A Handover Algorithm for Video Sharing over Vehicular Networks

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***Abstract*—Vehicular networks over 5G are a promising solution that provides the requirements for an extensive amount of applications, such as Video Streaming. However, the higher number of cells deployed in 5G scenarios causes a high number of disconnections and handovers, which may compromise the quality of the user experience. In this paper, we introduce a predictive QoE- and mobility-aware handover algorithm for vehicular networks called HoVe. HoVe takes into consideration user location (current and predicted), QoE, and radio resources to provide a robust handover decision and high QoE for video-based applications in 5G VANETs. Simulation results show the efficiency of HoVe, delivering video with 18% better QoE when compared to state-of-the-art algorithms in vehicular scenarios.**

***Index Terms*—Handover, Heterogeneous Networks, QoE-aware, and VANETs**

I. Introduction

The next generation of mobile communications, 5G, is expected to offer significant improvements in terms of latency, bandwidth, and ubiquity [1]. 5G networks will carry 1000 times more traffic compared to 4G systems in a highly heterogeneous environment, with the presence of Macro Cells, Micro Cells, Small Cells, Relays, among others [2]. 5G is a promising solution to the heavy use of video-based services for mobile devices every time and everywhere [3].

Video streaming is already an important market driver, and where not only personal videos are shared, but also videos coming from entertainers and marketers [4]. These videos must be shared with Quality of Experience (QoE) and Quality of Service (QoS) support to deliver videos with a satisfactory quality for users [5]. One of the critical issues for the future and success of video distribution over 5G VANETs is the capacity in supporting efficient mobility management algorithms. This is a consequence of vehicles moving through different areas, and consequently, switching between different networks [6]. Since vehicles switch networks more than other users, like pedestrians, their mobility management must be optimized not to compromise the applications being consumed.

Applications over VANETs have stringent requirements in terms of latency and ubiquity and significantly benefit from the improvements of 5G [1]. However, the highly-dense and heterogeneous nature of 5G networks, while enabling higher data rates, also causes more frequent disconnections for mobile users. Video sharing over 5G-enabled Vehicular Networks, or 5G-VANETs, requires a seamless mobility and handover scheme in order not to compromise the user's QoE, and can significantly benefit from predictive schemes [7].

Taking into consideration QoE and QoS parameters in the mobility management can be a viable option to achieve a minimum quality required for video transmissions, but may not be enough in dense scenarios [8]. The trajectory of vehicular nodes is somewhat predictable and can be taken advantage of. Estimating a vehicle's future geographic position, even in the short term, can significantly improve network decisions [9]. In this sense, Traffic Management Systems (TMSs) can be integrated into the QoE-awareness handover process to improve the decision-making process [10].

The use of Multiple-Criteria Decision-Making techniques, such as the Analytic Hierarchy Process (AHP) [11], is a potent tool to perform handover decision-making and balance several inputs, like QoE, QoS, and location metrics. For instance, the degree of importance of each parameter changes continuously at runtime, and it has a significant influence on the handover decision. In this context, AHP decomposes a complex problem into a hierarchy of simpler sub-problems by combining qualitative and quantitative factors for the analysis, allowing the system to find an ideal solution when several criteria are considered in the handover process.

In this paper, we propose a QoE handover algorithm for video sharing in 5G vehicular networks (composed of small and macro cells), called HoVe (HandOver algorithm for VEhicular networks). HoVe provides high QoE by taking into consideration the vehicle's route, speed, radio resources, and QoE to guarantee seamless handovers. HoVe uses AHP to assign different degrees of importance for each criterion according to the vehicle and network conditions and balance attribute a score to each network. Simulation results show that the HoVe algorithm provides 18% superior performance regarding QoE compared to state-of-the-art algorithms in vehicular scenarios.

