Executive Overview

TITLE: D1.3.8-Simulation and evaluation of the TSCU 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 communications between *TSCU (Traffic Service Central Unit)* and *MEUs (Mobile End Users)*. The MEUs receive information from the TSCU through the *TSBSs (Traffic Service Base Stations)* that join the MEUs wireless network to the TSCU, which is located in the fix network beyond the TSBS. We have simulated different scenarios using the VanetMobiSim/Ns-2 simulation tool, where we have used the WiFi MAC Layer Standard to communicate MEUs with TSBSs and wired links to connect the TSBSs to TSCU. The goal of this document is to present the obtained results to offer to the consortium some measurements of transferring data from TSCU to MEUs. This information is important since the three scenarios which compose the whole CARLINK project are based on ITSs (Intelligent Transportation Systems).

GOALS:

1. Presenting the communication between TSCU and MEUs.
2. Featuring the different simulation experiments for VanetMobiSim/Ns-2.
3. Studying the simulation results to offer some conclusions about communication between TSCU and MEUs.

CONCLUSIONS:

1. According to the obtained results, we conclude that the communication between TSCU and MEUs through the TSBSs may be successful under certain conditions. The two main parameters to take into account to deploy this kind of communications are the MEUs velocity and the data rate generated by the TSCU to send the information.

D1.3.8-Simulation and evaluation of the TSCU communications in CARLINK scenarios by using VanetMobiSim/Ns-2

CARLINK::UMA

January, 31 2008

1 Introduction

In this deliverable we use the *VanetMobiSim/Ns-2* simulator to evaluate the performance of the *ITS (Intelligent Transportation Systems)* which consists of a *TSCU (Traffic Service Central Unit)* communicating to the *MEUs (Mobile End Users)*. They exchange the data through the *TSBSs (Traffic Service Base Stations)* . These three participants have different roles in the network:

- The TSCU sends the data generated to the MEUs and receives the collected data from them.
- The TSBS is the connection that links the TSCU with MEUs.
- The MEU receives the data generated from the TSCU and sends the data collected to it.

The TSBSs need two different network interfaces, since they belong to a fix wired network infrastructure composed by the TSCU and the TSBSs, but it has also to connect with MEUs that use a wireless connection. So the TSBSs use wired and wireless network interfaces. For this reason, the communication between TSCU and MEUs depends on both the services provided by the telecommunication company, which offers the wired connection, and the wireless network MAC layer standard to be used. The most appropriate wireless standards to be used in this environment are *IEEE 802.11b/g (WiFi Standard)* and *IEEE 802.16 (WiMAX Standard)*. Although WiMAX has better characteristics to be used in this scenario, WiFi is widely used because the network interfaces are less expensive nowadays.

We have simulated different scenarios using the VanetMobiSim/Ns-2 simulation tool. We have used IEEE 802.11b MAC Layer Standard to develop the wireless network in order to use the most used network interfaces, and wired links to connect the TSBSs to TSCU.

The goal of this document is to present the obtained results to offer to the consortium some measurements of transferring data from TSCU to MEUs. This information is important since the three scenarios by which is composed the whole CARLINK project [1] are based on ITSs (Intelligent Transportation Systems).

This document is organized as follows: Section 2 presents the different experiments carried out to analyze communication environment between TSCU and 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 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 different experiments carried out to simulate the ITS communications. We have generated various tests that outline different situations where the TSCU sends data to the MEUs.

Each test is composed of several simulations of one specific scenario. These scenarios are composed by the TSCU, two TSBSs, and one MEU.

In the following subsections, we present the different defined scenarios and the different tests carried out to measure the TSCU-MEUs transfers.

2.1 Scenarios definition

Using the scenarios defined for the simulations, we try to reflect different real world situations where the TSCU sends updated information to the MEUs. We have represented four situations where the MEU is traveling through a straight line road and the TSCU deliver data to the vehicle through the TSBSs. These TSBSs are next to the road and separated each other by 400 meters. The difference between the scenarios are the MEU's velocities. We have chosen four velocities: 30 Km/h, 50 Km/h, 100 Km/h, and 120 Km/h. These scenarios are named TSCU-MEU-30, TSCU-MEU-50, TSCU-MEU-100, and TSCU-MEU-120 respectively (see Figure 1).

