UNIVERSIDAD DE MÁLAGA

Executive Overview

TITLE: D1.3.6-Simulation and evaluation of the CARLINK-UMA multi-hop scenario by using VanetMobiSim/Ns-2

SUMMARY: This deliverable describes the different simulations carried out to evaluate the performance of multi-hop Vehicular Ad-hoc NETworks (VANETs). The term multi-hop is used to express that the VANET is composed of more than two Mobile End Users (MEUs).
We have simulated different scenarios using the VanetMobiSim/Ns-2 simulation tool where the MEUs use only ad-hoc operation mode of the IEEE 802.11b MAC Layer Standard to communicate each other; these features characterize the CARLINK-UMA scenario.
The goal of this document is to present the obtained results to offer to the consortium different measures about transferring files in CARLINK-UMA scenario without deploying the VANET in real testbeds.

GOALS:

1. Presenting the different situations where ad-hoc communication mode can be used.
2. Featuring the different simulation experiments for VanetMobiSim/Ns-2.
3. Studying the feasibility of using ad-hoc communication mode to communicate two MEUs.

CONCLUSIONS:

1. According to the obtained results, we conclude that the IEEE 802.11b ad-hoc standard operation mode may be successfully used to communicate two MEUs under certain conditions. As a consequence, we propose the IEEE 802.11b ad-hoc operation mode as an alternative to be considered for the CARLINK consortium.

D1.3.6-Simulation and evaluation of the CARLINK-UMA multi-hop scenario by using VanetMobiSim/Ns-2

CARLINK::UMA

January 30, 2008

1 Introduction

Vehicular Ad-hoc Networks (VANETs) are attracting the attention of researchers, industry, and governments because they can offer almost the same services than the Intelligent Transportation Systems (ITSs) reducing costs. By definition, VANETs do not need any external hardware, and the nodes which compose the VANET only need an interface to connect to the network using wireless technologies. In the CARLINK-UMA scenario the Mobile End Users (MEUs) communicate by using the ad-hoc operation mode of the IEEE 802.11b MAC Layer Standard.

The use of ad-hoc communication between MEUs is interesting for the CARLINK architecture in different situations; some of them are shown next:

- Critical information for some specific area has to be broadcasted, i.e., an emergency message [7] as an accident advise. Using ad-hoc communication mode the message is received by the adjacent MEUs independently of the Traffic Service Base Stations (TSBSs) state or location.
- There is not any TSBS accessible (i.e., the TSBS is out of service or the area is a restricted one for any reason and the authorities have not installed one in it) and any other one is to far to connect directly to the MEU. The multi-hop ad-hoc communication mode is a solution since it allows the MEUs to communicate with the TSBSs through any other MEU.
- Data streaming applications (e.g., media applications [8]) between close MEUs do not suffer delays as a consequence of the traffic that TSBSs have to manage.

For analysing the CARLINK-UMA scenario, we have carried out different simulations of multi-hop scenarios using VanetMobiSim/Ns-2 [3] simulator, in order to achieve measures about transferring files between two MEUs which are separated by two or more hops.

This document is organized as follows: In Section 2, we present the different experiments carried out to analyze CARLINK-UMA scenario. In Section 3, we explain how to set up VanetMobiSim/Ns-2 to achieve the multi-hop CARLINK-UMA scenario simulations.In Section 4 shows the obtained results and it presents the analysis of these results. Finally, Section 5 offers a set of conclusions about the results of the simulations. These conclusions, achieved empirically, can be taken into account in order to select the most appropriate technology for the communications between MEUs.

2 Experiments

This section presents the different experiments carried out to simulate the CARLINK-UMA scenario. We have generated various tests that outline different multi-hop situations. Each test is composed of several simulations of a specific scenario, where there are transferences of files between two MEUs which are separated by two or more hops.

In the following subsections, we present the four different defined scenarios and the different tests carried out to measure the multi-hop files transference.

2.1 Scenarios definition

The scenarios defined for the simulations try to reflect different real world traffic situations where there could be multi-hop communication between the MEUs. These scenarios are presented bellow.

Scenario A

The Scenario A represents the situation where the file petitioner and file owner follow the same direction. This scenario is based on the one used to simulate simple ad-hoc communications of CARLINK-UMA scenario in [4]. We have three different situations where the file owner and petitioner can be separated by two hops, three hops or four hops. These different situations have been named Scenario A2, Scenario A3, and Scenario A4, respectively. These scenarios are shown in Figure 1.

