2015 Models and Technologies for Intelligent Transportation Systems (MT-ITS)
3-5. June 2015. Budapest, Hungary

ICT IN ROAD VEHICLES – Reliable vehicle sensor information from OBD versus CAN

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***Abstract*— The focus of the research and development activities in Intelligent Transportation Systems is to increase road traffic safety and improve transport efficiency. Telematics Systems can provide values on both fields, by providing real-time reliable vehicle specific information [1]. Road vehicle related information can be categorized into several types, but technical information provided through the electronic network of today's vehicles is becoming an increasingly important segment. Using the standard on-board diagnostics (OBD) is a popular solution nowadays for getting out technical data from the vehicle, but it has its limitations [2]. Professional systems rather use direct access to the vehicles CAN network to extract more detailed technical data out from the ECU communication [3]. Even automatic vehicle location (AVL) service providers have difficulties in differentiating between the possibilities and potentials of CAN bus and OBD. This article clearly identifies the differences between the solutions available on the market, by means of comparing the FMS CAN standard, the OBD standard and the Proprietary Vehicle CAN protocol. The comparison is not only theoretical, but it is based on different measurements and analysis. The measurement results demonstrate the benefits and limitations of these information sources. For the measurement we have used our VehicleICT [4] framework that provided the platform for storing and analyzing the data. Based on the provided comparison, the identified advantages and disadvantages of certain source types, we can select the proper solution for a specific requirement. One objective of this research activity is to clarify confusions about the relation of OBD and CAN from the Telematics Systems providers point of view. Besides that this research can be also considered as a pioneer work that demonstrates the capabilities of our VehicleICT framework.**

Keywords: CAN bus, Fleet Management, FMS standard, ICT in road vehicles, ITS, OBD, Proprietary Vehicle CAN, Smart Transportation, Telematics, Vehicle diagnostics

I. Introduction

State-of-the-art technology enables on-board vehicle sensors to be connected on-line. The devices and applications based on technical information obtained from vehicle sensors are providing greater value to drivers, fleet owners, even insurance companies. Consequently it is important to understand how vehicle sensor data can be accessed by current technology, how can we get extensive, accurate and up to date information from vehicle sensors.

The rest of the paper is organized as follows. Section 2 introduces the *VehicleICT* framework and how it was used in this paper. Section 3 highlights the limitations of the research. Section 4 introduces the OBD for telematics, while Section 5 introduces the FMS standard CAN and Proprietary Vehicle CAN. Section 6 describes the measurement setup. From Section 7 the measurements are presented. Section 8 summarizes the results. Section 9 introduces related work in this field. Finally, Section 10 concludes the paper.

II. Related Work

There are other ongoing researches that focus on "smart car" solutions by using some wireless interface for accessing real time car information.

The increasing activity in the Intelligent Transportation Systems (ITS) area faces a strong limitation: the slow pace at which the automotive industry is making cars "smarter". On the contrary, the smartphone industry is advancing quickly. By combining smartphones with existing vehicles through an appropriate interface we are able to move closer to the smart vehicle paradigm, offering the user new functionalities and services when driving. In [4] the authors propose an Android-based application that monitors the vehicle through an OBD interface, being able to detect accidents. Experimental results using a real vehicle show that the application is able to react to accident events in less than 3 seconds, a very low time, validating the feasibility of smartphone based solutions for improving safety on the road. OBD can not only be used for accessing car data, but it is also an interface for diagnostics. In [5] the authors introduce automobile diagnostic technique and OBD system, compares and analyzes several kinds of diagnostic protocols widely used in on-board diagnostics system. As for the problems of hand-held diagnostic devices used in the current market, a general PC automobile fault diagnostics system based on OBD system design scheme is presented in the paper.

There are already some existing services that try to use the OBD interface for different purposes. In [6] the Driving Styles solution is introduced. The proposed architecture integrates both data mining techniques and neural networks to generate a classification of driving styles by analyzing the driver behavior along each route. In particular, based on parameters from OBD such as speed, acceleration, and revolutions per minute of the engine (rpm), the authors have implemented a neural network based algorithm that is able to characterize the type of road on which the vehicle is moving, as well as the degree of aggressiveness of each driver.

In our paper we aimed to clarify the difference between OBD and FMS CAN and to provide real measurements that can be used in further research and solutions.

