CHOSeN

Project Report

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1 Introduction

This document is aimed at collecting the testing results obtained with the system prototype mounted on the final automotive demonstrator.
In particular, three different testing scenarios have been identified in order to check the effectiveness of the proposed automotive application, both in terms of responsiveness and feasibility.
Two of them (i.e., the deflating tyre and the decreasing visibility scenarios) have been already tested under the simulation framework developed in the WP2. Given that, it will be possible to compare the results obtained in the virtual and real environments, in order to check the correctness of what has been implemented in both domains.
A third testing scenario (related to brake efficiency) has been identified in order to obtain additional data on the functioning of the system prototype.
The rest of the document will be organized as follows. The architecture of the automotive demonstrator will be described. After that, the description of the testing scenarios will be provided and the results obtained in each of them will be presented. Finally, the conclusions will be drawn.

2 Automotive system prototype architecture

As stated in the project document D4.1.1 “Demonstrator HW setup for automotive application” accompanying the prototype delivery, the automotive demonstrator has been realized with the following hardware components:

- 3 sensor node platforms
- 2 middleware node platforms
- 1 ALIX board
- 1 interfacing with the in-vehicle CAN bus
- 1 personal digital assistant (PDA)
- 1 sensor aimed at measuring the brake disk temperature (BDT)
- 1 sensor aimed at measuring the tyre pressure and temperature (TP, TT)

Those components have been mounted on the car depicted in Figure 1, a Lancia Delta.

Figure 1: CHOSeN demonstrator

The hardware components have been displaced inside the car according to the physical architecture depicted in Figure 2.

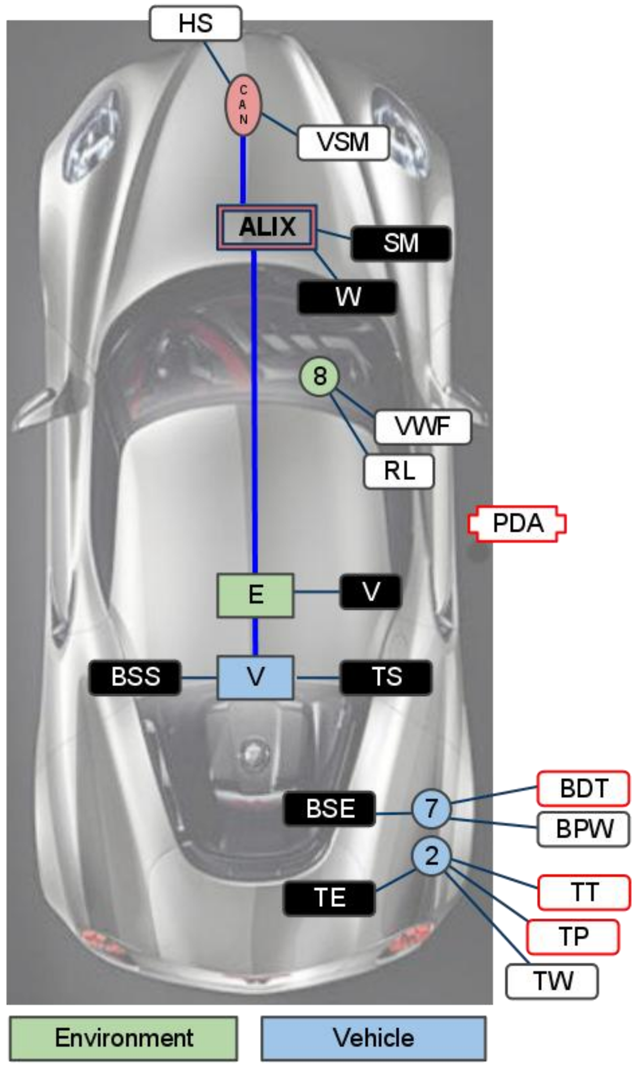
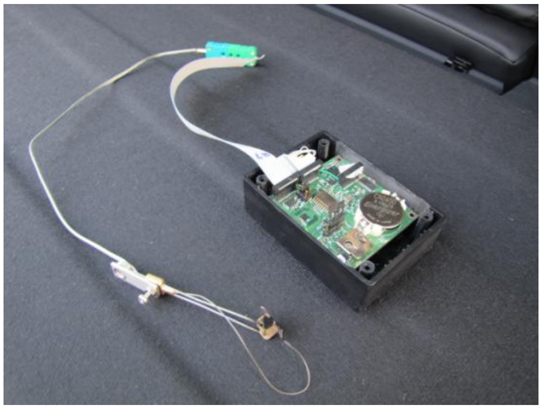


