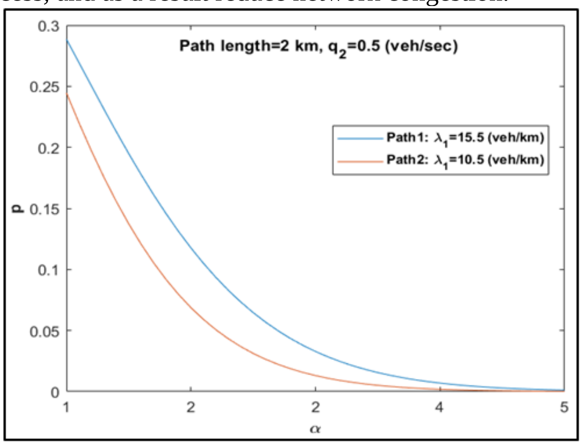


Figure 5. Skellam Distribution of the two paths of the adopted scenario

According to the second stage of the proposed algorithm, three routes were identified between the two vehicles in path-1 as detailed in Table 3. The estimated lifetime of the link per segment ELTS represents the period of time during which two consecutive vehicles in the network remain within each other's transmission range. Thus, the estimated connectivity lifetime between each two consecutive vehicles for each route is calculated by applying Equation (10). Then, according to Equation (7), the minimum lifetime is used to express the ELTR of each route. Among these routes, and based on Equation (8), the route with the highest ELTR value is chosen as the current active route. In view of this, and according to the details mentioned in Table 3, Route-3 was obtained as the route with the BELT value and accordingly it was chosen as the active communication route between the source and destination vehicles. Each time the active route is used, its lifetime is updated.

Table 3. Routes Obtained from Path-1

Route no.	Vehicles numbers	NoH	ELTR (sec)	Rank
Route-1	5 – 36 – 4 – 21 – 16 – 44 – 11 – 22 – 9 – 49 – 23 – 32 – 24 – 10 – 15 – 1 – 12 – 35	17	1.23	2
Route-2	5 – 36 – 42 – 21 – 31 – 19 – 22 – 18 – 49 – 23 – 32 – 24 – 50 – 40 – 35	14	0.91	1
Route-3	5 – 36 – 42 – 21 – 16 – 44 – 11 – 22 – 18 – 49 – 23 – 32 – 24 – 50 – 40 – 35	15	1.48	3 BELT

The route lifetime value has a great influence on the and the throughput of a given source-to-destination pair in the network. Moreover, increasing the lifetime of the route will reduce the number of control messages, which reduces congestion in the network. As a result, it will increase the network ability to manage a larger number of packets. This will positively affect the network’s performance. For the details mentioned in Table 3, and according to Equation (9), the ratio of improvement in the lifetime of the BELT route compared to each of Route-1 and Route-2 is about 1.2 and 1.63 respectively. This means that an increase in the permanence of communication has been achieved.

Several tests were carried out in which different number of vehicles were distributed in different densities and traffic-flows. In each test, the Skellam distribution was applied, after which the second stage was implemented to determine the BELT route. In each test, the average of the ImLT ratio was calculated with respect to the shortest path. The result obtained is as shown in Figure 6. Where it turns out that the greater the number of vehicles distributed in the specified region, the greater the chances of obtaining a long lifetime route.

In the remainder of this section, the results of the proposed algorithm are presented compared to both AODV and the improved-LAR (I-LAR) in various aspects, including the route lifetime versus the number of hops and the number of the detected routes, as well as the energy consumed and the amount of throughput for each protocol.