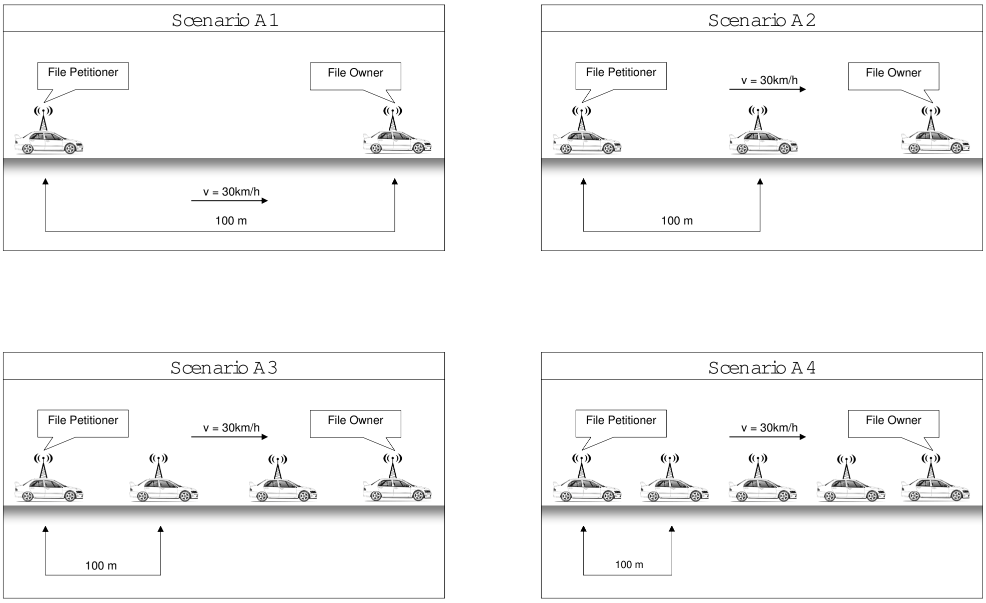


Figure 1: Scenarios A representation

The distance between MEUs is enough to make multi-hop communication necessary; in this case is 100 meters. The MEUs velocity is 30 Km/h (8.3 m/s) for all vehicles.

Scenario B

The Scenario B represents the situation where the file petitioner and file owner follow the same road but they move in opposite directions. We have placed stopped MEUs between the file owner and file petitioner to achieve multi-hop communications. This scenario is based on the Scenario B defined in [4] . In this scenario, we have defined three different situations where the MEUs which interact are separated each other by two hops, three hops or four hops; these different situations have been named Scenario B2, Scenario B3, and Scenario B4, respectively (see Figure 2).

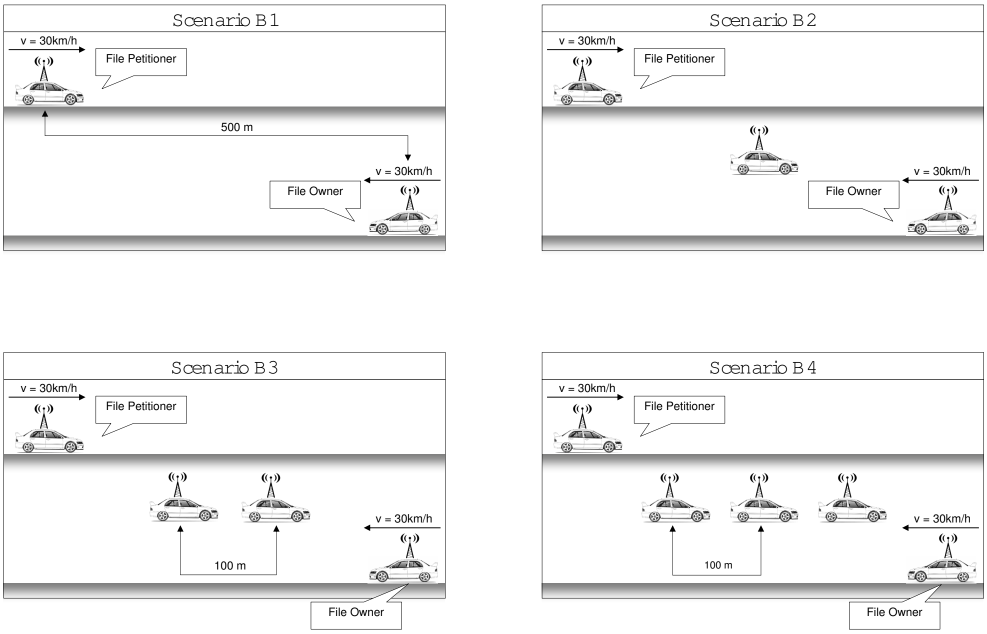


Figure 2: Scenarios B representation

The distance between MEUs is enough to necessary multi-hop communication make; in this case is 100 meters. The MEUs velocity is 30 Km/h (8.3 m/s) for all vehicles.

