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Predicting the longest route lifetime as the most stable route between two vehicles in VANET

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Abstract: **One of the most critical issues of VANET is the frequent failure of the route caused by the high mobility of vehicles. Short communication route lifetime often breaks down in progress data packet transmission between the source and the destination vehicles, and launches a new route reconstruction that becomes more frequent and depletes a significant amount of network resources. To face these frequent communication disconnections much research has considered the stability of route between source and destination vehicles as an important factor to improve the quality of service in the VANET network. however, this research did not take into account the longest route lifetime as the most stable route and assumes that vehicles move at a constant speed during a direct communication between them. For this reason, we propose two protocols that use vehicles' movement information to determine the longest route lifetime as the most stable route taking into account the variation of the vehicles' velocity for comfort applications in a highway environment. One of them uses the beacon message and the other does not use it. Our schemes are evaluated as function of vehicles density by measuring the route duration, the percentage of packets delivery, the control overhead, the throughput and the number of link failures generated during the transmission of data packets. The Intelligent Driver Model with Lane Changing (IDM-LC) based on VanetMobiSim tool is used to generate realistic mobility traces in highway.**

Keywords: most stable route; link lifetime; route lifetime; IDM-LC; highway Scenario; VANET; NS2.

I. Introduction

Vehicular Ad Hoc Networks (VANETs) allow vehicles to communicate with each other directly through the device On Board Unit (OBU) forming vehicle-to vehicle communications or without infrastructure via fixed equipment beside the road, referred to as Road Side Unit (RSU) forming vehicle-to-infrastructure communications and are a key component of intelligent transportations systems (ITS)[1]. VANETs support a wide range of safety and non-safety applications to make accurate decisions by drivers and to provide passengers comfort. They will play a vital role in road by providing and sharing information to the drivers or passengers such as traffic signals, location, speed of the neighboring vehicles, play online games, access the internet and check emails[2][3][4][5].

Most of these applications have rigid requirements in terms of route lifetime and throughput. they still need improvements in the quality of service because of the highly dynamic network topology characteristics that cause a short route lifetime between the source and the destination vehicles, and a frequent link breakages for vehicles moving in opposite directions and also for vehicles traveling in the same directions. High speeds of vehicles, especially on the highway, lead to frequent and rapid network topology changes that lead at an increase in packet wait time in queue. Therefore, these characteristics of VANET lead a more frequent reconstruction of route, a higher data packet loss with reduced throughput.

To deal with these problems many researchers improved communication efficiency in vehicular ad hoc network by using route lifetime as a metric. These researchers seek to determine a stable route by choosing vehicles that travel in the same direction, or by dividing the vehicles in groups, as in [6]; or by building stable backbones on road using connected dominating sets (CDS), as in [7]; or by using an evolving graph from the source to the destination, as in [8]; or by dividing the moving vehicles to several clusters, and then select one vehicle as a cluster head in every cluster, as in [9][10]. All this research still suffers from a great number of route discovery messages for reactive schemes and suffers from vehicles density in case of proactive schemes. Other researchers determine a stable route using methods that allow choosing next forwarder vehicle by calculating the link lifetime, as in [11][12]. These latter proposals do not really determine the most stable path basing on the next link lifetime. For instance as illustrated in fig.1, the route between source and destination vehicles is S-I-K-D basing on the longest next link lifetime and its lifetime is 3s. But it is not the most stable route compared to the route S-A-K-D. The latter is the most stable route and its lifetime is 5s. Hence, the most stable route is not determined by the largest next link lifetime, but it will be determined upon arrival at the destination vehicle. These researchers assume that vehicles move at a constant speed during a direct communication between them. In this case, links lifetimes are not accurate due to the variation of the vehicles' velocity during the route establishment. Hence, the accurate link lifetime is an important metric that significantly affects the stability of multi-hop routing protocols in VANETs.

In this paper, we predict the most stable route between sources and destinations vehicles by using link duration and route lifetime as metrics in a highway environment. The novelty of this work is to ensure that the most stable links are chosen when route establishment taking into account the variation of the vehicles' velocity. The idea is that each vehicle can retransmit the same route request message again if it allows increasing the route lifetime. A mathematical calculation is used to predict the durability of the link taking into account the acceleration and deceleration of vehicles' speed.

The remainder of this paper is organized as follows. Section 2 presents related work. Section 3 presents link lifetime prediction model. Section 4 shows the most stable route construction. Section 5 presents simulation and results. Finally, we give a conclusion in Section 6.