The rest of this paper is organized as follows. Section II outlines the state-of-the-art about handover algorithms, their main drawbacks to provide video dissemination with QoE support in vehicular network scenarios. Section III describes HoVe Handover Algorithm. Section IV discusses the simulation description and results. Finally, Section V introduces the conclusions and future works.

II. Related Works

This section explores the solutions proposed in recent years to improve handover performance and improve QoE for users in heterogeneous and dense mobile networks. This type of scenario is challenging in the sense that handover failure rate and ping-pong handovers become more frequent in these scenarios.

Gong *et al.* [12] propose a multi-criteria handover algorithm for heterogeneous networks considering Fuzzy AHP with a predictive scheme. Cross-tier handover performance is improved in this scheme in terms of failure probability and ping-pong rate. The authors use a long-term parameter as well as instant metrics to improve the handover decision. However, the paper does not consider QoE or mobility parameters, which could improve the algorithm performance.

In this matter, Qu *et al.* [13] proposed a Fuzzy forecasting model for long-term and short-term metrics, such as RSRP (Reference Signals Received Power) and user location. While this module only forecasts traditional handover parameters, it shows improvements in handover metrics over two-tier networks. The proposed solution is compatible with standard handover protocols and can be integrated with other metrics.

Silva *et al.* [14] proposed an adaptive Time-To-Trigger handover based on Fuzzy logic and user velocity. Such a scheme collects mobility parameters to predict user location, although not for handover purposes, but for content dissemination, showing that the offloading from Macro Cells to Small Cells can be essential in a heterogeneous environment. One of the main benefits of the proposed scheme is the reduced ping-pong rates in dense scenarios.

Another velocity-aware approach is presented by Arshad *et al.* [15], in which the impact of frequent handovers in dense cellular networks is studied, and a handover skipping approach is suggested. In this approach, the best SINR relation is sometimes sacrificed to avoid a disruption in the user's connection. The proposed solution does not consider QoE parameters but could be integrated with such for better performance.

Heterogeneous cellular networks and applications usually have a transparent barrier to trigger handovers, such as hysteresis and Time-To-Trigger. This may be inadequate for the management of high-performance cellular networks, such as 5G scenarios. Zhang *et al.* [16] proposed a classification of applications sensitive and insensitive for the user experience. A handover decision switches to a more energy-efficient network during idle timer and a high-performance network when predicted.

In the work by Chen *et al.* [17], a QoE estimation was proposed to correlate QoS and QoE to improve the user satisfaction not focusing only on call blocking probability and handover dropping probability. However, video sharing requires a more consistent QoE measurement to improve user experience as desired.

Medeiros *et al.* [18] developed a QoE-aware handover algorithm for heterogeneous networks based on AHP. The solution improves the quality of video streaming over mobile networks but is not optimized to take into account mobility information. Its execution in a dense scenario can cause a high number of ping-pong handover and failure.

Zineb et al. [19] improved the quickness of VHO decision improving or maintaining QoS levels using artificial neural networks based on previous knowledge. However, these solutions do not consider the mobility characteristics of vehicular networks.

Table I compares the algorithm proposed in this paper to various others described in the literature about the provisioning of QoE support, Mobility awareness, and their predictive nature. As we can see, none of the studies cited supports these three parameters simultaneously. By integrating mobility prediction into the algorithm, the

Table I
COMPARISON BETWEEN THE RELATED WORKS

Work	Technique	QoE Support	Mobility Support	Predictive
Gong et al. [12]	Fuzzy AHP			✓
Qu et al. [13]	Fuzzy Logic		✓	✓
Silva et al. [14]	Fuzzy Logic		✓	
Arshad et al. [15]	Handover Skipping		✓	
Chen et al. [17]	Q Learning	✓		
Medeiros et al. [18]	AHP	✓		
Zineb et al. [19]	Artificial Neural Networks	✓		
HoVe	AHP	✓	✓	✓

handover may adapt to the changes in neighboring cells and link quality much faster than other solutions.