Scenario C

The Scenario C represents a road with two lanes, where the file owner is stopped in one of them and the file petitioner moves towards the file owner position by the other lane. This scenario is usual in urban environment where the file owner can be stopped because of traffic lights and the file petitioner moves through the other lane. This scenario is shown in Figure 3, left.

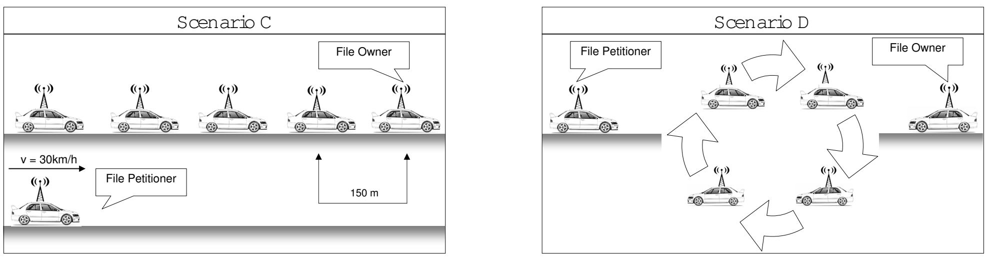


Figure 3: Scenarios C and D representation

The distance between MEUs is enough to make multi-hop communication necessary; in this case is 150 meters for stopped MEUs. The file petitioner velocity is 30 Km/h.

Scenario D

The Scenario D represents the situation where both the file petitioner and the file owner approach to a roundabout. Once they cross the roundabout, they move away to the opposite start position (see Figure 3, right). The distance between the start position of the MEUs that interact each other is enough to need the intermediate hops. In this case, the intermediate hops are four cars circulating inside the roundabout. The MEUs velocity is 30 Km/h (8.3 m/s) for all vehicles.

2.2 Tests definition

After deciding the scenarios we wanted to simulate, we had to define the different tests to carry out depending on the nature of each scenario.

The tests for the scenarios A and B (figures 1 and 2) consist of transferring specific files. As in [4], we use two different file types: **file type 1** with 1 MByte size (representing traffic information documents) and **file type 2** with 10 MBytes size (representing multimedia files or larger information documents). In the following, we name the tests according to the scenario and the file type that we are evaluating: e.g., the TestB3-1 means to transfer the file type 1 in the Scenario B3.

The tests for Scenario A and Scenario B are different. On the one hand, the tests for Scenario A lies in one simulation of transferring 100 files. On the other hand, the tests of Scenario B consist of five different simulations transferring as much as files as possible.

The tests for the scenarios C and D (see Figures 3) are different from the others presented above. We decided that for these scenarios it would be interesting to transfer as much data as we can from file owner to file petitioner while the connection between these MEUs is possible.

3 VanetMobiSim/Ns-2 Simulation

In order to achieve our purposes and obtaining useful results, we have to tune the simulator in order 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 CARLINK-UMA scenario in a trustworthy manner.

As we presented in [3], we use VanetMobiSim/Ns-2 because it offers the possibility of specifying realistic mobility models [5], using VanetMobiSim, and communication environments, using ns-2. In the following, we show how the mobility models and the communication environment have been defined.

3.1 Mobility models definition using VanetMobiSim

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

- Macro-mobility features:
  - The road topology is user-defined placing different set of vertexes depending on which scenario we want to simulate (see Section 2).
  - The initial and destination points are defined by attraction points.
  - The roads speed limit is 50 Km/h.
- Micro-mobility features are defined by the *Intelligent Driver Motion* (IDM) [2] module of Vanet-MobiSim, fitting the velocity in 30 Km/h.

3.2 Communication environment specification using ns-2

For tuning the communication environment using ns-2, we had to identify which parameters we should specify. 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 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) [6] has been used for the simulations. It is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad-hoc networks of mobile nodes.

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 fitting in 25 KBytes.

4 Results

This section presents the results of the experiments described above. First, we present the results of the experiments individually. Finally, we present some general conclusions about the whole multi-hop simulation.

4.1 Test A results

For this scenario, all the transfers were successfully completed. Meaning that the MEU who asks for the file has received the complete file without lousing packets. The results (average data rates) obtained simulating the different experiments defined over Scenario A are shown in Table 1. The maximum average data rate is 611.087 KB/s when file type 2 is transmitted in the scenario of one hop, and the minimum data rate is 152.243 KB/s achieved when file type 1 is transmitted in the ScenarioA4.