II. Related Work

The challenges of network routing protocols in VANETs have been attracting more research efforts, and a number of routing protocols have been proposed to determine the route based on the route lifetime. Authors in [14] propose a movement-prediction-based routing (MOPR) to avoid the link rupture until the end of data transmission. MOPR predicts the future nodes' positions in order to choose the most stable route that has enough lifetimes for data transmission. The performance of the MOPR depends on the prediction accuracy and the estimation of the data transmission time that depends on various components such as network bandwidth and driver's behavior. To determine a more stable route, authors in [6] proposed the scheme ROMSGP that group vehicles according to their movement directions. The most stable route is determined by selecting the path that has the longest links expiration time. The authors did not take into consideration the case where there are no vehicles travelling in the same direction of group movement. In [13], authors propose a prediction-based routing (PBR) protocol that determines a stable route on highway giving priority to vehicles that travel in the same direction of source motion. This protocol predicts the route lifetime and preemptively determines new routes prior old ones break. Authors assume that vehicles travel at a constant velocity at the duration of the link. In [15], authors propose a cross-layer approach that estimates the remaining time for which the link's quality will remain above the specified threshold, called link residual time (LRT). The latter is defined as the time left of a given link that will be continued to be useful for satisfactory data transmission. The route construction is based on the selection of the link that has the largest link residual time. these authors do not determine the most stable route and they assume that vehicles travel at a constant velocity for the duration of the link. In [16], authors propose a stable direction-based routing protocol (SDR) that combines direction broadcast and path duration prediction into AODV [17]. In SDR, vehicles are grouped based on the position, and the route selection is based on the link duration. The authors did not take into consideration the case where there is not enough vehicles in a given direction range participating in the route discovery process. In [8], authors propose an evolving graph-reliable ad hoc on-demand distance vector (EG-RAODV) that allows finding the most reliable route from the source to the destination. they proposed an extended version of the evolving graph model to model and formalize the VANET communication graph (VoEG) and they developed a new evolving graph Dijkstra's algorithm (EG-Dijkstra) to find the most reliable journey (MRJ) based on the journey reliability in VoEG. The problem of this protocol is that at each any given time, the source vehicle must have full knowledge of a VANET communication graph. Furthermore, the authors assume that vehicles travel at a constant velocity along the same direction on the highway and they do not take into account the vehicles density. In [11], the authors propose a method to select a reliable neighbor based on the residual lifetime of the corresponding communication link. They present an algorithm to predict the residual lifetime of links by making use of Kalman filter based prediction technique. The forwarding vehicle tries to predict the residual lifetime of one-hop links to all of its neighbors vehicles. The neighbor with maximum value for the link residual lifetime is chosen as the next forwarding vehicle. The authors did not determine the most stable route. in [18] authors propose the scheme ARP-QD that is an QoS-based routing protocol in terms of hop count, link duration and connectivity, so as to cope with dynamic topology and keep the balance between stability and efficiency of the algorithm. However, it is not enough to use only a global distance to reflect the overall QoS of a routing path. Authors of [19] propose an Enhanced version of AODV, named En-AODV, protocol to deal with routes instability issue for multimedia applications requirements. En-AODV leverages cross-layer information on the link quality combined with the knowledge of the final destination of the receiver vehicle to establish most stable path relaying the source and destination vehicles and quickly react to the occurrence of a link failure in this path and provide an alternative links of good quality. The authors did not take into consideration the case where there are no vehicles moving towards the destination region.

All these schemes assume that vehicles move at a constant speed during a direct communication and they do not predict the most stable route at a given moment. Furthermore, they gave priority to determined directions. Therefore, the goal of this work is to predict the longest route lifetime as the most stable route whatever the direction of the vehicles on highway for non-safety applications.

III. Link Lifetime Prediction

Let (X_m, Y_m), V_m and $A_m$are the position, the speed and the acceleration of the vehicle m at moment t_0, respectively. (X_n, Y_n), V_n and A_n are the position, the speed and the acceleration of the vehicle n at time t_0, respectively. (X'_m, Y'_m), (X'_n, Y'_n) are positions of vehicles m and n at moment t_1, respectively.

We assume that the acceleration of each vehicle is constant during a direct communication. The abscissa axis is parallel to the direction of movement of vehicles m and n to facility the calculation. The distance between vehicles m and n on the ordinate axis is negligible per report to the radius (R) of the coverage area of each vehicle (i.e $|Y_m - Y_n| \approx 0$).

