OEM 3rd Party Telematics - General Analysis

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Table of Contents

1 Executive Summary

The future mobility network will be built as a network of connected cars. Features like autonomous driving rely on the fact that cars connected to the cars around them and to road side communication stations for fast and reliable message interchange. To keep these mobility networks up and running with nearly zero downtime and with as less maintenance and repair effort as possible, the future cars have to be connected to the service providers for these repair and maintenance services.

1.1 Requirements for a fair online Repair and Maintenance market

In the past, the vast majority of repair and maintenance tasks had been carried out "offline" in the workshop. Cars were sent to the workshops for inspection based primarily on fixed mileage intervals, problems on the road were signalled to the driver via a malfunction indicator light (MIL) and either allowed for a "limping home" to the next workshop with reduced engine power or they needed to be towed in (e.g. by a roadside assistance club).

The diagnosis of the root cause for the problem was determined in the workshop using a diagnostic tool that was connected to the car via the On-Board-Diagnostic-Port (OBD-Port). Subsequently, either a mechanical repair (e.g. replacement of brake pads) or an electrical or software repair took place: e.g. updating an Electronic Control Unit (ECU) of a car with a new software version and/or resetting Diagnostic Trouble Codes in the car. Based on the Euro 5/6-regulation, by which Independent Aftermarket (IAM)-Suppliers could buy all needed information for repair and maintenance services (RMI) from the Original Equipment Manufacturers (OEMs), independent diagnostic tools could be developed apart from just the OEM diagnostic tools that allowed independent garage networks and roadside assistance clubs to come up with innovative and price worthy services for repair and maintenance.

To sum it up: the Euro 5/6 regulation, despite the fact that some of the information was offered via websites of the OEM, in general allowed for a fair "offline" competition in the workshop between OEM and IAM service providers.

With the increasing importance of software in the car, increasing expectations from the customers with regard to downtime ("Zero Breakdown"-Expectation), increasing bandwidth and lower airtime costs the balance between “offline” and “online” tasks for the repair and maintenance services will be heavily shifted towards “online”.

Of course even in the future a standard mechanical repair like the replacement of a brake pad will not be possible “online” and still require a trip to the workshop. But taking into account that modern cars are a network of computers and that most problems in computer systems can be solved with adaptions to the software, the customer will expect that just for a “software” issue with his car no trip to the workshop is needed and all. Instead, a safe and secure “Over the Air” (OTA)-software update shall and can fix these kinds of problems in the same way that every smartphone, tablet or Laptop has been already “repaired” via a software update for years.

Fair competition in this part of the “Online” Repair and maintenance market requires that IAM as well as OEM service providers can update cars with signed and trusted software upgrades and/or security updates.

Should a problem require a mechanical repair or a local diagnosis at workshop level, it is nevertheless expected that via an “Online” Ad Hoc diagnosis in the vehicle the root cause for a problem and the set of possibly needed spare parts can be determined as precise as possible so that the repair process with all spare part logistics involved can be sped up significantly in comparison to today.

And to prevent unnecessary downtimes caused by premature visits to workshops and a too early exchange of wear and tear parts that likely come along with a standard “Fixed Mileage”-approach for servicing, the future cars will rely heavily on “prognostics” inside the car.

For a fair and undistorted competition between OEMs and IAMs in these two domains of the future “Online” repair and maintenance market an equal ability to monitor in-vehicle signals in real-time as well as trigger in-vehicle functionality remotely is vital for in-depth diagnostics as well as prognostics.

Last not least, the customer has to be integrated into the future “Online” repair and maintenance process. In the past, he made his choice between competing IAM and OEM offers for a repair or maintenance service by either calling them via phone and/or he was forced to take his car to different providers to allow a detailed analysis of his service need and get a quote.

In the online future he should be put in a position to commercially decide between competing offers from inside his car (The dashboard as the new Point of sale) and pick up his role as a participant in a guided diagnostic and repair process on the road when a service provider software tells him that he should stop his car, make sure that brakes are applied during a software update and other basic instructions.

For a fair competition in this part of the online repair and maintenance market OEMs as well as IAMs must have a safe and secure interface to the customer inside the vehicle to offer him services and guide him by instructions.

1.1.1 Annotation: Access technologies via smartphone

The least preferred option to get access to and communicate with the customer whilst driving is a simple smartphone application, e.g. an application for Apple IOS or Google Android, because the caused driver distraction is a major reason for road accidents, as multiple reports have confirmed (See e.g. https://blog.cinfin.com/2018/04/10/distracted-driving-smartphones-distraction/). There is however another set of technologies which also use the smartphone as one component, but which have an in-vehicle component that in combination with the smartphone allows a safe &secure interaction with the driver.

Examples for this approach are Apple Carplay, Android Auto, Ford SDL or Mirrorlink. Schematic and simplified overview for this approach and process: The application programmer writes his application as a “normal” application for e.g. either Google or Apple but adds additional code/information for the specific in-car technology (so an Apple application as well as a Google application might contain additional SDL-code). The app is sent to the “normal” app stores and can be downloaded to the user’s smartphone. In normal operating mode of the smartphone the additional in-car technology code has no effect. If the app is started, it displays the user interface for smartphone mode that might e.g. contain animations, long texts or complex handling that require greater attention from the user: features, that whilst driving might cause a high degree of driver distraction.

Once the smartphone is connected to the in-vehicle-component of the technology – e.g. via cable, Bluetooth – the in-car-component queries all applications on the smartphone for the respective technology support. Most applications on a normal smartphone won’t have this support, so the number of apps that e.g. Apple CarPlay displays is a very small subset of all apps on the user's phone (e.g. phone, messaging, maps and some audio player like amazon music). The additional technology specific code in the app is now responsible for two essential functionalities:

a.) The code displays a user interface on the car screen and/or communicates with the driver via speech control in a less distractive way than in normal operating mode. The Android Auto version of the Messenger Whatsapp e.g. relies on speech control and some very basic touch input, it explicitly does not offer the possibility to read through old conversations or type in long replies letter after letter.

b.) It receives input from car actors and sensors (control buttons, microphone) and can access displays and actors/sensors in a limited way. How deep this access is and how many actors/sensors can be controlled depends on the chosen technology (SDL, Android Auto, Apple CarPlay) and on the Software Development Kit (SDK) available for the respective technology. Android Auto and Apple CarPlay offer OEM-specific SDKs which allow for potentially far deeper access into the car than the normal SDKs who are limited to non-vehicle-specific app categories like media players or messengers.

If within this study the term "smartphone access" is used without further explanation, then the approach with "normal" apps is meant with it's risks for driver distraction. The other technologies – e.g. SDL, Apple CarPlay or Android Auto are described in their respective sections.

1.2 Methodology

This study tries to give an overview to what degree independent service providers are enabled by OEM solutions to enter and to compete with the OEM as the biggest competitor in the evolving online market for repair and maintenance services for the connected car.

Because the "online" abilities as well as the technical abilities used by OEM and the often different technical abilities offered to IAM by the OEM in general vary from OEM to OEM, the study was conducted for a selected subset of OEMs. For each OEM in scope the technical abilities offered to the IAM were compared with the abilities used by the OEM in respect to the vital requirements for a fair "online" Repair and Maintenance market.

1.3 Timeframe for research, Limits of the Approach

The market for technical solutions for telematics is a rapidly evolving market. Technologies appear, mature over time, become deprecated and market players set up consortiums, leave alliances and switch technologies over time. Thus, it is a difficult up to an impossible task to deliver a full picture of every solution in the market.

The research on the internet for the overview and the practical tests with available Software Development Kits were conducted during a period of 1.1.2018 up to 31.07.2018. Together with the focus on the selected set of OEMs this was enough to identify trends as well as developments and describe general characteristics and advantages/disadvantages of solutions especially for RMI-Applications but of course, developments prior or after this period or for other OEMs had been intentionally left out.