Table 1: Average data rate in multi-hop Scenarios A.

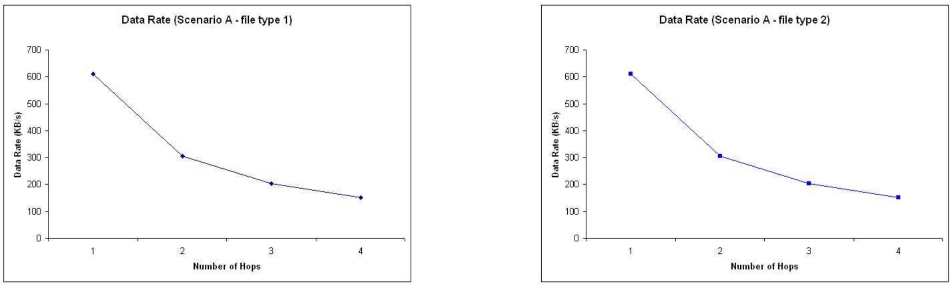
File type	1 hop	2 hops	3 hops	4 hops
File type 1 (1 MB)	609.886 KB/s	304.818 KB/s	203.070 KB/s	152.243 KB/s
File type 2 (10 MB)	611.087 KB/s	305.374 KB/s	203.457 KB/s	152.547 KB/s

Figure 4 shows the average data rates depending on the number of hops. 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, the path increases too, so the PDUs have to be processed and re-sent by more MEUs increasing the transmission time. The experimental results can be represented by the analytical function:

$$f(x) = \frac{1}{a + bx^{-c}}$$

where $a = 0.0001$, $b = 0.0018$, and $c = 0.95$ for Scenario A file type 1, and $a = 0.00015$, $b = 0.0018$, and $c = 0.95$ for Scenario A file type 2.

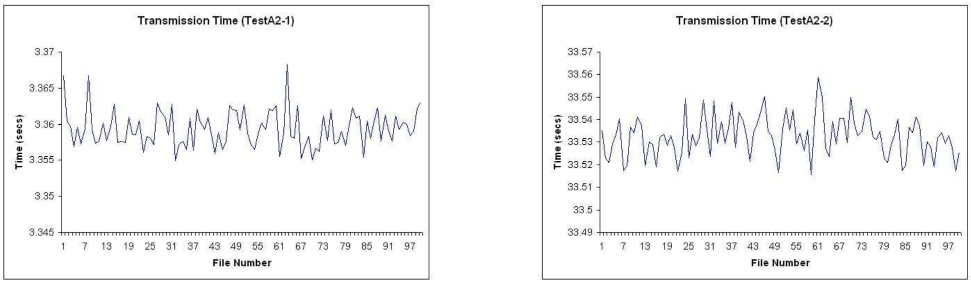
[1] http://www.proxim.com



a) Scenario A file type 1 data rates   b) Scenario A file type 2 data rates

Figure 4: Relation between the download average rate when increasing the number of hops in the scenarios A during the transfers of 1 MB files (a) and 10 MB files (b).

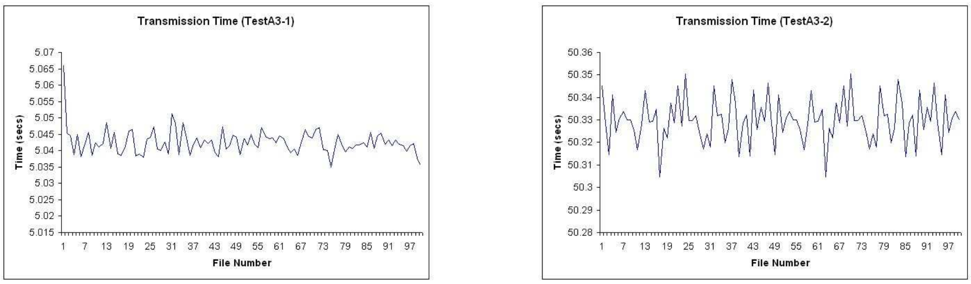
Figure 5 shows the results of transferring files in Scenario A2. The average transmission time is 3.359 seconds, with an average transmission rate equal to 304.818 KB/s, for file type 1 (see Figure 5.a), and the average transmission time is 33.532 seconds, with an average transmission rate equal to 305.374 KB/s, for file type 2 (see Figure 5 b).



a) TestA2-1 transmission time   b) TestA2-2 transmission time

Figure 5: Download time in the Scenario A2 during the transfers of 1 MB files (a) and 10 MB files (b).

