# Executive Overview

TITLE: D1.3.9-Simulation and evaluation of realistic MEU ad-hoc communications in CARLINK scenarios by using VanetMobiSim/Ns-2

SUMMARY: In this deliverable we use the *VanetMobiSim/Ns-2* simulator to evaluate the performance of the ad-hoc communications between the *MEUs (Mobile End Users)*, which compose a *VANET (Vehicular Ad-hoc NETwork)* located in real environments. The MEUs exchange information with each other using only the ad-hoc operation mode of the IEEE 802.11b MAC Layer Standard. The data transfers are carried out by using *VDTP (Vehicular Data Transfer Protocol)*.
The MEUs have been located in different scenarios. These scenarios are located in both urban and highway environments. VanetMobiSim/Ns-2 is the simulation tool chosen for the CARLINK project, so we use it to simulate the different experiments which compose the simulation of this scenario in order to achieve realistic results.
The goal of this document is to present the obtained results, offering to the consortium some measurements of transferring data between MEUs using VDTP protocol in different real environments.

GOALS:

1. Establishing the different experiments for simulating real world MEUs ad-hoc communication.
2. Featuring the different simulation experiments for VanetMobiSim/Ns-2.
3. Studying the simulation results to offer some conclusions about the viability about communication between MEUs.

CONCLUSIONS:

1. According to the obtained results, we conclude that the ad-hoc communication between MEUs in a real environment may be successfully used under certain conditions.
2. The success on the file transfers depends on the file size to transfer, the data path size among the vehicles, and the mobility model of the vehicles.

# D1.3.9-Simulation and evaluation of realistic MEU ad-hoc communications in CARLINK scenarios by using VanetMobiSim/Ns-2

CARLINK::UMA

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## 1 Introduction

In this deliverable we use the *VanetMobiSim/Ns-2* simulator to evaluate the performance of the ad-hoc communications between the *MEUs (Mobile End Users)*, which compose a *VANET (Vehicular Ad-hoc NETwork)* located in real environments. The MEUs exchange information with each other using only ad-hoc operation mode of the IEEE 802.11b MAC Layer Standard. The data transfers are carried out by using *VDTP (Vehicular Data Transfer Protocol)* [1], a file transferring protocol defined specically to be used in ad-hoc communication between vehicles in the CARLINK project. The VDTP protocol applied over VANETs composed of more than two vehicles have been analyzed in [4]. In this deliverable we have simulated real world environments to offer a set of results about the possible communication between the MEUs in different real situations.

The MEUs have been located in different scenarios, where the communication have been carrying out. These scenarios are located in both urban and highway environments. There is a dependence between the behavior of the vehicles and the kind of the road where they are moving. This fact determines the data transfers, so it is necessary to analyze them individually.

The goal of this document is to present the obtained results, offering to the consortium some measurements of transferring data between MEUs using VDTP protocol in different real environments. This information is important since the results have been achieved during simulations of scenarios close to the real world.

This document is organized as follows: in Section 2, we present the different experiments carried out to analyze the communication environment between MEUs. In Section 3, we explain how to set up VanetMobiSim/Ns-2 to achieve the simulations. In Section 4, we show the obtained results achieved empirically and some analysis about them. Finally, Section 5 presents the conclusions about the performance of this kind of network. These conclusions can be taken into account in order to deploy the network.

## 2 Experiments

This section presents the experiments carried out to simulate and evaluate the ad-hoc files transference between vehicles using VDTP protocol. We have generated several tests where the MEUs move through different kinds of roads defined by the scenarios. Each test is composed of several simulations of a specific scenario, where files are transfered between MEUs which are separated by two or more hops.

In the following subsections, we present the four different scenarios and the tests carried out to measure the ad-hoc transference of files.

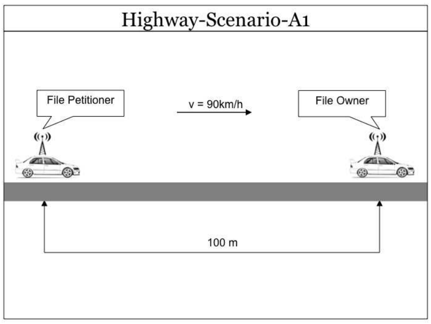
## 2.1 Scenarios definition

This section presents the simulated scenarios for analyzing the ad-hoc communications. These scenarios reflect different real world traffic situations where there are one-hop or multi-hop communications between the MEUs. Highway and urban environments are represented by these scenarios, which are presented next.