Figure 2: Physical architecture of the system prototype

The blue network is aimed at collecting measurements from the vehicle, mainly related to tyres and brake system. In particular, node 2 is equipped with an Infineon SP37 sensor, able to measure the temperature and the pressure of the tyre (TT and TP, respectively). The remaining “Tread Wear” (TW) value is simulated on the node. The three aforementioned L1 data are used to calculate the L2 data “Tyre Efficiency” (TE).
The second node of this network (node 7) is equipped with a TC Direct 401-130 K-type thermocouple, able to monitor the brake disc temperature (BDT). The “Brake Pad Wear” (BPW) value is simulated in order to be able to calculate the L2 data “Brake System Efficiency” (BSE).
The pictures of the nodes 2 and 7 are depicted in Figure 3 (a) and (b), respectively.

(a)



(b)

Figure 3: Node 2 (a) and node 7 (b) of the “Vehicle” wireless sensor network

The central node V collects the data necessary to calculate the “Brake System Status” (BSS) and “Tyres status” (TS) values. These last two quantities are related to the whole vehicle and should therefore be calculated using data coming from all the 4 wheels. However, in such a context only the available values are used to calculate them. The node V is located in the rear part of the car, as depicted in Figure 4.

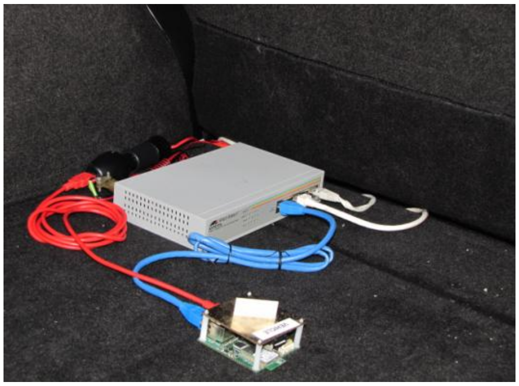


Figure 4: Node V of the “Vehicle” wireless sensor network

The green network collects data coming from the environment. The two quantities connected to the node 8 (“Visibility With Fog”, VWF and “Rain Level”, RL) have been emulated by using manual triggers connected to the analog interface of the platform. These data are used in the central node E to calculate the “Visibility” (V). The nodes 8 and E are located in the cabin of the car, as depicted in Figure 5.

(a) (b)

Figure 5: Node 8 (a) and node E (b) of the "Environment" wireless sensor network

The two resulting subnetworks are connected through an Ethernet bus (straight blue line in Figure 2) to the ALIX board (the Ethernet switch used to create this local area network is visible in Figure 4). This embedded platform is also connected to the in-vehicle CAN bus in order to acquire the headlight status (HS) and the vehicle speed (VSM). This component collects the data coming from the two central nodes and from the CAN bus in order to evaluate the safety margin (SM) and to detect some possible warning or dangerous situations for the driver (W). For testing purposes, a data logger has been implemented on the ALIX board in order to acquire all the measurements taken from the wireless sensor networks.

(a) (b)

Figure 6: ALIX board (a) and PDA (b)

A personal digital assistant (PDA) is finally integrated in the demonstrator in order to visualize all the data coming from the wireless sensor networks and also to warn the driver through visual alerts. Both the ALIX board and the PDA are visible in Figure 6 (a) and (b), respectively.