A. Vehicles m and n travel in same direction

It is assumed that the vehicles m and n travel in the positive sense of the abscissa axis. Therefore distances traveled by vehicles m and n during the delay t (t1-t0) are represented by the following equations:

$$X'_m - X_m = \frac{1}{2}A_m t^2 + V_m t \; . \tag{1}$$

$$X'_n - X_n = \frac{1}{2}A_n t^2 + V_n t \; . \tag{2}$$

We can write again:

$$X'_m - X_m = -(X_m - X_n) + (X'_n - X_n) + (X'_m - X'_n) \; . \tag{3}$$

So from (1), (2) and (3) we represent the time t, during which the distance between vehicles m and n will be $|X'_m - X'_n|$ on the x-axis, by the following equation:

$$\frac{1}{2}(A_m - A_n)t^2 + (V_m - V_n)t + d - d' = 0 \; . \tag{4}$$

Where $d = X_m - X_n$ and $d' = X'_m - X'_n$.
If vehicles m and n have the same acceleration, then the time which vehicles stay in communication direct is formulated by:

$$t = \frac{d' - d}{V_m - V_n} \tag{5}$$

Where $V_m \neq V_n$ and $|d'| \approx R$
If vehicles m and n have not the same acceleration, then in this case, we calculate the delta of equation (4) that is:

$$\Delta = (V_m - V_n)^2 - 2(A_m - A_n) * (d - d') \tag{6}$$

- Si ($V_m > V_n$ and $A_m > A_n$) or ($V_m < V_n$ and $A_m < A_n$) : The maximum time in which the vehicles m and n remain in direct communication is the time t in which the distance between these vehicles will be R (i.e. $|d'| \approx R$). This time is represented by the following formula:

$$t = \frac{-|V_m - V_n| + \sqrt{\Delta}}{|A_m - A_n|} \tag{7}$$

- Si ($V_m > V_n$ and $A_m < A_n$) or ($V_m < V_n$ and $A_m > A_n$) : In this case there are two possibilities:

  First case: One vehicle leaves the coverage area of the other before their speeds become equal (i.e. $|d'| > R$). In this case, the maximum time t in which the two vehicles remain in direct communication ($|d'| \approx R$) is formulated by:

$$t = \frac{|V_m - V_n| + \sqrt{\Delta}}{|A_m - A_n|} \tag{8}$$

  Second case:Vehicles m and n stay in direct communication (i.e. $|d'| \leq R$) at the moment when their speeds are the same. In this case, the maximum time in which the two vehicles remain in direct communication ($|d''| \approx R$) is t+t' where $t = t_1 - t_0$ is the time in which the speed of one is inferior or equal to the other and $t' = t_2 - t_1$ is the time in which these vehicles stay in direct communication after the speed of one overtakes the other. Thus

$$t = \frac{|V_m - V_n|}{|A_m - A_n|} \tag{9}$$

  And

$$\frac{1}{2}(A_m - A_n)t'^2 + d' - d'' = 0 \; . \tag{10}$$

  Where $d' = -\frac{1}{2}\frac{(V_m - V_n)^2}{A_m - A_n} + d$ and $d'' = X''_m - X''_n$ ($X''_m$and X''_n are positions of vehicles m and n at moment t_2, respectively). The time t' in which the distance between the two vehicles becomes R ($|d''| \approx R$) is:

$$t' = \frac{\sqrt{-2(A_m - A_n) * (d' - d'')}}{|A_m - A_n|} \tag{11}$$

  Hence:

$$t + t' = \frac{|V_m - V_n| + \sqrt{-2(A_m - A_n) * (d' - d'')}}{|A_m - A_n|} \tag{12}$$

Remark: in the case where vehicles m and n travel in the negative direction of the x-axis, then we change d - d' by d'- d and d'- d" by d" - d' in previous formulas.

B. Vehicles m and n travel in opposite direction of each other

The time t during which the distance between vehicles m and n will be $|X'_m - X'_n|$ on the x-axis, is represented by the following equation:

$$\frac{1}{2}(A_m - A_n)t^2 + (V_m - V_n)t + d - d' = 0 \; . \tag{13}$$

Where $d = X_m - X_n$ and $d' = X'_m - X'_n$.
The maximum time t in which the two vehicles remain in direct communication ($|d'| \approx R$) is formulated by:

$$t = \begin{cases} \frac{d' - d}{V_m + V_n} & if A_m = A_n \\ \frac{-(V_m + V_n) + \sqrt{\Delta}}{A_m + A_n} & otherwise \end{cases} \tag{14}$$

Where $\Delta = (V_m + V_n)^2 + 2(A_m + A_n) * (d' - d)$

IV. The most stable route construction

The network model consists of one road ended by two intersections in highway environment or in urban environment for road segments. This road has the same characteristics such as length, width, number of lanes. Each lane has a distinctive traffic density (see Fig. 2). Each vehicle is equipped with a global positioning system (GPS) that provides information about its location, speed, and direction. Finally, each source vehicle knows the location of the destination by using a location service such as RLSMP [20] and ZGLS [21].
Given a directed graph G(V;E) that is defined by a finite set V = $\{v_1, v_2, v_3, ..., v_n\}$ of vertices where v_i is a vehicle,

and by finite set $E = \{t_1, t_2, t_3, ..., t_m\}$ of edges where t_j is the remaining time between any two vehicles to stay in direct communication with each other.

