# V2X Solutions for Real-time Video Collection

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***Abstract*—Quickly identifying the severity of highway accidents, as well as the resources required to assist the people involved in those accidents, is a basic requirement for future intelligent transportation systems. In this context, vehicular communication technologies currently being standardized are able to provide novel solutions to address this problem.**

**In this work we study the feasibility of combining vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications to deliver a video stream from the place of the accident to the traffic authorities. Our approach relies on vehicles as data relays, thus having the additional advantage of providing drivers with a clear view about the accident, thereby helping to reduce stress and improving traffic flow.**

**An experimental analysis comparing different traffic flooding mechanisms for wireless networks show that the proposed system is viable for highways with moderate/high amounts of traffic, although highlighting the need for more efficient mechanisms specifically addressing broadcast propagation in highway environments.**

## I. Introduction

The research community has been interested in Vehicular Ad-Hoc Networks (VANETs) for several years since the deployment of this type of networks will be able to provide significant improvements in terms of road safety, as well as to obtain valuable real-time traffic information [1]. VANETs include both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, and the combination of both is often referred to as V2X.

Several types of applications and protocols have been proposed to propel the possibilities that this type of network provides [2]. However, every proposed application and protocol has to cope with the problems and characteristics inherent to this type of networks, such as high relative speeds, Doppler effect, low transmission rate, etc.

Automatic accident warning and notification has become a critical safety application in VANETs [3], where the majority of protocols adopted flooding techniques to warn all the nodes, as well as the traffic authorities, about the accident.

Other type of applications useful for everyday life relies on DTN protocols to spread traffic information, such as traffic jams and pollution levels in different areas of the city [4], [5]. Both applications have in common that the amount of information to transmit can be considered "low", and both require that the information is able to reach its final destination (high reliability).

Additionally, several studies have built upon the idea of providing Video On Demand (VoD) to vehicle users with a combination of V2V and V2I. Vehicles are only acting as receivers and, although video delivery implies a high amount of information, this can be scheduled and distributed among a set of RSUs, and stored in the vehicle's buffer.

The recent approval of the new H.265 video compression standard [6], which intends to replace the widely used and well-known H.264 standard [7], provides a new opportunity for real-time video transmission in critical contexts. The new standard, which outperforms the old one achieving the same video quality with only 50% of the bit-rate, is expected to become an enabling technology when attempting to provide real-time video transmission in vehicular networks; thus, H.265 was selected to carry out the different experiments in the scope of our work.

The motivation of this paper is to address the challenges that arise when attempting to provide an innovative service in vehicular environments: vehicles involved in traffic accidents shall produce a high amount of information (a video sequence), which is of interest to all the nodes in the network (both vehicles and RSUs), and this information flow must experience a low delay (soft real-time).

This work does not attempt to present an application that makes use of this type of traffic, focusing instead on evaluating the effectiveness of different flooding schemes with the purpose of achieving a real-time video transmission over multiple hops under different vehicle densities. Based on the results achieved, we assess the feasibility of distributing a live video stream between vehicles at long distances using flooding. In our study we take into consideration both the packet delivery ratio and the end-to-end delay experienced by video data.

The rest of the paper is structured as follows. In section II we review the state of the art in terms of both flooding in wireless networks and video transmission over VANETs. Afterwards, in section III, the different flooding schemes used for testing are described. In section IV we provide details about the simulation scenario, as well as an overview of the methodology adopted. Section V presents the obtained results and, finally, section VI presents the conclusions obtained and discusses future works.

## II. Related work

The IEEE 802.11p protocol is the standard for Vehicle-to-Vehicle (V2V) communications, and it is based upon the IEEE 802.11 protocol and its quality of service extensions, IEEE 802.11e. So, IEEE 802.11p provides a contention-based broadcast mechanism, and its behavior is closely related to IEEE 802.11; therefore different solutions proposed for the original standard can be adapted to this new type of networks.

