ReViV: Selective Rebroadcast Mechanism for Video Streaming over VANET

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***Abstract*— Video content delivery for vehicular ad hoc networks (VANET) under dense network conditions poses non trivial issues because of the scarcity and volatility of the wireless medium. In this context, video communication is envisioned to be of high benefit for traffic management as well as for providing value-added entertainment and advertising services. In this paper, we propose a new mechanism for efficient video streaming over VANET. The proposed mechanism selects a minimum sub-set of rebroadcaster vehicles in order to reduce interferences and achieve high video quality. The vehicles are ranked based on their strategic location in the network and their capacity to reach other vehicles using a new centrality metric inspired from the Social Network Analysis (SNA), called dissemination capacity. Through simulations, we compared our mechanism with the multichannel vehicular communication standard IEEE 1609.4 and another pioneering video streaming mechanism over VANET. The performance evaluation shows that it outperforms the abovementioned mechanisms by providing higher video delivery ratio, lower end-to-end transmission delay and lower frame loss ratio in both fully and intermittently connected networks.**

Keywords*— *VANET, Streaming; QoS; SNA

I. INTRODUCTION

Vehicular ad-hoc network (VANET) is a special class of the mobile ad-hoc network MANET with vehicles acting as fast moving mobile nodes. More specifically, a VANET is composed of On-Board-Units (OBUs) mounted on the vehicles and Road-Side Units (RSUs) installed along sides of the urban roads/highways which facilitate both vehicle-to-vehicle (V2V) communications and vehicle-to-infrastructure (V2I) communications. Intelligent transportation systems (ITS) for vehicular ad-hoc networks (VANETs) have stimulated the development of several interesting applications such as vehicle collision warning, security distance warning, driver assistance, cooperative driving, cooperative cruise control, etc. The vehicle engine provides sufficient power for intensive data processing and communications. The on-board buffer storage, positioning system, and intelligent antenna further facilitate efficient video forwarding and collaborative downloading among vehicles or from/to RSUs.

Besides the traditional applications of VANET such as accident alert and traffic information exchanged in form of simple text messages, the scientific and industrial communities envisage video communication within vehicular networks to be of major benefit for traffic management as well as to provide a value-added entertainment / advertising services. Indeed, in a road emergency, streaming a live video of the accident area allows vehicles approaching the scene, mostly official vehicles, to better understand the nature of the accident and take the right decision consequently. Similarly, videos showing cars traffic is more expressing for the conductor to make decision about the road to take than text message announcing high density traffic.

In addition, the distribution of multimedia content for OBUs in a certain area of interest is a promising service. Example of such services includes a local hotel broadcasting video advertising to vehicles entering the city, a travel company promoting their activities in touristic areas to passing vehicles, and highway management companies broadcasting films (for rear seat passengers) in long distance part of the highway.

A candidate exploitation scenario for video streaming in vehicular network could be broadcasting video content using RSUs, where a vehicle downloads video via license-free wireless spectrum when it is within the RSU transmission range. However, supporting video streaming services by RSUs using the license-free wireless communication is still an open issue due to the following two concerns. First, the wireless channel suffers from interference, shadowing and time-varying fading, which leads to degradation of link throughput and consequently the video quality. Second, the RSUs deployment is highly cost which make the deployment of sufficient RSUs to cover an entire roads and highways infeasible. Thus the necessity of ad hoc V2V communication, or Vehicular Ad-Hoc Networks (VANETs), to ensure the video dissemination.

Recently, the 802.11p standard (WAVE) [1] was proposed, with the main concern to ensure safety communication for vehicular traffic, and then serve applications for improved mobility and reduced environmental impact. The WAVE standard allocates a dedicated time slot for emergency and safety communication and six communication channels for other services. Studies [2-5] show that, for both WAVE and IEEE 1609.4, the secondary services suffers from large packet delays and lack of available bandwidth in high density environment and high bandwidth demanding applications. This is due mainly to the spectrum scarceness of DSRC channels in such conditions.

In this paper we propose ReViV, a selective Rebroadcaster selection mechanism for Video streaming for VANET. ReViV is designed for urban environment where the channels are overloaded and the network suffers from high interference degree. In such conditions, ReViV selects the best vehicles to rebroadcast the data in order to reduce interference and perform high video quality delivery. Indeed, the proposed mechanism selects a subset of strategic broadcasting nodes, rather than traditional all node broadcasting mechanism. For that purpose, the vehicles are ranked based on a new centrality metric called *dissemination capacity* DC(v) that we propose. This metric is inspired from node centrality metrics of Social Network Analysis (SNA).