Based on our analysis of the state-of-the-art, we conclude that it is vital to employ a QoE- and Mobility-aware seamless handover in 5G VANETs. The use of dense heterogeneous networks can provide adequate coverage and transmission quality for the users, however, in the mobility management of such networks, it is desirable to use multiple parameters in a multi-decision evaluation. So far, not all of these critical features have been provided in a unified scheme for enhancing video transmission over vehicular networks.

III. HoVe Handover

This section introduces the HoVe algorithm. HoVe provides handover with QoE support for video flows in 5G VANETs, considering Navigation History, QoE, and radio parameters for the handover decision. We consider a 5G scenario composed of Small Cells and Macro Cells and a TMS. HoVe relies on AHP to adjust the degree of importance of each parameter, as well as to compute the quality of each available network to select the best network for the vehicle to connect.

The handover process is performed in three distinct steps: measurement, decision, and execution. The first step consists of information gathering, where the algorithm collects important metrics for decision-making, *i.e.*, radio resources, packet delivery ratio, QoE, and Vehicle Mobility. Afterward, this information is evaluated in the Decision step to choose the best network available. If the algorithm decides so, a handover is performed. HoVe uses a seamless handover process (make-before-break).

The decision phase occurs individually in each cell, where the handover manager entity that receives measurements and performs the decision and coordinates the handover execution. Moreover, each network component has information about the location of the network cells and can use this information in the evaluation process.

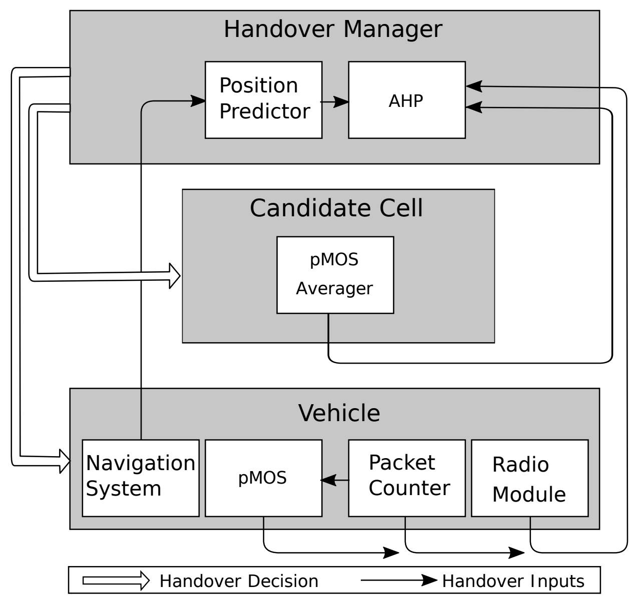


Figure 1. System Overview

Figure 1 illustrates the interactions between the vehicles, access points, and the Handover Manager. Mobile nodes continuously monitor packet flows to obtain current QoE levels; this information is then sent to the Handover Manager along with Radio measurements and the vehicle's coordinates. Navigation Information/routes of vehicles are used to predict the user's near future positions, and when all the inputs are available, the AHP algorithm is executed to evaluate all networks. If a handover is necessary, the current serving cell initiates the communication with the target cell and transfers the user. HoVe is compatible with traditional handover protocols and can be easily integrated.

Due to the highly mobile nature of vehicular networks, wireless links may last for very short amounts of time. Therefore, the handover algorithm must choose a network that remains available for a longer time window according to a short-term position predictor.

We consider that every vehicle in the network can access its position through a global positioning system. In theory, any predictor could be integrated into HoVe to perform the position prediction; in this context, a simple predictor is integrated into HoVe based on the position and velocity measured by each vehicle. A short-term prediction is performed based on the vehicle's velocity and position using kinematics equations. This has been shown to provide up to a 90% accuracy for vehicles since their mobility is approximately linear [20]. Based on the estimated future position of the vehicle and the known cell positions in the network, HoVe estimates is the distance between the vehicle and the available cells in the near future to avoid cells from which the vehicle is distancing itself.