During the past few years, several authors have proposed different algorithms to achieve efficient flooding in MANET and VANET environments, proposing several ways of controlling the broadcast storm problem.

Yu-Chee Tseng et al. [8] proposed and improved versions of the Counter-Based, Distance-Based, and Location-Based schemes. These schemes have some weak points, such as failing to provide any kind of delivery guarantee. Nevertheless, they have some interesting features including (i) low overhead, (ii) being highly adaptable to different conditions, and (iii) providing a completely autonomous broadcast system.

Martínez et al. [9], following the guidelines of the Distance-Based scheme, proposed a flooding mechanism that takes into account the specificities of VANETs; in particular, they tweak it to provide a fast dissemination of accident alerts in urban scenarios by using information such as the street layout to achieve a smarter flooding. For highway scenarios their algorithm does not significantly differ from the Distance-Based approach. Also, although a really high warning rate is achieved, they do not guarantee the alert delivery to every node in the network.

Other authors, like Osafune et al. [10], introduce the concept of "Backfire" for flooding schemes. This concept proposes that, when a node receives a copy of a message from another node which is considered to be a better retransmitter, the first node cancels the retransmission of the packet, thereby achieving reductions in terms of sent messages and channel contention.

Ros et al. [11] try to ensure the message delivery by addressing the problem of temporary disconnections which occur in VANET scenarios. They make use of the beaconing system to piggyback acknowledgements in beacon messages, allowing nodes to start the retransmission of a message when some neighbor has not received the alert message.

With the same idea of making use of the beaconing system to ensure a proper message delivery through acknowledgment piggybacking, Na Nakorn et al. [12] present DECA and DECA-Bewa. Both flooding schemes requires a modified beaconing system, being the later characterized by a variable beacon interval time. Additionally, the flooding algorithm is only based on 1-hop neighbor density information, thereby avoiding the use of GPS. Authors claim that GPS precision and availability is critical for GPS-based flooding schemes.

F. Soldo et al. [13] presented the SUV protocol, a distributed solution to disseminate video streams in VANETs. The protocol proposes dividing the neighbors into four sectors, and selecting as a candidate for rebroadcasting one node in every sector, although a special MAC layer is required to support TDMA scheduling; such requirement prevents its implementation on actual IEEE 802.11p devices.

In this work we will compare proposals from different authors in order to determine which is more effective when attempting to deliver high amounts of data (in our case video data) through flooding. The proposals chosen for our experiments are described in more detail in the next section.

## III. Description of the flooding schemes

In this section we will briefly describe the behavior of the different flooding algorithms we have implemented in our simulation platform for testing. We have split the algorithms in two groups: basic schemes and adapted schemes, being the latter a slightly more sophisticated group of schemes compared to the former.

### A. Basic schemes

*1) Counter Based Scheme:* This scheme was one of the first solutions proposed to effectively reduce the broadcast storm problem. The main idea is that every node resends a packet until it has received $C$ copies of that packet from other nodes.

To avoid a large number of collisions when receiving a packet, every node waits from a random time before resending it, so it can listen to the medium and wait for the $C$ counter to increase.

All the flooding schemes presented in this paper, except DECA, adopt the concept of receiving $C$ copies of a packet to stop rebroadcasting it.

This scheme has several advantages over other solutions. The first one is that it is quite easy to implement, not having any relevant requirements except for a wireless card. The second advantage is the possibility of tuning the algorithm by modifying both the maximum amount of time a node can wait to rebroadcast a packet, and the number of copies a node should hear to stop rebroadcasting; this way, merely by modifying a simple parameter, we are able to increase the redundancy. The third advantage is that it is a good reference for other algorithms and, in case of problems with any of the required modules (GPS or Beaconing system), it can be used as a fall-back scheme without dramatically degrading the flooding performance.

The reason for selecting the Counter-Based scheme instead of other sophisticated schemes such as [14], [11] and [12], is the type of traffic we intend to transmit (video traffic), especially when fast data spreading is more relevant than high reliability.