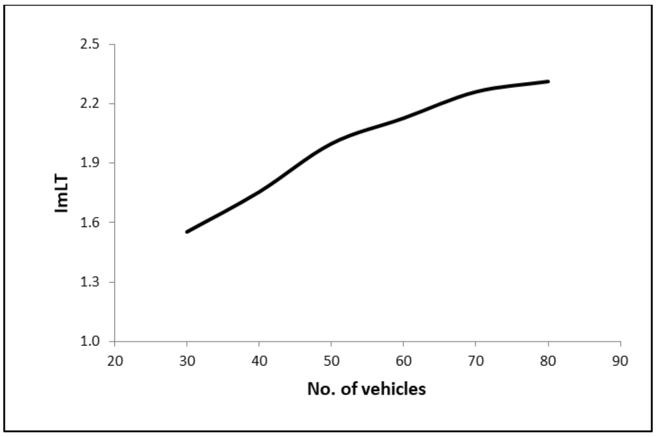


Figure 6. Average ratio of lifetime improvement for different number of vehicles

Figure 7 shows the average lifetime of the routes versus the number of hops for each of the proposed algorithm, AODV and I-LAR. The average lifetime with BELT clearly yielded better results. It outperforms AODV by approximately 17% and I-LAR by approximately 14%. The reason for this is that the process of detecting potential routes in the proposed algorithm focuses on the region that has a preference in the probability of connection. Moreover, the evaluation of the routes depends on comprehensive calculations of their lifetimes before the decision is made to determine the best.

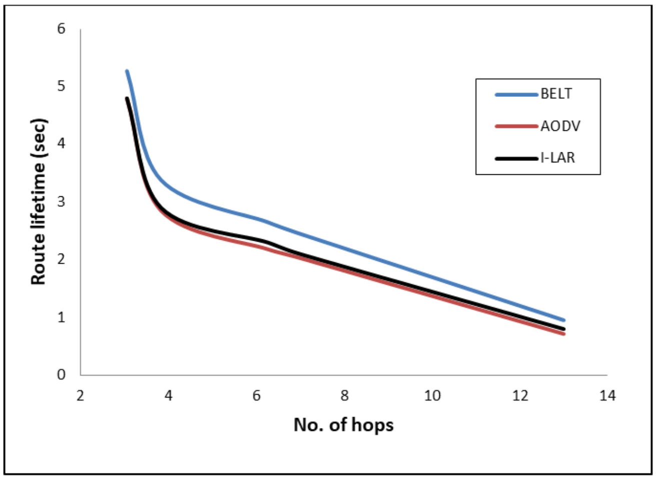


Figure 7. Average route lifetime vs. number of hops

To assess the stability of the network, 80 vehicles were deployed on the network roads. The routes were then determined and then their estimated lifetime was calculated for each protocol during the simulation period as shown in Figure 8. It can be seen that the BELT algorithm identified the best possible route lifetimes, followed by I-LAR and AODV respectively. This reflects the ability of the proposed algorithm to maintain the connection for a longer period of time, thus ensuring higher network stability.

The average energy consumed versus the number of detected routes during the VANET simulation period is shown in Figure 9. The proposed algorithm achieved the lowest energy consumption due to the fact that path selection depends on the highest Skellam's connectivity probability, which means the path have a high vehicle density and, as a result, most of its active routes remain longer than both AODV and I-LAR. On the other hand, it can be observed that as the number of the detected routes is increased, the energy consumption decreased significantly in both BELT and AODV, whereas this decrease in I-LAR is relatively small, since the latter protocol specifies the subsequent hops depending on local zones. BELT algorithm achieved average reductions in energy consumption of approximately 10% and 13% compared to both AODV and I-LAR, respectively

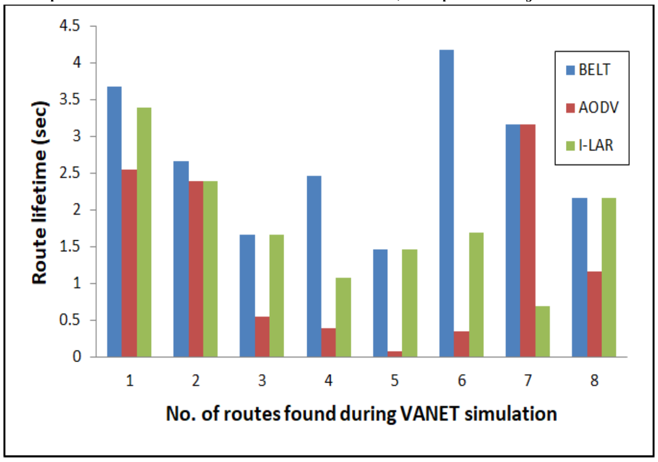


Figure 8. Sample of routes lifetime with 80 vehicles during the simulation periods