The prediction granularity, in a spacial and temporal context, may be defined by the frequency of the measurements. Every time a new measurement is made, a new prediction is performed, given the simplicity of the prediction module, in this work, we adopted a granularity of 1 second. The predicted position is based on the point in space where the vehicle is likely to be 1 second after the measurement and is quickly updated after a new measurement arrives.

Hove uses pMOS, a low complexity QoE monitor presented by Medeiros et al. [18]. Videos are typically composed of the frame types Intra-coded picture (I), Predicted picture (P), and Bidirectional predicted picture (B), each with a different degree of importance when reconstruction the video sequence. The I-Frames carry all the information needed in a picture, as P-Frames and B-Frames only carry the bits of information that changes from the previous image to the current.

pMOS consists of a random forest that receives as input the loss rates for I-, P- and B-frames and outputs a Mean Score Opinion (MOS) value. pMOS was trained with a subjective analysis performed by human subjects for imitating human perception to frame losses. In this context, users consuming video content identify lost frames in the video and their respective types. The loss-ratio for each frame type is reported to HoVe and fed to the pMOS module.

Furthermore, radio measurements are also reported to HoVe in a traditional manner. SINR uses a signal quality metric and is also weighted in the handover decision.

The handover Manager finds the best network given the collected metrics, configuring a Multiple-Criteria Decision-Making problem. We chose AHP to balance the input metrics. AHP considers a pairwise comparison between the numerical values of each collected parameter and their relative degrees of importance, in order to adjust their weights of each parameter at runtime. The weights of the inputs must be defined when configuring the algorithm. High weight means more importance should be attached to this particular metric, and we define five importance levels, as shown in Table II.

Table II
PAIRWISE CONTEXT IMPORTANCE

$c_{i,j}$	Definition
4	i is much more important than j
2	i is more important than j
1	i is as important as j
1/2	i is less important than j
1/4	i is much less important than j

The Handover Manager constructs for each vehicle a matrix to compare all pairs of metrics. We denote $c_{i,j}$ as how important the $i-th$ element is compared with the $j-th$ element. In addition, $A = (C_{i,j})_{nxn}$ represents the comparison matrix, where n denotes the number of elements to be compared, as shown in Eq. (1).

$$A = (C_{i,j})_{nxn} = \begin{array}{c} \\ c_1 \\ c_2 \\ c_3 \end{array} \begin{array}{c} \begin{array}{ccc} c_1 & c_2 & c_3 \end{array} \\ \begin{pmatrix} c_{1,1} & c_{1,2} & c_{1,3} \\ c_{2,1} & c_{2,2} & c_{2,3} \\ c_{3,1} & c_{3,2} & c_{3,3} \end{pmatrix} \end{array} \quad (1)$$

In order to guarantee consistent QoE throughout a transmission, the pMOS metric has the highest priority when compared to mobility and QoS and Signal. We define the trajectory parameter as the estimated distance between the vehicle and the access point in the short-term future. QoS and Signal parameters are combined into a single input for the algorithm.

$$I = \begin{array}{c} \\ QoE \\ Distance \\ QoS/Signal \end{array} \begin{array}{c} \begin{array}{ccc} QoE & Distance & QoS/Signal \end{array} \\ \begin{pmatrix} 1 & 2 & 4 \\ 1/2 & 1 & 2 \\ 1/4 & 1/2 & 1 \end{pmatrix} \end{array} \quad (2)$$

After the selection of the relative importance, the matrix is normalized by dividing each element by the sum of its column and finding the eigenvector for the matrix. For instance, in Eq. 2 we find the eigenvector $W = [0.57\ 0.28\ 0.14]$, meaning that that QoE will have a weight of 0.57, 0.28 for Distance and 0.14 for QoS/Signal.