III. Methodology

The different data access methods and the available technical information is tested on an open framework, that is capable of handling all the aforementioned information sources, like OBD, FMS-CAN or OEM specific Proprietary CAN. The test uses a common platform, a joint development of BME, the so called *VehicleICT* platform [7], where the intention was to create an open platform for market oriented smart applications. The flexible platform is ideal to demonstrate the capabilities of the different vehicle technical data sources. The platform and its ICT (Information and Communications Technology) components are installed into the test vehicles and real traffic test are carried out to have reliable measurement data. The measured data is analyzed and different value added services are based on it.

VehicleICT is data collection, transmission and backend platform, developed by a research institute and an automotive industrial partner. The objectives are focusing on providing ICT services and solutions in the Vehicle domain:

1. On-board services: services for the vehicle driver and passengers.
2. Connected Car related services: vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) – services provided for other vehicles, and the communication between the cloud-based backend and the vehicle.
3. Backend services: driver behaviour history, smart city, social services

The goal of the *VehicleICT* framework is to provide a common platform (for creating Connected Car apps and for utilizing the overwhelming amount of data) for the mobile devices (taking care of data collection, visualization and communication) and for the server side (creating a highly accessible data warehouse and making the data available for state of the art stream and batch processing) so developer teams can focus on their ideas. Focusing on their ideas means that the platform can be used as an engine to effectively develop applications and services both for the vehicle domain and based on the data collected in the vehicle domain. Utilizing this platform a specific application has been developed to access vehicle sensor information via Bluetooth, collect, display and transfer the data for further analyses to the central server in the cloud. The structure of the system can be observed on the following figure:

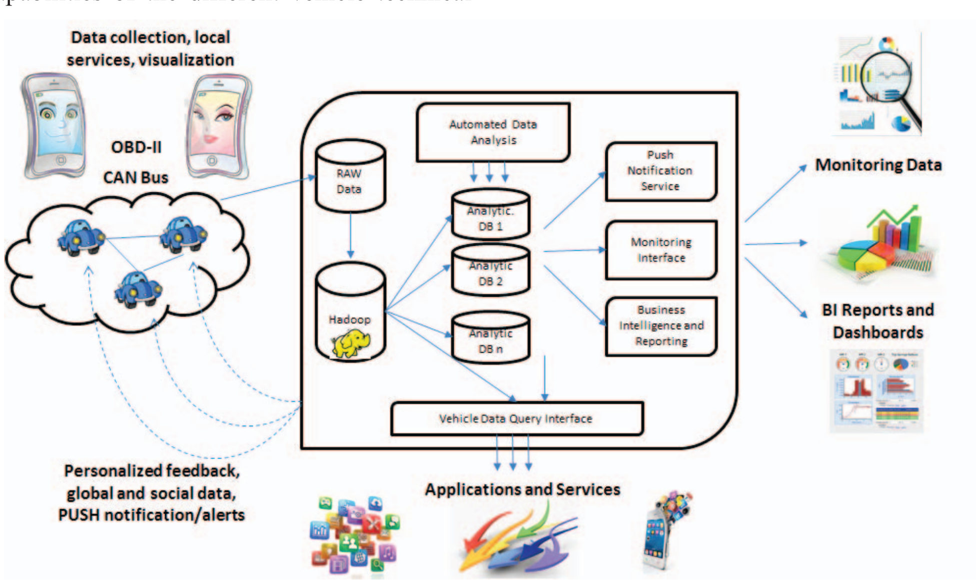

Fig. 1. The *VehicleICT* architecture, that was used for the measurements [7]

The framework is prepared to serve an arbitrary number of applications at the same time. The standard operation involves providing a set of data to applications periodically, so it is possible to optimize the access to the sensor devices by requesting data only once, even if multiple applications need it. Besides automatically handling the data, the solution supports various building blocks, which application developers can use in their application logic. The simplified query API can be used to query application data via HTTP, so no special connection is needed

In this research we have used *VehicleICT* to collect and analyze measurements made with OBD and FMS CAN.

IV. Limitations of this study

The study focuses on the on the data sources on the logical level and compares the information accessible from the OBD, the FMS-CAN and the Proprietary Vehicle CAN. The study does deal with the required physical layers, we suppose that the telematics system has the proper dedicated interface and is capable of handling information from either source. The purpose of this study is to clarify common misunderstandings about OBD versus CAN, so the measurement data are rather for demonstration and not for analytical comparison which we intend to do also in the future.

V. OBD for telematics

A. Generally about OBD

Despite the fact that OBD was not invented for telematics application, in practice telematics solution providers use often this technology as a low cost alternative for accessing vehicle technical information.