Two examples illustrate the limits but also the merits of the approach:

a.) In 2014, Toyota described it's new approach for a Toyota Open Vehicle Architecture (TOVA) https://newsroom.toyota.co.jp/en/detail/3203921. This approach was very similar to the General Motors Approach described in this study. Developers could develop apps in the categories driving assistance, communication, information and lifestyle with a Toyota Software Development Kit. Like Apple in the Apple app store, Toyota verified the apps, hosted them in a Toyota App store and established a payment model .

In 2016, however, Toyota changed it's approach and decided to join the SDL-consortium https://newsroom.toyota.co.jp/en/filedownload/14131717 (Slide 12), described in this study. This is just one example how market players can switch technologies. There was no reason given for this change but it is very likely that also Toyota had to realize that a proprietary technology for just one OEM simply does not address a large enough potential customer base for app developers, an insight that has led Ford to create SDL as on consortium for more OEMs and thus more potential customers from it's formerly proprietary system Ford Sync.

b.) Two months (27.09.2018) after the closing of the research period Mercedes revealed it's API for Remote Diagnostic support. (https://developer.mercedes-benz.com/apis/remote_diagnostics_api). It is announced that for the first time there

will be support for Remote Diagnostics available for independent operators. Technically this API is based on the Extended Vehicle Solutions, for which three examples are depicted in this study: The BMW CarData system, the PSA solution and the Beta version of the Mercedes ExVe. So although the actual pros and cons of the newly released API had to be investigated (currently they are subject of a Proof of Concept study between OEMs and independent operators), also the new Mercedes API will share the pros and cons of the other Extended Vehicle solutions, e.g. that it is easy to implement as a webservice solution, but lacks means to communicate with the driver or to develop real time applications and use cases.
What is unusual from a software developer's perspective is, that the connected vehicle API from Mercedes described in this study is declared as "Experimental" and is since 17.01.2018 in this phase and now a different API (the RDS API mentioned above) is declared ready for usage without an experimental phase. The normal approach would be to have the connected vehicle API in beta testing and then declare it ready for production – maybe augmented with additional RDS-features.

So, although the report could not cover these two technologies in detail because of it's limited scope in time and OEMs, the trends and characteristics of the solutions described in this report are still sufficient to put these solutions into context. (Toyota TOVA an example for a proprietary OEM that was apparently abandoned to join a consortium, Mercedes another example of a solution following the ExVe-architecture.)

1.3.1 Annotation to term "Real Time ability"

The terms "Real time", "Real Time system", "Real Time ability" or "Hard real time" are often used in a rather vague sense or just another phrase for a "very fast system".
For this study, Real Time is used in the context of control engineering. Here, hard real time systems must guarantee (!) a system response after a specified time constraint that is fast enough to assure that the control purpose of the system can be achieved.
So obviously it depends on the purpose of the system how fast in milliseconds, seconds, minutes or even hours or days a "Real time system" really must react.
If the control purpose is just to inform the driver when he has to refuel his vehicle based on the current fuel level in his tank, then a system with a response time of 1 Minute might be fast

enough and thus declared "Real Time enabled" for this purpose A. If, however, a system like the PSA ExVe described in this study would read data every second but then send it out only after 1 Minute of collection, it would not be able to build a navigation system with this latency. The response time in this case would be 1 Minute and – assumed, GPS position of the vehicle would be sampled every second and then transmitted after 1 minute, the best advice a navigation system based on this approach would be "Judging your positions in the last minute and taking into account your destination: 23 seconds ago you should have turned left".

Because this study is focussing on RMI aspects, real time for RMI also depends on the specific Use Case. A response time of e.g. 1 Minute after a permanent problem in the vehicle appeared and a Diagnostic Trouble Code was stored might be enough to inform the driver in time that the system has detected a problem and might advise him how to proceed.

However, diagnostics is all about detecting problems inside the systems of the vehicle. Most core systems in the vehicle are hard real time systems with very short time constraints (E.g. the braking system, the ignition control system etc.) To be able to detect errors and problems for these systems, the observing diagnostic system has to be as least as fast as the observed system, so the real time constraints shrink to milliseconds or even lower values.

The same holds true for systems that take care of autonomous or collaborative driving where reactions of approaching vehicles or pedestrians have to take place in milliseconds.

The server based Extended Vehicle Solutions will likely never be able to fulfil these timing constraints (The communication speed in the car will always be faster than the speed achievable via an additional server transmission) and the reliability of a diagnostics real time software in the car (please remind that a real time software must guarantee a system response) will always be much higher than the reliability of a server based system where as an additional weak point the loss of server connectivity may occur in areas of limited coverage.

1.4 Results

Currently server based solutions, so called "ExVe"-solutions are being standardized at ISO Level (ISO 20077, ISO 20078). However, commercially available for productive usage as of now is only the system of BMW CarData in Germany that has been investigated in a pilot to this study (see Attachment BMW CarData) already in 2017. The ExVe-system of Mercedes is officially in a beta stage and only ready for developer testing, the system of PSA which was the first system to enter the market at the end of 2016 has apparently never overcome these early phases of development and – according to internet research - not gained much interest from the market as of now. Therefore the market for server based solutions is very limited and the solutions to come will suffer from the inherent shortcomings of their technical approach: No server based solution will ever be able to operate in offline conditions, no server based solution will ever be so quick as an onboard approach to ensure real time surveillance of time critical processes in the vehicle and – as of now – no effort in the ISO group is directed towards the development of a standardized driver interface which is vital for a safe and secure driver interaction prior and during the future online parts of the repair and maintenance process.

In strong contrast to the relatively slowly developing market for offboard, ExVe-solutions the field of onboard platforms presents a variety of solutions from single OEMs (e.g. General Motors Next Generation Infotainment system or Renault's R-Link), OEM consortiums (e.g. the Smart Device Link Initiative led by Ford et.al.) and even worldwide standardization efforts (W3C proposal of VAWI) led by OEMs (e.g. Volkswagen) together with the evolving platform cooperations with the silicon valley companies Apple (e.g. Seat CarPlay App) and Google (approach of Volvo and Audi to integrate Google far deeper in the car for future cars than currently with a standard Android Auto).

Some of the solutions are already available for years (e.g. Apple CarPlay in 2014, GM NGI since start of 2017), they offer real time access to in-vehicle signals that is not(!) limited to just Infotainment data (see GM's list of 400+ signals), allow a safe&secure communication with the driver via in-vehicle displays and controls or even speech control integration (SDL, GM, Apple,Google) and are either based on open standards (GM's approach) or are even submitted for worldwide standardization (W3C automotive group proposal "VaWi").

So the notion that a safe&secure access for 3rd-party providers is technically not possible and would endanger the vehicle's safety and security is apparently wrong as demonstrated by the solutions investigated in this study. Unfortunately, as of now there is no right of access for IAM providers to the on-board systems. The legal and commercial aspects are always dealt with on a non standardized B2B-basis.

An outlook at the vehicle's internal architecture of the future indicates that the push for on-board software solutions will increase heavily. Few ("Super")-Computers from silicon valley companies like e.g. Nvidia will be able to host und run multiple software applications that formerly resided on dedicated electronic control units (ECUs). (https://www.electronicdesign.com/automotive/bmw-and-audi-want-separate-vehicle-hardware-software)

Already now – in the absence of legislation that would force and standardize an access for IAM service providers – OEMs have started to exploit the benefits of the technical evolution in the field of RMI by e.g. determining service intervals based on user behaviour (e.g. Mercedes in the field study where "hard" driving forced inspections already after 15.000 and 14.000km), using the enhanced remote diagnostics abilities for a pre-diagnosis that led to the recommendation to drive to the next subsidiary despite the fact that the car was parked intentionally just meters away from an OEM workshop (field study BMW). In terms of privileged access to the driver, where the OEMs are already now able to use the in-vehicle displays as a sales channel for service needs (see Mercedes field study) the OEMs are also aiming at an even enhanced level of control by introducing digital assistants (see e.g. Mercedes: https://www.mercedes-benz.com/en/taubenheim-13/taubenheim13blog/simply-talking-to-your-car/ or BMW: https://www.forbes.com/sites/sebastianblanco/2018/09/06/bmw-intelligent-personal-assistant/).