The Handover manager computes the score S_i for all available networks based on Eq. (3), where c_i represents the weight for a given metric, and P_j is the value for a given metric, *i.e.*, QoE, QoS, and Link Duration, obtained in the handover measurement phase. Finally, the handover manager selects the cell with the highest S_i value, which is the most suitable access point for the vehicle to connect at the moment and what the video.

$$S_i = \sum_{j=1}^{n} c_j \times P_j \quad (3)$$

Figure 2 details the steps involved in the HoVe execution. The current serving cell periodically requests measurement reports to the user, in our case, the vehicle. The vehicle evaluates the current QoE, in the case of video content being consumed, and sends it to the current cell its radio, QoE, and coordinates measurements. If a handover is necessary, the Serving Cell requests the transfer to the Target Cell and the channel allocation, and synchronization can begin. When the process is complete, the user sessions will now be handled by its new serving cell.

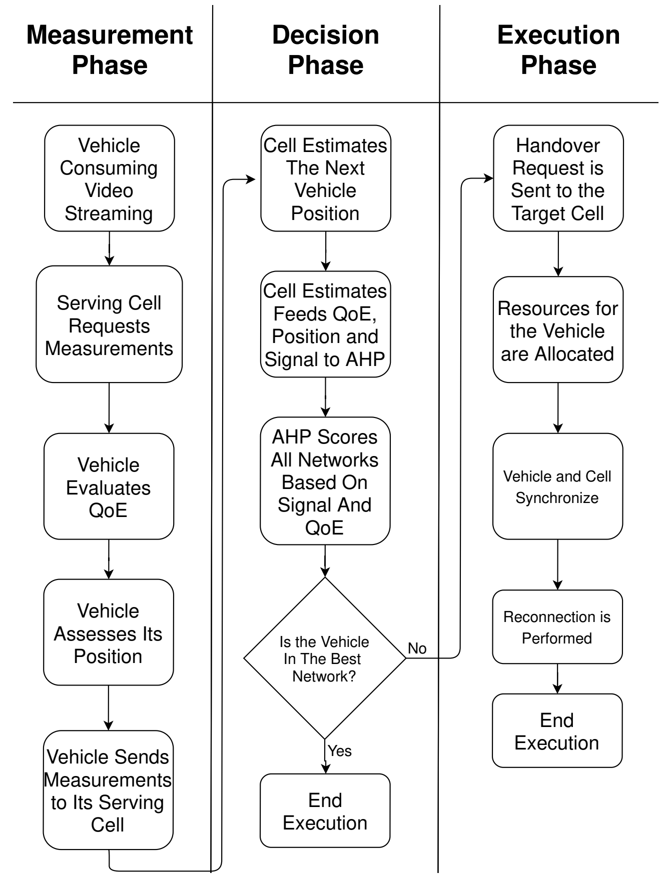


Figure 2. Execution Flowchart for HoVe

IV. Evaluation

A. Simulation Description and Metrics

HoVe was implemented and tested on the NS-3.27[1] simulator, where 33 simulations were conducted with different randomly generated seeds that were fed to its default pseudo-random number generator (MRG32k3a). Thus, it is possible to provide independent streams of random variables for each probabilistic model used. Results show the values with a confidence interval of 95%.

NS-3 implements the LTE protocol stack for communication between the mobile user with the radio base station. We consider simulation parameters presented by Tartarini et al. [21]. The scenario is choosen as a typical urban ultra-dense vehicular network woth two tiers, composed of two High Power eNodeBs (Macro Cells / LTE) and Low Power eNodeBs (Small Cells / WiFi) randomly distributed in the simulation scenario. In this scenario, nodes move in a grid topology at a 2D rectangular area of $4km^2$ (2000m X 2000m).

For the simulation of traffic and vehicle mobility, we employed the Simulation of Urban Mobility (SUMO)[2], which is an open-source traffic simulator to model and to manipulate objects in the grid scenario. SUMO allows us to reproduce the desired vehicle movements with a predefined path and speeds based on empirical data. We consider a scenario composed of vehicles at different speeds as expected in real cities (ranging between 10-70 km/h).