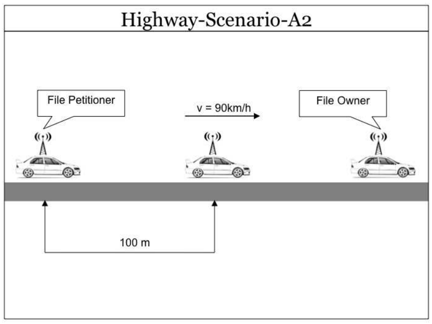
Note that in the highway scenarios the distance among the vehicles is restricted by the necessity of having multi-hop communications, thus the distance may be larger than in the congested highways.

### Highway-Scenario-A

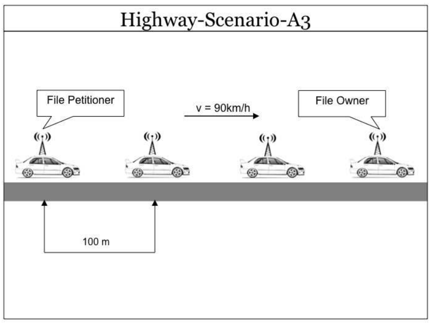
The Highway-Scenario-A represents a highway where the file petitioner and the file owner follow the same direction through the same lane. During the communication, the distance between MEUs is 100 meters and their velocity is 90 Km/h (25 m/s). We have four different situations, where the file owner and requester can be separated by one hop, two hops, three hops or four hops. These different situations have been named Highway-Scenario-A1, Highway-Scenario-A2, Highway-Scenario-A3, and Highway-Scenario-A4, respectively (see Figure 1).



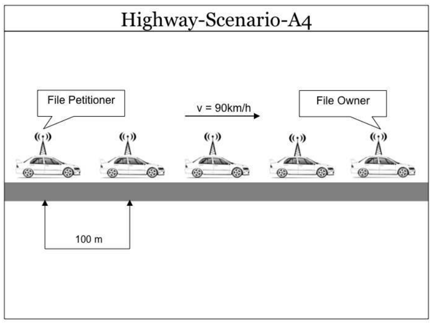

a) Highway-Scenario-A1 representation




b) Highway-Scenario-A2 representation




c) Highway-Scenario-A3 representation

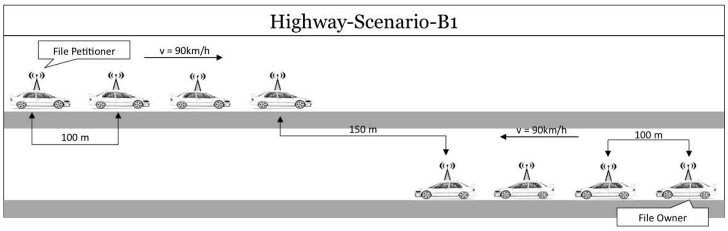



d) Highway-Scenario-A4 representation

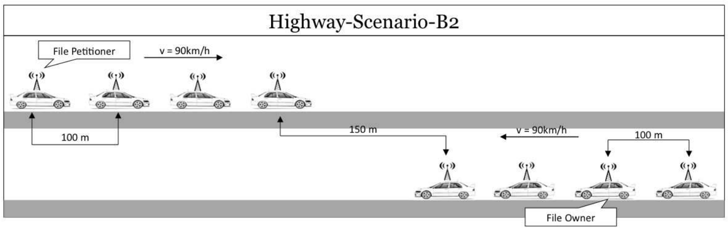
Figure 1: Representation the different configurations which Highway-Scenario-A is composed.

### Highway-Scenario-B

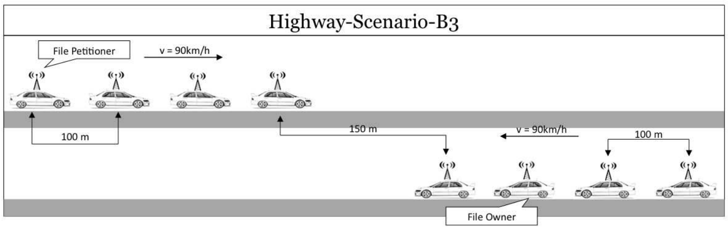
The Highway-Scenario-B represents a highway where the file petitioner and the file owner follow opposite directions through parallel lanes. There are eight MEUs, four per lane. The distance between the vehicles is 100 meters and they move with a velocity of 90 Km/h. We have defined four different scenarios, in each scenario the file owner is closer to the file petitioner. These scenarios are named Highway-Scenario-B1, Highway-Scenario-B2, Highway-Scenario-B3, and Highway-Scenario-B4, respectively. The representation of these scenarios are shown in Figure 2.