*2) Distance Based Scheme:* This scheme builds upon the Counter Based Scheme by adding a new requirement: a positioning system (GPS).

Due to this new requirement, we can easily improve the intelligence of the algorithm to decide which node can be a better next-hop when rebroadcasting a packet.

Since the algorithm should remain autonomous, and since the decision about whether to rebroadcast a message should be taken independently by each node, this scheme makes use of the waiting time to resend messages. The time a node waits for before resending is inversely proportional to the minimum distance between the original node and the resending node. This way, nodes are virtually ordered according to the additional area of coverage, prioritizing those nodes whose additional area is supposed to be bigger.

To implement this scheme we need some kind of location mechanism, such as GPS, and the packets should be marked with the original sender node position and the resending node position.

This mechanism allows a rapid spreading of the packets while obtaining a profitable message forwarding process in terms of extra coverage area achieved by every new transmission.

### B. Adapted schemes

*1) DECA:* DECA [12] is a flooding scheme that does not rely on positioning mechanisms to spread information. Instead, it makes use of the beaconing system to estimate the 1-hop neighbor density and, thus, select as resending node the neighbor with more 1-hop neighbors. Also, it makes use of the beaconing mechanism to piggyback acknowledgement messages, thereby reducing the channel resources consumed.

DECA was adapted to video streaming particularities by including in the beacons information about the last packet properly received.

*2) Backfire Scheme:* The basic behavior of this algorithm is similar to the Distance Based Scheme. As proposed in [10], the major improvement introduced has to do with an analysis of area covered by neighboring nodes. In particular, if a node receives a packet from another node that is supposed to provide more additional coverage area, it stops rebroadcasting that packet. This strategy allows reducing the number of collisions by minimizing the number of unnecessary transmissions.

## IV. Scenario and Methodology.

The simulation environment is composed by three main components:

- OMNeT++ [15], an event-driven simulator which provides a base for implementing several types of models.
- INET framework [16], an implementation of the different network models for the OMNeT++ simulator, which includes several network models, from the physical to the application layer.
- SUMO (Simulation of Urban MObility) [17], which provides realistic vehicle behavior. SUMO runs coupled with the OMNeT++ simulator by using TRaCI, allowing several mobility parameters, such as vehicle speed, to be changed in simulation time.

The transmission range in the INET framework is not defined as a fixed distance. Instead, it requires tuning different parameters such as the frequency or the level of attenuation with distance. To achieve the highest degree of similarity with reality we adopted the parameters proposed by Báguena et al. [18].

Table I
Vehicle types and associated probability.

| Vehicle Type | Maximum Speed (m/s) | Length (m) | Probability |
|---|---|---|---|
| Truck | 25 | 12 | 0.10 |
| Car | 33 | 4 | 0.79 |
| Slow Car | 25 | 5 | 0.10 |
| Fast Car | 39 | 4 | 0.01 |

For a more realistic mobility behavior that includes vehicle overtaking, we defined a set including different vehicle types with an associated probability of occurrence. All this data can be seen in table I.

To perform our experiments with predefined vehicle densities we used VACaMobil [19], a tool that allows defining a vehicle arrival rate, maintaining a stable mean number of vehicles throughout the entire simulation.

Additionally, the SUMO step value was configured to $0.1s$ in order to achieve a more realistic scenario. Notice that, when vehicles move at highway speeds ($30m/s$), the default SUMO step ($1s$) provides a level of granularity that is too coarse for our experiments. By setting this step to a lower value, position updates become more frequent, allowing the vehicles' movements in the simulation become smoother, and making communications between vehicles more realistic.

### A. Scenario

Figure 1 shows the simulated scenario, which is a 10 kilometer straight highway with two ways and two lanes per way.

A set of RSUs has been deployed at every kilometer, and the distance between the RSUs and the road is $5m$. RSUs do not cooperate in the flooding mechanism, being mere traffic sinks used to measure the expected quality at every kilometric point of the highway. This strategy allows measuring the expected video quality when deploying RSUs with different spacing between them.