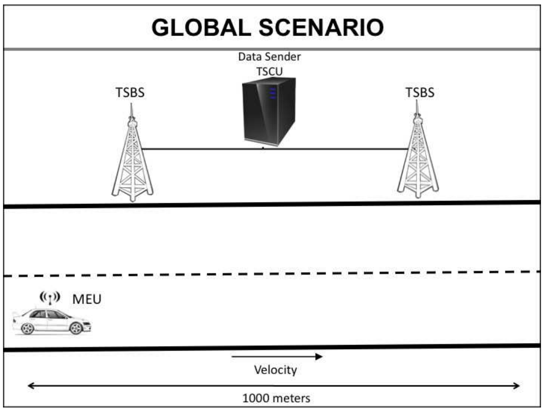


Figure 1: Representation of the global configuration which defines the different scenarios to be simulated.

We have chosen these four velocities because we want to represent the behavior of this kind of communications in urban and highway environments. The two firsts velocities (30 Km/h and 50 Km/h) represent the common vehicles velocity at urban environments. The two lasts velocities (100 Km/h and 120 Km/h) represent the usual vehicles velocity in highways.

2.2 Tests definition

Different tests have been defined for each scenario presented above (see Figure 1). The tests consist of transferring as much data as possible from the TSCU to the MEU during the connection time. The distinctive feature of each test is the data rate (kilobytes per second) generated for the TSCU to send the information to the MEU. We have chosen four different values 50 Kbytes/s, 100 Kbytes/s, 200 Kbytes/s, and 500 Kbytes/s. These values have been chosen to check the behavior of this kind of networks when increasing data rates. The evaluation is made in terms of *Data Rate*, *Data Sent*, *Path Duration* and *Lost PDUs*.

In the following, we name the tests according to the data rate and the scenario that we are evaluating: e.g., the *Scenario TSCU-100-50* means to transfer the data from the TSCU to the MEU with a generated rate of **100** Kbytes/s in the TSCU-MEU-**50** scenario.

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 2.1) in a trustworthy manner.

As we presented in [3], we use VanetMobiSim/Ns-2 since 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 which represent the different scenarios using VanetMobiSim have been featured as follows:

- Macro-mobility features:
  - The road topology is user-defined by two 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 VanetMobiSim, fitting the velocity in 30 Km/h, 50 Km/h, 100 Km/h, and 120 Km/h, depending on the simulated scenario.

The TSBSs have been located by two different vertex in the scenario.

3.2 Communication environment specification using ns-2

The simulations have two different kind of connections (see Section 1), both wireless and wired connections have to be defined to simulate these scenarios (see Figure 2). On the one hand, the wired connection between TSBSs and TSCU is defined by a **duplex link** with a bandwidth of **5 Megabit per second**, a delay of **2 ms**, trying to reflect a possible network offered by the telecommunication services providers. On the other hand, the wireless connection between the MEU and the TSBSs are featured by the link layer defined by **IEEE 802.11b** Standard.

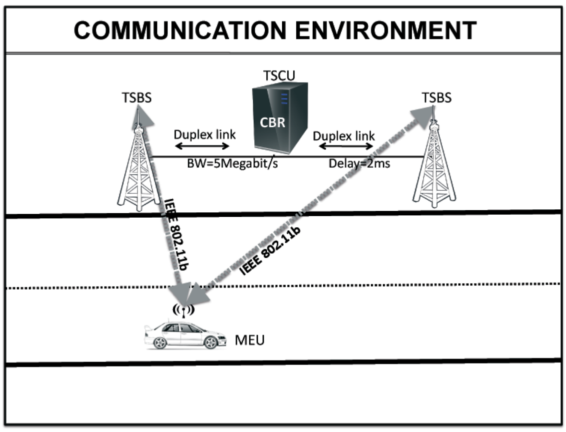


Figure 2: This figure outlines the communication environment defined for the simulations.

Finally, we have defined a *Constant Bit Rate (CBR)*, which generates the traffic from the TSCU to the MEU using different data rates depending on the scenario we want to simulate. The CBR generates PDUs with **25 Kbytes** of size. This CBR is used over User Datagram Protocol (UDP) transport protocol which sends the PDUs to the MEU.