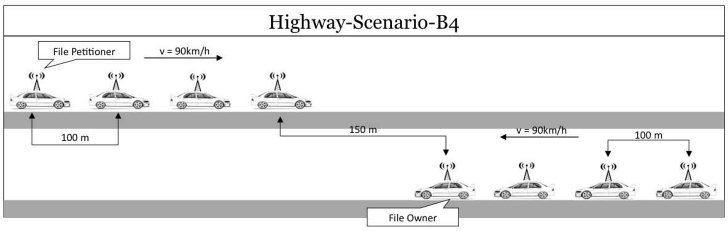

a) Highway-Scenario-B1 representation




b) Highway-Scenario-B2 representation




c) Highway-Scenario-B3 representation



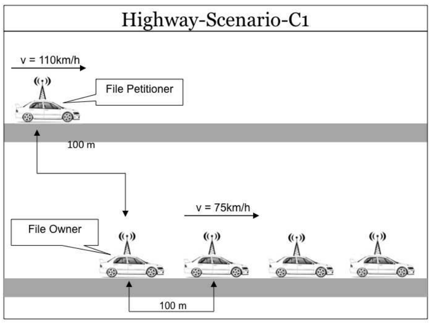

d) Highway-Scenario-B4 representation

Figure 2: Representation of the different configurations which Highway-Scenario-B is composed.

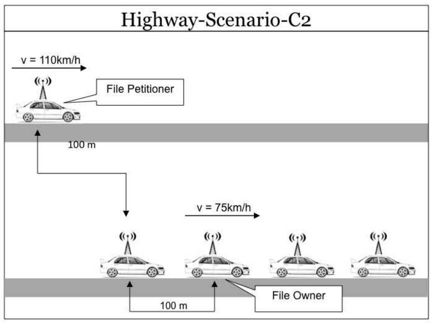
### Highway-Scenario-C

The Highway-Scenario-C represents a highway where the file petitioner and the file owner follow the same direction but through different lanes. The file petitioner is overtaking the file owner which belongs to a group of four vehicles. During the communication, the distance among the four MEUs is 100 meters and their velocity is 75 Km/h (20.83 m/s), and the file petitioner moves with a velocity of 110 Km/h (30.55 m/s). There are four different scenarios depending on which MEU is the file owner.

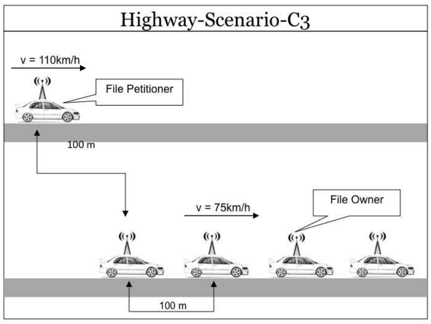
These different situations have been named Highway-Scenario-C1, Highway-Scenario-C2, Highway-Scenario-C3, and Highway-Scenario-C4, respectively. These scenarios are shown in Figure 3.



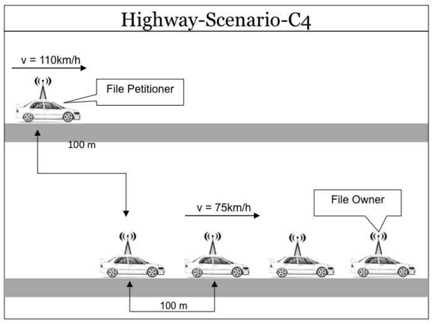

a) Highway-Scenario-C1 representation




b) Highway-Scenario-C2 representation




c) Highway-Scenario-C3 representation



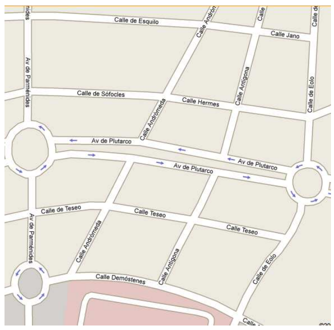

d) Highway-Scenario-C4 representation

Figure 3: Representation of the different configurations which Highway-Scenario-C is composed.