3 Application demonstration scenarios and experimental results

The previously described architecture has been used to define three different demonstration scenarios. It is worth noting that in each scenario all the nodes and the networks installed on the car are functioning in parallel, but only the quantities involved in each of them will be reported to better understand their behavior. Each test has been also executed several times for several tens of minutes and their most significative parts will be presented in this paragraph.
The test campaign on the vehicle has been executed without moving it, both for safety and legal issues.
The first application scenario takes into account a tyre that is slowly decreasing its inflating pressure. It therefore involves the vehicle wireless sensor network, and in particular its node 2. In Figure 7, the trend of all the involved quantities is depicted.
As stated before, the value of the tread wear quantity has been simulated on the node and then normally transmitted through the wireless sensor network. Its almost constant value of 20 can be mapped in a 2 mm depth.
The inner temperature and pressure of the tyre were directly measured with the real sensor connected to the node 2. The temperature was slightly greater than 20 °C for the whole duration of the test. The pressure has a starting value of almost 300 kPa when the tyre is fully inflated. At a certain time, we deflate the tyre by acting manually on its valve. The deflating operation continues for almost 5 minutes, till the pressure reach the atmospheric value and the tyre is fully deflated. This operation has been repeated several times during the test duration. In order to inflate again the tyre, we disconnected the external sensor leaving the CHOSeN node normally functioning, we inflated the tyre and then we reconnected the sensor to the node.
The tyre pressure value affects the tyre efficiency, that has a starting value near to 100% when the tyre is fully inflated and start decreasing when the pressure decreases. This L2 data is elaborated on-board and then sent to the central node of the network in order to evaluate the overall status of the vehicle tyres. We assume the other three tyres of the car do not have any kind of problems and are therefore providing a 100% efficiency. This is the reason why the “Tyres Status Vehicle” reflects the trend of the single “Tyre Efficiency” depicted in the graph.
The “Tyres Status Vehicle” quantity controls the “Network Status Vehicle” on a thresholds base. When its value goes below 80%, a change of status is triggered on the vehicle subnetwork, passing from “safe” (value 1) to “active” (value 2). After passing the 30% threshold, another change of status is triggered on the vehicle subnetwork, passing from “active” (value 2) to “dangerous” (value 3). This change of status is visualized on the PDA, making aware the driver with a detailed report of the current status of the vehicle.