Summing up: If independent service providers are effectively excluded from this future in-vehicle market for online repair and maintenance services via a functionally limited slow offboard access and a potentially unsafe smart phone interface to the driver while the OEM in his role as a repair and maintenance service provider has a fast, onboard and bidirectional access to all systems and a firm control over the driver via in car controls and digital assistants, the customer choice will likely be severely limited.

2 Introduction

The ability to connect remotely to a vehicle for a range of new services is an increasingly important ability for a range of stakeholders and thus ensure fair and undistorted competition for 'services around the car' that support consumer choice and the growth of the digital economy, as well as the ability to innovate new digital services for the wider benefit of European mobility services, society and the economy.

However, access to the vehicle, its data and resources is fundamental to the ability to develop, offer and implement these remote digital services and the current situation only provides the vehicle manufacturer and their selected partners the ability to offer services, but (in general) these exclude any services which may compete with the vehicle manufacturer's own service offers. To provide access to the vehicle generated data, the vehicle manufacturers propose to provide access through the back end of their server – their 'extended vehicle' (ExVe) concept or as an extension to this, via a 'neutral 3rd party server'.

Therefore, this study was commissioned to investigate what data is provided by different ExVe offers from various vehicle manufacturers and the difference in what is possible as a comparison between the vehicle manufacturers and other service providers.

In December 2016, PSA was the first OEM to release a technical solution, by which Independent Service Providers could get access to PSA vehicles via a remote server using an API. This general ExVe concept (accessing the cars of a given OEM via an OEM backend server) is currently subject to an ISO Standardisation process. (ISO 20077, 20078 and 20080).

Other OEMS released similar solutions – e.g. BMW's CarData in 2017 - or are currently in development of ExVe implementations. (e.g. Mercedes is already showcasing a Beta Version of its forthcoming ExVe solution on the Internet for first tryouts)

While these server-based solutions are favoured by some OEMs, the first analysis of such a solution that was conducted in 2017 (BMW Car Data Analysis) revealed serious shortcomings in terms of data extent, data access, data quality, access to the driver and access to vehicle functionalities, as well as concerns of aftermarket stakeholders with regard to pricing models and monitoring by the OEM as a competitor for aftermarket services.

After BMW's Car Data Analysis, new ExVe solutions arrived (e.g. Mercedes), whilst others evolved with technically very different approaches like the General Motors Next Generation Infotainment system (GM NGI), so consequently an alliance of AFCAR stakeholders (independent operators) decided to compile this overview about the different telematics solutions that are currently offered by OEMs for competing telematics based services, but with a strong focus on the abilities to fulfil new remote and predictive vehicle diagnostic or repair and maintenance (RMI) services.

If a solution offers abilities for other service providers (e.g. services like insurance premiums based on "How you drive") this will be mentioned, but the focus is on RMI. The rationale behind this is that most service chains for vehicle repairs start with the detection of a Repair- or Maintenance requirement of the car. Also, insurers are currently striving to set up more cost efficient service chains around repair services with contracted workshops and contracted parts suppliers to minimise costs (and these service chains start with the early possibility to detect a malfunction of the car) instead of trying to just benefit from driving style based premiums – illustrating some of the innovative new remote services that are being proposed.

The study presents a rapid first (but more superficial) analysis of the data, functionalities and user interfaces made available to the consumer by the OEM and to alternative service providers.

The comparison with the OEM-abilities is based solely on the services currently offered to the customer.

As already stated, the (likely) competitive disadvantages of the IAM-solutions will be highlighted by a comparison of the capabilities needed to offer services in the future Digital Single Market in the Internet of Things (in this case, the internet of 'things' being cars):

1. Capability to offer a service to the customer
2. Capability to conduct a service with a customer
3. Capability to monitor the need of the thing (the car) for a specific service
4. Capability to actually perform the service in/on/for the thing (the car)

The analysis is done OEM by OEM and the structure/presentation of the analysis is the same for each OEM, although the depth of detail may vary from solution to solution. This is due to the following facts:

a.) Some OEMs simply don't offer anything at all for IAMs

b.) The offer from some OEMs is very similar to an already analyzed solution from another OEM.

c.) Some concepts like the GM NGI differ so significantly in technical design and functional extent and development process to other solutions, that a more in-depth analysis is justified. (e.g. GM NGI has some of the requirements of an (albeit proprietary) in-vehicle Open Telematics Platform and thus is covered in greater detail in the following analysis.)

Some technologies/approaches are intentionally left out of scope for this study.

OBD based dongles and other retrofit telematics units have been the technical foundation for telematics services for years now, especially in the field of fleet telematics. Consequently, their general abilities and inherent shortcomings are considered to be well known and understood within the independent Aftermarket. This study focusses on new developments in the rapidly evolving market for telematics solutions.

'Neutral platform' solutions like Caruso, Carmunication, Neutral Vehicle or others are also excluded from the study. All these platform solutions are based on the "native" Access methods to the car and the driver that a specific OEM does, or does not offer. They all aim at making the use of different OEM technologies and/or OEM development/registration processes easier for an aftermarket stakeholder, but their general technical capabilities and limitations are determined by the capabilities and limits of the respective OEM's basic technology.

If an already analyzed ExVe solution (e.g.) like BMW Car Data doesn't offer abilities to read or reset Diagnostic Trouble Codes (DTCs), then any subsequent 'neutral platform' provider cannot implement such a feature for an IAM stakeholder (This is of course unless he doesn't have a separate B2B agreement with an OEM that would offer him additional technical capabilities. But at the time of this report, the authors are unaware of such an approach for any platform).

This study therefore aims at a thorough investigation on the technical capabilities and limitations for the “native” solutions offered by various OEMs to their own customers and to the IAM stakeholders.

1.5 Field Study: What OEMs can really do

For a selected subset of OEMs, the study examined within a small field study, what they are really able to detect and to accomplish in case of an RMI-problem.

This was done by intentionally manipulating a car of the selected OEM to provoke an error, then watch and report the following actions and recommendations from the OEM-side.

The document will start with this field study to put the following descriptions of the single OEM solutions in a context.

2 Field Study: What OEMs can really do

In the past, the aftermarket's repair and maintenance process and the related value chain usually started with the event "The customer arrives with his car at the workshop".

In times of modern telematics, this description is factually wrong.

The modern, telematics based RMI-process starts far earlier: in the car by means of in-car real-time diagnostics.

The following examples from a small field study show, what already today, with readily available cars can be accomplished by a service operator who has the technical ability of in-car real-time diagnostics.

This is shown for two reasons:

1. To put the possibilities offered to an IAM into context. It is nice that an aftermarket operator can (e.g.) retrieve some pieces of information via telematics solutions offered to him by the OEMs from the car. However, if – up to now – no solution investigated is designed to deliver Diagnostic Trouble Codes (DTCs) to IAMs and in addition, only an OEM has the real time in-vehicle access to monitor and determine DTCs, then the aftermarket is still at a significant disadvantage.
2. To eliminate the concern about "Real time access is a security issue". Given the fact that OEMs already today use real time diagnostics in cars that are certified as roadworthy and secure, then obviously, these OEM solutions were found safe and secure. As for most parts of a modern car, the real time diagnostics were developed by the Tier1 suppliers. It is therefore difficult to understand, why a Tier1, who has developed such a solution within his OEM-division, should not be able to develop and operate a solution with the same safety and security standards to be used for his aftermarket division.