The paper is organized as follows. In section II we give an overview on related work on content dissemination in VANET. Section III describes our proposed solution ReViV in details, and section IV discusses its performance evaluation. Finally, section V concludes this paper.

II. RELATED WORK

Recently, video dissemination over VANET has particularly attracted researcher attention and many research works have been achieved in this field. The state of the art works can be classified into two categories: urban vehicular communication and highways vehicular communication. In this work we focus on the first category where the vehicles traffic is relatively dense and the communications are more exposed to interferences and fading phenomena.

Among solutions that consider vehicular urban communication scenarios is StreetCast [6]. StreetCast makes use of beacon suppression mechanism to reduce massive beacon message exchanged at the congested intersections. In addition, StreetCast takes advantage of RSUs deployed in roads intersection to select the best vehicle to rebroadcast the message. Authors in [7] proposed Urban Multi-hop Broadcast protocol (UMB), an 802.11-based protocol, designed to suppress broadcast redundancy by selecting the furthest vehicle from the sender to acknowledge the reception of the message and rebroadcast it. UMB relies also on a set of RSUs in intersections to propagate the messages to all road directions in a fully connected scenario. Along the same lines, authors in [8] propose Adaptive Information Dissemination (AID), a statistical based broadcast protocol for VANET. This protocol do not use any kind of infrastructure support neither any neighbor information. A vehicle takes the decision to broadcast based only on statistics about the inter-arrival time between the received packets. A redundantly received message is not rebroadcasted, assuming that it was rebroadcasted by many other neighbors. We note that all the proposed mechanism either they relies on RSUs to suppress redundant transmissions, or they are based on statistical approaches.

On the other hand and in order to overcome the problem of interferences and exploit the different DSRC channels, the standard IEEE 1609.4 DSRC multi-channel [9] has been proposed. It defines a time-division pattern for DSRC channels to alternatively switch between these channels to support different applications simultaneously. The standard suggests to allocate alternatively a time slot of 50 ms for control channel (CCH) which conveys safety messages and another equal time slot to service channel (SCH) which conveys other services messages. The main issue with IEEE 1609.4 is the underutilization of the spectrum [9] due to high probability of synchronized collisions at start of a channel interval (CCH or SCH) and mainly it incompatibility with the broadcast transmission mode in high density scenarios, since it does not implement any rebroadcast suppression mechanism. Hence, to the best of our knowledge, we are the first to propose a VANET multichannel protocol for rebroadcaster vehicles selection based only on the "sociality" and the strategic position of the vehicle in the network without any RSU support. In the following section, we detail the proposed mechanism.

III. THE PROPOSED MECHANISM : REVIV

In the urban environment where the spectrum availability is more and more rare, handling the interference problem is a primordial issue to ensure a high content delivery in VANET. Indeed, the traditional broadcasting mechanism advocates that each node in the network receiving the content will rebroadcast it. This intensive rebroadcasts increase the interferences. Consequently, the packets loss increases and the video quality is degraded. This funding prompted us to enhance our video streaming system over VANET by new rebroadcaster selection mechanism, which selects a minimum subset of neighbors' vehicles to rebroadcast the content. The selected nodes should be as central as possible in order to broadcast the content to a maximum number of neighbors without need to further retransmissions.
The proposed mechanism is inspired from the Social Network Analysis (SNA) methods to select the central nodes in their communities. The problem of broadcaster's nodes selection is illustrated in Figure 1, where a roadside unit is broadcasting content in a road corner. Only vehicles A, B, C are in its range. The other vehicles receive the content in ad hoc manner. In this example only nodes A and C (and not B) are selected to rebroadcast the content. Then only node G (and not H or I) will rebroadcast again the content. In this case 3 redundant rebroadcasts are omitted, namely the rebroadcast of nodes B, H and I.