4 Results

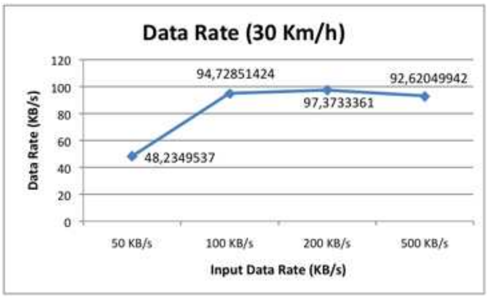
This section presents the results of the experiments described above. The results are grouped and analyzed depending on the scenario.

4.1 Scenario TSCU-MEU-30 results

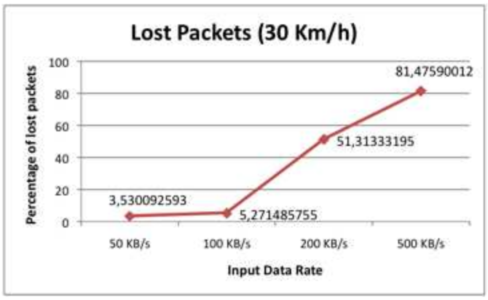
As we present in Section 2.1, in this scenario the MEU moves with a velocity of 30 Km/h, representing the mobility model of an urban scenario. For this velocity the average duration path (connection time) is 28.53 seconds. It means that during this time the TSCU is able to send information to the MEU through a TSBS. It indicates that the MEU is receiving information while it covers 238.194 meters (30 Km/h during 28.53 seconds). Table 1 presents the average results obtained during the simulations of this scenario.

Table 1: Scenario TSCU-MEU-30 simulation results.

TSCU data rate	Download data rate	Data sent	Percentage of lost PDUs
50 KB/s	48.23 KB/s	1378.71 KB	3,53 %
100 KB/s	94.72 KB/s	2707.65 KB	5,27 %
200 KB/s	97.37 KB/s	2783.25 KB	51,3 %
500 KB/s	92.62 KB/s	2647.40 KB	81,47 %



a) Transmission data rates



b) Percentage of lost PDUs

Figure 3: These figures present the results obtained during the Scenario TSCU-MEU-30 simulation.

The maximum data rate achieved during the simulations is obtained when the TSCU generates a data rate of 200 Kbytes/s being 97.37 Kbytes/s. But, in this case, the percentage of lost packets is greater than the 50 % (51.3 %), meaning that during the connection time more than the half number of generated packets are lost. This phenomenon is more noticeable when TSCU generates a data rate of 500 Kbytes/s, since for this data rate the percentage of lost packets is 81.47 %. For this reason, the data is downloaded with a rate lesser than in the previous case being just 92.62 Kbytes/s (see Figure 3.a). The lesser percentage of lost PDUs obtained during the simulations is obtained when the TSCU generates a data rate of 50 Kbytes/s, but the transmission data rate in this case is 48.23 Kbytes/s. Figure 3 outlines the results obtained during the simulations.

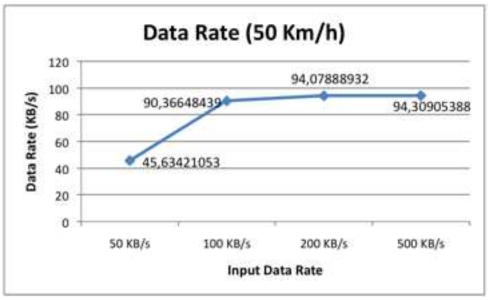
4.2 Scenario TSCU-MEU-50 results

This scenario represents the mobility model of a urban scenario, where the MEU moves with a velocity of 50 Km/h (see Section 2.1). For this velocity the average duration path is 18.05 seconds. Meaning that the MEU is receiving data while it covers 250.694 meters. Table 2 presents the average results obtained during the simulations of this scenario.

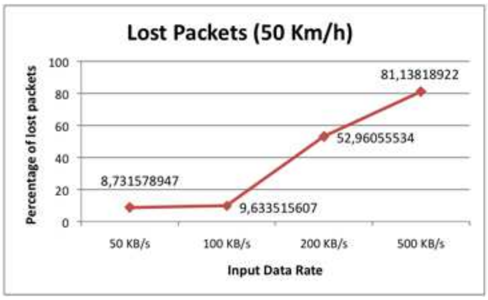
Table 2: Scenario TSCU-MEU-50 simulation results.