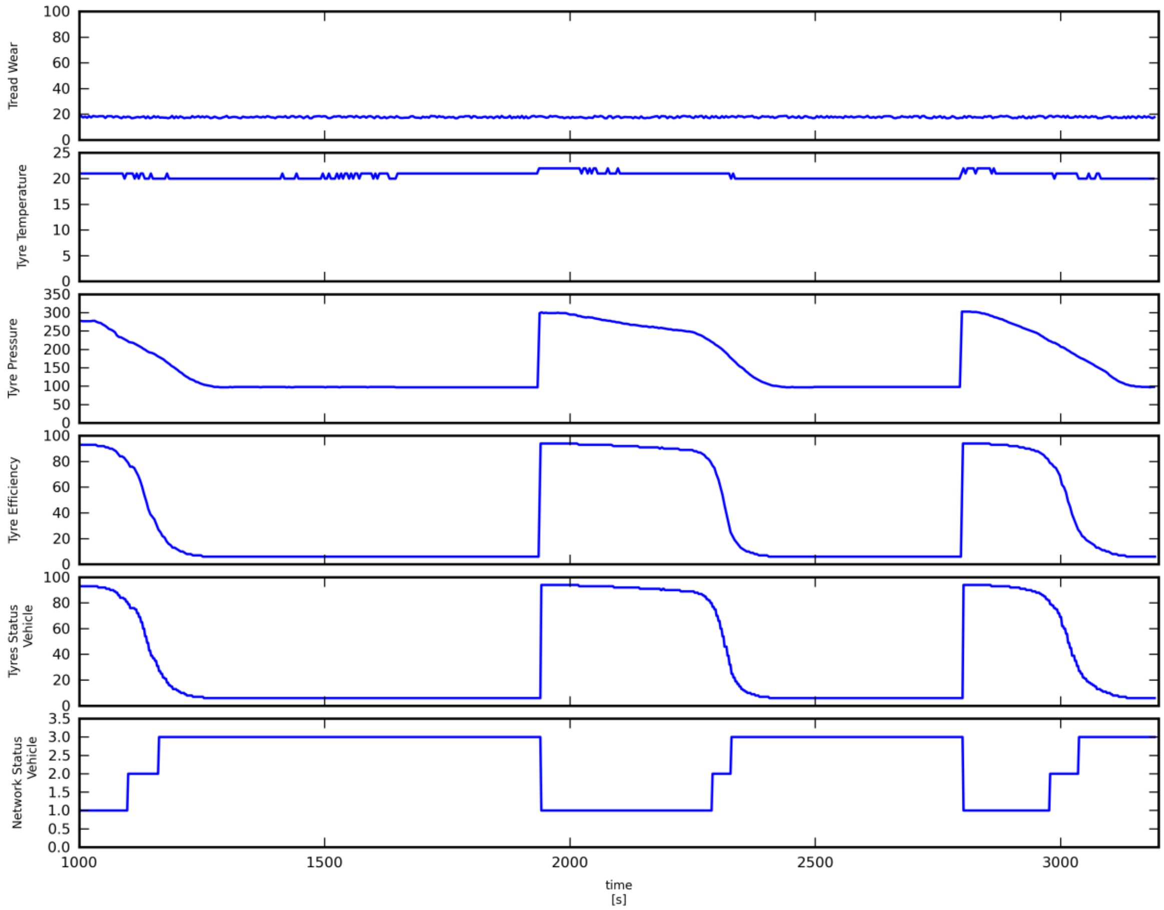


Figure 7: Trend of the quantities involved in the deflating tyre scenario

The second application scenario considers a reduction of the visibility due to fog and rain. It therefore involves the environment wireless sensor network. In Figure 8, the trend of all the involved quantities is depicted. As previously described, the two main quantities involved in such a scenario ("Rain Level", RL and "Visibility With Fog", VWF) are emulated through manual triggers connected to the analog interface of the node. In the first part of the test (till around 450 s), we assume that no rain is present. In such a situation, we increase and decrease the VWF quantity from zero to its maximum value (1100 m), and viceversa. This measurement is collected on the peripheral node 8 and sent to the central node where it is used to calculate the overall visibility of the vehicle. As shown in the graph, these two quantities have almost the same trend but the absolute values are different. This is due to the fact that the visibility depends from other quantities that we assume to be constant during the test. All the relationship and dependencies between L1 and L2 data have been already widely described in the previous documents of the project.
The "Visibility Vehicle" quantity controls the "Warning Vehicle" on a thresholds base. When its value goes below 150 m, a change of status is triggered on the vehicle subnetwork, passing from "safe" (value 0) to "active" (value 1). Below the 40 m threshold, another change of status is triggered on the environment subnetwork, passing from "active" (value 1) to "dangerous" (value 2). This change of status is visualized on

the PDA, making aware the driver with a detailed report of the current status of the vehicle.
In the second part of the test (from 450 s to 650 s), we fixed the VWF at its maximum value and we changed the rain level parameter in order to check the effectiveness of the developed data fusion algorithm. These conditions replicate the case in which there is no fog but just rain. When the rain level increases, the overall visibility of the vehicle is reduced. On the other side, when the rain decreases also the visibility increases accordingly.
In the last part of the test, we changed simultaneously both the quantities related to fog and rain, in order to check their combined effect on the environment subnetwork status.