ReViV protocol is built on top of IEEE 1609.4 by adding a rebroadcaster selection module. It selects a sub set of neighbors' vehicles, which ensure a large dissemination in the network, to rebroadcast the content. The rest of vehicles (non-rebroadcaster) will not retransmit the received content. Our target in ReViV is to select a minimum set of neighbors' vehicles which are more "central" in the network and which covers all the 2 hops neighbors. In Social Network Analysis (SNA) the centrality problem has been widely studied [10] and many centrality metrics have been proposed such as the node out-degree, the Shortest-Path Betweenness Centrality (SPBC) [10]. In the example of Figure 2, we note that the nodes C,D,F and G are equally central in terms of out-degree; they have all an out-degree c equal to 4. In addition, if we calculate the SPBC [10]for each node in the graph, we found that node G is the most central (SPBC=13), followed by nodes C, D (SPBC=10, 8 respectively) and finally node F (SPBC=7). This is somewhat unexpectedly, since node F has all network nodes at its range (at distance 2-hops). Based on this observation, we propose a new centrality metric, named the dissemination capacity (DC) defined as follows:

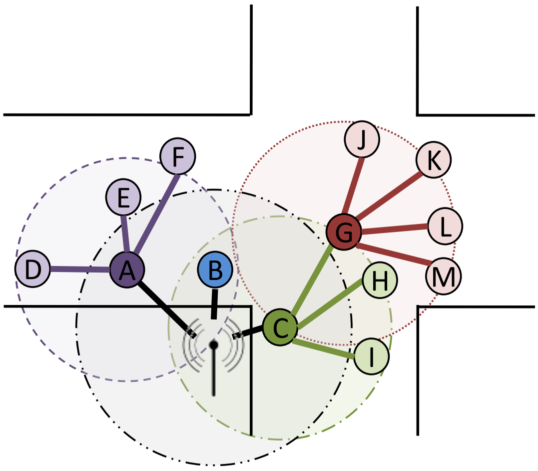


Figure 1: Example of rebroadcaster nodes selection

Definition: The dissemination capacity DC(*v*) of a node *v* is the maximum node *v* degree *n* which ensure that *n* 1-hope neighbor has a degree equal to *n*.

Applying this definition to the graph in Figure 2, we find that DC(G) = DC(D) = 2, whereas DC(F) = DC(C) = 3.

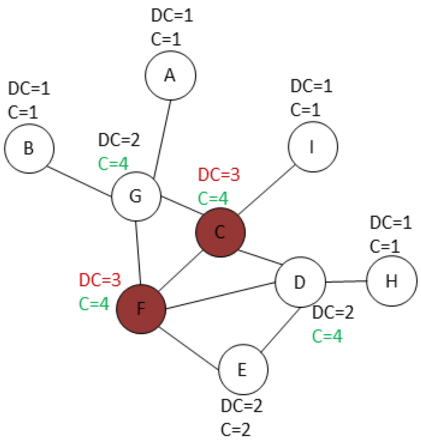


Figure 2: Node dissemination capacity example

It is clear that the network nodes which have more connections (larger degree) are more likely to be "powerful" to disseminate the content in the network, since they can directly touch more other nodes. But, their power depends also on the degrees of their 1-hop neighbors. Large values for the DC(*v*) of a node *v* indicate that this node *v* can reach others nodes on relatively short paths. Consequently the proposed centrality metrics, in addition to the reducing the amount of redundant rebroadcast, allows also to minimize the end to end delay.

Despite of the advantages that the DC metric offers, its calculation is not computational costly neither introduces an important communication overhead. Indeed, each vehicle in the network computes locally its DC and disseminates it to its neighbors in beacon message. In order to compute its DC, a vehicle needs only the out-degree of its 1-hope neighbors. This parameter is piggybacked in beacon message broadcasted periodically. In the following section we study the performance of ReViV in different vehicles density conditions and using videos encoded with different streaming rate.

IV. Performance Evaluation

In this section we evaluate the performance of our proposed mechanism ReViV, using the network simulator NS2 coupled with SUMO to generate real traffic mobility. Realistic maps were also selected from Aachen city by using the OpenStreetMap Project [11].

We measure the performance of our protocol in terms of frames loss, frame delay and Peak Signal to Noise Ratio (PSNR). Evaluation metrics were captured and compared to the multichannel vehicular communication standard IEEE 1609.4 [9] and the protocol AID [8]. Recall from our discussions on section II that AID and IEEE 1609.4 were designed for urban vehicles communication environment. AID based on statistics about the received messages tries to reduce the redundant transmissions. While IEEE 1609.4 takes advantage of the different DSRC channels in order to reduce interferences.

