Executive Overview

TITLE: D1.3.7-Simulation and evaluation of the CARLINK-UMA multi-hop scenario by using JANE

SUMMARY: In this deliverable we use the *JANE* simulator to evaluate the performance of multi-hop *VANETs (Vehicular Ad-hoc Networks)*; i.e., an ad-hoc network made up by more than two *MEUs (Mobile End Users)*. We use the term *CARLINK-UMA scenario* when talking about scenarios where the MEUs can only communicate by using the ad-hoc operation mode of the *IEEE 802.11b/g MAC Layer Standard*, also known as WiFi. The goal is to present the simulation results about the data rates that can be achieved when transferring files between two MEUs which are separated by two or more hops. These results are interesting for the global consortium in order to select the most appropriate technology for the ad-hoc communications among all those considered in the deliverable *D2.1 Architecture Definition* (see Chapter 5).

GOALS:

1. Justify the use of the ad-hoc communications in the CARLINK architecture.
2. Study the performance of the IEEE 802.11b ad-hoc operation mode standard in multi-hop VANETs through simulation.

CONCLUSIONS:

1. We propose to include the IEEE 802.11b ad-hoc operation mode standard as an alternative to be considered for the CARLINK consortium, under certain conditions, in order to exchange data between two MEUs through multi-hop communications. These conditions are detailed in the remaining of this deliverable.

D1.3.7-Simulation and evaluation of the CARLINK-UMA multi-hop scenario by using JANE

CARLINK::UMA

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1 Introduction

In this deliverable we use the JANE simulator [2] to evaluate the performance of the multi-hop communications between MEUs. We use the term *CARLINK-UMA scenario* when talking about scenarios where the MEUs can only communicate by using the ad-hoc operation mode of the *IEEE 802.11b/g MAC Layer Standard*. The ad-hoc communications between MEUs might be interesting for the CARLINK architecture due to several reasons:

- Providing a cheaper alternative, compared to GPRS, in order to conect MEUs to TSBSs *(Traffic Service Base Stations)* by using multi-hop communications when the one-hop communication is not possible.
- Sharing and broadcasting updated information among MEUs which are close to each other. It is important to avoid the congestion of V2I *(Vehicle to Infrastructure)* communications.
- Moreover, the ad-hoc communications could be also useful to offer new complementary services for the consortium, e.g., gaming.

The remainder of this deliverable is as follows: Section 2 explains how to set up JANE to accurately simulate the CARLINK-UMA scenario. Section 3 outlines the experiments to evaluate the multi-hop scenario. Finally, Section 4 presents the simulation results and conclusions about the data rates that can be achieved when transferring files between MEUs through multi-hop communications. These results can be taken into account to assist the selection of the most appropriate technology for the ad-hoc communications inside the CARLINK project.

2 JANE Simulation

This section specifies the JANE components that have been tuned to simulate the CARLINK-UMA scenario in a trustworthy manner. As detailed in [2], JANE consists of a set of interacting modules that can be customized to exactly simulate the scenario under study. We have identified the *link layer*, *the mobility models*, and *the routing protocol* as the components that need to be fit.

Link Layer

The *medium access control* is carried out in JANE by an implementation of the IEEE 802.11b standard. Each MEU has an implementation of the *PROXIM ORiNOCO PCMCIA transceivers*[1]. The output power of the wireless network cards was set to 12 dBm and the wireless antennas gain to 7 dBi, resulting the coverage range equal to 80 metres.

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

Mobility Model

JANE allows us to configure the mobility model by means of XML scripts. In this work we extend from one-hop to multi-hop the scenarios simulated in [3] and we also study new different ones. We increase the number of MEUs to force the multi-hop communications among them.

The name of the scenarios denotes both the kind of scenario itself and the number of hops concerning the communications. For example, the *Scenario B3* refers to the Scenario B with 3 hops (see Figure 2).

Scenario A represents the situation where the *file petitioner* follows to the *file owner* in the same direction (see Figure 1). All the cars move with a constant velocity (30 km/h) and they keep separated 50 m to each other during all the path.