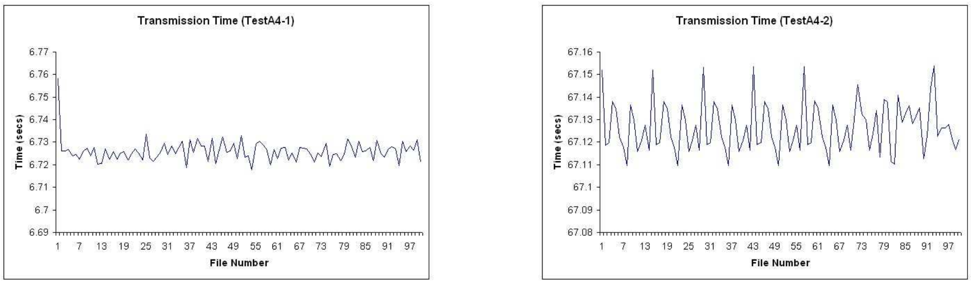
Figure 6 shows the results of transferring files in Scenario A3. The average transmission time is 5.042 seconds, with an average transmission rate equal to 203.071 KB/s, for file type 1 (see Figure 6.a), and the average transmission time is 50.329 seconds, with an average transmission rate equal to 203.457 KB/s, for file type 2 (see Figure 6.b).



a) TestA3-1 transmission time   b) TestA3-2 transmission time

Figure 6: Download time in the Scenario A3 during the transfers of 1 MB files (a) and 10 MB files (b).

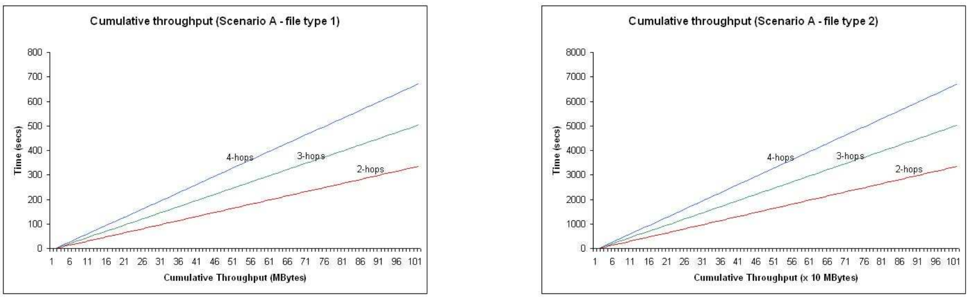
Figure 7 shows the results of transferring files in Scenario A4. On the one hand, the average transmission time is 6.726 seconds, with an average transmission rate equal to 152.243 KB/s, for file type 1 (see Figure 7.a). On the other hand, the average transmission time is 67.126 seconds, with an average transmission rate equal to 152.547 KB/s, for file type 2 (see Figure 7.b).



a) TestA4-1 transmission time b) TestA4-2 transmission time

Figure 7: Download time in the Scenario A4 during the transfers of 1 MB files (a) and 10 MB files (b).

We have computed also the *cumulative throughput* (total throughput) of transferring the 100 files. Graphically, the cumulative throughput can be seen as a straight line with a slope of average data rate (see Figure 8), because there is just some small differences between the different transfers of the same test. The main reason for that phenomenon is that there is no any topology changes during all the simulation.



a) TestA file type 1 cumulative throughput b) TestA file type 2 cumulative throughput

Figure 8: Cumulative throughput (total amount of data downloaded during all the simulation) when increasing the number of hops in the scenarios A during the transfers of 1 MB files (a) and 10 MB files (b).

Studying the outcomes of the tests, we can conclude that for this kind of scenario the data transference between MEUs is possible and reliable.

4.2 Test B results

The experiments carried out for simulating the Scenario B are different from the experiments for Scenario A (see Section 2), so the results have to be analyzed in a different way.

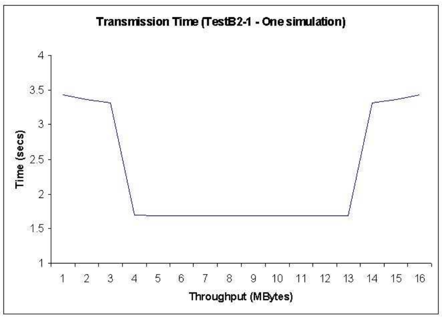
First, we will analyze individually an experiment for each test composing the simulation of Scenario B when transferring the file type 1. Then, we will study and present some conclusions about the whole experimentation over Scenario B. The analysis of transmitting the files of type 1 is made because it can show clearly the behaviour of this scenario; if we use the file type 2, some information could be lost because it is possible to send just one file completely.