**Urban-Scenario**

The Urban-Scenario represents a real urban area of 50000 square meters located in Málaga. In this area, there are roads with one and two lanes and roundabouts (see Figure 4). There are 30 MEUs that during the simulation exchange data with each other when some path between them exists. The vehicles move randomly but the movement fulfill the traffic rules of this area.

a) Satellite photo of the simulated area



b) Road map of the simulated area

Figure 4: The selected area in Málaga defined as Urban-Scenario.

The vehicles move with a velocity between 30 Km/h (8.33 m/s) and 50 Km/h (13.88 m/s). The distance between the vehicles is conditioned by the traffic density.

## 2.2 Tests definition

The test defined for these simulations have been addressed to analyze the behavior of this kind of network (VANETs) over different possible situations. The tests consist of transferring different files in each one of the previously specified scenario. The difference between the files is their size.

The transmitted files between the MEUs that belongs to the simulation have the next sizes: **256 Kbytes**, **512 Kbytes**, **1 Mbyte**, **2 Mbytes**, **5 Mbytes**, and **10 Mbytes**. In the following, the files will be named *file file type 1* to *file type 6*, respectively (see Table 1).

Table 1: Relation between sizes and names (types) of the files used during the simulations.

| File type | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| File size | 256 KB | 512 KB | 1 MB | 2 MB | 5 MB | 10 MB |

The test of each scenario consists of 50 different transfers of each file type, during the time in which some data path between the MEUs can be established.

To analyze the whole simulation, we have evaluated different measures of each test: the *transmission time*, the *transmission data rate*, and the *percentage of complete transfers*.

# 3 VanetMobiSim/Ns-2 Simulation

In order to achieve our purposes and obtaining useful results, we have to tune the simulator to reflect as close as possible the real world interactions in the simulations. This section presents the different VanetMobiSim/Ns-2 parameters that have been fitted to simulate the defined scenarios (see Section 2.1) in a trustworthy manner.

As we presented in [3], we use VanetMobiSim/Ns-2, it offers the possibility of specifying realistic mobility models [2] by means of VanetMobiSim and communication environments using ns-2. Next, we show how the mobility models and the communication environment have been defined.

## 3.1 Mobility models definition using VanetMobiSim

The mobility models which represent the different scenarios using VanetMobiSim have been featured as follows:

- Macro-mobility features:
  - The road topology is user-defined by using vertexes.
  - The initial and destination points are defined by attraction points.
  - The roads speed limit is 50 km/h for urban roads and 120 km/h for highways.
- Micro-mobility features are defined by the *Intelligent Driver Motion* (IDM) [2] module of Vanet-MobiSim, fitting the velocity in 30 km/h, 75 km/h, 90 km/h, and 110 km/h, depending on the simulated scenario.

## 3.2 Communication environment specification using ns-2

For tuning the communication environment using ns-2, we have specified different parameters. These parameters are the *Link Layer*, the *Routing Protocol*, and *Application Layer*. They have been fit as follows.

### Link layer

For developing the CARLINK-UMA scenario, each MEU have been provided with *PROXIM ORiNOCO PCMCIA transceivers*[1] working in ad-hoc operation mode of the IEEE 802.11b standard. These transceivers define the physical and link layer protocol to use, the IEEE 802.11b. According to the values indicated in the technical specification of the ORiNOCO PCMCIA cards, the signal strength has been set to 12 dBm and the antenna gain to 7dBi.

### Routing protocol

The Dynamic Source Routing protocol (DSR) [5] has been used for the simulations. It is a simple and efficient routing protocol designed specifically for use in *MANETs (Mobile Ad-hoc NETworks).*

The protocol is composed of the two main mechanisms of Route Discovery and Route Maintenance, which work together to allow nodes to discover and maintain routes to arbitrary destinations in the ad-hoc network. All the aspects of the protocol operate entirely on-demand.

### Application layer

We have used Vehicular Data Transfer Protocol (VDTP) [1] for transferring files between MEUs. This protocol is used over User Datagram Protocol (UDP) transport protocol. For each transfer, VDTP splits the file into several chunks, for the simulations the chunks size has been fitted to 25 Kbytes. The retransmission time is 4 seconds and the maximum number of attempts for resending a PDU is 8. The file size have been fit depending on the test (file type to send) to simulate.

# 4 Results

This section presents the results of the simulations described above. This results are showed individually for each scenario. In the next section, we draw some general conclusions about the whole ad-hoc communication simulation.