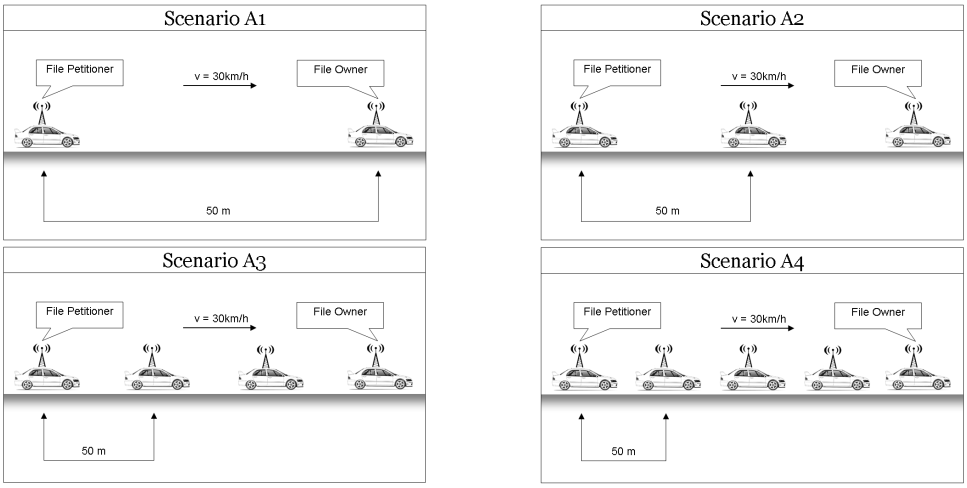


Figure 1: Scenarios A

Scenario B represents the situation where the file petitioner and the file owner move in opposite directions, passing one close to the other (see Figure 2). They start moving 500 m separated with a constant velocity equal to 30 km/h. In order to achieve multi-hop links, we place stopped cars in the middle of the path.

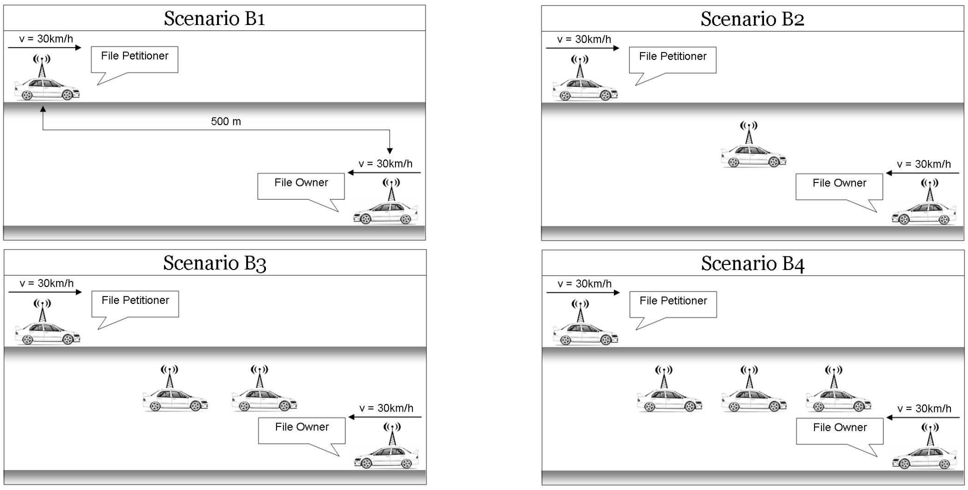
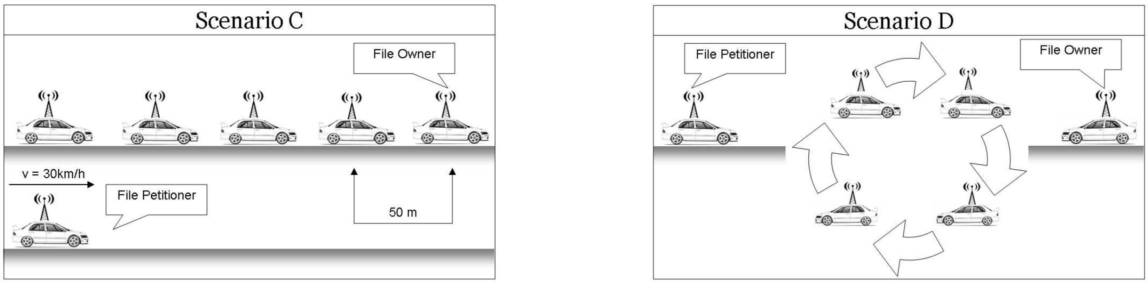


Figure 2: Scenarios B

The one-hop scenarios A1 and B1 were already simulated in [3]. In this deliverable we focus on the multi-hop scenarios and we study the impact of increasing the number of hops in the download rate when transferring files between the source and the receiver.

The Scenario C represents the situation where the file petitioner approaches the file owner position (see Figure 3a). The file owner is stopped and connected to 4 cars more and the file petitioner passes close to them with a velocity equal to 30 km/h.



(a) (b)

Figure 3: Scenarios C and D

The Scenario D represents the situation where both the file petitioner and the file owner approach to a roundabout (see Figure 3b). They can not connect directly to each other but through the 4 cars circulating inside the roundabout which act as intermediate hops between the source and the receiver.