2.1 The setup of the field study

Following points were taken into account for the setup of the field study:

1. Test objects:

The field study was performed using the following vehicles:

- Mercedes Benz CLA Shooting Brake construction year 05/2016
- BMW 5 Series station wagon construction year 04/2018
- Mercedes Benz B-Class construction year 08/2010

2. Framework conditions

At the beginning the registration process were performed at the respective vehicle manufacturer websites entering e.g. personal data of the owner. The Mercedes Benz registration website offers also the possibility to define different drivers per registered vehicle. After the registration the smartphone application was downloaded using Play Store for smartphones based on an Android operating system, or the App Store for smartphones based on an IOS operation system. In addition to the previous steps, the connection between the vehicle and the manufacturer's server has finally to be done. For this the owner of the vehicle has to follow the instructions presented on the in vehicle display. To complete the connection between vehicle and server on the Mercedes Benz system the vehicle needs to be presented to an authorised workshop or to a subsidiary of the vehicle manufacturer.

The Mercedes Benz B Class was already registered. The registration procedure follows the above mentioned steps.

3. Test cases

Priorities were defined according to the used vehicles. The main focus of the field study was to detect in which way and method remote diagnostic and the maintenance process is performed by the respective manufacturer using his proprietary telematics system. In detail during the test it was tested if the respective VM has the following capabilities:

a.) Capability to offer a service to the customer
b.) Capability to conduct a service with a customer
c.) Capability to monitor the need of the thing (the car) for a specific service

d.) The Capability to actually perform the service in/on/for the thing (the car)

Finally, the processes performed today regarding diagnostic and maintenance were compared with the processes (remote diagnostics and maintenance management) done by the respective manufacturer using his proprietary telematics system.

2.2 Results and observations for OEM example A

The digital strategy of Mercedes Benz follows a two-step approach.

- Step 1 refers to modern vehicles which have an on board proprietary telematics system
- Step 2 refers to “older” vehicles which can be equipped with a so called OBD2-Adapter.

Both systems were tested regarding the provided use cases. A detailed test was performed using Mercedes Benz CLA Shooting Brake construction year 05/2016 equipped with an on board proprietary telematics system in case of maintenance.

2.2.1 OBD2-Adaper

The OBD2-Adapter is used as a telematics retrofit solution for vehicles which has no in vehicle proprietary telematics system on board. The OBD2-Adapter supports different use cases (business models) depending on the vehicle model and construction year.

2.2.1.1 Supported business models using OBD2-Adapter

Following use cases exist for the tested vehicle.

NAME OF BUSINESS MODEL	SHORT DESCRIPTION/DATA
My Vehicle	Access to the vehicle data via Smartphone App like tank fill level, odometer reading, parking time, Battery voltage

My Journeys (Drivers logbook)	Access to a list of all trips with export and editing function to get an overview of all journeys made in a certain time period. Example of data which can be accessed/added: 12th September 2017, start xyz at XX o`clock, 12th September 2017 end zyx at XX o`clock, distance xxx km, time x hour xx minutes. Additionally, the owner/driver can add information like “Business Trip to xyz”.
Parking & Locating	Location of the vehicle at the end of a trip is stored to locate the vehicle at any time. Example of data: Geographical latitude and longitude (GPS). In addition, through the smartphone app the parking time can be added and a timer to remind the owner/driver when the meter is about to expire.
Accident & Breakdown	This use case supports the owner/driver in the case of an accident or breakdown, e. g. assistance. It is possible to send a damage report with supplemented information like pictures and voice messages to Mercedes Benz. Example of data: Geographical latitude and longitude (GPS), vehicle status data like tank fill level, odometer reading, Battery voltage, pictures of damage, voice massage
Maintenance Management	This use case support the owner/driver to maintenance his vehicle under the Mercedes Benz conditions. A personalized offer is

	created based on the send data (data refers to the actual maintenance status of the vehicle) and an appointment can be done via the Mercedes me portal.
Refuelling	All refuelling stops can be stored automatically e. g. in the application. Additional it is also possible for the owner/driver to add supplementary information such as the price or a note.
Cockpit mode	With the cockpit view the owner/driver can access live data whilst driving like, range, average speed, oil temperature

Table 1: Supported use cases

2.2.1.2 General guideline for the use of the OBD2-Adapter

The OBD2-Adapter is inserted into in vehicle the diagnostics interface (OBD connector specified in ISO 15031-X) of the vehicle. Through the OBD2-connector with plugged OBD2-Adapter it is possible for the owner/driver to read vehicle data and send to this directly to Mercedes Benz for further analysis and support.

2.2.1.3 Vehicles authorised for OBD2-Adapter usage

Following vehicles can be equipped with the OBD2-Adapter.

MODEL	CONSTRUCTION YEAR
A-Class	2004 until 09/2015
B-Class	2005 until 11/2014
C-Class	2007 until 09/2014
C-Class Coupé	2011 until 06/2015
CLA	2013 until 11/2014
CLS	2004 until 09/2014
E-Class	2002 until 03/2015

E-Class Cabriolet	2010 until 03/2015
E-Class Coupé	2009 until 03/2015
GL	>09/2009
GLA	2013 until 09/2015
GLK	>2008
M-Class	>200
R-Class	>2005
S-Class	2005 until 09/2014
SL	2012 until 03/2016
SLK	2003 until 03/2016
SLS AMG	from 2010
Sprinter	>2006
V-Class	2014 until 09/2016
Viano	>11/2010
Vito	>2014

Table 2: Authorised vehicles

2.2.2 On board proprietary telematics system

As mentioned before a detailed test was performed using Mercedes Benz CLA Shooting Brake construction year 05/2016 equipped with an on board proprietary telematics system in case of maintenance.

The use case maintenance management starts as follows:

1. Message appears on the in-vehicle display; in our case whilst driving.

The message which appears on the in-vehicle display is:

Maintenance AO has to be performed. Do you want to fix an appointment?

Two possibilities are now feasible for the owner/driver

Call for an appointment or Call on a later stage

Figure 1: Message on in vehicle display

2. Connection to Mercedes Benz

The mobile connection is done if the owner/driver accepts to call Mercedes Benz for an appointment using the in-car controls (activate the field "***Call for an appointment***"). After the call is established the Mercedes Benz Concierge Service guides the owner/driver until a slot for maintenance is found. Up to know to owner/driver decides on his favourite Mercedes Benz authorised partner or the subsidiary of the vehicle manufacturer.

Figure 2: Activation mobile and internet connection

Additionally to the mobile connection, an internet connection is activated to Mercedes Benz. The aim is to do a remote diagnostic of the vehicle and to send data to Mercedes Benz for a tailor-made personalized offer.

3. Tailor made personalized offer (only in German language available)

The tailor made personalized offer is done based on the send data and remote diagnostic performed on the vehicle directly with Mercedes Benz (Annex 1).

4. Maintenance at Mercedes Benz premises

Based on the tailor made personalized offer the owner/driver knows exactly the price, parts and the tasks which have to be done for the maintenance before even contacting any workshop.

2.3 Results and observation for OEM example B

The BMW 5 Series station wagon construction year 04/2018 was tested in detail in case of remote diagnostics using the proprietary telematics system with the support of BMW. Various errors have been simulated to check the possibilities of the manufacturer during the remote diagnostics. As an example, the first test focused on an error in the emissions relevant system (error air mass meter). Safety systems like pedestrian protection (deactivation of that system (broken wire) and comfort systems, like air conditioning, were also tested.

As a conclusion, it can be stated that with proprietary telematics system with the support of BMW all errors were detected. Due to the nature of the error corrective measures have always been proposed to the owner/driver.