A) Simulation environment and parameters

To evaluate our proposed protocol, the implementation and simulation were done using NS2 version 2.31 [12] and we used SUMO [13] which is a microscopic traffic simulator. SUMO performs simulations of vehicle movements in real word maps following multiple lanes, speed limits and traffic lights. Different maps of 4km x 3km from Aachen city were selected for performance evaluation of ReViV. Vehicle routes are computed using SUMO shortest path computation, by using the DUAROUTER [14].

The radio propagation model adopted in our simulation is two-ray ground implemented in NS2. If not specified otherwise, the vehicle transmission range is 200m. In ReViV, Beacon messages are transmitted every 1s on the DSRC control channel.

Regarding the transmitted video, we used the widely known akiyou cif video, composed of 300 frames at a resolution of 360x486. The frames are packed up in 560 messages of 1024 bytes. The video is initially transmitted by a vehicle at the center of the network.

In addition, the video blocks are generated at different bitrates: 100kbps, 500 kbps and 1 Mbps. These data are conveyed exclusively by the service channel (SCH): The DSRC service channels or CR channels.

All the results are represented at a confidence interval of 95%, the mean of 30 excursions for each scenario.

In order to evaluate the PSNR metric of the three protocols we use the video quality evaluation tool-set EvalVid [14] on the reconstructed raw videos.

B) Results

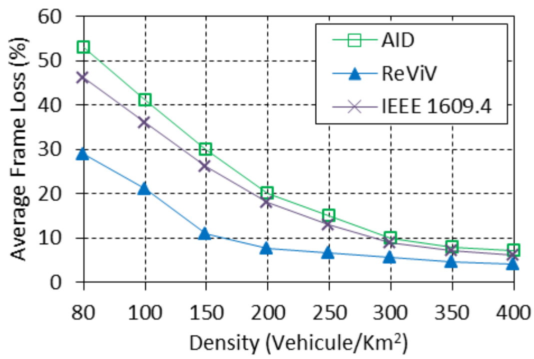
1) Frames loss

In Figure 3 we study the frame loss in ReViV, IEEE1609.4 and AID while varying the vehicles densities under different video bitrates conditions: 100 kbps, 200 kbps and 1Mbps.

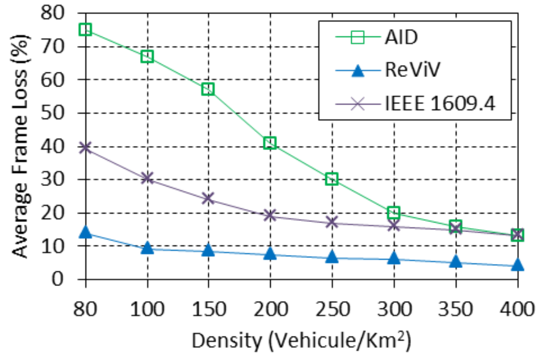
Figure 3 (a) shows that at 100 kbps, ReViV presents the low frames loss. The common remark in this scenario is that in low vehicle densities scenarios (<200 vehicles/km^2), all protocols experiences high frame losses, and this is due to the intermittently connection of the network. Indeed, in this case, the connections between vehicles are shorts and at lower bitrates it takes longer time to stream the whole video from a vehicle to another. Hence the high frame loss. The frame loss is less in IEEE 1609.4 comparing to AID because it exploits different channels for data transmission. This reduces the amount of collision and consequently the frame loss.
We note also that the ratio of frame loss converges for the three protocols to acceptable values (<10%) at high densities (≥300 vehicles/km^2).

Increasing the bitrate to 500 kbps (Figure 3 (b)), the channel turns out to be overloaded and the advantages of ReViV becomes more visible. Indeed, we note that the frame loss in ReViV is very low (<4%) at densities higher than 100 vehicles/km^2, while we note the increase of frame loss in AID and IEEE 1609.4. Low frames loss in ReViV is thanks to rebroadcaster selection proposed mechanism, which takes selects a sub-set of vehicles to rebroadcast the content. Consequently reducing the interferences.
IEEE 1909.4 outperforms AID because it exploits the different service channels of DSRC band to transmit video data, while AID transmits the video data in a single channel.