Figure 9.a outcomes performance of one simulation of TestB2-1. As we can see, there is three different states:

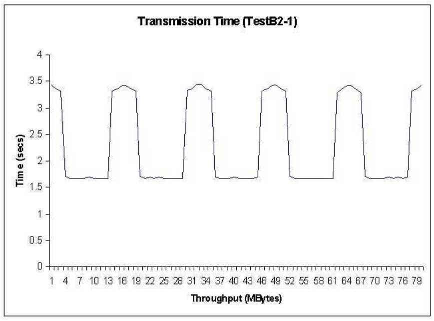
- First state, the MEUs are bringing near,the communication between the MEUs is carried out through the MEU which is in the middle.
- Second state, the MEUs are near, so there is a communication without multi-hop, because it is not necessary.
- Third state, the MEUs are moving further away, the communication is multi-hop again.

As we show in the Test A, when the number of hops increases, the data rate decreases (see Section 4.1). This behaviour also appears during all the tests that compose the whole simulation of Scenario B; the difference is just the number of hops.

Figure 9 shows the results of transferring files in TestB2-1. The average transmission time is 2.313 seconds and the average transmission rate is 442.557 KB/s.



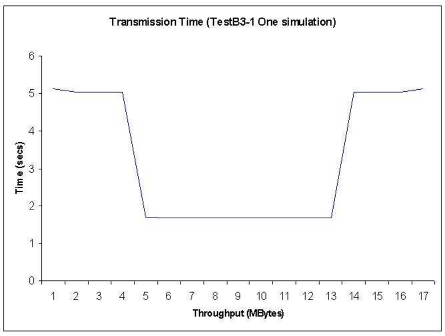
a) TestB2-1 throughput during one simulation



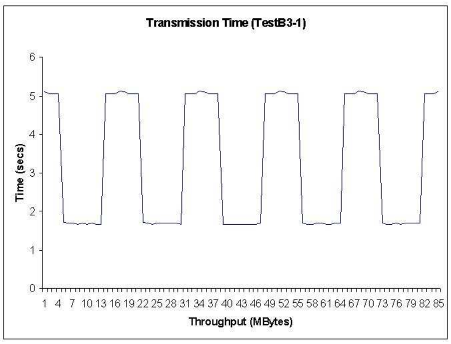
b) TestB2-1 throughput during the five simulations

Figure 9: Download time in the Scenario B2 during the transfers during one simulation (a) and during the five simulations consecutively (b).

Figure 10 shows the results of transferring files in TestB3-1. The average transmission time is 3.271 seconds and the average transmission is 313.021 KB/s.



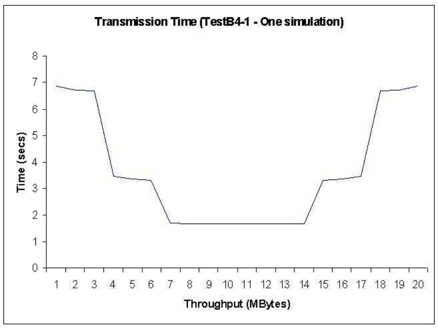
a) TestB3-1 throughput during one simulation



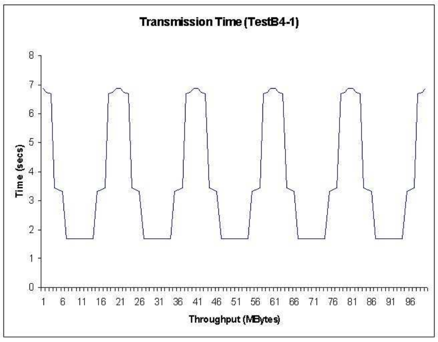
b) TestB3-1 throughput during the five simulations

Figure 10: Download time in the Scenario B3 during the transfers during one simulation (a) and during the five simulations consecutively (b).

Figure 11 shows the results of transferring files in TestB4-1. The average transmission time is 3.713 seconds and the average transmission rate is 275.717 KB/s.



a) TestB4-1 throughput during one simulation



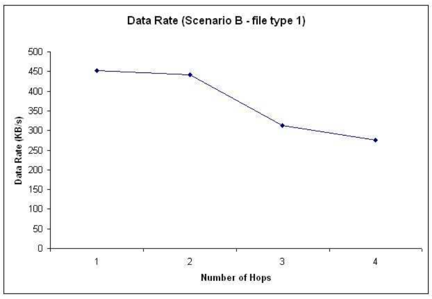
b) TestB4-1 throughput during the five simulations

Figure 11: Download time in the Scenario B4 during the transfers during one simulation (a) and during the five simulations consecutively (b).