TSCU data rate	Download data rate	Data sent	Percentage of lost PDUs
50 KB/s	45.63 KB/s	823.69 KB	8.73 %
100 KB/s	90.36 KB/s	1631.11 KB	9.63 %
200 KB/s	94.07 KB/s	1698.12 KB	52.96 %
500 KB/s	94.30 KB/s	1702.27 KB	81.13 %

The highest data rate achieved during the simulations of this scenario is 94.30 Kbytes/s and it is obtained when the TSCU generates the maximum data rate (500 Kbytes/s). In this case the percentage of lost packets during the connection time is 81.13 %. The minimum percentage of lost PDUs is obtained when the TSCU generates a data rate of 50 Kbytes/s, but the transmission data rate in this case is 45.63 Kbytes/s. Figure 4 outlines the results obtained during the simulations.



a) Transmission data rates



b) Percentage of lost PDUs

Figure 4: These figures present the results obtained during the Scenario TSCU-MEU-50 simulation.

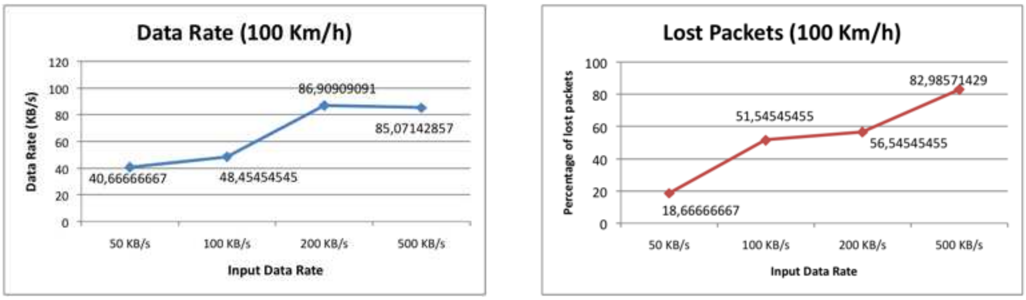
4.3 Scenario TSCU-MEU-100 results

In this scenario, we represent a highway environment, where the MEU moves with a velocity of 100 Km/h (see Section 2.1). For this velocity the average duration path decreases to 1.29 seconds. The vehicle is receiving data while it covers just 36 meters. Table 3 presents the average results obtained during the simulations of this scenario.

Table 3: Scenario TSCU-MEU-100 simulation results.

TSCU data rate	Download data rate	Data sent	Percentage of lost PDUs
50 KB/s	40.66 KB/s	52.71 KB	18.66 %
100 KB/s	48.45 KB/s	62.81 KB	51.54 %
200 KB/s	86.90 KB/s	112.66 KB	56.54 %
500 KB/s	85.07 KB/s	110.27 KB	82.98 %

The maximum data rate achieved during the simulations is obtained when the TSCU generates a data rate of 200 Kbytes/s being 86.90 Kbytes/s. For this data rate, the percentage of lost packets is 56.54 %. As in Scenario TSCU-MEU-30, the download data rate decreases when the TSCU generates data faster than 200 Kbytes/s (see Figure 5.a). The minimum percentage of lost PDUs obtained during the simulations is obtained when the TSCU generates a data rate of 50Kbytes/s, but the data rate in this case is 40.66 Kbytes/s. Figure 5 outlines the results obtained during the simulations.



a) Download data rates

b) Percentage of lost PDUs

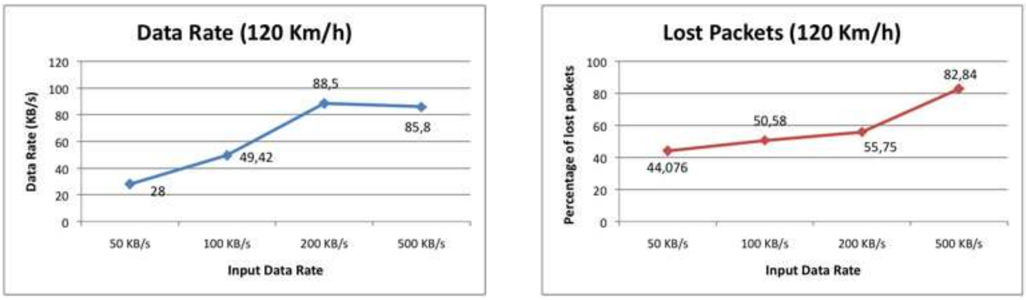
Figure 5: These figures present the results obtained during the Scenario TSCU-MEU-100 simulation.