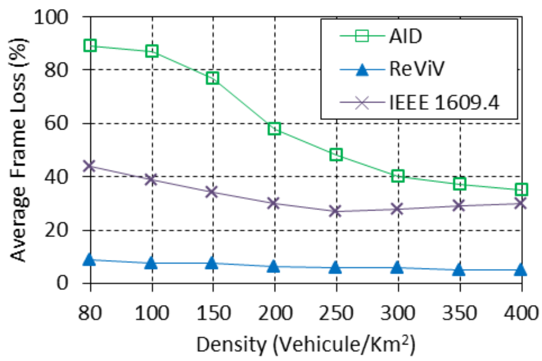
At bitrate of 1Mbps (Figure 3 (c)), the channel becomes extremely loaded. We note that in this case the frame loss increases for the protocols IEEE 1609.4 and AID in high densities scenarios, but in different degrees. High frame loss is observed in AID (~45% at 250 vehicles/km^2), and IEEE 1609.4 (~28% at 250 vehicles/km^2) while ReViV performances do not degrade comparing to the other protocols. This confirms the effectiveness of rebroadcasters selection mechanism proposed in ReViV.



a) Average frame loss at streaming rate of 100 Kbps



b) Average frame loss at streaming rate of 500 Kbps



c) Average frame loss at streaming rate of 1 Mbps

Figure 3: Frames loss Vs vehicles density

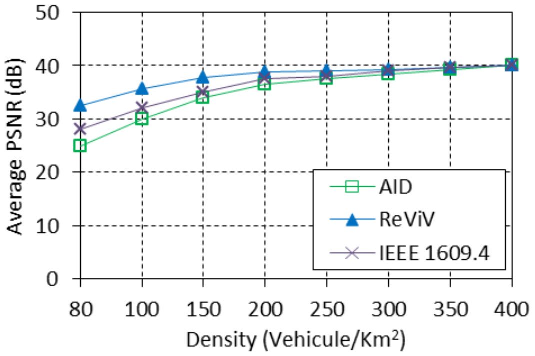
2) PSNR

Figure 4 shows the average Peak Signal-to-Noise Ratio (PSNR) of the reconstructed video at the receivers' vehicles in different vehicles densities scenarios. We remind that a PSNR value between 30 and 40 shows that the video quality is of a good enough.
Figure 4 (a) shows that ReViV outperforms AID and IEEE 1609.4 in terms of the received video quality at 100 kbps. ReViV enhance the video quality by 4 dBs at 80 vehicles/Km^2 comparing to the standard IEEE 1609.4. We explain this by the good selection of rebroadcaster vehicles which ensures a wide propagation of the content in the network with less interferences. The results low fewer packets loss, which leads to a better video PSNR.

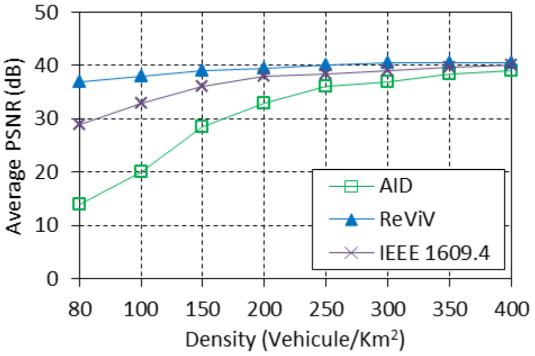
Increasing the bitrate to 500 kbps (Figure 4 (b)), ReViV the video quality is enhanced by ~8 dBs at 80 vehicles /km^2 comparing to the standard. We note that AID presents the worst PSNR scores. This is due essentially to the fact that AID exploits only one channel for transmitting the video. This is why it suffers from a high collision ratio and consequently low PSNR.

At bitrate of 1Mbps (Figure 4 (c)) the overall PSNR quality degrades for the three protocols. Neither AID nor IEEE 1609.4 ensures an acceptable reconstructed video quality (PSNR < 30). However, ReViV ensures the best quality among the four protocols. The quality of the received video in ReViV is of good quality (PSNR>30), and the gap in PSNR, between ReViV and the two other protocols widens in more dense scenarios. For example the PSNR of videos ensured by ReViV is outperforms the PSNR in the case of IEEE 1609.4 by 200%

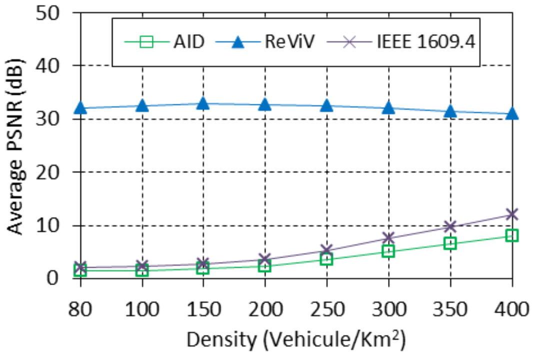
at 400 vehicles/km^2. This confirms the effectiveness of the ReViV channels selection mechanism in dense scenarios.