For analyzing the whole simulation, we have evaluated different measures of each test, they are: the *transmission time*, the *transmission data rate*, and the *percentage of complete transfers*.

## 4.1 Highway-Scenario-A results

This scenario is characterized by the fixed topology, because during all the simulation the MEUs have the same relative position each other. Thus, the data path is the same during the complete simulation.

Table 2: Highway-Scenario-A average transmission times.

| File type | Highway-Scenario-A1 | Highway-Scenario-A2 | Highway-Scenario-A3 | Highway-Scenario-A4 |
|---|---|---|---|---|
| 1 | 0.454 s | 0.915 s | 1.370 s | 1.826 s |
| 2 | 0.862 s | 1.733 s | 2.596 s | 3.461 s |
| 3 | 1.678 s | 3.365 s | 5.050 s | 6.732 s |
| 4 | 3.353 s | 6.718 s | 10.079 s | 13.441 s |
| 5 | 8.379 s | 16.768 s | 25.164 s | 33.582 s |
| 6 | 16.750 s | 33.458 s | 50.206 s | 67.059 s |

All transfers were successfully completed, meaning that the MEU which asks for the file has received it completely. The results obtained simulating the different tests defined for the Highway-Scenario-A are shown in Table 2 (transmission time) and in Table 3 (transmission data rate). The maximum data rate is achieved during the transmission of the largest file (file type 6, i.e., 10 MB files), being 611.321 KB/s achieved when file type 6 is transmitted in the Highway-Scenario-A1. The minimum

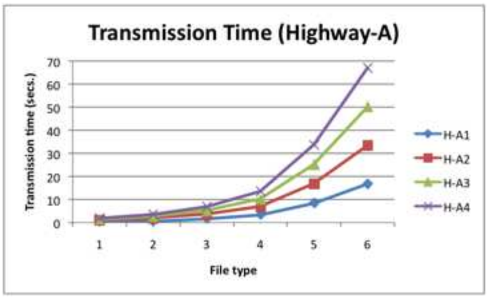
[1] http://www.proxim.com

data rate is 140.164 KB/s, when a file type 1 (smallest file) is transmitted in the Highway-Scenario-A4 (see Table 3).

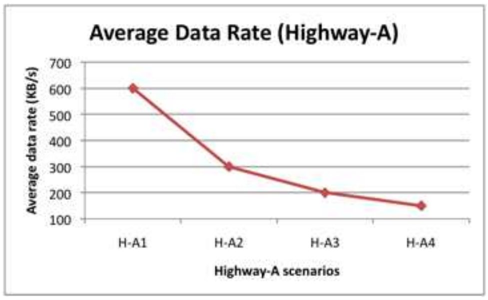
Table 3: Highway-Scenario-A average data rates.

| File type | Highway-Scenario-A1 | Highway-Scenario-A2 | Highway-Scenario-A3 | Highway-Scenario-A4 |
|---|---|---|---|---|
| 1 | 563.803 KB/s | 279.620 KB/s | 186.822 KB/s | **140.164 KB/s** |
| 2 | 593.626 KB/s | 295.387 KB/s | 197.177 KB/s | 147.928 KB/s |
| 3 | 609.900 KB/s | 304.231 KB/s | 202.745 KB/s | 152.094 KB/s |
| 4 | 610.618 KB/s | 304.814 KB/s | 203.179 KB/s | 152.359 KB/s |
| 5 | 611.049 KB/s | 305.332 KB/s | 203.457 KB/s | 152.460 KB/s |
| 6 | **611.321 KB/s** | 306.049 KB/s | 203.957 KB/s | 152.701 KB/s |

Figure 5.b shows the average data rates depending on the whole scenario simulation (sending all file types). We observe that when the number of hops increases, the data rate decreases. The main reason for these results is that when the number of hops increases (see Figure 5.a), the path increases too, so the PDUs have to be processed and re-sent by more MEUs increasing the transmission time.




a) Highway-Scenario-A transmission time




b) Highway-Scenario-A data rate

Figure 5: Graphic representation of the results of the whole Highway-Scenario-A simulation: Transmission time of the different file types (a). Average data rates achieved (b).

The percentage of lost PDUs is 0 %, i.e., during all transfers in this scenario no PDU was lost. According to the results, we can conclude that for this kind of scenario the data transference among MEUs is possible and reliable.

## 4.2 Highway-Scenario-B results

This scenario is different from the Highway-Scenario-A presented above, since during the simulations the topology changes very quickly. Thus, the data path that exists during the complete simulation changes, making the transmission time variable for the same file type depending on the instant of the transfer.