For our simulations we varied the vehicle arrival rates to compare the effectiveness of the protocols at different vehicle densities.

When the number of vehicles in the network becomes stable we schedule an accident at the centre of the scenario ($5km$ point). Since vehicles driving in the direction of the accident vehicle attempt to move from kilometer $0$ to kilometer $10$, the accident produces a small traffic jam from kilometers $0$ to $5$ on both of the lanes. For vehicles moving in the opposite direction, traffic continues to flow undisturbed.

Concerning video traffic generation, the damaged vehicle immediately starts transmitting video through flooding.

### B. Methodology

To evaluate the four different algorithms under the same traffic conditions, we run a set of 15 repetitions per configuration with different node mobility patterns, thereby achieving a good data significance.

We compare the effectiveness of the different flooding schemes in terms of packet arrival ratio and delay.

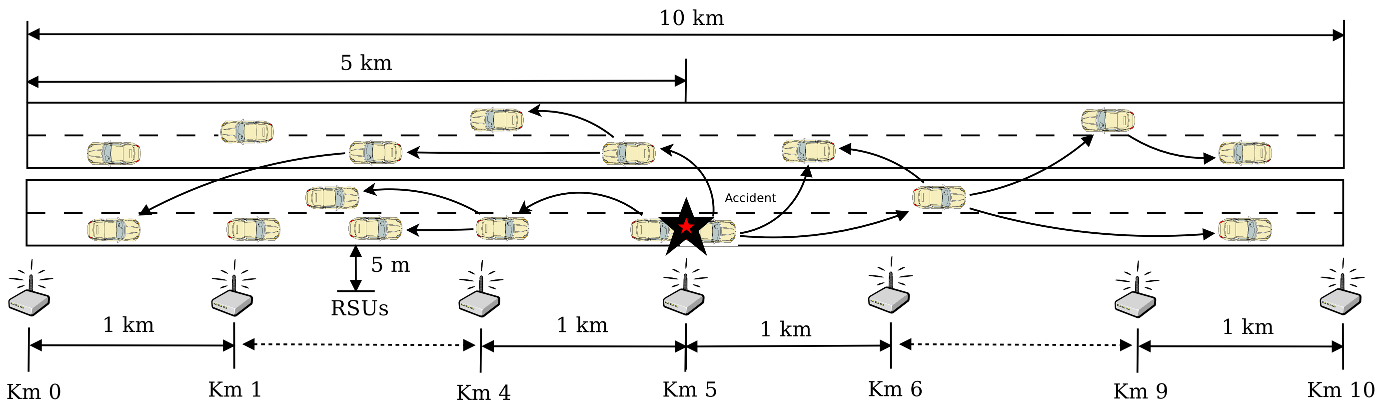


Figure 1. Highway scenario.

Table II
PARAMETERS FOR BEST-CASE SIMULATIONS.

| Density | High | | Medium | | Low | |
|---|---|---|---|---|---|---|
| | C | Time (ms) | C | Time (ms) | C | Time (ms) |
| Counter | 1 | 400 | 2 | 400 | 3 | 500 |
| Distance | 1 | 300 | 2 | 500 | 2 | 500 |
| Backfire | 2 | 300 | 3 | 200 | 5 | 300 |

*1) Simulation setup:* The different flooding schemes have been tested under three vehicle densities. These densities are achieved by setting an exponential Inter-Arrival Time of vehicles equal to $0.25s$, $1s$, and $3s$ respectively. Such Inter-Arrival Times correspond, approximately, to a mean density of 100, 30, and 10 *vehicles/km*. These three vehicular densities have been labeled as "High", "Medium", and "Low" in the figures of this paper.

Additionally, for each algorithm and vehicular density, we tested all the possible combinations for the $C$ and *Waiting Time* parameters. Possible $C$ values are $1, 2, 3, 4$, and $5$; *Waiting Time* values can be $100, 200, 300, 400$, and $500$*ms*.