Nowadays OBD system is a widespread solution for obtaining sensor information on vehicles. Since 1 January 1996 all cars built contain OBD systems [8]. For ITS and telematics application purposes OBD has a great potential, but one has to be aware of its limitations as well.

B. Advantages and disadvantages of OBD

It is a generally said that the greatest advantage of using OBD is the ease of access, and the fact that no professional mechanic is needed for the installation. It is also assumed that due to the standardization the data access method is the same on every vehicle, all vehicles provide all the values defined by the standard, and thus the same device can be used in all vehicles.

Theoretically that is true, but when it comes to practice it soon turns out that the situation is not that simple. First, the physical placement of the OBD connector does not always allow a dedicated device to be operated during driving as it is designed for being used as a diagnostic opportunity in a service station. The connected measuring device may disturb the driver or make the use some of the controls (pedals, hand brake, etc.) impossible (e.g. see Fig. 2.).

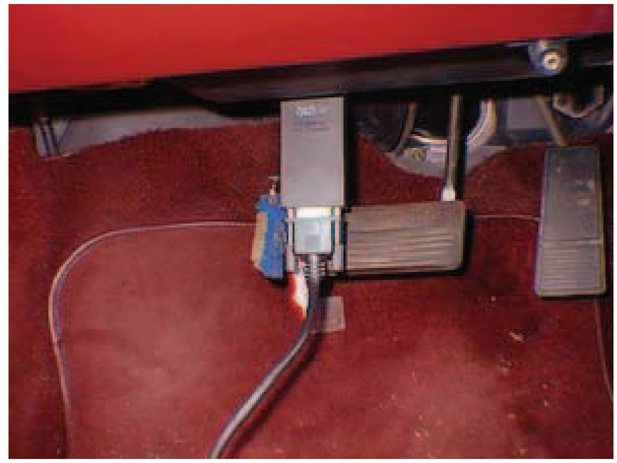

Fig. 2. Inconvenient position of the OBD connector (example) [9]

Further difficulties usually arise because of the deficiency in the OEM specific implementation of the standard. According to The OBD Home Page: There are five basic OBD protocols in use, each with minor variations on the communication pattern between the on-board diagnostic computer and the scanner console or tool. (…) CAN is the newest protocol added to the OBD specification, and it is mandated for all 2008 and newer model years [8].

It may also be confusing for the unexperienced eye that on OBD there is a CAN physical layer based OBD protocol which has nothing to do with the Proprietary Vehicle CAN protocol (except some OEMs like Toyota or Ford where they share the same physical layer, e.g. wires) [10].

The OEM specified codes and the available sensor information may vary car by car, and the standard accessible useful data contain no more than 4-7 parameters in OBD Standard Mode 1-10. For example the OBD Streamer Family of B&B Electronics lists 26 parameters, but most of these are status information about the engine and its auxiliary equipment [11].

Another important characteristic of OBD is the repetition rate of the available data. Due to the fact that these data are accessible on a question-answer basis, the more (different) data is read out the lower the repetition time will be for each data type. As a rule of thumb it has to be considered that the repletion rate of ODB data is in the magnitude of 1 second.

VI. FMS standard CAN and Proprietary Vehicle CAN

The FMS (Fleet Management System) standard is dedicated to the telematics industrial requirements. It was created in 2002, when six major truck manufacturers (Volvo, Scania, Iveco, MAN, DAF, Mercedes-Benz) decided to create a standardized vehicle interface for Automatic Vehicle Locator (AVL) or commonly known as GPS based tracking systems. Like that, no matter which OEM produced a vehicle, if it was equipped with an FMS interface, there was the same output for all vehicles [12]. For example the FMS Standard 1.0 interface provides 19 parameters apart from the Tachograph information. Regarding that a Digital Tachograph (DTCO) information message can contain 13 pieces of data by itself, so the FMS Standard 1.0 is able to provide information up to 32 different types altogether [13].

FMS Standard 2.0 contains 8 more parameters in addition. FMS Standard 3.0 issued in 2012 contains (Truck) FMS Standard and Bus FMS Standard harmonized in one document. FMS 3.0 defines 33 common messages for trucks and buses, further 16 for trucks and 26 for buses only and is available since 2012 [12].

Another noteworthy fact that CAN data repetition time is around 10-50 millisecond magnitude. That means the possibility of greater accuracy in measurement, especially when mathematical integration or statistical distribution of the measured data is required.

A. Available sensor information

Despite the number of parameters available on FMS significantly exceeds the relevant data on OBD, Proprietary Vehicle CAN contains orders of magnitude more information. “In a high-end vehicle, such as the VW Phaeton, there can be more than 2500 distinct signals ...” [14].