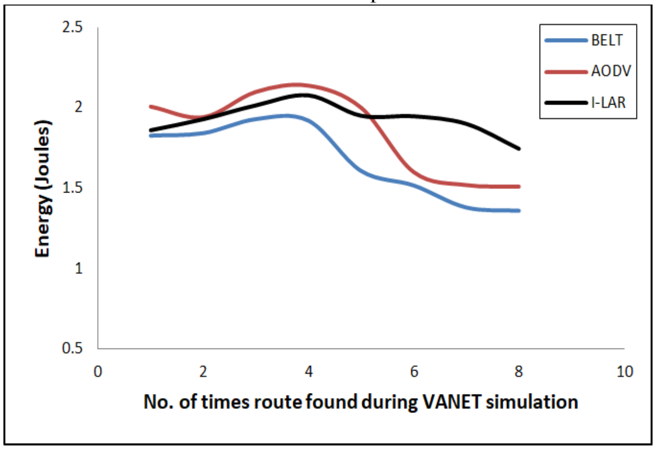


Figure 9. Energy consumed

The network performance in terms of throughput is shown in Figure 10. As it turns out, the productivity of BELT algorithm is better than both AODV and I-LAR. The proposed algorithm achieved an average increase in throughput of about 6% and 10% compared to AODV and I-LAR, respectively. This is due to the improvement in route lifetimes, in addition to the presence of the selected routes within appropriate vehicle density. As a result, this reduces the potential of route downtime, which leads to fewer control packets, resulting in increased throughput.

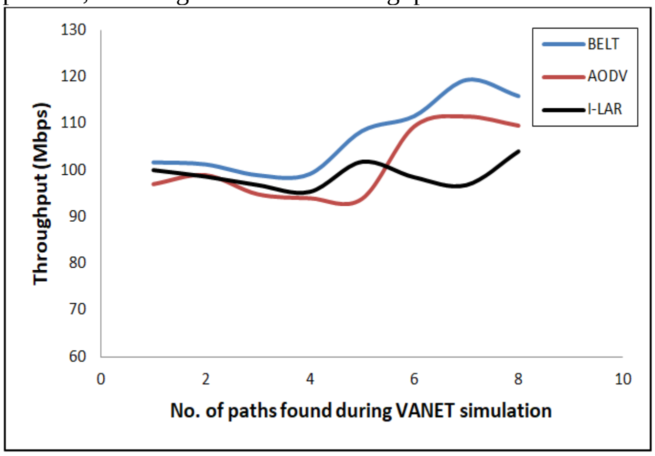


Figure 10. Throughput for the paths found during the simulation

4. Conclusions

This paper proposed an algorithm that searches for a longer life path between source and destination in an ad hoc vehicle network (VANET) to improve performance and throughput as well as network stability. VANET networks are highly dynamic due to the continuous joining and leaving of vehicles on the network. This affects dramatically on route stability. To consider this effect, the proposed algorithm used in its first stage Skellam distribution to determine the connectivity probability of the potential roads covered by the network, taking into account the density of the vehicles joining and departing as two basic variables in addition to the rated vehicle speed and road length. This technique has proven its ability to identify the road with the highest connectivity probability, as it allows searching for the appropriate route within the vehicles deployed in the chosen path only, resulting in a decrease in the number of control packets. In the second stage the algorithm attempts to take advantage of the abundance of control messages that are sent during the route detection process between the source and the destination vehicles by calculating their estimated life and thus assigning a rank to each. The vehicles involved in these paths store some information about them, including the rank of each path for the purpose of maintaining the route. In addition, maintaining route connectivity will be easy due to the appropriate density of vehicles within the area in which the route is located. The results showed that the algorithm increases network efficiency by reducing the number of control packets, thus reducing congestion in the communication channel. In addition, the proposed algorithm achieved higher performance and greater network stability compared to AODV and the modified LAR protocol, at the level of network lifetime, amount of energy consumed, and throughput.

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