All the different results presented in the next section correspond to the best possible configuration of every algorithm, for each density, in terms of parameters $C$ (Number of copies required to stop resending) and *Waiting Time* (Maximum time that a node waits to resend a message). The optimal parameters for the selected schemes are shown in table II.

As expected, higher node densities are associated with lower count values (parameter $C$), and in general lower timeout values as well, since the existence of more nodes makes the process quicker and more resilient.

## V. RESULTS

In this section we present the results from our experiments, which were obtained using the simulation setup and methodology described above. We focus on two different metrics: packet delivery ratio and end-to-end delay. These metrics are assessed on RSUs deployed every kilometer.

Figure 2 (left) shows the percentage of received packets for the different flooding schemes when vehicle density is high. We can appreciate how almost every single flooding scheme is able to achieve more than $92\%$ of packet arrival ratio, even at a distance of $5km$ from the accident (kilometers 0 and 10).

We can see that the Backfire scheme performs better than any other scheme due to the reduced number of collisions produced. DECA is the worst performing solution among all presented algorithms, with packet delivery ratios ranging from $21.2\%$ to $48.4\%$ (values below the range shown in the figure). Due to the high requirements of video traffic in terms of bandwidth, a significant amount of collisions occurs when vehicles piggyback the information about missing packets. Notice that, if some nodes experience packet losses, a high number of retransmissions are scheduled by different nodes, thus increasing the chances of collapsing the wireless medium.

In terms of delay, if we look at the right part of figure 2, the differences between the selected algorithms are very noticeable. The Backfire scheme is able to deliver the packets in a very short time (less than 500 ms), while for Counter and Distance schemes the delay is quite higher (about 2.7 s). As a high number of collisions occur, the wireless medium is extremely congested, and so the delay experienced by DECA is quite high; in fact, DECA's delay values are about eight times higher than the average delay achieved when using the Backfire scheme.

Figure 3 shows the results for the medium density scenario. In this scenario, the Backfire flooding scheme is able to provide the best results up to $4km$, achieving a delivery ratio of more than $90\%$. If we focus on the Counter and Distance schemes, we can see that the delivery ratio drops below $90\%$ at a distance of $3km$. Notice that packet losses greater than $10\%$ are prone to cause frequent video artifacts or even severe decoding problems.

Concerning delay, the values achieved do not significantly differ from those obtained under high node densities.

Again, we find that the behavior of the DECA-based scheme is still highly compromised, although slight improvements are detected.

Finally, figure 4 shows the results for the low density scenario. We find that now the Distance-based scheme achieves better results that the Backfire scheme, although all the flooding schemes evaluated are unable to achieve an acceptable