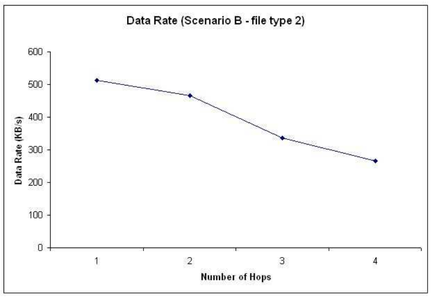
After this analysis of each experiment, we will present the whole Scenario B results. Table 2 contains the average data rate of each test carried out for this scenario. Figure 12 presents the correspondence between the average rate (in KB/s) and the number of hops.

Table 2: Average data rate in multi-hop Scenarios B.

File type	1 hop	2 hops	3 hops	4 hops
File type 1 (1 MB)	371.404 KB/s	442.557 KB/s	313.021 KB/s	275.717 KB/s
File type 2 (10 MB)	502.017 KB/s	466.301 KB/s	336.739 KB/s	265.315 KB/s



a) Scenario B file type 1 data rates

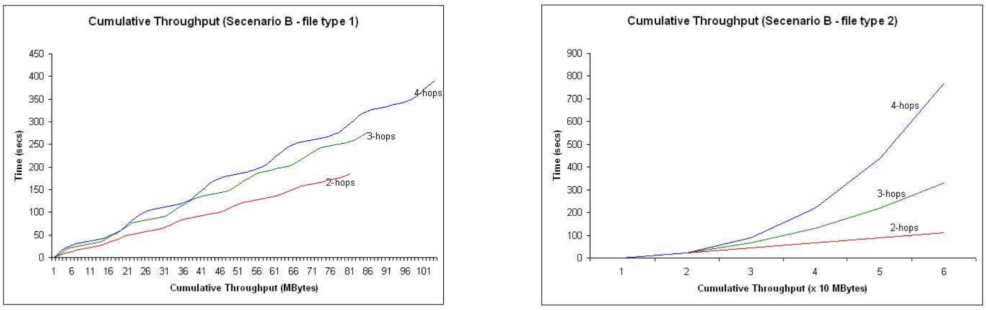


b) Scenario B file type 2 data rates

Figure 12: Relation between the download mean rate when increasing the number of hops in the scenarios B during the transfers of 1 MB files (a) and 10 MB files (b).

During the transfers, the number of needed hops to communicate the sender and the receiver changes. For this reason, the transmission data rate is not as stable as the transmission data rate is Scenario A. Figure 13 presents the cumulative throughput. In this case, it is not a straight line as in Scenario B (see Figure 8) because of the changing of number of hops.

The Scenario B is delimited by the timeframe in which the two MEUs can communicate with each other. For this reason, we can transmit successfully just one file of 10 MBytes. So, in these kinds of



a) Scenario B file type 1 cumulative throughput

b) Scenario B file type 2 cumulative throughput

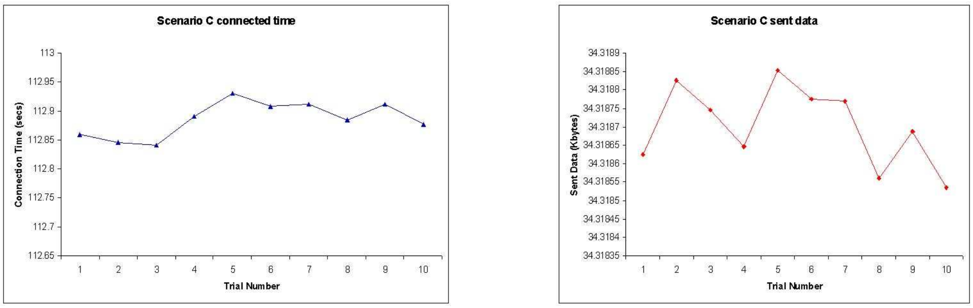
Figure 13: Cumulative throughput (total amount of data downloaded during all the simulation) when increasing the number of hops in the scenarios B during the transfers of 1 MB files (a) and 10 MB files (b).

scenarios the size of the file to transmit is very important. The distances between the MEUs and the number of hops restrict also the transmission data rate.

4.3 Test C and D results

For these two tests, we have simulated ten different trials where the MEUs try to send as much data as possible. The measures analyzed in these cases is the time that the MEUs have been connected and the sent data during the simulations.