The diagram below shows the approximate amount of vehicle sensor information using the different access technologies.

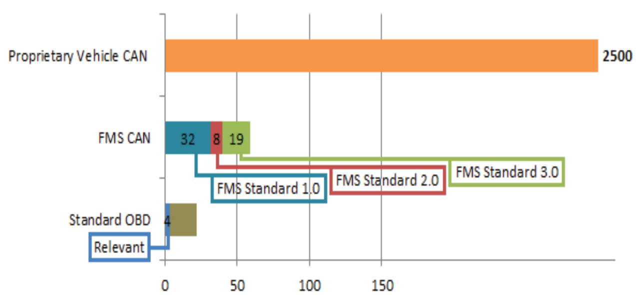

Fig. 3. Approximate amount of available vehicle sensor information using different access technologies

B. FMS Standard

The FMS Standard is based on the SAE J1939/71 application layer and SAE J1939/21 Data link layer, providing an ISO 11898-2 compliant 250 kbit/s speed CAN bus as the standardized output communication interface. Proprietary Vehicle CAN protocols differ from that in a way that the higher layers are not standardized but they are OEM (and Model) specific. This means that all different car makes have their own specific CAN protocols.

To be able to access Proprietary Vehicle CAN data one has to “understand” all the different “vehicle languages”, that for example Inventure Automotive does [12].

VII. MEASUREMENT LAYOUT

Test measurements were performed to find out the usability of the two ways obtaining vehicle sensor information: OBD and CAN. The demonstrator measurements are based on two devices connected to the bus system of the measured vehicle, transmitting the measured data continuously via mobile internet.

A. OBD Diagnostic Interface

Fig. 4. The OBD Diagnostic Interface used for the vechicle tests

The OBD interface used for the demonstration is a Bluetooth diagnostic interface. After being connected to the on-board diagnostic socket of the vehicle it collects data available on OBD. The data can be received and processed through the dedicated mobile phone application connected to it.

B. FMS CAN Interface

Fig. 5. The FMS CAN Interface used for the vechicle tests

The FMS CAN Interface is connected to the Proprietary Vehicle CAN bus of the motor vehicle. It collects the data in vehicle specific language, it calculates and converts the data into FMS Standard, that is available on the output via the built-in Bluetooth interface.

C. *Measuring system design*

The measurement setup was designed in a way that is close to a potentially marketable application. There are a lot phone based applications available on the market that can monitor certain vehicle sensor data. Within this paper the objective of the authors was to demonstrate the relevant differences between the OBD based and FMS CAN based application potentials. Consequently the data acquisition devices are used in on-line mode, not in logger mode. Phone 3, providing mobil Internet via Wi-Fi for Phone 1 and 2 simulates the situation when the phones running the *Vehicle ICT* application even do not have to have direct Internet access. Like that Phone 1 and 2 do not even have to contain a SIM card.

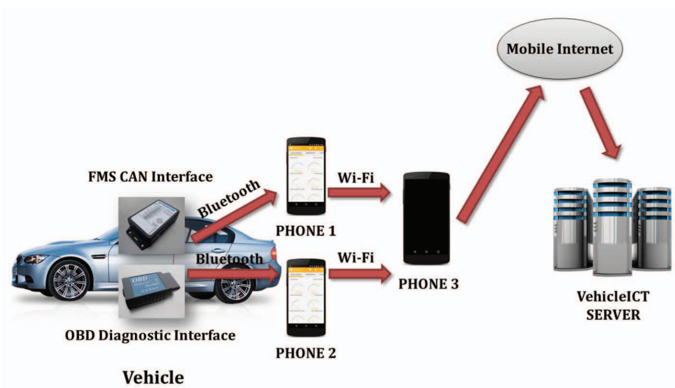

Fig. 6. System design of applied data transmission during the measrements

The figure above (See Fig. 6.) indicates the data transmission from the vehicle to the VehicleICT server, realized over mobile Internet communication. It has a limited throughput, so despite CAN data acquisition could have provided even higher repetition rates, in the current demonstrator measurement setup repetition rate has been limited to 5 Hz (5 message blocks per second) in case of CAN data.

VIII. MEASUREMENT RESULTS

Besides the theoretical investigation of different vehicle sensor data sources the authors carried out in-vehicle demonstration measurement. The aim of the measurement was to provide real data to demonstrate the differences of OBD and FMS CAN sources and identify the directions of further research. The tests were performed on two passenger cars, a gasoline and a diesel-powered one. Different scenarios were sampled, containing dynamic acceleration, urban traffic and highway cruise.