The overall process is as follows:

1. Error code occurs whilst driving (visible for owner/driver in vehicle display)

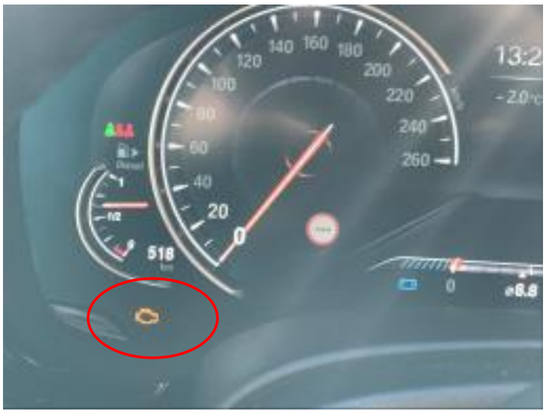

Figure 3: MIL on because of error in air mass meter

2. Owner/driver activates the diagnostic service per in car control - vehicle parked

Figure 4: Connected Drive BMW Assistance

BMW support contacts the owner/driver over mobile connection to clarify in detail the needs. Internet connection is established for remote diagnostic using the on board proprietary telematics system. Remote diagnostic of all vehicle systems starts in order to detect the error. Remote diagnostic functionality detects in detail the problem.

In our experience from the test case, the following priorities apply:

Priority 1: Remote repair if possible (e.g. through reset of fault codes).

Priority 2: If Priority 1 is not possible than the complete repair procedure is organised through BMW Support. At this stage, it is also possible to receive additional information from BMW information directly on the in-vehicle display, this means entering a new address in the navigation system. The owner/driver is then sent to the subsidiary of the vehicle manufacturer or to an authorised workshop.

2.4 Summary of the field study

The results after the field study are the following:

a.) Mercedes Benz uses the MAINTENANCE MANAGEMENT to contact the owner/driver long before other third parties like workshops have the possibility to do so. Through this contact point, an appointment is fixed and a tailor made personalized offer is created based on vehicle generated data and diagnostics of the vehicle. So, the manufacturer has a timely privileged contact to the owner/driver and also a privileged access to the vehicle and its data using the proprietary telematics system.

b.) BMW uses the REMOTE DIAGNOSTICS mainly in cases of a breakdown, when fast support is needed for the owner/driver. With the proprietary telematics system and the BMW support a fast fix (i.e. delete a fault code) can be performed in order to allow the travel to the subsidiary of the vehicle manufacturer or to an authorised workshop. Third parties, like independent workshops do not have such a possibility.

	MERCEDES BENZ	IAM	BMW	IAM
	MAINTENANCE MANAGEMENT		REMOTE DIAGNOSTICS	
Capability to offer a service to the customer	YES	NO	YES	NO
Capability to conduct a service with a customer	YES	NO	YES	NO

Capability to monitor the need of the thing (the car) for a specific service	YES	NO	YES	NO
The Capability to actually perform the service in/on/for the thing (the car)	YES	NO	YES	NO

Table 3: Evaluation

3 Analysis of OEM Mercedes

Mercedes has not yet released an Aftermarket Solution that is "ready for professional use". Instead, the OEM followed the approach to firstly release a Beta version to get initial feedback from interested developers and customers.

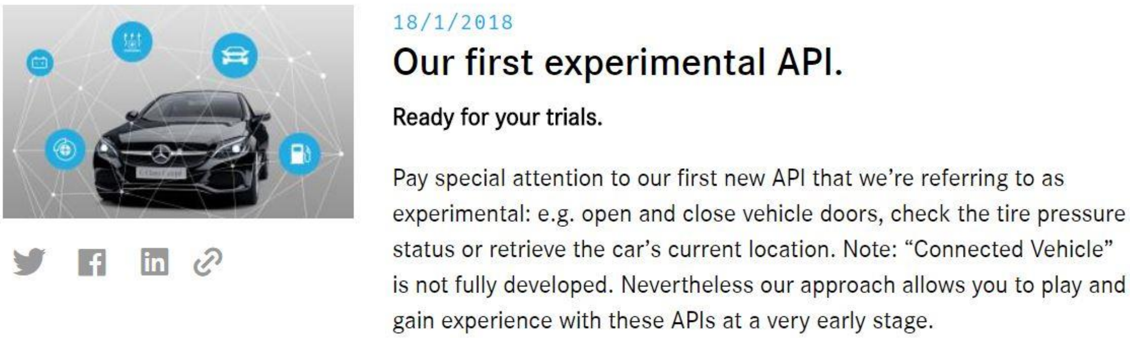

Figure 5: Announcement of the experimental API

The comparison between OEM capabilities – which are already used by professional services offered to a customer – and this experimental API has taken the experimental characteristics into account. However, the overall characteristics of the solution are likely to remain unchanged, as only the amount of data points may expand in upcoming releases.

3.1 Technical Capabilities for IAM

The solution for first try outs can be found at the URL:
https://developer.mercedes-benz.com/apis/connected_vehicle_experimental_api

3.1.1 Solution Description

This solution represents a typical architecture of an “Extended Vehicle” (ExVe). Data is transferred from the car to a server operated and controlled by the OEM. IAMs have to register themselves at the OEM website and have to get consent from their respective customers (granted also on the OEM Website) to be able to access data from their customer’s cars via the OEM server using REST-web service calls. The tool support and documentation are sufficient for an experimental API. The figure below shows a simulated “Sandbox car”, which developers can use to get first experiences with the API.

Figure 6: The sandbox car and the Diagnostics capabilities of Mercedes ExVe

3.1.2 Access to Data

Overall, the solution offers 23 data points. A clustering by category can be found in the diagram below.

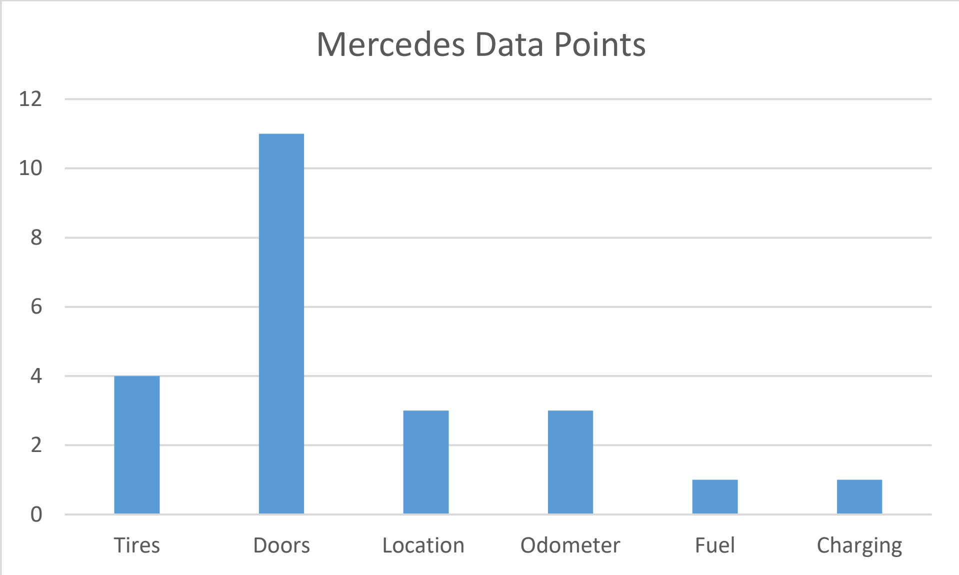

Figure 7: Data points by Category for the Mercedes ExVe (Total: 23 data points)

The sampling frequency for the data (how fast new data is sent from the car to the OEM backend) is not documented in the current API.

However, as opposed to the BMW ExVe solution "BMW Car Data", the experimental solution already offers (albeit a limited) write access to the customer's car.
The doors of the car can be locked and unlocked remotely. Given the fact that in the past OEMs have not provided any write access to the car for "Safety & Security reasons" (even a simple reset of a Diagnostic Trouble Code was deemed a threat to safety and security), this feature shows that obviously a safe & secure remote access to safety & security relevant elements of the car (e.g. the doors) is indeed possible.

3.1.3 Capabilities by Service

As for every ExVe solution thus far, the access to the customer is possible only via their Smartphone, which makes any service offering and execution unsafe whilst driving.