Whenever a vehicle receives a discovery message of route, it saves message' identifier and the traveled route lifetime in a table, called Route Request Table (RRT).

We seek to determine the most stable route between the source and the destination vehicles. The route lifetime (RLT) is the minimum link lifetime (LLT) between links that build the route between source and destination vehicles. As in Fig. 3, the most stable route is that built by vehicles S-A-I-K-D and the lifetime of this route is 4s at instant t.

When the source vehicle wants to determine a new route between itself and the destination vehicle, it broadcasts a new route discovery message in the side close to destination of its communication range. To determine this route, we propose two schemes, one uses beacon message and the other does not use it. These schemes are an extension of our work [22].

A. Scheme without beacon message

In this scheme, each source vehicle (s) knows the distance d(s, d) that separates it to the destination vehicle (d); because each source vehicle knows the location of the destination by using a location service. We use distance to determine the expiration parameter for the route request message so that it will not be rebroadcast indefinitely on the entire network.

When the source vehicle wants to determine a new route to the destination vehicle, it adds in the route request message (RRM) its information (identifier, location, d(s, d), speed, direction, and RLT that is 0s at the source vehicle) and broadcasts it in its communication range. Then, each vehicle (v) receives this message on the side close to destination vehicle of its communication range; it calculates the LLT and d(s, v) between itself and the source vehicle; and it saves the LLT and RRM's id in its table RRT. Next, it modifies the source information (id, location, d(s, d), speed, direction, and the RLT) in RRM by its information (id, location, d(v,d) that is d(s,d)-d(s,v), speed, direction, and the new RLT that is the LLT in this case); respectively. After that, it broadcasts RRM in the half circle of its communication range on the side close to the destination. Each receiver vehicle (r) determines d(v, r) and the new RLT that is the minimum between the RLT in the RRM and the LLT between itself and the previous forwarder vehicle. Then, it checks whether d(r,d) (d(v,d)-d(v,r)) is less than or equal to zero meter. If it is, it deletes it. Otherwise, it checks its table RRT whether it has not already received the same RRM. If it has, it updates the RLT in its table R-RT by the new RLT, and then it puts its information in place of those of the previous forwarder vehicle in the RRM; next, it broadcasts the latter in the half circle of its communication range in the side close to the destination. Otherwise, it checks whether the new RLT is greater than the RLT in its table RRT; if it is the case, it modifies the RLT in its table RRT by the new RLT, then it puts its information instead of those of the previous forwarder vehicle in the RRM; next, it broadcasts the latter in the half circle of its communication range in the side close to the destination. Otherwise, it deletes it. Each next receiving vehicle will do the same operations that have been done by the previous receiving vehicle until the route discovery message arrives to the destination or the distance to the destination vehicle becomes zero meters (see algorithm 1).

B. Scheme with beacon message

It is assumed that each vehicle periodically sends its information in beacon message (location, speed, direction of movement, identifier, and current time) to its neighbors. Then, each vehicle constructs its neighboring list by information extracted from beacon messages. Whenever a new neighbor is discovered, a new entry is added and a timer is set. A vehicle waits two consecutive beacon intervals to hear from its neighbor. If no message was received, the neighbor's entry is deleted.

Each vehicle calculates periodically the time left (link lifetime) between each of its neighbor and itself. Then, it saves the link lifetime value and the identifier of its neighbor in its table, called Neighbors-Life-Time (NLT).