A. *Measurement 1*

The result described hereinafter is a 6 minutes long period of the following measurement:

Date:	23 February, 2015
Car:	VW Passat MY2009
Engine:	1968 cm^3 CRTDI (CCB119366)
Environment:	Urban traffic

Two of the measured values – vehicle speed and engine speed – are plotted below (See Fig. 7. and Fig. 8.).

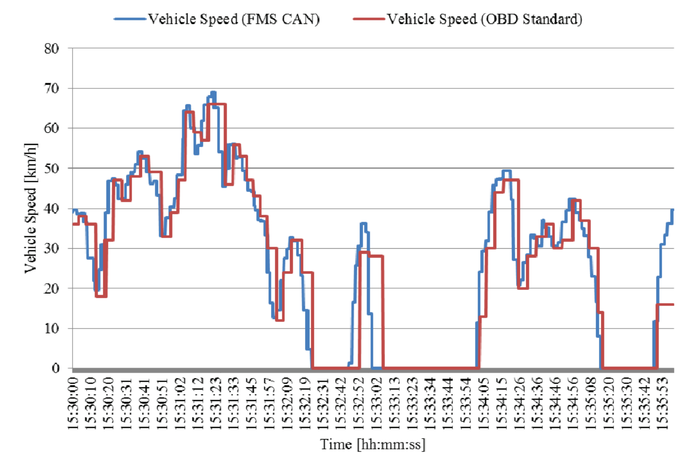

Fig. 7. Measured vehicle speed – VW Passat

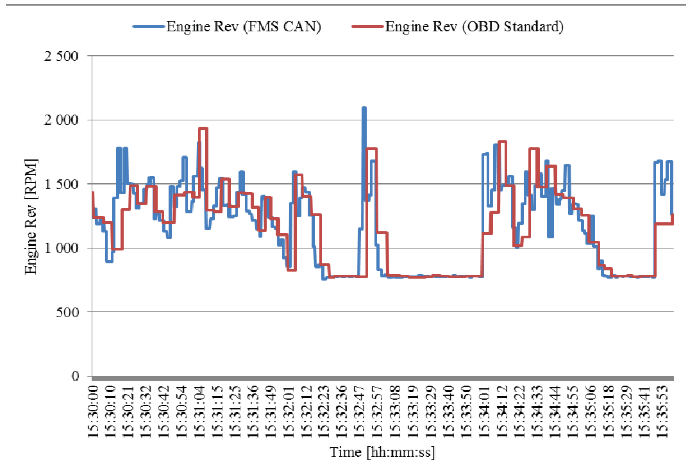

Fig. 8. Measured engine revolution – VW Passat

As this study is for demonstration only, the test car was not equipped with an absolute measuring device (there has not been a surely accurate reference data), the two ways of obtaining information can be compared to each other. We can draw important conclusions even this way.

As the diagrams show, both vehicle speed and engine speed are measured more accurately by using CAN. It contains more measuring points, and the peak values are clearly plotted too which are missing from the OBD measurement.

Notice: This deficiency of OBD occurs in all cases where a parameter's momentary value is needed for statistic distribution calculation, eco-driving, etc. For example: remarking suddenly rising edges (peaks) on engine speed – time diagram is especially important, because it correlates with wasteful driving. Other parameters carrying similar information: brake pedal position, moment, acceleration pedal position.

B. *Measurement 2*

The same method of measurement was tested on a Suzuki make passenger car too.

Date:	12 February, 2015
Car:	Suzuki Splash MY2014
Engine:	993 cm3 GLX (K10BN1702104)
Environment:	Urban traffic

Measured vehicle speed and engine speed are plotted below (See Fig. 9. and Fig. 10.).