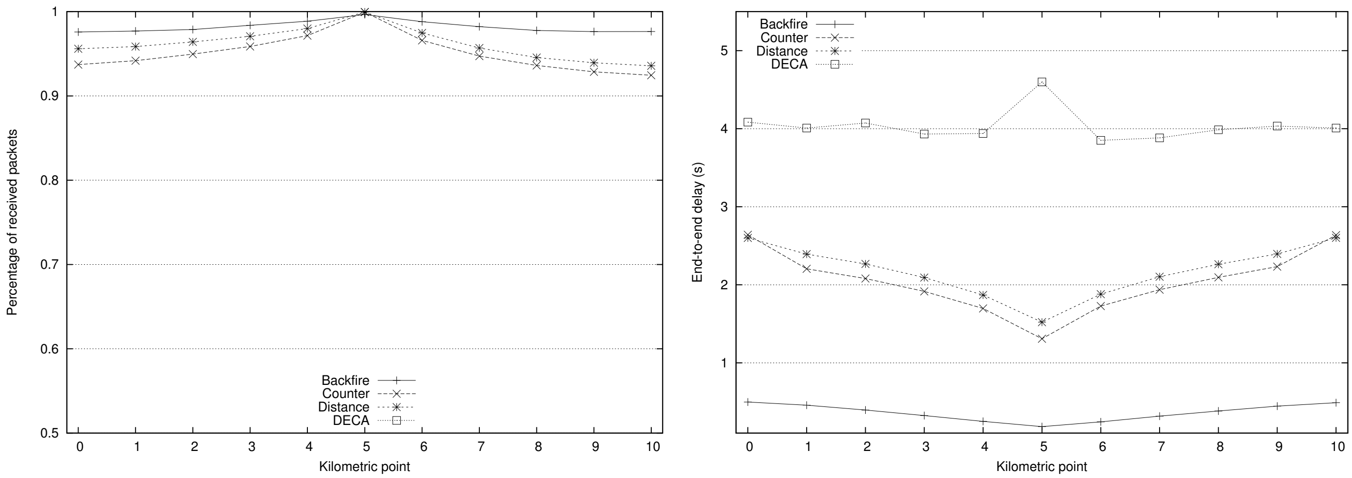


Figure 2. High density scenario. Percentage of packets received.

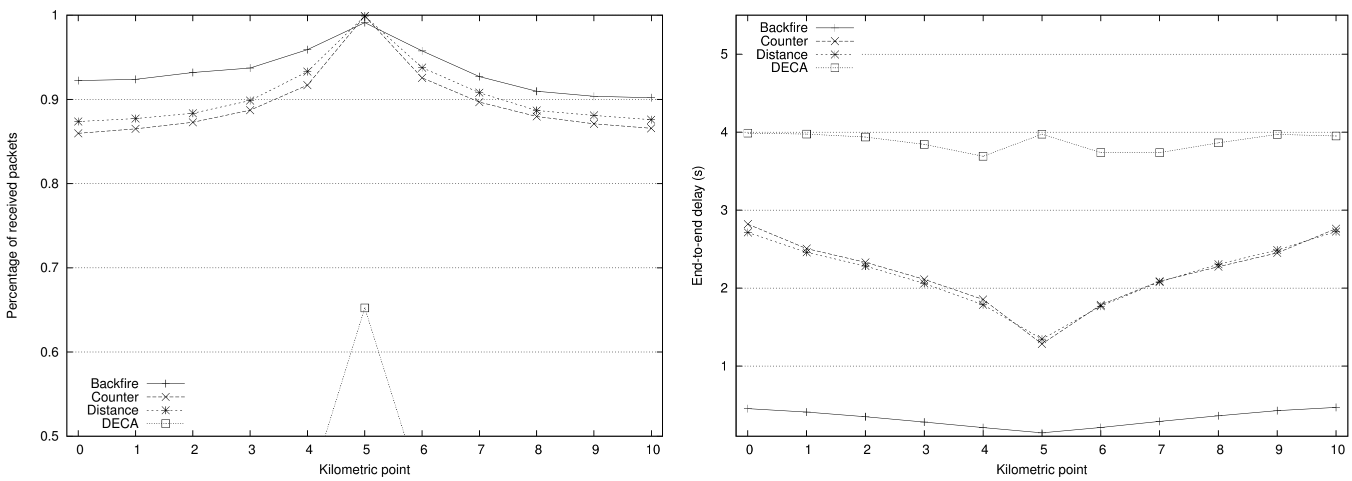


Figure 3. Medium density scenario. Percentage of packets received.

percentage of received packets from the video decoding perspective (more than $90\%$) when the density of vehicles is low.

If we focus in the delay for the received packets, we can see that the times are maintained with respect to the high and medium density scenarios, except for the DECA scheme which experiences a slight improvement.

Summarizing, we find that flooding schemes like DECA, which make use of the beaconing system to request missing packets, are unsuitable for real-time video flooding due to the packet losses and high delays introduced. We also find that schemes like Backfire, which aggressively try to reduce collisions in the medium while introducing low delays, are more suitable for real time video transmission, providing better overall results that the other schemes tested in terms of both packet delivery ratio and delay.