In this scheme, the source vehicle adds in the route request message (RRM) its information (identifier, and RLT that is 0s at the source vehicle) and broadcasts it in its communication range. Then, each vehicle receives this message on the side close to destination vehicle of its communication range; it calculates the LLT between itself and the source vehicle, then it saves it and RRM's id in its table RRT. Next, it modifies the source information (identifier, and the RLT) in RRM by its information (identifier, and the new RLT that is the LLT in this case); respectively. After that, it broadcasts RRM in the half circle of its communication range on the side close to the destination. Each receiver determines the new RLT that is the minimum between the RLT in the RRM and the LLT between itself and the previous forwarder. Then, it checks its table RRT whether it has not already received the same R-RM. If it has, it updates the RLT in its table RRT by the new RLT, and then it puts its information in place of those of the previous forwarder vehicle in the RRM; next it broadcasts the latter in the half circle of its communication range on the side close to the destination. Otherwise, it checks whether the new RLT is not strictly greater than the RLT in its table RRT. If it is, it deletes it. Otherwise, it checks if there is a vehicle that stays a time strictly greater than the new RLT, in its communication range on the side close to the destination. If is the case, it modifies the RLT in its table RRT by the new RLT, then it puts its information instead of those of the previous forwarder vehicle in the RRM; next it forwards the latter to each vehicle that stays a time strictly greater than the new RLT, in its communication range on the side close to the destination. Each next receiving vehicle will do the same operations that have been done by the previous receiving vehicle until the route discovery message arrives to the destination (see algorithm 2).

V. Simulation and Results

We have used the pattern IDM-LC that is a microscopic mobility model in the tool Vehicular Ad Hoc Networks Mobility Simulator (VanetMobiSim) [23][24] and we have used NS2 [25] to implement our protocol. Vehicles are deployed in a 5000m x 80m area. This area is a highway with four lanes bidirectional. Vehicles are able to communicate with each other using the IEEE 802.11p MAC layer. The vehicles'

```
Notations;
SV : Source Vehicle; DV : destination Vehicle and FV :
Forwarder Vehicle;
RV: Receiver Vehicle on the side close to destination of
the coverage area;
RRM: Route Request Message;
RRMID: RRM id;
RRT: Route Request Table;
LLT(FV,RV) : Link LifeTime between forwarder vehicle
and receiver vehicle;
RLT: Route LifeTime;
d(FV,RV) : distance between forwarder vehicle and
receiver vehicle;
Information: id, location, speed, direction, RLT,
d(FV,DV);
R: communication range;
RLT = 0;
d(FV,DV) = d(SV,DV);
SV adds its information in RRM ;
if d(FV,DV) ¡ R then
    RLT = LLT(SV,DV);
    SR sends RRM to DV;
else
    SV broadcasts RRM RV calculates LLT(FV,RV) and
    d(FV,RV) ;
    d(RV,DV)=d(FV,DV)-d(FV,RV);
    if d(RV,DV) == 0 and RV ≠ DV then
        RV deletes RRM;
    else
        newRLT = min(LLT(FV,RV), RLT in RRM);
        if RRMID is not in RRT of RV then
            RV saves new RLT and RRMID in its table
            RRT;
            if RV = DV then
                DV replies by RRP;
            else
                RV modifies FV information in RRM by
                its information;
                RV broadcasts RRM;
            end
        else
            if new RLT ¡= RLT in RRT of RV then
                RV deletes RRM;
            else
                RV modifies RLT in its RRT by new
                RLT;
                if RV = DV then
                    DV replies by RRP;
                else
                    RV modifies FV information in
                    RRM by its information;
                    RV broadcasts RRM;
                end
            end
        end
    end
end
```

Algorithm 1: MSRP: Most Stable Route Prediction.

```
Notations;
SV : Source Vehicle ;
DV : destination Vehicle;
FV : Forwarder Vehicle;
RV : Receiver Vehicle on the side close to destination of
the communication range;
NRV : Next RV on the side close to destination of the
communication range;
RRM :Route Request Message;
RRMID: RRM id;
RRT : Route Request Table;
LLT(FV,RV) : Link LifeTime between FV and RV;
RLT : Route LifeTime;
d(FV,RV) : distance between forwarder vehicle and
receiver vehicle;
information : id, RLT;
Initialization;
RLT = 0;
FV = RV;
if DV is neighbor of SV then
    RLT = LLT(SV,DV);
    SV sends DATA to DV;
else
    SV adds its information in RRM;
    SV broadcasts RRM;
    RV calculates newRLT = min(LLT(FV,RV), RLT in
    RRM);
    if RRMID is not in RRT of RV then
        RV saves new RLT and RRMID in its table RRT;
        RV modifies FV information in RRM by its
        information;
        if DV is neighbor of RV then
            RV sends RRM to DV;
        else
            RV brroadcats RRM;
        end
    else
        if new RLT ¿ RLT in RRT of RV and
        LLT(RV,NRV)¿ RLT in RRT of RV then
            RV modifies RLT in its RRT by new RLT;
            RV modifies FV information in RRM by its
            information;
            if DV is neighbor of RV then
                RV sends RRM to DV;
            else
                RV brroadcats RRM;
            end
        end
    end
end
```

Algorithm 2: MSRP-BM: Most Stable Route Prediction by Beacon Message.