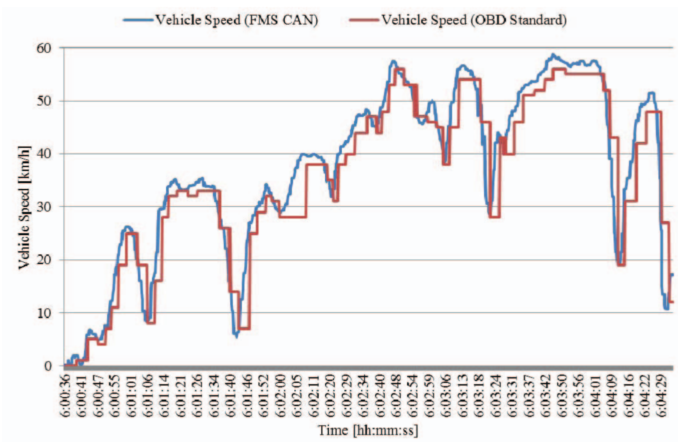

Fig. 9. Measured vehicle speed - Suzuki Splash

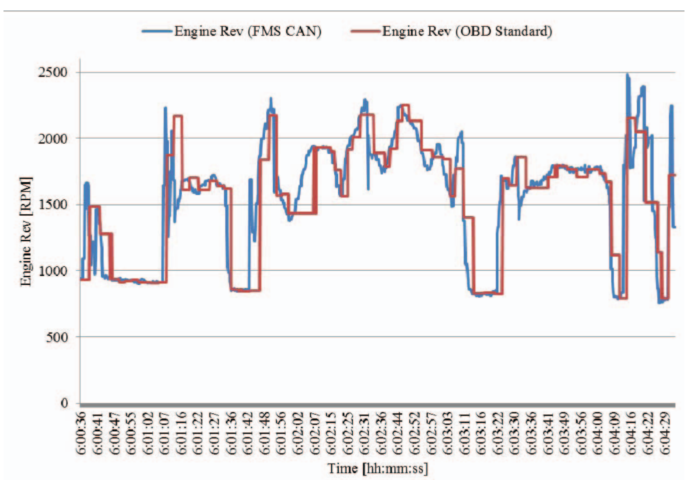

Fig. 10. Measured engine revolution - Suzuki Splash

Similarly to the VW test results it can be observed that OBD measurements have less resolution in time and in value also. The notices and conclusions of the previous measurement are valid here.

C. *Measurement 3*

Dynamic acceleration measurement was carried out on the VW Passat, starting from standstill to 140 km/h.

Date:	23 February, 2015
Car:	VW Passat MY2009
Engine:	1968 cm^3 CRTDI (CCB119366)
Environment:	0-140 km/h intensive acceleration

Measured vehicle speed and engine speed are plotted below (See Fig. 11. and Fig. 12.).

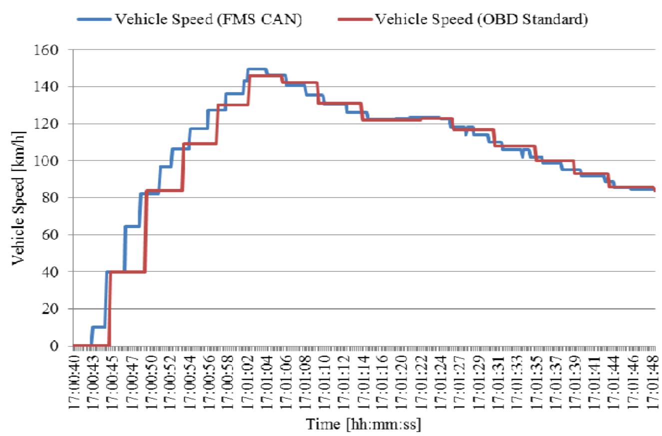

Fig. 11. Measured vehicle speed during dynamic acceleration

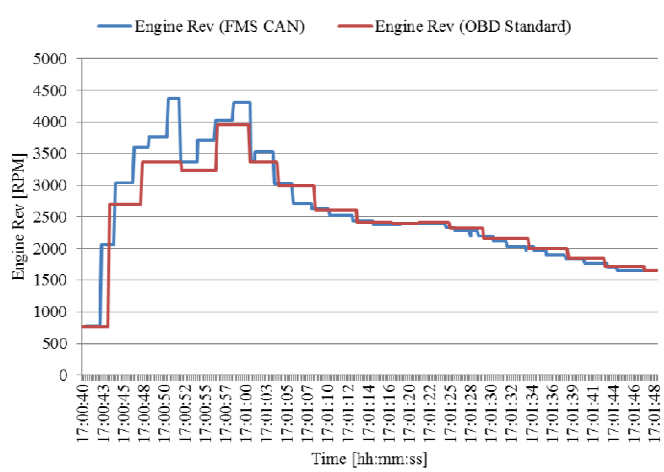

Fig. 12. Measured engine revolution - VW Passat

On the diagrams above short and intensive acceleration is plotted. The parameters change relatively fast, thus the difference of sampling frequency is conspicuous. In the OBD measurement one of the peaks on engine revolution diagram is missing.