We considered video sequences with different motions and complexity levels, *i.e.*Football, Mobile, and Highway, which are downloaded from a well-known Video-trace repository[3]. Even small differences in the videos' characteristics can influence the obtained QoE values [22]. These videos mainly have a duration of 10 seconds (except Highway with 20 seconds) and 300 frames each (except Highway with 600 frames), encoded

[1]http://www.nsnam.org/

[2]http://sumo.dlr.de

[3]http://media.xiph.org/video/derf/

with an H.264 codec ranging from 210 kbps (Highway) up to 230 kbps (Container), 30 fps and intermediate size (352 x 288 pixels). It should be noted that all the videos evaluated are streamed in a loop. The decoder uses a Frame-Copy method as error concealment, replacing each lost frame with the last received one to reduce frame loss and to maintain video quality. The main simulation parameters can be seen in Table III.

Table III
SIMULATION PARAMETERS

Parameter	Value
Nodes speed	$[10 - 70]\ km/h$
Number of UEs	60
Number of Macro Cells	2
Number of Small Cells	50
Macro Cell Transmission Power	46 dBm
Small Cell Transmission Power	23 dBm
Propagation Loss Model	Nakagami
Scenario Size	$2km \times 2km$
Network Topology	6×6 grid
Video Tested	Highway, Container and Mobile
Simulated Time	60 Seconds
Transmission Start Time	20 Seconds
Number of Simulations	33

The handover algorithms compared are implemented on the lte-handover API present in the NS-3 Simulator, where all the relevant metrics can be accessed and evaluated for the decision and execution of the handover. NS-3 implements a hard handover mechanism (break-before-make) and the measurements and evaluation are performed periodically.

HoVe is tested against the SER [18] algorithm and standard LTE handover mechanisms such as RSSI-based handover and Strongest Cells, referred to as PBGT (Power Budget). SER is a QoE-aware handover algorithm for Heterogeneous Networks (HetNets), it has showed superior quality in the delivery of videos for mobile users. The Strongest Cell handover performs a signal strength based decision, in which the handover is executed if a neighbor cell's received strength is superior to the serving cell's plus a hysteresis value and such difference is maintained throughout a previously set Time-To-Trigger [23]. Furthermore, the RSSI-Based Handover Algorithm uses LTE's events A2 and A4 to trigger the handover execution. Both solutions take into account solely radio measurements in the process. RSSI-based and Strongest Cell are present by default in the simulator. SER was implemented as described in the paper where it is defined [18].

QoE metrics overcome the limitations of QoS metrics for video quality assessment since QoS metrics fail to capture subjective aspects of video content related to the human experience [5]. In this way, we consider Structural Similarity (SSIM) as the QoE metric to evaluate the video degradation to end-users. SSIM compares the variance between the original video and the original sequence concerning luminance, contrast, and structural similarity. SSIM values range from 0 to 1, where 0 is the worst case, and 1 means that the transmitted video has the same quality as the original video.

B. Simulation Results

Figure 3 shows the average SSIM achieved by each algorithm tested in the form of a bar chart, with a confidence interval of 95%. We can see that HoVe was able to deliver videos with a higher user experience when compared to the competing algorithms. Even SER, which takes QoE into consideration, wasn't able to adapt well to a denser scenario, causing decreased QoE to the users. We consider that a satisfactory user experience requires SSIM of at least 0.8. HoVe shows an average of 0.92. Considering the lowest bound of HoVe's confidence interval with the other algorithm's highest bound, HoVe performs 18% better than SER, 19% better than the RSSI-based, and also 19% better than PBGT.