Table 1: Simulation parameters

Parameter	Value
Simulation Time	400 s
Simulation area	5000m x 80m
Nb. of Vehicles	30 - 90
Transmission range	250 m
Packet rate	4 packets/s
Packet Size	512 bytes
Traffic Type	CBR
Mobility model	IDM-LC
Speed	0-100 km/h

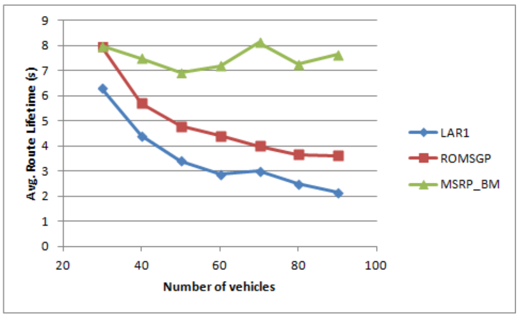

Figure. 4: Average route lifetime versus vehicles density.

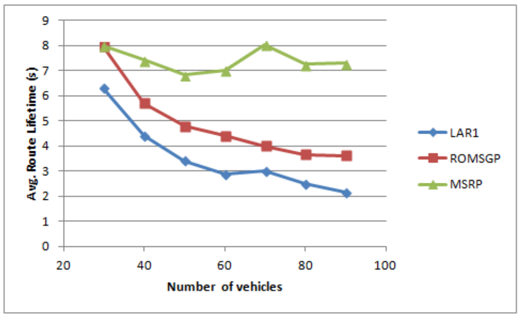

Figure. 5: Average route lifetime versus vehicles density.

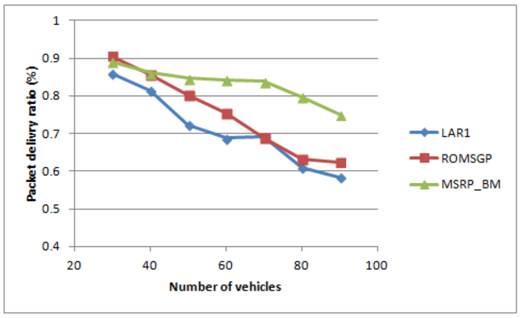

Figure. 6: Packet delivery ratio versus vehicles density.

speed fluctuates between 0m/s and 27m/s. We have considered packet size of 512 bytes, Simulation Time of 400s, hello interval of 1s and packet rate of 4 packets per second. We setup ten multi-hop CBR flow vehicles over the network and start at different time instances and continue throughout the remaining time of the simulation. The transmission range is kept at 250m. Simulation results are averaged over 20 simulation runs.

We evaluate the performance of our routing schemes MSRP-BM and MSRP against of ROMSGP which more closely resembles the nature of our algorithms, and Location-Aided Routing (LAR1)[26] that selects the shortest path. These schemes are evaluated for average route lifetime, packet delivery ratio, throughput and number of link failures according to vehicles density.

Simulation parameters are summarized in the following table:

Fig. 4 and Fig. 5 show the higher stability of MSRP and MSRP-BM compared to that of ROMSGP and LAR1. Because, our schemes determine the route that has the longest lifetime. Hence, it becomes more stable compared to others, where LAR1 gets the lowest route lifetime value. LAR1 chooses the shortest route that breaks quickly when speeds of vehicles and their number increase. ROMSGP chooses the shortest route among the vehicles belonging to the same group; for this reason, its route is stable compared to that of LAR1.

Fig. 6 and Fig. 7 show that our schemes achieve a good packet delivery ratio than both ROMSGP and LAR1. This is because our protocols forward data packets over road by predicting the most stable route by taking into account the variation of speed; in contrary of ROMSGP that determine a stable route by selecting the shortest route among the vehicles belonging to the same group, and LAR1 that selects the shortest path. The selection of the most stable route allows the decrease of the number of route breaking and the increase of the packet delivery ratio. The latter decreases during the increases of network density because of several possibilities that are represented in the non-uniform distribution of vehicles in our mobility model, or the bandwidth is jammed and therefore causes data packet being dropped.