Table 4: Highway-Scenario-B average transmission times.

| File type | Highway-Scenario-B1 | Highway-Scenario-B2 | Highway-Scenario-B3 | Highway-Scenario-B4 |
|---|---|---|---|---|
| 1 | 2.865 s | 2.406 s | 1.939 s | 3.331 s |
| 2 | 5.320 s | 4.453 s | 3.578 s | 5.873 s |
| 3 | 7.855 s | 6.742 s | 5.760 s | 9.142 s |
| 4 | 11.423 s | 10.227 s | 7.434 s | 12.109 s |
| 5 | N/A | N/A | N/A | 17.132 s |
| 6 | N/A | N/A | N/A | N/A |

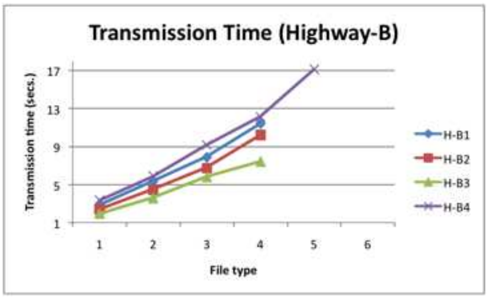
The average transmission times achieved during the simulation of the Highway-Scenario-B are shown in Table 4, and the average data rates are shown in Table 5. The main characteristic of this kind of this scenario is that the connection time is limited; that is, there is a fixed time to transfer the files, the time during the data path exists. So, the file size to transfer is limited by the data path, too. In this case, the 10 MB files (file type 6) cannot be sent in this kind of scenarios, and the 5 MB files can be transferred just in the Highway-Scenario-B4 (see Figure 6.a).

The maximum data rate (298.845 KB/s) is achieved when the largest file is transfered, and the minimum (76.850 KB/s) appears when the smallest is transfered, as in the results of the scenario presented above.

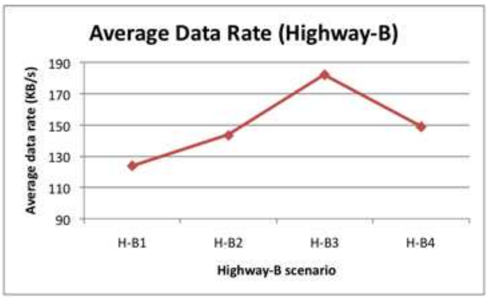
Table 5: Highway-Scenario-B average data rates.

| File type | Highway-Scenario-B1 | Highway-Scenario-B2 | Highway-Scenario-B3 | Highway-Scenario-B4 |
|---|---|---|---|---|
| 1 | 89.339 KB/s | 106.370 KB/s | 131.989 KB/s | **76.850 KB/s** |
| 2 | 96.232 KB/s | 114.958 KB/s | 143.068 KB/s | 87.167 KB/s |
| 3 | 130.362 KB/s | 151.873 KB/s | 177.770 KB/s | 112.005 KB/s |
| 4 | 179.281 KB/s | 200.244 KB/s | 275.458 KB/s | 169.123 KB/s |
| 5 | N/A | N/A | N/A | **298.845 KB/s** |
| 6 | N/A | N/A | N/A | N/A |

In contrast to the Highway-Scenario-A, where the average data rates decrease when there are more hops between the communicated MEUs at the beginning; in the Highway-Scenario-B, this assessment is not really true, since the topology changes during the file transfer and the PDU paths change making the transmission time variable. (see Figure 6.b). The average data rate of the Highway-Scenario-B3 (5 hops) is 182.071 KB/s; however, in the Highway-Scenario-B4 (4 hops) is 148.798 KB/s (see Table 5).




a) Highway-Scenario-B transmission time




b) Highway-Scenario-B data rate

Figure 6: Graphic representation of the results of the whole Highway-Scenario-B simulation: Transmission time of the different file types (a). Average data rates achieved (b).

The average percentage of lost PDUs is 0 % for the file of types 1, 2, 3, and 4, and for the files of types 5 and 6 is higher than 50 %. Thus, the percentage of successful transfers is 100 %, for the first group of files, and for the second one are 25 % and 0 %, respectively (see Table 6).

Table 6: Highway-Scenario-B percentage of complete transfers.

| File type | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Percentage of complete transfers | 100 % | 100 % | 100 % | 100 % | 25 % | 0 % |

According to these results, the data transference between MEUs in this scenario is possible and reliable just for files no larger than 2 MB.