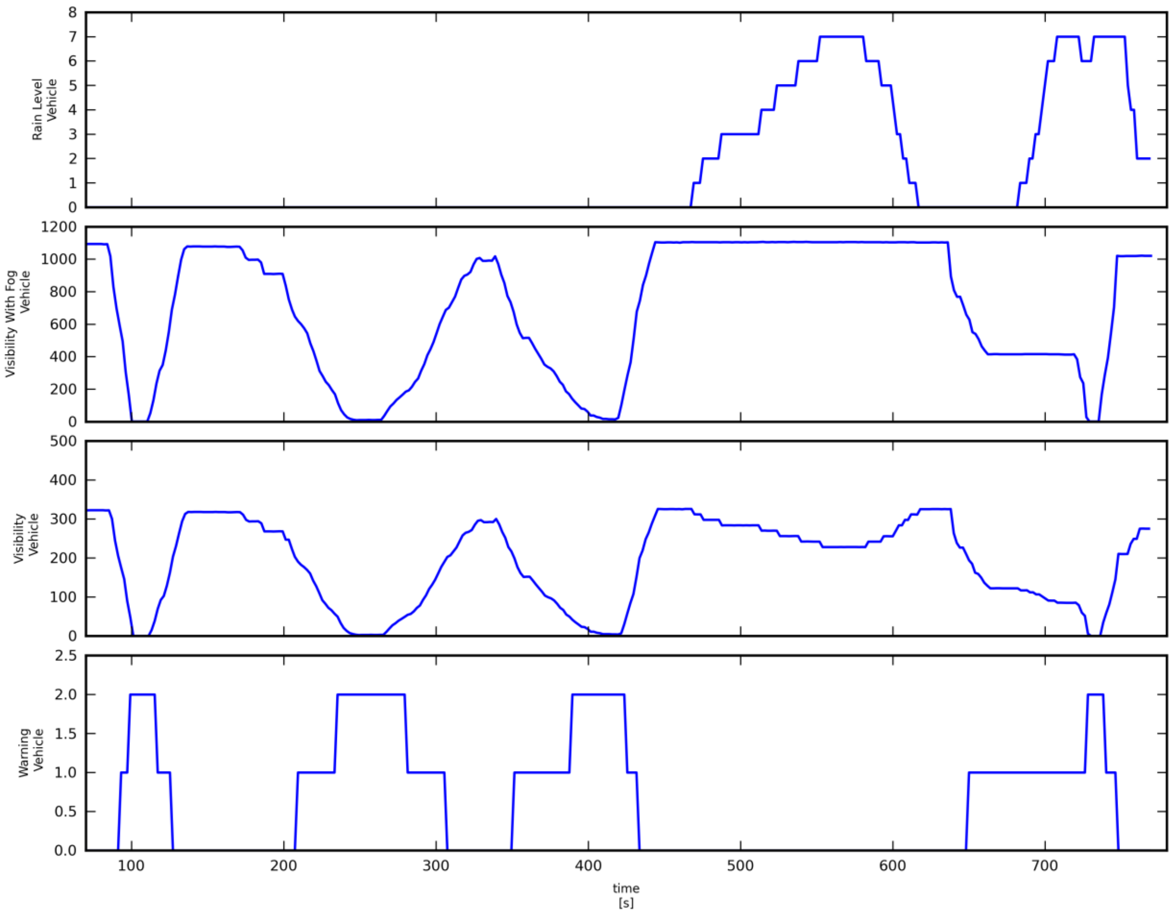


Figure 8: Trend of the quantities involved in the decreasing visibility scenario

These first two scenarios have been already simulated in the simulation framework developed in the WP2. The results reported in the project deliverable D2.2 “System Model Definition and Simulation Results” are completely comparable in terms of behavior.
The third application scenario is related to the brake system. It therefore involves again the vehicle wireless sensor network, and in particular its node 7. In Figure 9, the trend of all the involved quantities is depicted. The “Brake Pad Wear” quantity is simulated on the node, with an almost fixed value of 20 that can be mapped in a 2 mm thickness. The

"Brake Disc Temperature" is measured through a real sensor. Considering that we weren't allowed to move the vehicle, we used a lighter to vary its value by putting directly the flame on the sensing part.
In this way, we have been able to reach a temperature of almost 600 °C. This quantity directly influences the "Brake Efficiency" of the single brake, that is calculated on the peripheral node and then sent to the central node, where it is used to calculate the overall "Brake System Status" of the vehicle. As shown in the graph, these two quantities have almost the same trend. This is due to the fact that we are considering just a single brake and we assume that the remaining three have a 100% efficiency.