The Figure 14 shows the transmission time and the sent data during ten simulations of Scenario C. The mean values are 34.318 MB of sent data and 112.856 seconds of connected time. It means that the average data rate is 311.308 KB/s.



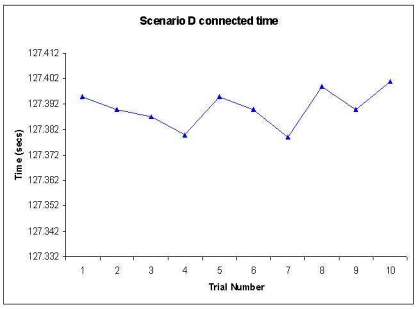
a) Scenario C connected time

b) Scenario C sent data

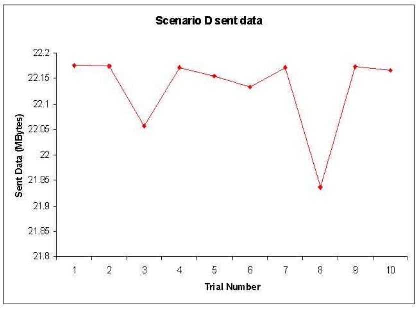
Figure 14: Time while the MEUs have been connected (a) and the downloaded data (b) during the Scenario C simulation.

In the case of the simulations of Scenario D, the time during the MEUs were connected was 127.39 seconds and in this time the average data sent was 22.135 MB. Meaning that the average data rate was 177.927 KB/s. The Figure 15 shows the results achieved during the simulation of this scenario.

According to these results, it is possible to send files longer than 20 MB in the complex scenarios. In these conditions, files containing multimedia or text data could be send using multi-hop communications.



a) Scenario D connected time



b) Scenario D sent data

Figure 15: Time that the MEUs have been connected (a) and the downloaded data (b) during the Scenario D simulation.

5 Conclusions

The best results of simulating CARLINK-UMA Scenario were achieved in ad-hoc communication through one hop [4], and these results were getting worst when the number of hops increased (see tables 1 and 2). During the simulations the worst results were obtained during the TestD (see Figure 15), the smaller size of a data file transmitted completely was larger than **20 MB** and the smaller data rate achieved was higher than **175 KB/s**.

Analyzing the results obtained during the simulations, inside the CARLINK-UMA scenario (i.e., ad-hoc communications using the IEEE 802.11bg standards) exists a dependence between the **number of hops** involved in the communications and the amount of data that can be transmitted between the MEUs. The higher is the number of hops, the lesser must be the file size in order to transmit it completely, as we expected.

There are also other parameters which affect to the quantity of data that can be transferred. These parameters are the **network topology** (MEUs location) and the **velocity of the MEUs**. The MEUs location defines the packet relays through the VANET. The difference between the file sender and file requester velocities affects negatively to the amount of data that can be transfered, since when this difference increases the communication time decreases.

References

[1] CARLINK::UMA. D2006/10 - VDTP: A file transfer protocol for vehicular ad hoc networks. Technical report, University of Malaga, Spain, 2006.

[2] CARLINK::UMA. D1.3.1-VanetMobiSim: The vehicular mobility model generator tool for CARLINK. Technical report, University of Malaga, Spain, 2007.

[3] CARLINK::UMA. D1.3.2-VanetMobiSim/Ns-2: A VANET simulator for CARLINK. Technical report, University of Malaga, Spain, 2007.

[4] CARLINK::UMA. D1.3.3-simulation and evaluation of the CARLINK-UMA scenario by using vanetmobisim/ns2. Technical report, University of Malaga, Spain, 2007.

[5] J. Härri, F. Filali, and C. Bonnet. Mobility Models for Vehicular Ad Hoc Networks: A Survey and Taxonomy. March 2007.

[6] David B. Johnson, David A. Maltz, and Josh Broch. Dsr: the dynamic source routing protocol for multihop wireless ad hoc networks. pages 139–172, 2001.

[7] Giovanni Resta, Paolo Santi, and Janos Simon. Analysis of multi-hop emergency message propagation in vehicular ad hoc networks. In *MobiHoc '07: Proceedings of the 8th ACM international symposium on Mobile ad hoc networking and computing*, pages 140–149, New York, NY, USA, 2007. ACM.

[8] Yunpeng Zang, Lothar Stibor, Guido R. Hiertz, and Hans-Juergen Reumerman. Vehicular wireless media network (vwmn): a distributed broadband mac for inter-vehicle communications. In *VANET '05: Proceedings of the 2nd ACM international workshop on Vehicular ad hoc networks*, pages 95–96, New York, NY, USA, 2005. ACM.