4.4 Scenario TSCU-MEU-120 results

The MEU moves with a velocity of 120 Km/h, representing the maximum highway velocity (see Section 2.1). For this velocity the average duration path decreases critically to 0.974 seconds, which means that the MEU is receiving data only during 32.46 meters. Table 4 presents the average results obtained during the simulations of this scenario.

Table 4: Scenario TSCU-MEU-120 simulation results.

TSCU data rate	Download data rate	Data sent	Percentage of lost PDUs
50 KB/s	28 KB/s	27.23 KB	44.07 %
100 KB/s	49.42 KB/s	48.13 KB	50.58 %
200 KB/s	88.52 KB/s	86.19 KB	55.75 %
500 KB/s	85.83 KB/s	83.56 KB	82.84 %



a) Download data rates

b) Percentage of lost PDUs

Figure 6: These figures present the results obtained during the Scenario TSCU-MEU-120 simulation.

The maximum data rate achieved during the simulations is obtained when the TSCU generates a data rate of 200 Kbytes/s, being 88.52 Kbytes/s. With this data rate the percentage of lost packets during the connection time is 55.75 %. As in the other scenarios, the download data rate decreases when the TSCU generates data faster than 200 Kbytes/s (see Figure 6.a). The minimum percentage of lost PDUs obtained during the simulations is obtained when the TSCU generates a data rate of

50 Kbytes/s, but the data rate in this case is 28 Kbytes/s. Figure 6 outlines the results obtained during the simulations.

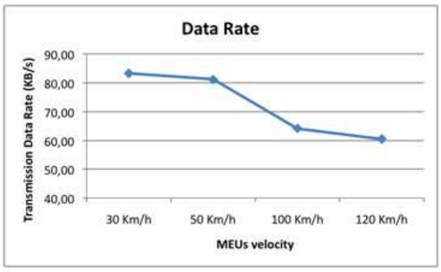
4.5 Global results analysis

After the individual studies for the the results of each scenario, in this section we analyze the whole results obtained during the simulations in order to achieve the global conclusions.

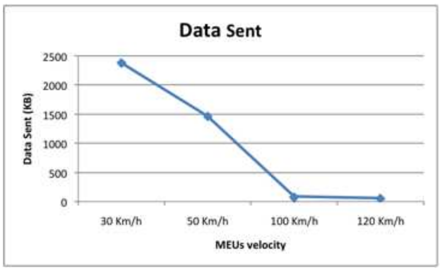
There are two parameters affecting mainly the quality of the communicaions in terms of transmission *data rate*, *data sent*, and percentage of *lost PDUs*. These two parameters are the **velocity** of the MEUs and the **data rate** generated by the TSCU.

Table 5: Simulation average results for each scenario (according to the MEU's velocity).

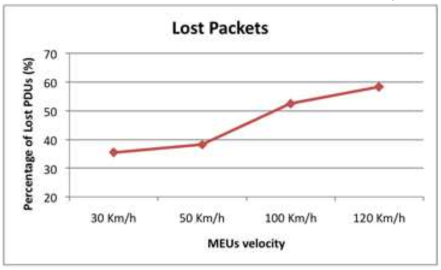
MEU velocity	Download data rate	Data sent	Percentage of lost PDUs
30 Km/h	83.24 KB/s	2379.25 KB	35.39 %
50 Km/h	81.10 KB/s	1463.80 KB	38.11 %
100 Km/h	64.03 KB/s	82.99 KB	52.43 %
120 Km/h	60.42 KB/s	58.84 KB	58.31 %