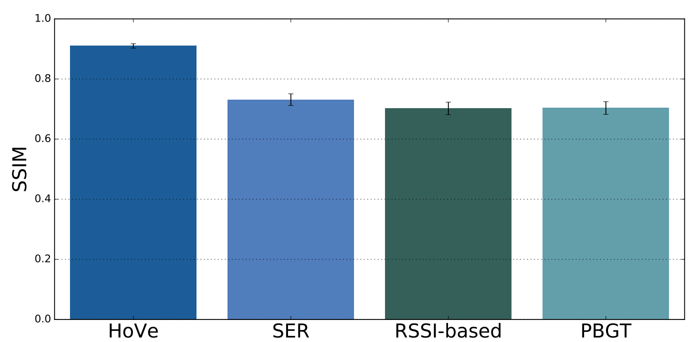


Figure 3. SSIM Obtained by Each Algorithm Over the Simulations

Figure 4 shows the average amount of handovers necessary in order to deliver a single video as the simulated time increases. We notice that the SER algorithm performs the highest amount of handovers, given that it has no constraints like a hysteresis or a Time-To-Trigger. The RSSI-based approach also has a higher number of handovers, due to it being more sensitive to channel variations, while the Strongest Cell mechanism makes the least amount of handovers among the tested algorithms because it tends to connect to Macro Cells more frequently, which can be less effective in terms of bandwidth. HoVe averages around 344 handovers for each transmission, at an average of 8% of handovers being ping-pong. We can see that after 20 seconds into the simulation, the rate at which handovers are performed stabilizes as the decision is optimized in order to maximize the duration of the link while maintaining acceptable QoE levels.

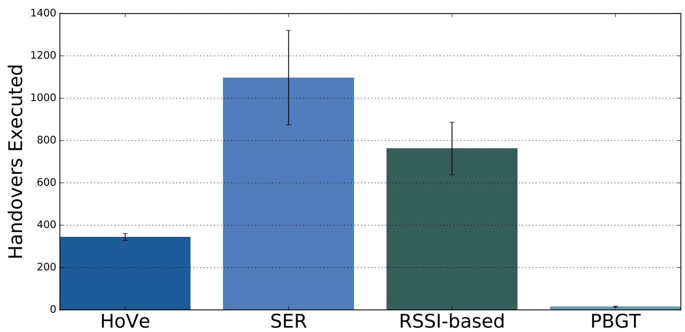


Figure 4. Average Number of Handovers in the Transmission of one Video

Figure 5 shows that proper QoS levels were also ensured with the use of HoVe, which maintains the PDR at around 80%, at least 30% more than any of the other algorithms. SER, RSSI-based, and PBGT maintain the PDR between 50% and 40%, due to more inefficient mobility management: a high number of handovers in the case of SER and RSSI-based, and keeping connected to an overloaded cell in the case of PBGT.

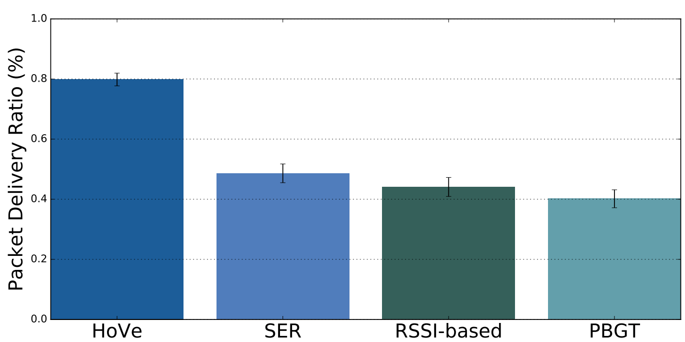


Figure 5. PDR Obtained by Each Algorithm

A random video was selected to illustrate the behavior of the perceived QoE at each moment of the transmission regarding SSIM, as shown in Figure 6. HoVe provides a consistently better SSIM score at each frame of the video throughout all of its duration. We can see three moments where the SSIM value for HoVe dropped, corresponding to instants where a handover was performed. SER delivered better QoE than RSSI-based and PBGT, however, the quality was volatile. We notice that the quality of the transmission dropped around frame #1241, this is because this is a more complex frame with a higher probability of being lost, compromising then the following frames in the GoP.