Service: RMI

The very few data points render the solution almost useless for RMI business cases. With just Fuel level, tyre pressure and the water fluid level, but without the essentials for RMI (Report of Diagnostic Trouble Codes, Brake pad status etc.) there is hardly any valid business case possible and consequently, a highly restricted possibility to offer competing services.

Other Services: Package delivery

The new write access to the customer's car to lock and unlock the door allows a use case for package delivery to a vehicle as a delivery address. Customers who are not at home to accept a shipment could e.g. open their parked vehicle for the shipment service supplier to drop the package in the car.

3.2 Technical Capabilities for OEM

When the customer buys a new Mercedes, he agrees a contract to access the OEM solution for telematics, 'Mercedes.Me'. The solution offers more data points and advanced remote diagnostics support in the car than is being offered by Mercedes to competing service providers.

3.2.1 Description Solution

The customer has at least three channels to be informed about OEM service for his car. Firstly, he can check the status of his car and potential problems using his in-vehicle Entertainment system. For Mercedes, this system is called "Command Online".

Secondly, in case of an actual or potential problem with the car, he can call remote assistance from a Mercedes Call centre. The call centre has a very advanced set of diagnostics functions at its disposal to allow a remote analysis of the vehicle.

As a third option, the driver can access his car via a Website or his smartphone app in a similar way to the experimental IAM solution described above, albeit with an already enhanced functionality.

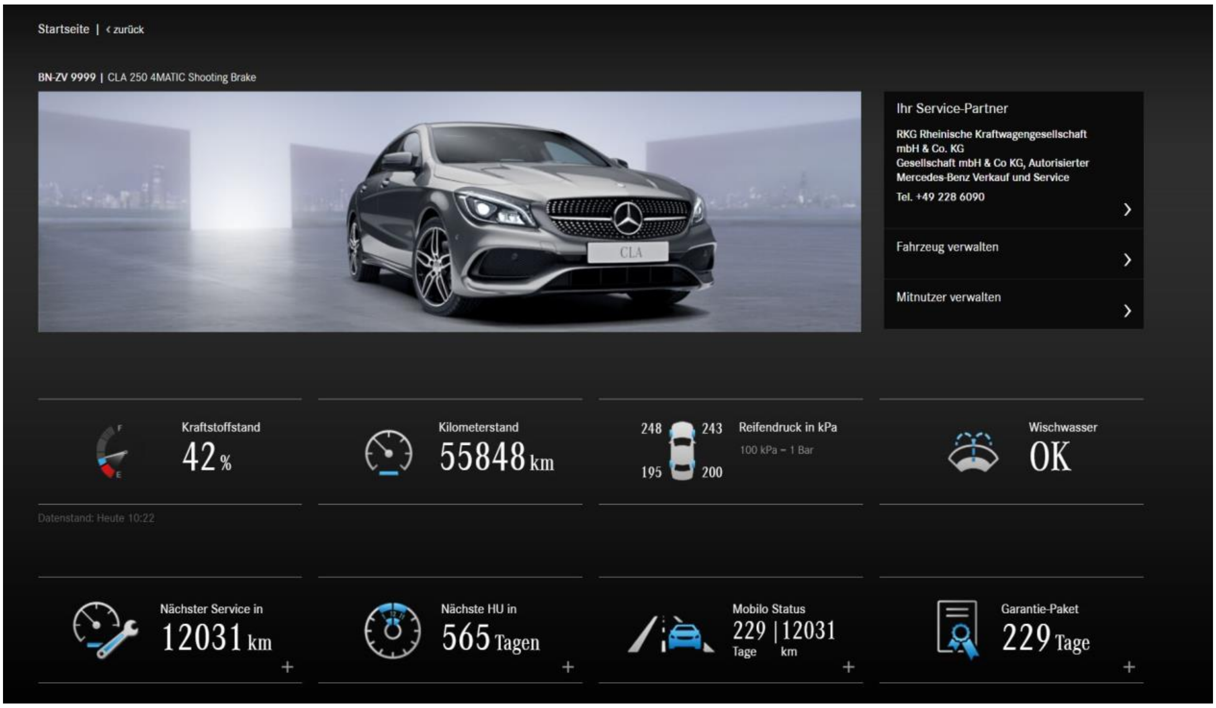

Figure 8: Startscreen OEM offer Mercedes.Me (Top content)

In addition to the very few data points included in the experimental IAM solution for RMI, the user of Mercedes.Me receives hints for the next PTI-Service and the next Service-Inspection.

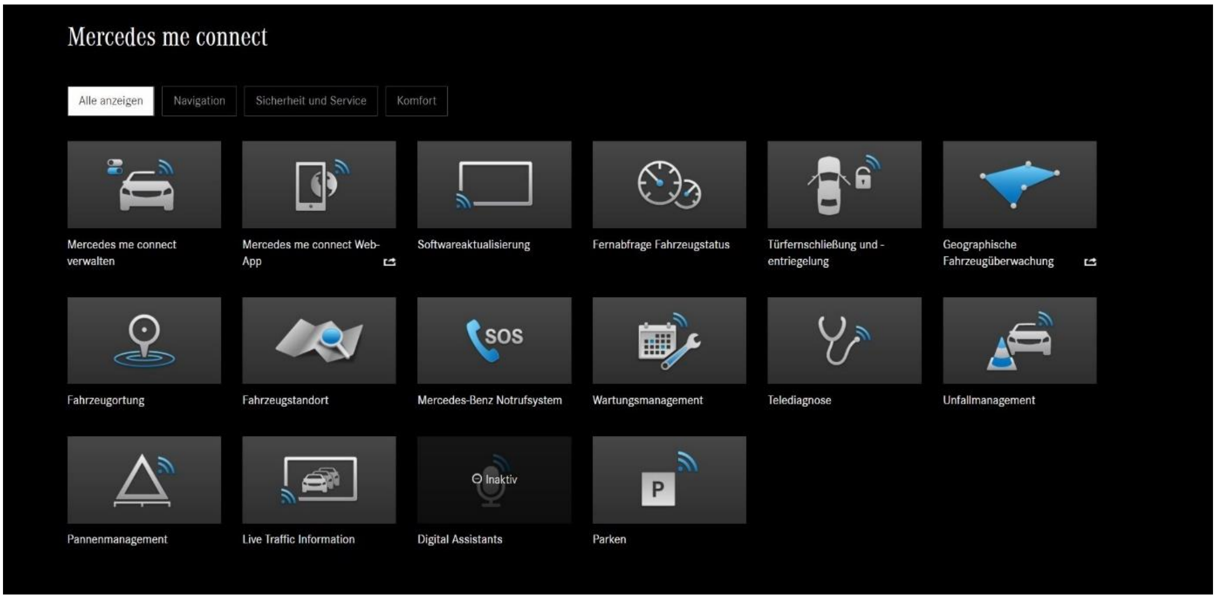

Figure 9 : Startscreen of OEM offer Mercedes.Me (Mid section)

Along with non-RMI services like parking, eCall, Car location or Real time traffic information the user receives an advanced functionality for Maintenance services covering e.g. brake pad and brake fluid status or cooling fluid status.

3.2.2 Access to Data

The full extent of data points available to the OEM for aftermarket services is not disclosed on the website or other formats of documentation (e.g. in the user manual).

But obviously, there are enough data points available to offer remote service for PTI, for regular service calls and for services based on wear & tear parts like brake pads.

During a real life test scenario, the extent of diagnostic capabilities of the call centre was checked and proved that e.g. all emission relevant data points and diagnostic trouble codes are available to the OEM call centre agents.

3.2.3 Capabilities by Service

The OEM has full access to the customer via three channels: In vehicle dashboard, voice (Call centre) and via Smartphone/website.

Service RMI:

The OEM is able to perform mileage/time based service calls, PTI calls and service calls based on wear & tear analysis (prognostics.)

In the case of actual problems, the OEM remote support has advanced diagnostics at its disposal.

Other services

Mercedes is currently trying (like other OEMs) to extend their services deeply into the aftermarket value chain.