## VI. Conclusions and future work

Future intelligent transportation systems are expected to provide sophisticated applications to improve traffic safety and make driving a more effort-free and amenable task. To support these services, solutions combining V2V with V2I communications can help to alleviate the infrastructure deployment cost. Such costs are especially significant in highway environments, where several kilometers of road should be served while avoiding very high costs.

When accidents occur in a highway, providing the traffic authorities a real-time video from the accident scene can be quite helpful to assess accident severity and deploy the adequate services (fireman, ambulances, traffic regulation personnel, etc.). However, performing real-time video streaming in vehicular environments while relying on flooding for data propagation is a quite complex task, especially when considering the low channel capacity available and the high number of nodes involved.

In this paper we analyzed the viability of delivering video towards RSUs deployed at different distances from the accident. In our study we compared four different flooding schemes, and provided both packet arrival ratio and end-to-end delay results under low, medium and high traffic congestion

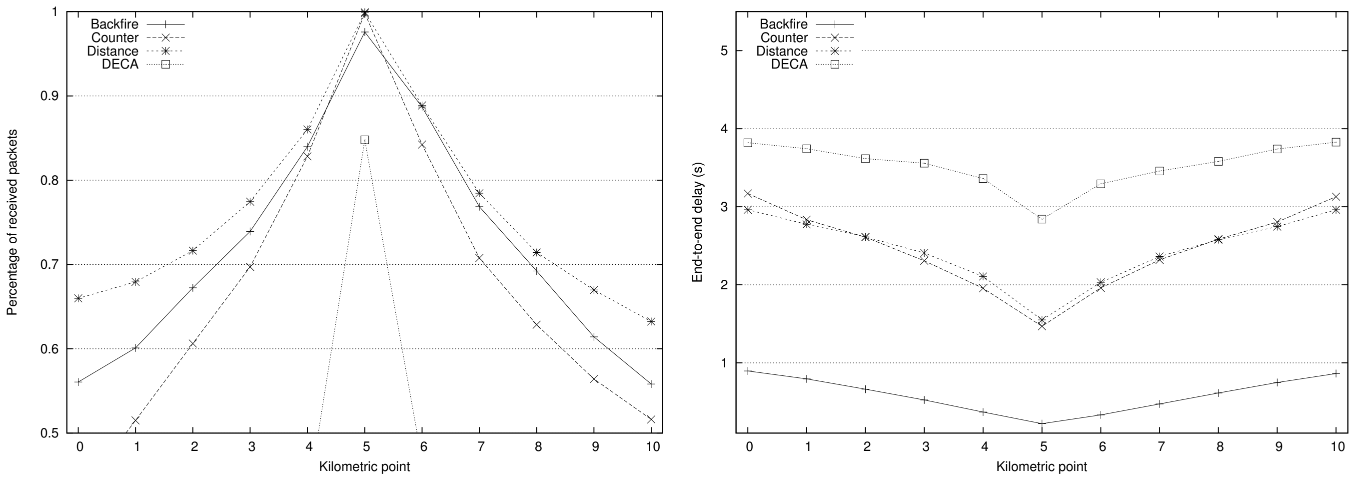


Figure 4. Low density scenario. Percentage of packets received.

levels. Experimental results show that the Backfire algorithm, or even simpler solutions such as the distance-based algorithm, are able to provide acceptable performance results. More specifically we show that:

- Under high vehicle densities, video delivery to RSUs located up to 5km away from the accident position is feasible, being the packet loss rate maintained below 10% using all available protocols (except DECA).
- Under medium vehicle densities, video delivery to RSUs located up to 5 km away is possible only when using the Backfire scheme, being that simpler schemes, like counter-based and distance-based, are only able to provide an acceptable delivery rate up to 2 km away.
- Under low vehicle densities, an effective video delivery is not achievable with any of the schemes tested, being quality significantly degraded just 1km away from the accident location.

As future work we plan to develop and evaluate new flooding schemes optimized for video delivery in highway scenarios, especially under medium and low vehicle densities.

## ACKNOWLEDGEMENTS

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