Routing Protocol

VANETs topology changes very frequently. Therefore, the selection of the routing protocol is an important decision in order to achieve multi-hop communications. We use the *Lightweight Mobile Routing protocol* [4]. It is lightweight since each node only works with information about its one-hop neighborhood. Furthermore, it only calculates the route between the source and the destination when the route is required by the source, i.e., it is a reactive protocol. Hence, we consider that LMR is suitable for the multi-hop VANETs that we are going to evaluate.

3 The Experiments

This section outlines the experiments carried out to simulate the CARLINK-UMA multi-hop scenario. The experiments were composed of different tests. Each test consists of transferring files in one of the previously specified scenarios: A, B, C, and D (figures 1, 2 and 3, respectively). We use two different file types: **type 1 file** with 1-MB size (representing traffic information documents) and **type 2 file** with 10-MB size (representing multimedia files). In the following, we name the tests according to the scenario and the file type that we are evaluating: e.g., the TestA4-2 means to transfer the file type 2 in the Scenario A4.

The experiments in scenarios A and B are the same that the ones performed in [3]: **10 transfers** of file type 1 and 2. The experiments C and D changes the previously defined scenarios as well as the experiments. Here, the goal is to download as much data as we can from file the owner to the file petitioner in the scenarios C and D.

In Scenario C (see Figure 3a) the download begins when the file petitioner connects to the VANET and it finishes when the file petitioner reaches the file owner position. Note that the number of hops decreases from 5 to 1, and therefore the LMR routing protocol needs to be effective to complete the transfer while the file petitioner is moving close to all the stopped cars.

In Scenario D (see Figure 3b), the file petitioner and the file owner stop when reach the roundabout and then they start to exchange data. They can not connect to the other directly, so they need to communicate through the moving vehicles inside the roundabout. We want to measure the quantity of data that can be exchanged while the vehicles inside the roundabout give a complete tour.

We use the VDTP protocol [1] to transfer files between the MEUs. For each transfer, VDTP splits the file into several chunks. The chunk size can be configured manually with VDTP and we have set its value to 25 KB in all the tests.

4 Results

This section presents the results of the experiments described in Section 3. We firstly present the simulation results of tests A and B. Later, we compare these results with those obtained in [3]. Finally, we present the simulation results of the tests C and D.

4.1 Tests A and B

Table 1 shows the mean data rate (in KB/s) achieved when transferring 10 times each file type in each scenario. The columns are firstly divided by the file type and secondly by the number of hops. The rows specify the type of scenario.

Table 1: Mean data rate (KB/s) in multi-hop scenarios A and B

	1-MB File			10-MB File		
	2 hops	3 hops	4 hops	2 hops	3 hops	4 hops
Scenario A	281.35	150.45	110.08	242.88	134.82	N/A
Scenario B	469.62	307.93	258.53	N/A	N/A	N/A

All the transfers in the scenarios A were successful. We consider a test as successful when the file is completely downloaded from the sender to the receiver. This is not always possible due to the node mobility and the network bandwidth. For example, the transfers in scenario B were not all successful (denoted with the N/A symbol). In fact, some of them failed due to the inconvenient also found in [3]: the scenarios B delimits the time frame in which the two MEUs can communicate with each other.

Note that the unsuccessful transfers do not mean that we could not transfer any data. Actually, the simulations showed that the file transfer starts, but it does not finish. Let us remember that we are using the VDTP transfer protocol [1]. VDTP waits two seconds for requesting a new file chunk when the source does not answer. It retries to connect to the file owner up to 8 times, but afterwards the download is finally cancelled by the file petitioner.

4.2 Tests C and D

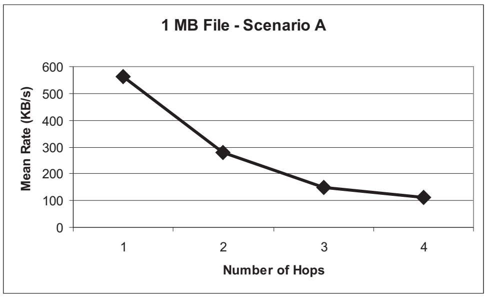
In the case of Test C, the maximum quantity of transferred data was equal to 7 MB during 27.98 seconds, i.e., a mean data rate equal to 256.18 KB/s. This 7 MB could represent multimedia files like pictures or small videos.

In the case of the Test D, the maximum quantity of transferred data was equal to 2 MB (note that this is a more complex scenario, see Figure 3b). It took 12.85 seconds, what means 159.32 KB/s on average. In these conditions, the users could exchange smaller files such as *pdf* documents.