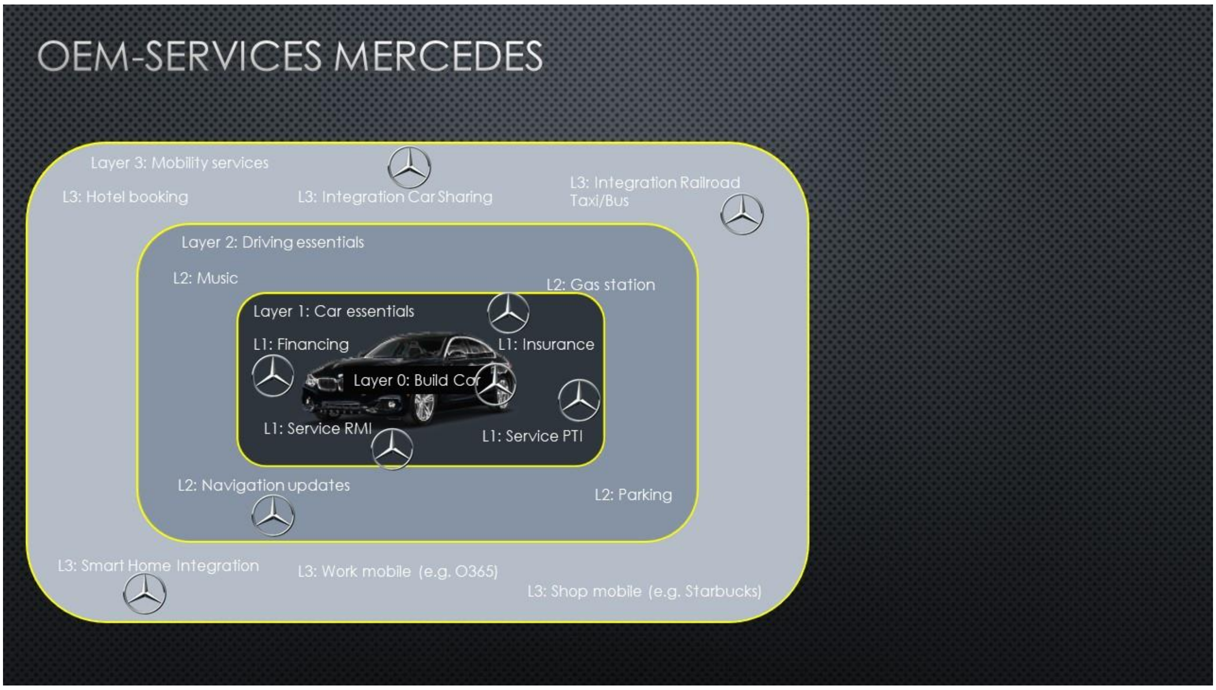

Figure 10: OEM Services Mercedes

Along the already discussed typical aftermarket services (like RMI), Mercedes is currently aiming to become a real “overall mobility provider” by integrating other providers like Taxis or busses:

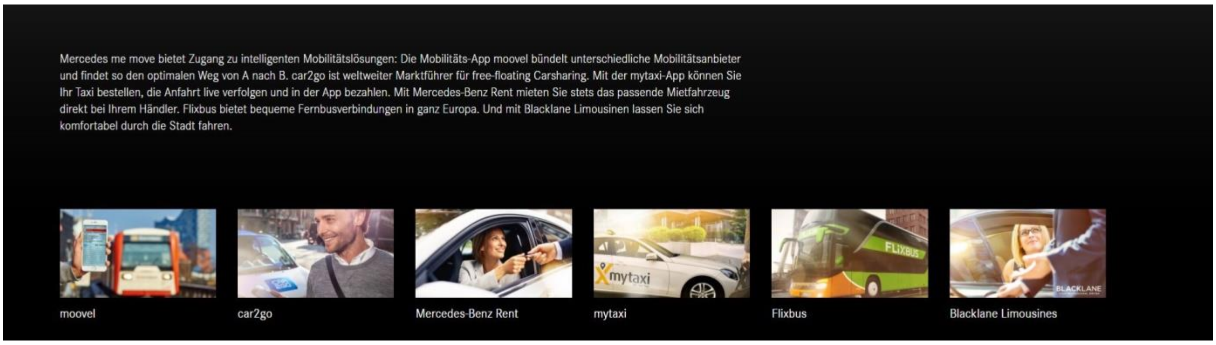

Figure 11: Mercedes as a mobility provider

The second strategical goal of Mercedes seems to be an even better integration with the customer and his daily lifestyle by using digital assistants like Amazon Alexa or Google Home:

Figure 12: Embedding the customer by using next gen communication channels

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3.3 Comparison and Rating

When compared, the technical advantages of the OEM are strikingly superior.

3.3.1 Capability to offer a service to the customer

VM capabilities:

The OEM can use Smartphones and in addition: vehicle to call centres, In-vehicle Displays, Digital Assistants and Wearables.

IAM capabilities:

The IAM has to rely on Smartphone communication only.

Abilities	VM	IAM
Smartphones	✓	✓
In-vehicle display	✓	X
Wearables	✓	X
Digital assistants	✓	X
Vehicle to call centres	✓	X

Rating for Service Offering:

IAM: 20%

OEM: 100%

3.3.2 Capability to conduct a service with a customer

VM capabilities:

The OEM can use in-car controls and voice integration for safe & secure service execution whilst driving.

IAM capabilities:

The IAM can only conduct their service while the car is stationary due to his limitations with the smartphone access.

Abilities when driving	VM	IAM
Smartphones	X	X
In-vehicle display	✓	X
In-vehicle voice control	✓	X
Vehicle to call centres	✓	X

IAM: 0%

OEM: 100%

3.3.3 Capability to monitor the need of the thing (the car) for a specific service

VM capabilities:

The OEM can monitor the full range of service needs.

IAM capabilities:

The IAM can only monitor the need for a refuel, for more air on the tyres and the fluid water level with this experimental ExVe. In summary, he could just advise the driver to drive to the next service station. For real RMI based on Service Intervals, current DTCs or prognostics like brake pad wear, the ExVe offers nothing.

Abilities for a specific service	VM	IAM
In-vehicle prognostics	✓	X
Predictive maintenance	✓	X
	✓	X
	✓	X

IAM: 0%

OEM: 100%

3.3.4 Capability to actually perform the service on the thing (the car)

VM capabilities:

OEMs can e.g. update software versions over the air.

IAM capabilities:

Write access for the IAM is only possible for door control, which is as a non RMI service, out of scope for this rating. There is no possibility for an IAM to conduct remote diagnostics, reset a DTC, control other RMI functions (e.g. re-code a replacement part, such as a battery) or update an ECU software with a newer version to fix a software problem.

Abilities to conduct a remote service	VM	IAM
Remote diagnostics	✓	X
Remote replacement part coding	✓	X
Remote software update	✓	X
Remote DTC reset	✓	X

IAM: 0%

OEM: 100%

3.3.5 Overall Rating

Although at first glance the Experimental ExVe from API looks good on the website, the documentation and the associated support, a deeper look revealed serious shortcomings in terms of access channels to the customer and a very narrow set of data points and functionalities available for RMI is just enough to get a rating of:

1 out of 5 stars.

Furthermore, the solution and its mode of presentation seem to serve a political purpose by “pretending to be a start-up”. The political story behind is that OEMs and IAMs are slowly trying to “Go digital in a common learning curve”, e.g. introduce APIs with limited data points, getting used to new techniques like web services or smartphone apps. That might be the reason why the API is declared “experimental” as if Mercedes would really need feedback to improve its telematics abilities like a typical startup that tries to build digital ecosystems based on OBD-Dongles.

However, this does not appear to be factually true. Mercedes is using the same technologies (web services, apps etc.) now for years for productive services and business advantages due to enhanced data extent and enhanced functionalities and is now seeking to improve on this with Next Gen technologies like digital assistant integration. The Experimental API looks like a severely restricted version of their already existing OEM backend server solution dressed in fresh web presentations.