a) Average PSNR at streaming rate of 100 Kbps



b) Average PSNR at streaming rate of 500 Kbps



c) Average PSNR at streaming rate of 1 Mbps

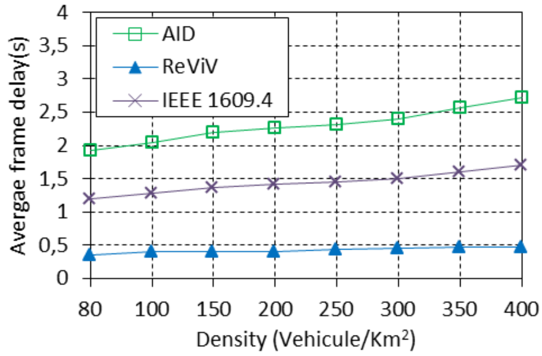
Figure 4: PSNR Vs vehicles density

3) Frames delay

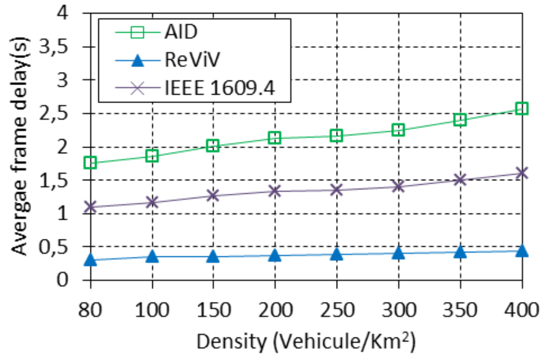
In Figure 5 we study the performance of ReViV in terms of average delay to deliver frames to receivers.

We note in Figure 5 (a) that the frames delay in ReViV is not influenced by the density of vehicles. It is stable at ~0.45 s, which is a good value for real time streaming application. However, we note that the average frames delay in AID and IEEE 1609.4 are relatively high. Upper than 1.2s for IEEE 1609.4 and upper than 2s for AID. We explain these high values in AID by the retransmissions due to the high interferences degree in this protocol, since it uses a single service channel for video transmission.

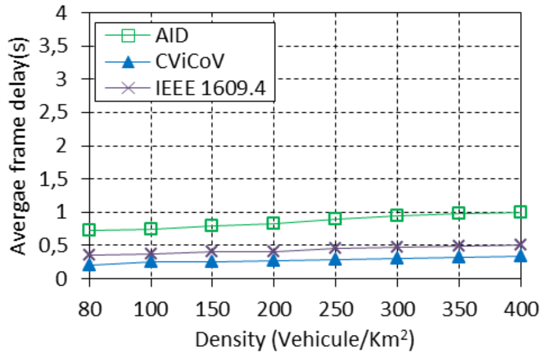
Figure 5 (b) shows the evolution of average frames delay under streaming rate of 500kbps. We note in this figure a little enhancement in frames delay for AID and IEEE 1609.4 comparing to the 100kbps streaming rate scenario. However, they are still of higher values. ReViV presents always the lowest frames delays around 0.25s. We explain the general decrease of the frames delay by the increase of the frame rate. ReViV still of the best performance since it selects the best vehicles to retransmit the content, consequently low interference and low delay. The same trend observed in the scenario of 1Mbps (Figure 5 (b)).



a) Average frames delay at streaming rate of 100 kbps



b) Average frames delay at streaming rate of 500 kbps



c) Average frames delay at streaming rate of 1Mbps

Figure 5: Average frames delay Vs vehicles density

V. CONCLUSION

In this paper, we proposed ReViV, a rebroadcasters selection mechanism for video streaming over VANET. ReViV selects a subset of vehicles in the networks to rebroadcast the content, based on their strategic location in the network and their capacity to reach a maximum of vehicles in a minimum of hops. When compared to two related protocols, we show that ReViV reduces the frame loss to its low values (<2%) and enhances the PSNR of the received video compared to a similar protocols while reducing the frames delay to acceptable values for real time streaming. The performances of ReViV are tangible mostly in dense traffic / high streaming rate scenarios.

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