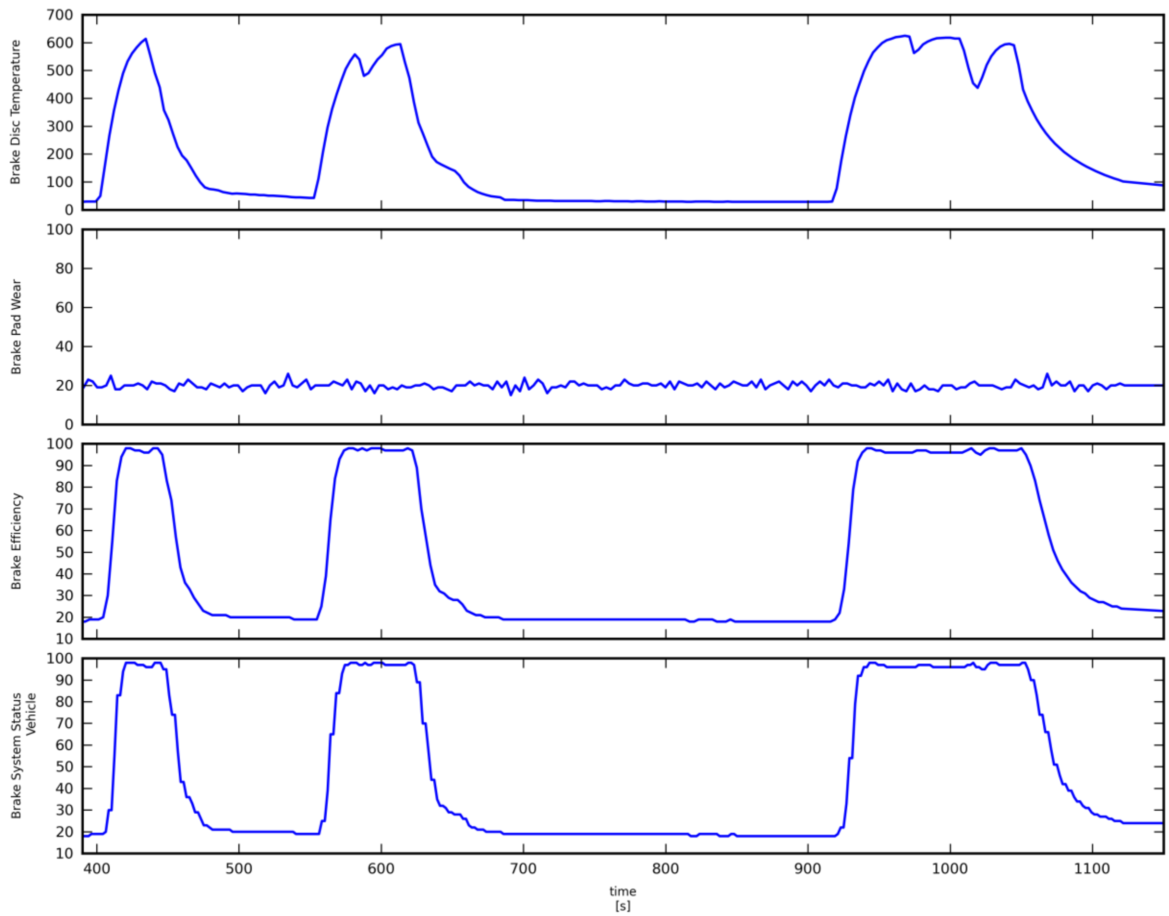


Figure 9: Trend of the quantities involved in the brake system scenario

4 Conclusions

In this document, the experimental results obtained with the system prototype mounted on the final automotive demonstrator have been presented. Three different application scenarios involving different wireless sensor networks have been considered, in order to prove the effectiveness of the overall architecture and to show the level of integration with the in-vehicle wired networks.
We verified that the application layer is able to acquire the data coming from the sensors and to correctly perform the appropriate data fusion algorithms. Moreover, the wireless

networks promptly collect data in their central nodes to provide them to the ALIX board. This one performs further data fusion algorithms (also using data coming from the native in-vehicle CAN bus) in order to detect potentially dangerous situations for the driver. It is also able to share this kind of information with the driver through the Wi-Fi connected PDA. On the same device, it has been possible to follow the behavior of the wireless sensor network by following the trend of each acquired measurement.
Before mounting the nodes on the car, several preliminary tests under controlled conditions in laboratory have been carried out in order to check both the correct functioning of the network stack of each node and their integration in the whole final architecture. This kind of activity has been useful in order to find the best positioning of the nodes inside the car, able to guarantee a robust and continuous functioning as experienced in the lab tests. In general, it has been possible to place the nodes without any impairments by putting them away from solid metallic objects and also using holes and opened parts of the chassis.