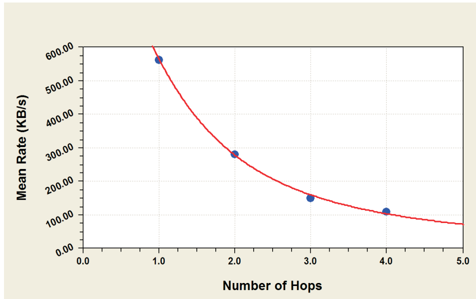
5 Conclusions

So far, we have presented the results of all the different tests. However, the interest of this deliverable is to analyze the relation between the number of hops and the mean data rate. Therefore, in this section we focus on the results of the tests A. In particular, we use the results obtained when transferring 1-MB file in the scenarios A (see Table 1).

The first conclusion is: the higher the number of hops the lower the mean data rate (see Figure 4a). It is understandable since each hop increases the data path length from the sender to the receiver, what also increases the time for transferring the same quantity of data. Note that we have also included the results of the one-hop transfers obtained in [3] to emphasize this conclusion.



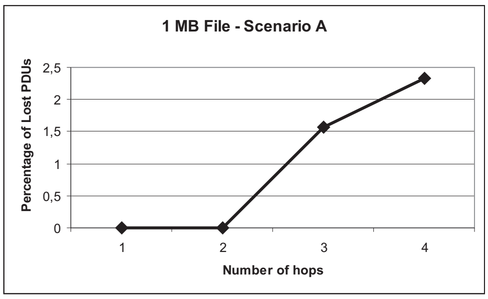
(a) Experimental data.



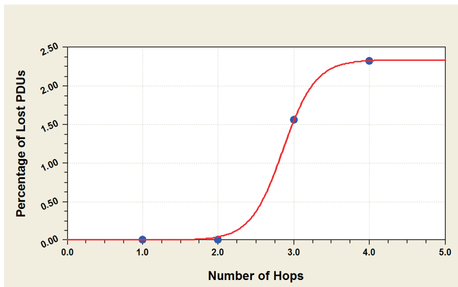
(b) Harrison Model: $y = \frac{1}{(a+bx^c)}$, where $a = 0.001$, $b = 0.0008$ and $c = 1.743$

Figure 4: a) Relation between the mean data rate per download and the number of hops. b) The analytical function representing the relation observed in the experimental data.

The higher number of hops is not the only reason to decrease the mean data rate. We also observed that the higher the number of devices involved in the multi-hop communications the higher the probability of conflicts when accessing to the physical medium. This increases the number of lost PDUs during the transfers and therefore the mean time per download goes up. Figure 5a shows the relation between the number of hops and the percentage of lost PDUs (*Protocol Data Units*).



(a) Experimental data.



(b) Logistic Model: $y = \frac{a}{(1+b*e^{-cx}))}$, where $a = 2.338$, $b = 599258.5$ and $c = 4.668$

Figure 5: a) Relation between the percentage of lost PDUs and the number of hops. b) The analytical function representing the relation observed in the experimental data.

Together with the number of hops, the number of PDUs to exchange between the sender and the receiver is also important to complete the transfer in dynamic environments like VANETs. The transfer of the 1-MB file implies the transmission of 41 PDUs whereas the transfer of the 10-MB file implies the transmission of 410 PDUs. This explains the higher number of uncompleted downloads when transferring the 10-MB file through more than three-hop links (see Table 1).

In general, the total quantity of data that can be downloaded from the sender to the receiver inside the CARLINK-UMA scenario (i.e., ad-hoc communications using the IEEE 802.11b standard) depends on the network topology, the vehicle mobility models, and the number of hops involved in the communications. According to the JANE simulations results, we will establish the following upper limits to ensure the success of the ad-hoc communications among the MEUs using IEEE 802.11b standard inside the CARLINK execution platform:

- Maximum quantity of data to exchange per transfer: 1 MB.
- Maximum number of hops between the source and the receiver: 4 hops.
- Maximum distance between adjacent MEUs: 50 metres in line-of-sight scenarios.

References

[1] CARLINK::UMA. D2006/10 - VDTP: A File Transfer Protocol for Vehicular Ad hoc Network. Technical report, University of Malaga, Spain, 2006.

[2] CARLINK::UMA. D2006/7 - JANE: A Tool for Implementing Applications in Real Ad-hoc Networks. Technical report, University of Malaga, Spain, 2006.

[3] CARLINK::UMA. D1.3.4 - Simulation and evaluation of the CARLINK-UMA scenario by using JANE. Technical report, University of Malaga, Spain, 2007.

[4] M. Scott Corson and Anthony Ephremides. A distributed routing algorithm for mobile wireless networks. *Wirel. Netw.*, 1(1):61–81, 1995.