D. Measurement 4

The purpose of Measurement No. 4 was to compare the fuel consumption measuring capabilities of OBD and FMS CAN. The data from the vehicle's board computer was also logged as a control.

Date:	10 March 2015, 3:47 – 5:00 PM
Car:	VW Passat MY2009
Engine:	1968 cm^3 CRTDI (CCB119366)
Environment:	155 km highway measurement

According to the vehicle's board computer, the fuel consumption was **6.9 l/100 km** on the given section. The FMS CAN based measurement data for the gives section are listed in *TABLE I.* below containing the respective total fuel used counter values for the respective odometer stands.

TABLE I. SUMMARY OF THE FMS CAN BASED FUEL CONSUMPTION

Total Distance (FMS CAN)	Total Fuel Used (FMS CAN)
139 435 km	36.7
139 590 km	47.3
DELTA DISTANCE:	155 km
DELTA FUEL USED:	10.6 liter
FUEL CONSUMPTION:	6.8 l/100 km

The OBD fuel consumption measurement results were calculated based on the momentary fuel consumption, using two different methods. The first one is based on the Mass Air Flow (MAF) sensor data. The second method is based on the Intake Manifold Absolute Pressure (IMAP), which is genarally used in case there is no MAF sensor available in the vehicle. These calculation methods are widely documented and published, e.g in the patent of Bimurugesan et Al. [15].

TABLE II. OBD FUEL CONSUMPTION DATA CALIBRATION

	Average Fuel Consumption [liter/100km]		
	OBD MAF (1)	***OBD IMAP*** (2)	***FMS CAN***
3:47-5:00 PM	14.52	3.96	6.80
Calibr. fact.	**0.468**	**1.717**	**-**
3:47-5:00 PM	*6.80* (3)	*6.80* (3)	*6.80* (3)

1 Mass Air Flow based calculation
2 Intake Manifold Absolute Pressure based calculation
3 Adjusted to FMS CAN consumption by using calibration factor

Without any calibration of the OBD data, the two methods gave 14.52 l/100 km and 3.96 l/100 km fuel consumption respectively, which are definitely not realistic.

Taking into consideration that FMS CAN values are closer to the board computer information and according to previous experiences are more robust, the OBD calculated fuel consumption data were calibrated to the FMS CAN data. There is a relatively long interval (3:47-5:00 PM) as a reference for calculating an OBD calibration factor for the two different OBD fuel consumption calculation methods (see *TABLE II).*

For cross-checking the OBD fuel consumption measurement results, the above OBD calibration factors were applied for shorter sections of the same measurement as well. The assumption was that in case of good OBD calibration the FMS CAN and calibrated OBD consumption gives nearly the same result either for specific sections.

As *TABLE III.* indicates, the OBD calibration factors that were good for the entire measurement are not valid for specific sections within the same measurement. There are three ten minutes sections selected from the more than two hours measurement. The fuel consumption results are calculated for these sections with the calibration factors determined for the entire measurement length. The results are then compared to the FMS CAN fuel consumption results for the same sections. The FMS CAN and the OBD fuel consumption calculated for the 3:48-4:00, 4:05-4:15 and 4:46-4:55 sections significantly differ from each-other.

TABLE III. CROSS CHECK OF CALIBRATED OBD FUEL CONSUMPTION

	Average Fuel Consumption [liter/100km]		
	OBD MAF (1)	***OBD IMAP*** (2)	***FMS CAN***
3:48-4:00 PM	5.69 (4)	5.34 (4)	6.25
4:05-4:15 PM	6.67 (4)	5.08 (4)	7.39
4:46-4:55 PM	5.84 (4)	4.40 (4)	6.50

1 Mass Air Flow based calculation
2 Intake Manifold Absolute Pressure based calculation
4 Average calculated with the use of calibration factor

As a further control, a similar comparison was carried out using the same OBD calibration factors but on different measurements, taken under different circumstances. *TABLE IV.* contains measurement results taken on different days in different traffic situations. By applying the same OBD calibration factors (determined in *TABLE II.*) to the original measurement data, the MAF and IMAP based calculations results show massive difference not only compared to FMS CAN but even compared to each other. Especially the second case (23 February), which seems to be unrealistic.