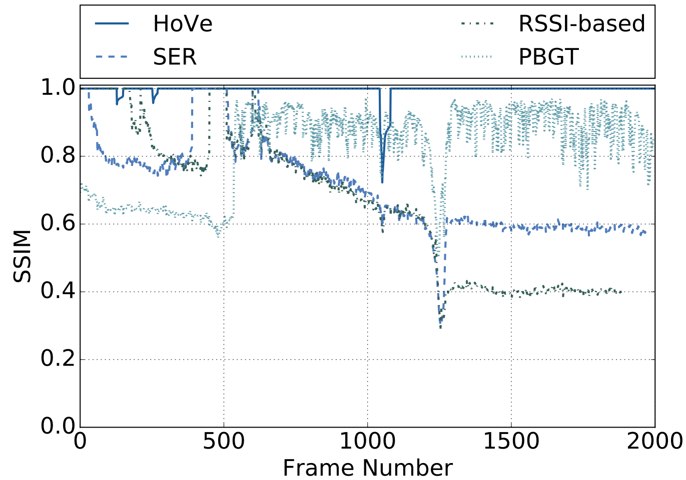


Figure 6. SSIM For Each Frame of Video number #42

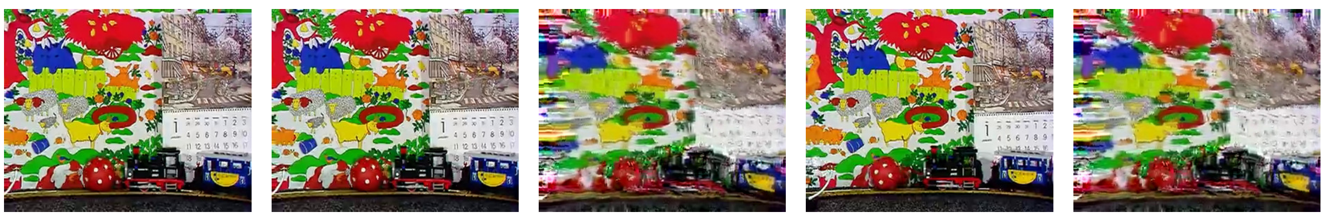
In Figure 7, random frames were selected from the videos transmitted under each algorithm. Figures 7(a), 7(f) and 7(k) show the frames from the original videos transmitted, alongside with the versions delivered to the end-users by each algorithm under the same scenario. We notice that frames are significantly closer to the original when HoVe is used in comparison to the other algorithms tested. The most accentuated degradation is perceived on the videos with the most motion, like Highway and Mobile, since it makes them more sensitive to frame losses, causing the most impact on the QoE to end-users.

V. Conclusion

Efficient mobility management in 5G VANETs is one of the main challenges faced by the next generation of mobile communication. The network densification trend transcends the limitations of previous generations but increases the complexity necessary in the management plane. In this context, predictive techniques constitute an essential tool to maintain users in vehicles connected and with sufficient QoE throughout all of their courses. State-of-the-art mobility management algorithms do not guarantee the proper delivery of multimedia content. This paper introduces a simple mobility prediction parameter in the handover decision while considering QoE and signal quality in a Multi-Criteria Decision. Simulation results show the effectiveness of the technique, with an improvement of 18% over state-of-the-art algorithms.

(a) Highway - Original (b) Highway - HoVe (c) Highway - RSSI-based (d) Highway - Strongest Cell (e) Highway - SER

(f) Container - Original (g) Container - HoVe (h) Container - RSSI-based (i) Container - Strongest Cell (j) Container - SER



(k) Mobile - Original (l) Mobile - HoVe (m) Mobile - RSSI-based (n) Mobile - Strongest Cell (o) Mobile - SER

Figure 7. Frames #111 from Highway, #213 from Container and #151 from Mobile

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