## 4.3 Highway-Scenario-C results

This scenario presents a vehicle which overtakes another group of vehicles. That is, it has a dynamic topology as the Highway-Scenario-B, where the data path that exists during the complete simulation changes and the transmission times is variable, too.

All the transfers were successfully completed. The results obtained simulating the different tests defined for the Highway-Scenario-C are shown in Table 7 (transmission time) and Table 8 (transmission data rate).

Table 7: Highway-Scenario-C average transmission times.

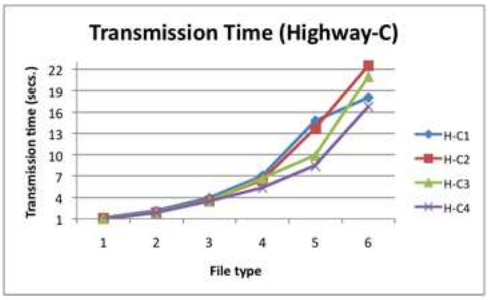
| File type | Highway-Scenario-C1 | Highway-Scenario-C2 | Highway-Scenario-C3 | Highway-Scenario-C4 |
|---|---|---|---|---|
| 1 | 1.149 s | 1.037 s | 1.031 s | 0.959 s |
| 2 | 2.091 s | 1.870 s | 1.852 s | 1.795 s |
| 3 | 3.902 s | 3.510 s | 3.494 s | 3.401 s |
| 4 | 7.004 s | 6.349 s | 6.582 s | 5.259 s |
| 5 | 14.755 s | 13.613 s | 9.824 s | 8.387 s |
| 6 | 18.009 s | 22.518 s | 20.978 s | 16.759 s |

The maximum data rate (610.982 KB/s) is achieved during the transmission of the largest file in the Highway-Scenario-C4, as in the other scenarios. The minimum data rate is 222.610 KB/s, when a file type 1 is transmitted in the Highway-Scenario-C1 (see Table 8).

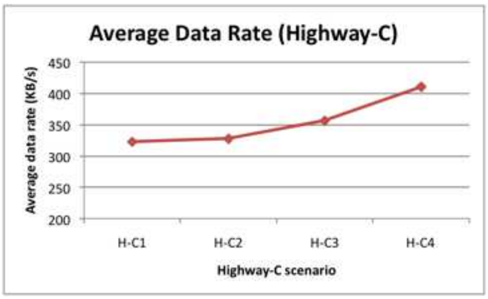
Table 8: Highway-Scenario-C average data rates.

| File type | Highway-Scenario-C1 | Highway-Scenario-C2 | Highway-Scenario-C3 | Highway-Scenario-C4 |
|---|---|---|---|---|
| 1 | **222.610 KB/s** | 246.763 KB/s | 248.123 KB/s | 266.692 KB/s |
| 2 | 244.775 KB/s | 273.695 KB/s | 276.403 KB/s | 285.164 KB/s |
| 3 | 262.389 KB/s | 291.681 KB/s | 293.014 KB/s | 301.055 KB/s |
| 4 | 292.388 KB/s | 322.543 KB/s | 311.146 KB/s | 389.390 KB/s |
| 5 | 347.000 KB/s | 376.086 KB/s | 521.141 KB/s | 610.435 KB/s |
| 6 | 568.604 KB/s | 454.736 KB/s | 488.119 KB/s | **610.982 KB/s** |

Figure 7 presents the results of the whole Highway-Scenario-C simulation. When larger files are transferred, the transmission time starts to not be stable since there are more changes of the data paths (see Figure 7.a the transmission time of the files of type 4, 5, and 6). Figure 7.b presents the transmission data rates that increases when the file owner is farther the file requester.




a) Highway-Scenario-C transmission time




b) Highway-Scenario-C data rate

Figure 7: Graphic representation of the results of the whole Highway-Scenario-C simulation: Transmission time of the different file types (a). Average data rates achieved (b).

There have not been any lost PDUs, that is, the percentage of lost of PDUs is 0 %. According to the results, the data transference between MEUs in this scenario is possible and reliable for all file types.