TABLE IV. COMPARIRISON OF CALIBRATED OBD FUEL CONSUMPTION FOR SECTIONS WITHIN OTHER MEASUREMENTS

	Average Fuel Consumption [liter/100km]		
	OBD MAF (1)	***OBD IMAP*** (2)	***FMS CAN***
8 March 4:57-5:07 PM	7.02 (4)	15.78 (4)	5.56
23 February 3:23-3:32 PM	17.90 (4)	52.59 (4)	10.00

1 Mass Air Flow based calculation
2 Intake Manifold Absolute Pressure based calculation
4 Average calculated with the use of calibration factor

This implies that the OBD based fuel calculation methods require a more sophisticated calibration method then just a single calibration factor. Without that the OBD based fuel consumption measurement results might be questionable. Concerning that the authors have the intention to investigate the topic further in details and release a publication subsequently.

IX. Results

The study has demonstrated the measurement possibilities of vehicle data both with OBD Diagnostic Interface and FMS CAN Interface. We have analyzed and compared simultaneously collected vehicle sensor data. We have shown the basic capabilities of both technologies.

The supporting environment is the *VehicleICT* framework, which provides a cloud-based environment for data collection analysis definition and execution.

We believe that this study helps the community with valuable information and supports their measurement environment related decisions in the future.

X. Conclusions

The selection of the vehicle technical information source is always a trade-off and that is why it is essential to be aware of the customer requirements in advance.

The OBD solution is more cost effective, but it has turned out immediately that it has less information available with much lower repletion time then either FMS-CAN or Proprietary Vehicle CAN. The OBD based fuel consumption measurement methods still have some challenges in the field of calibration. FMS-CAN interfaces are available as an OEM solution for heavy duty trucks. For all other vehicle categories there are third party suppliers providing Proprietary Vehicle CAN solutions. Where precision counts they provide good value for a reasonable price, especially when it comes to technical details.

Depending on the level of analytics and business intelligence put on top of the gathered data one can definitely choose the appropriate data source or data source combination.

References

[1] Gáspár P., Szalay Zs., Aradi Sz., Highly Automated Vehicle Systems, BME MOGI Budapest, 2014.

[2] Tölgyesi Z., Fedélzeti diagnosztika (OBD), Maróti Könyvkereskedés és Könyvkiadó Kft. Budapest , 2006. ISBN 963-9005-70-3

[3] Fodor, D., Szalay, Zs., Autóipari kommunikációs rendszerek, Pannon Egyetem, Veszprém 2014.

[4] Zaldivar, J., Calafate, C.T., Cano, J.C.; Manzoni, P.: Providing accident detection in vehicular networks through OBD-II devices and Android-based smartphones, Local Computer Networks (LCN), 2011 IEEE 36th Conference on , vol., no., pp.813,819, (2011)

[5] Hu Jie, Yan Fuwu, Tian Jing, Wang Pan, Cao Kai: Developing PC-Based Automobile Diagnostic System Based on OBD System, Power and Energy Engineering Conference (APPEEC), 2010 Asia-Pacific , vol., no., pp.1,5, (2010)

[6] Meseguer, J.E., Calafate, C.T., Cano, J.C., Manzoni, P.: DrivingStyles: A smartphone application to assess driver behavior, Computers and Communications (ISCC), 2013 IEEE Symposium on , vol., no., pp.000535,000540, 7-10, (2013)

[7] László Lengyel, Péter Ekler, Tamás Ujj, Tamás Balogh, Hassan Charaf, Zsolt Szalay and László Jereb: ICT IN ROAD VEHICLES – The VehicleICT Platform (2015)

[8] The OBD-II Home Page: OBD-II Background, http://www.obdii.com/background.html (2 March 2015)

[9] Motor Age: "OBD connector", http://www.samscars.com/mage15.html (2 March 2015)

[10] Kováts M., Szalay Zs., Gépjárművek Buszhálózatai, Maróti Könyvkiadó Budapest 2013., ISBN: 9789639945104

[11] B&B Electronics: OBD-II Parameters, http://www.bb-elec.com/Products/Manuals/Intelligent-OBDII-Gateway-Command-and-Response_251.pdf (3 March 2015)

[12] Inventure FMS Gateway: Fleet Management System standard, http://fmsgateway.com/glossary/fleet-management-system-standard-fms-standard, (3 March 2015)

[13] FMS-Standard description, Page 15 http://www.fms-standard.com/Truck/down_load/fms_document_ver03_vers_14_09_2012.pdf (3 March 2015)

[14] Robert I. Davis, Alan Burns, Reinder J. Bril, Johan J. Lukkien: Controller Area Network (CAN) schedulability analysis: Refuted, revisited and revised (2007); Page 241.

[15] S. Bimurugesan, S. Ghosh, A. Mishra : Fuel consumption computation device for internal combustion engine vehicles, Patetn No: WO 2013072939 A1, 2011