a) Download data rate



b) Size of sent data

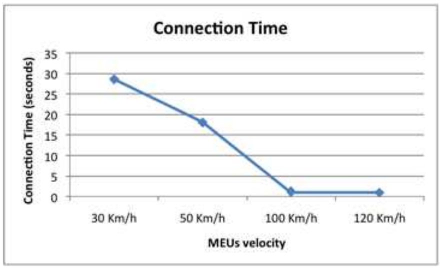


c) Percentage of lost PDUs

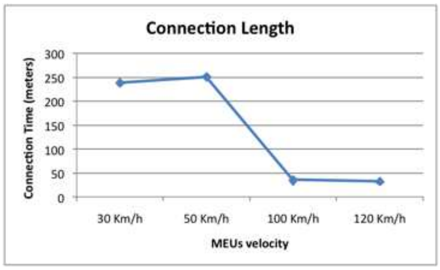
Figure 7: Average of whole simulation results achieved in terms of velocities.

Table 5 presents the average values of the whole simulation according to the MEUs velocities. The worst values are achieved during the simulation of the maximum velocity (120 Km/h). For this velocity, the download data rate is 60.42 Kbytes/s, the data sent is 54.84 Kbytes, and the percentage of lost packets is 58.31 %. The best values are achieved when the MEUs moves with a velocity of 30 Km/h. For this velocity, the download data rate is 83.24 Kbytes/s, the data sent is 2379.25 Kbytes, and the percentage of lost packets is 35.39 %. Figure 9 presents the behavior of the whole simulation when the velocity changes.

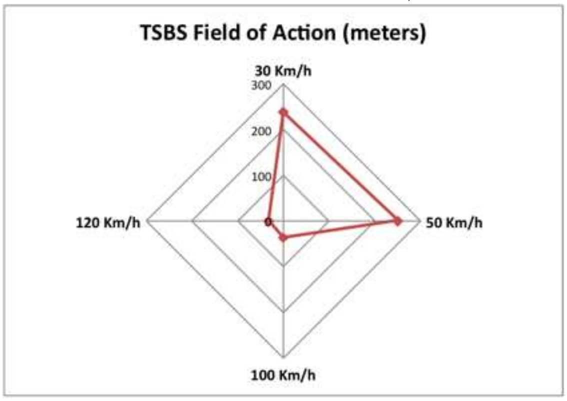
The velocity affects negatively to the path duration between the MEU and the TSBS, when the velocity increases the duration is lesser. It means that the amount of data that the MEU can download is smaller since the TSBSs' field of action is smaller. Figure 8 presents the duration path and the TSBSs' field of action (connection length) according to the MEUs velocities.



a) Connection time



b) TSBSs' field of action



c) TSBSs' field of action surface representation

Figure 8: These figures present the duration path (connection time) and TSBSs' field of action.

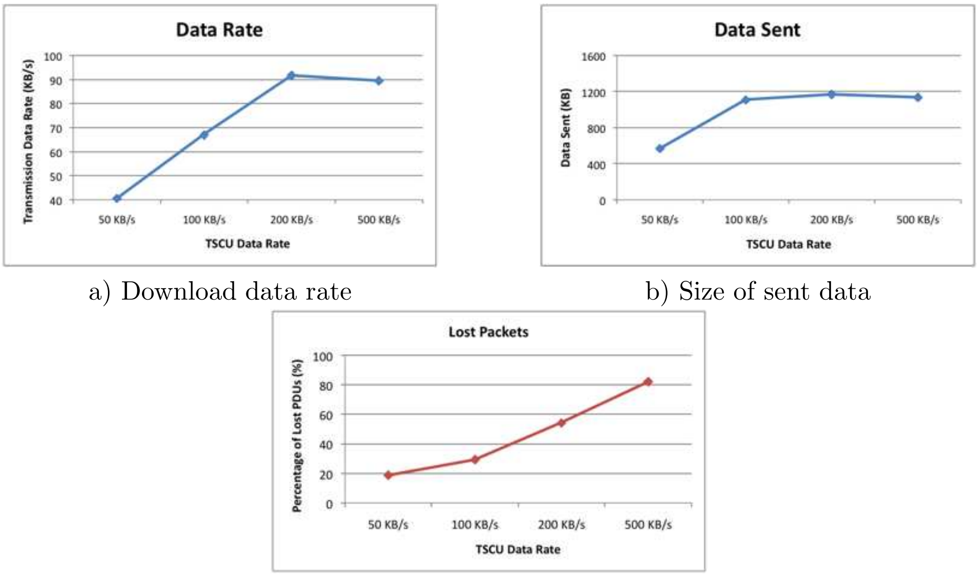
The other important parameter is the data rate generated by the TSCU to send the data. This parameter is important since it affects directly to the data that the TSBSs have to broadcast.Table 6 presents the average results in terms of the data generated by the TSCU. When the data rate increases over 200 Kbytes/s, the download data rate decreases and the percentage of lost PDUs increases dramatically. The best download data rate is achieved when the TSCU sends the data at 200 Kbytes/s, although the data downloaded by the MEU is not really larger than the others, both 100 Kbytes/s and 500 Kbytes/s. When the TSCU generates a data rate of 50 Kbytes/s the percentage of lost PDUs achieves the lowest value. However, the data sent to the MEU is also the lowest (570.59 Kbytes).