In Fig. 8 with a small number of vehicles (inferior to 60) on the length of the road, ROMSGP has the lowest throughput compared to our scheme with beacon (MSRP-BM) and LAR1. This is because ROMSGP determine the route by vehicles that travel in same group (they are not enough) in contrary of MSRP-BM and LAR1 that not take into account the direction of movement. When the number of vehicles increases our MSRP-BM becomes outperform ROMSGP and LAR1. This explained by selection the most stable route by our scheme. Also, ROMSGP has good throughput compared to LAR1; because, it detemines a stable route versus LAR1 that determines the shortest path. In Fig. 9 our scheme MSRP has better throughput than ROMSGP and LAR1. Because in MSRP, the duration of the paths is longer, the number of path breaks is reduced and also the control overhead is de-

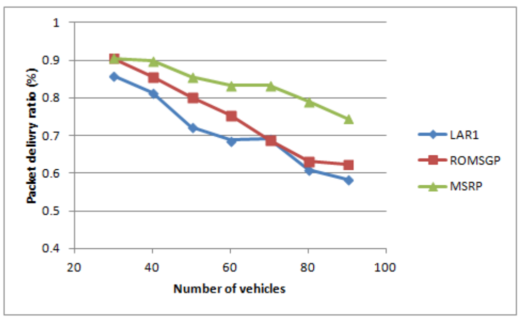

Figure. 7: Packet delivery ratio versus vehicles density.

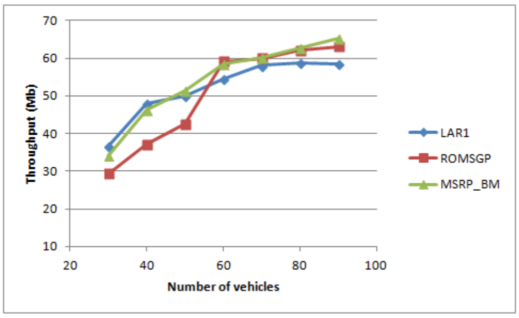

Figure. 8: Throughput versus vehicles density.

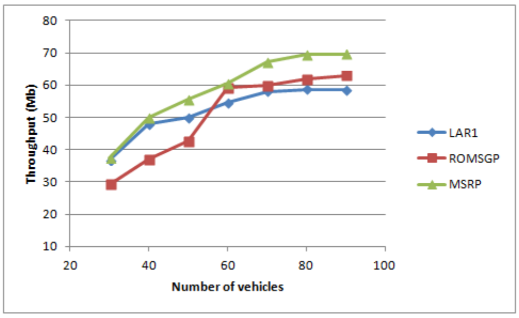

Figure. 9: Throughput versus vehicles density.

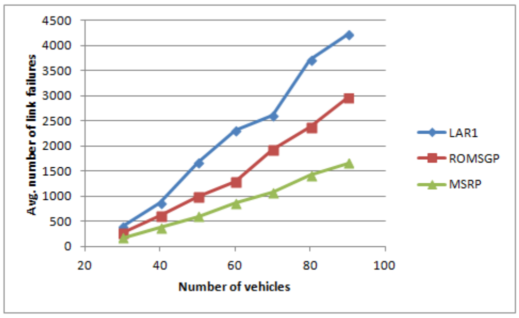

Figure. 11: Average of route failures versus vehicles density.

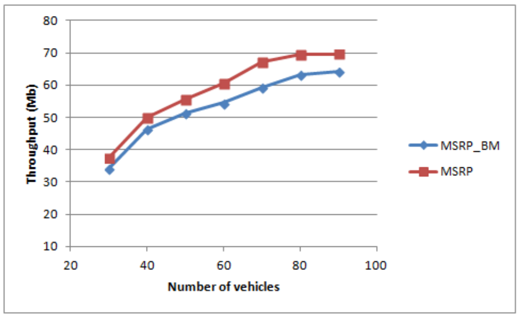

Figure. 12: Throughput between our schemes versus vehicles density.

creased.

As shown in Fig. 10 and Fig. 11, the average number of route breaks (number of errors) of MSRP-BM and MSRP protocols is lower than that of both ROMSGP and LAR1; because our schemes choose the most stable route. LAR1 chooses the shortest path, inattentive of whether it is reliable or not. ROMSGP outperforms LAR1 because it predicts a stable route by building the route by vehicles that travel in the same group, and creates a new alternative route prior a link breakage.

Our proposals have almost the same route duration, the same percentage of packets delivery and the same number of route failures during data packet transmission according to the vehicles density. As shown in Fig. 12 and Fig. 13, our scheme with beacon message (MSRP-BM) has the lowest throughput and the most normalized routing load compared to our scheme without beacon message (MSRP). This is explained by periodicity of beacon messages that charge the bandwidth.

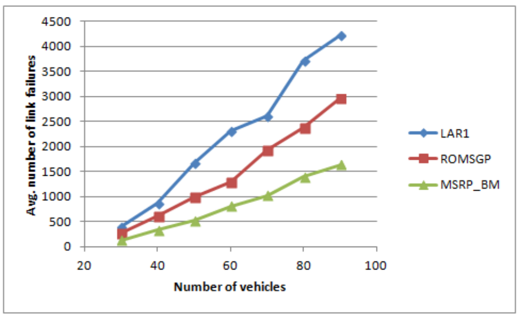

Figure. 10: Average of route failures versus vehicles density.