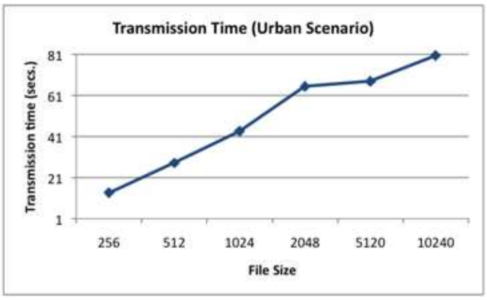
### 4.4 Urban-Scenario results

This scenario is composed by 30 vehicles which move through a complex set of roads located in a real place of Málaga. The MEUs move randomly fulfilling the traffic rules. The network topology changes and as well as the data paths.

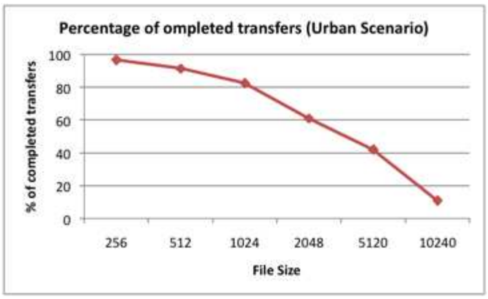
Table 9: Urban-Scenario average results.

| File type | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Transmission time | 13.562 s | 28.020 s | 43.559 s | 65.345 s | 67.797 s | 80.445 s |
| Data rate | 18.876 KB/s | 18.272 KB/s | 23.507 KB/s | 31.340 KB/s | 75.519 KB/s | 127.291 KB/s |
| Percentage of complete transfers | 96.67 % | 91.302 % | 82.441% | 60.861% | 41.822 % | 10.780 % |

The transmission time depends on the number of the lost PDUs, because according to our communication configuration, when a PDU is sent the file transfer protocol waits up to 4 seconds to consider that this PDU is lost and resend the same one. In this scenario there are a large percentage of lost PDUs; for this reason, the transmission times are longer than the ones achieved during highway environment simulations, thus the transmission data rates are low (see Table 9).




a) Urban-Scenario transmission time




b) Urban percentage of completed transfers

Figure 8: Graphic representation of the results of the whole Urban-Scenario simulation: Transmission time of the different file types in the Urban-Scenario (a). Average percentage of successfully completed transfers in Urban-Scenario (b).

The percentage of successfully completed transfers depends on the capacity of keeping or generating data paths between the MEUs during the communication. In this case, the larger the size of the file requested the lower the percentage of completed downloads (see Figure 8). The files of 256 Kbytes are the most probable to be received, with a probability of 96.67 %, and the files of 10 Mbytes are the less probable to be completed, with a probability of 10.78 % (see Table 9).

## 5 Conclusions

Although the ad-hoc communication between MEUs have been studied in [4], in this deliverable we analyze this communication in realistic scenarios to analyze the behavior of this kind of communications deeply. We have simulated several scenarios trying to reflect as close as possible the interactions between the vehicles in the real world, representing different real situations. Both urban and highway environments have been represented in the simulated scenarios.

The results achieved during the simulations are quite different depending on the environment where the communication is carried out. During the simulations of the Highway-Scenario-A the 100 % of the transfers were completed; however, during the simulation of the Urban-Scenario there is not any file type that can be sent with a success percentage of 100 %.

The ad-hoc multi-hop communications analyzed in this deliverable are really dependent on the mobility of the vehicles and the possibility of maintenance of a data path between the MEUs that are communicating. When the data path is smaller (less hops between the MEUs) the communication has a lower transmission time, so the transmission data rate is higher, e.g., in the Highway-Scenario-A1(one hop) the data rate is 600.053 KB/s and in the Highway-Scenario-A4 (four hops), 149.618 KB/s.

The quality of the communication in the environments of high degree of mobility (Urban-Scenario) is dependent on the size of the file that is transferred (see Table 9). In this kind of scenarios, the size of the file has to be the smallest possible, since the maintenance of the data path is more difficult doing lesser connection time, and during this time it is possible to transfer no larger files. Furthermore, when the data path is lost during some time the transmission time increases because VDTP protocol waits a timeout to resend the PDU.

In some scenarios it has been impossible to transfer files type 6 (10 MB files) and files type 5 (5 MB), or the possibility of sending completely is really low. Thus, the MEUs has to avoid transfers of large files (10 MB and 5 MB), since the larger the size, the lower possibility of successfully complete transfers.

According to the results, we conclude that it is possible the ad-hoc communication between the MEUs under certain conditions. These conditions are dependent on the **file size** to transfer, the **data path** size between the MEUs, and the **mobility model** of the vehicles.

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