Table 6: Simulation average results for each generated TSCU data rate.

TSCU data rate	Download data rate	Data sent	Percentage of lost PDUs
50 KB/s	40.62 KB/s	570.59 KB	18.75 %
100 KB/s	66.99 KB/s	1108.37 KB	29.25 %
200 KB/s	91.71 KB/s	1170.05 KB	54.14 %
500 KB/s	89.45 KB/s	1135.88 KB	82,10 %

5 Conclusions

In this Section, we analyze the whole results obtained during the simulations of the ITS communications, where TSCU sends information to the MEUs through the TSBSs. The TSCU and the TSBSs have a wired connection and the connection between TSBSs and MEUs is achieved using IEEE 802.11b Standard of wireless communications.



a) Download data rate b) Size of sent data

c) Percentage of lost PDUs

Figure 9: Average of the whole simulation results achieved in terms of the TSCU data rate.

The communications are conditioned by two parameters that affect mainly the quality of them: the velocity of the MEUs and the data rate generated by the TSCU. The quality of the communication are defined in terms of download data rate, data sent, and percentage of lost PDUs.

The velocity affects negatively to the path duration between the MEU and the TSBS, when the velocity increases the duration is lesser and the TSBSs' field of action is smaller and the amount of download data decreases. Thus, it is necessary having better connections in environments where the vehicles use to move with a higher velocity, e.g. increasing the number of TSBSs, then the *Roaming* problem could appear.

The data rate generated by the TSCU to send the data is important, since it affects directly to the data that TSBSs have to broadcast. Although when the TSCU sends the data with a higher data rate the download data rate increases, when it is higher than 200 Kbytes/s the quality of the communication decreases because the download data rate decreases and the percentage of lost PDUs increases dramatically. According to the results, the best choice is to send the data with a data rate of 100 Kbytes/s, since the MEUs for all simulated scenarios can download files larger than 1 Megabytes, and the percentage of lost PDUs is really lesser than when other TSCU generated data rates are used. In addition, it relives the traffic congestion on the network, since it generates less traffic than the larger data rates.

Finally, this kind of communications can be deployed in a urban environment, where the vehicles cannot have velocities larger than 50 Km/h, since the network has a good behavior (average data downloaded by the MEU is between 1463.84 Kbytes and 2379.25 Kbytes). However, in highways it seems that is not the best technology (IEEE 802.11b Standard) to deploy this kind of network, since the data downloaded by the MEU are really small, less than 100 Kbytes, and the percentage of lost PDUs are larger than 50 %.

Although the results are not encouraging, probably the use of the WiMAX Standard to deploy this kind of networks may offer better results than the use of the WiFi Standard, since WiMAX offers better features in terms of field of action and data rates, increasing the data that can be downloaded by the MEUs. However, there are a researching area which want to define more reliable MAC layer standard for this kind of networks [4].

References

[1] CARLINK. D1.2-Definition of Scenarios. Technical report, CARLINK consortium, 2007.

[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] Chun-Yuah Chiu, E.H. Wu, and Gen-Huey Chen. A reliable and efficient MAC layer broadcast (multicast) protocol for mobile ad hoc networks. *Global Telecommunications Conference, 2004. GLOBECOM '04. IEEE*, 5:2802–2807 Vol.5, 29 Nov.-3 Dec. 2004.

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