VI. Conclusion

Our schemes are designed to enhance the communication in highway scenarios for the comfort applications. They predict the most stable route by selecting the route that has the longest lifetime. They are based on the prediction of the link lifetime and the route lifetime taking into account the variation of velocity. Our schemes increase the route duration, the percentage of packets delivery,the throughput and decrease the number of route failures during data packet transmission. They are evaluated against of vehicles density and they are compared with ROMSGP and LAR1 in highway environment by using IDM-LC to generate realistic mobility files.

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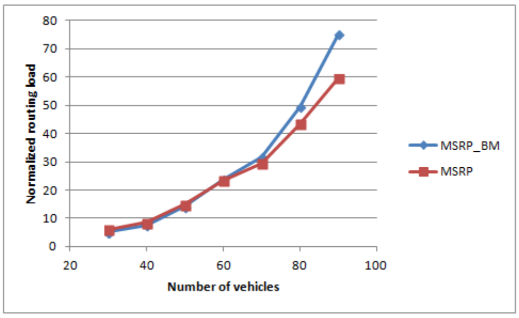

Figure. 13: Normalized routing load (NRL) versus vehicles density.

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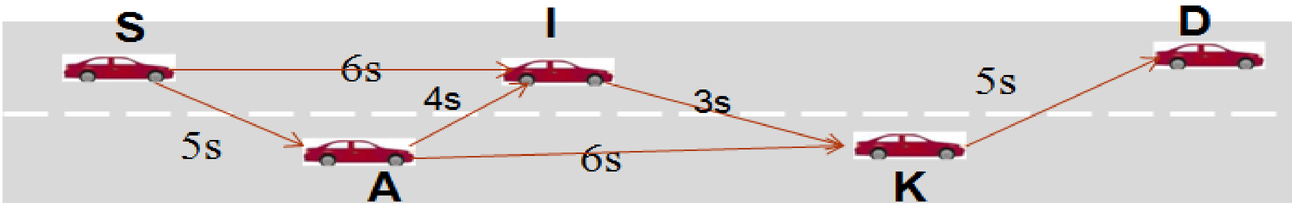

Figure. 1: Route lifetime.

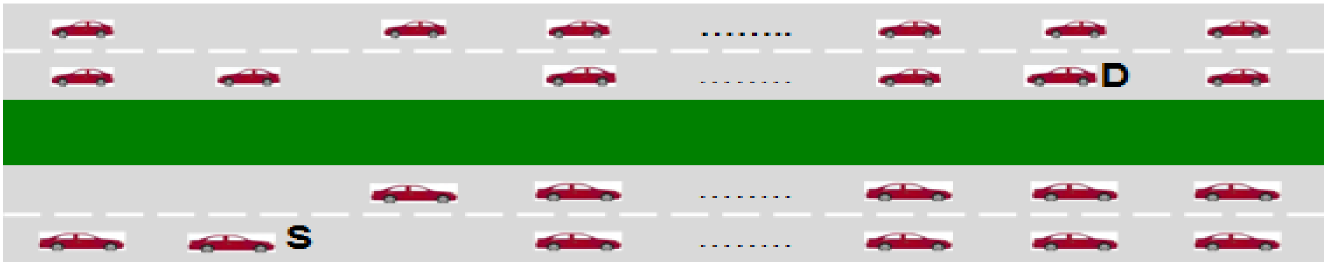

Figure. 2: Bi-directional highway model.

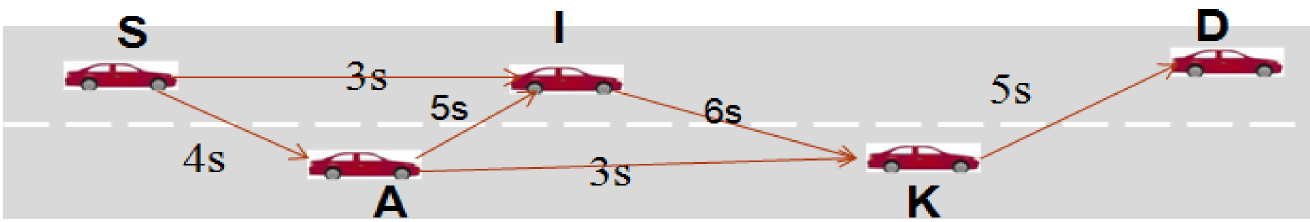

Figure. 3: Most route lifetime.