4 Analysis OEM General Motors

General Motors is currently offering the technically most advanced solution with its Next Generation Infotainment System (NGI) that could best be described as being 'en route' to a "proprietary" Open On-board Telematics Platform.

4.1 Technical Capabilities for IAM

With GM's NGI, the IAM service provider gets exactly the same capabilities to interact with the driver as GM uses themselves. In terms of access to data and functionalities, although the conditions are far better than with the solutions offered by BMW, Mercedes or PSA, they are still limited compared to the full set of telematics data and functionalities at the disposal of GM.

4.1.1 Description Solution

The solution can be found at:

https://developer.gm.com/ngi

The website is showcasing distinctive features like the on board real time access for more than 350 signals:

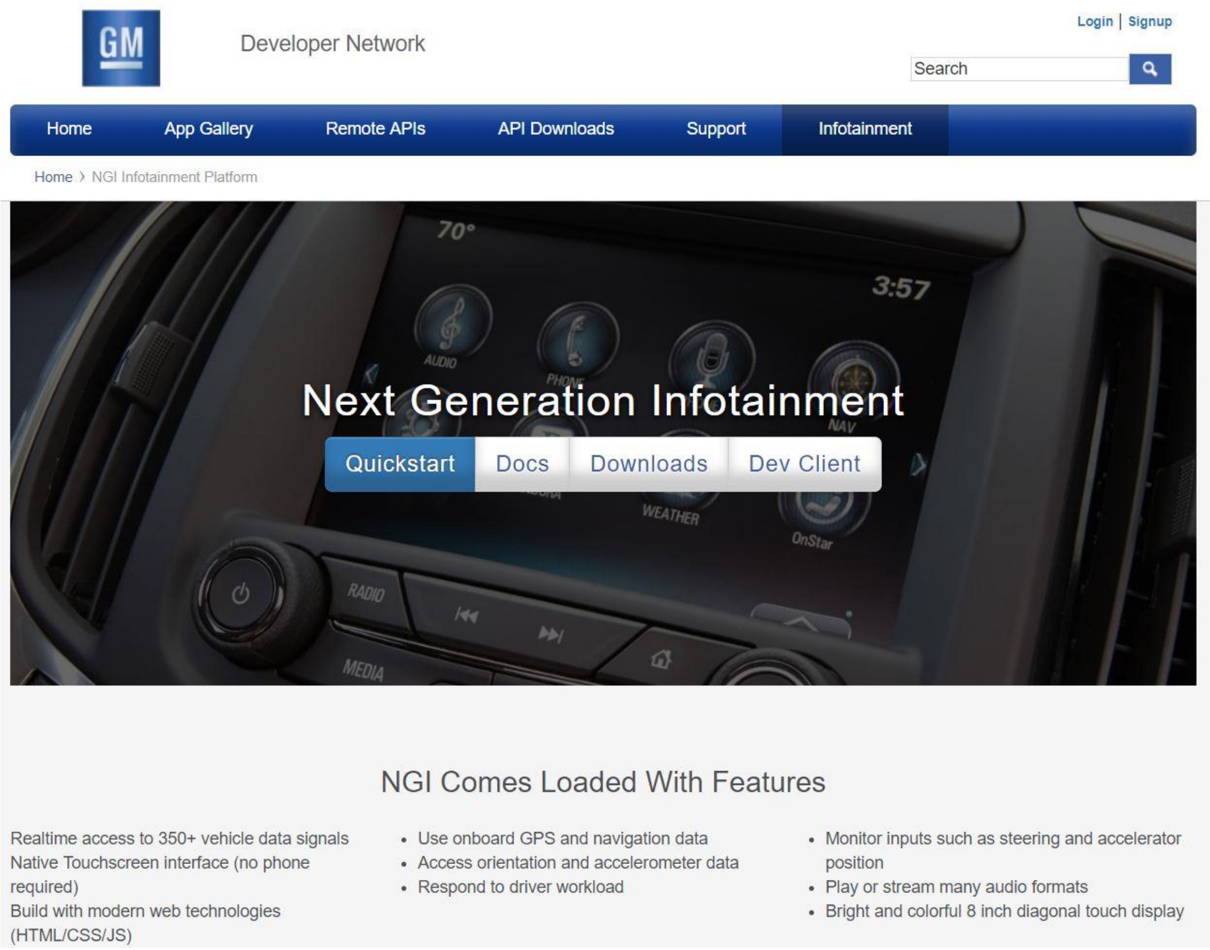

Figure 13: Website for GM NGI

With NGI, Independent Aftermarket service providers can write Apps based on the same technology that GM itself (or their chosen providers) use for the “original GM”-applications, have them tested according to the same standards like the “original GM”-Apps and finally have them sitting next to the “original GM”-Apps in the vehicle dashboard for safe & secure access to the driver. Thus, the IAM has exactly the same key capabilities in terms of “Capability to offer a service to the customer” and “Capability to conduct a service with the customer” as the OEM General Motors.

The tool support and documentation is the best currently being offered by any OEM.

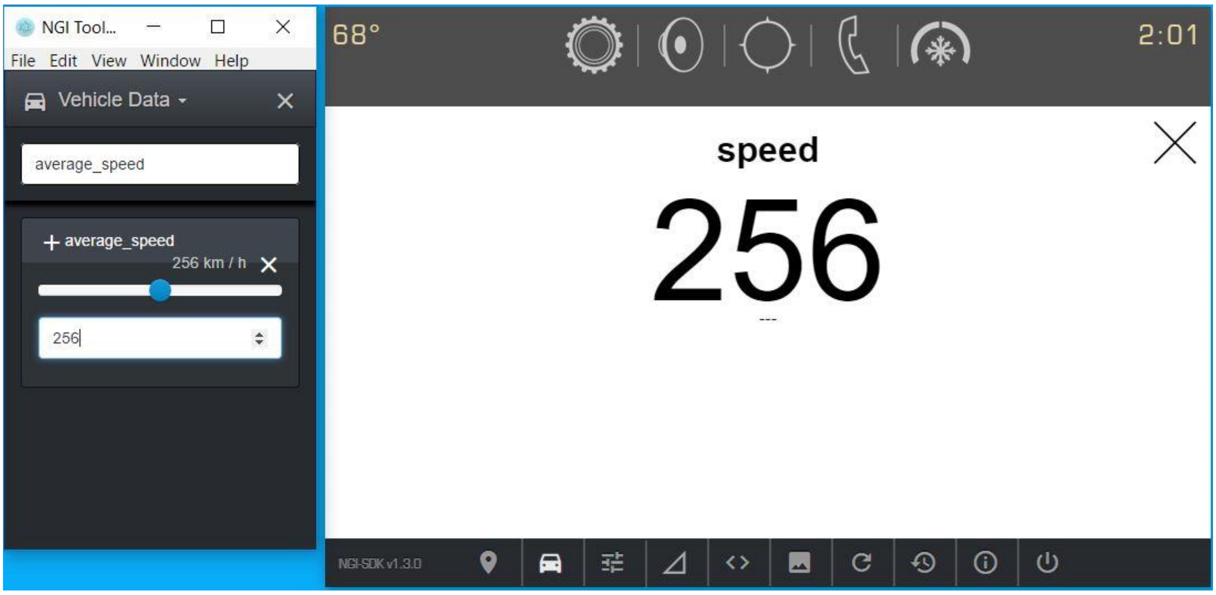

Figure 14: Starting to develop an app with the GM simulator

Along with the SDK and the corresponding documentation, the developer gets a simulator that allows him to develop his application and check its appearance before it is uploaded to run in a real GM car. The figure 14 above depicts a first tryout where the current vehicle speed is sampled from the car and displayed in real time (Right side of the picture). For testing purposes, the developer can alter vehicle signals of the simulated car using the controls on the left.

Upon completion of the coding, the developer wraps his application into a package and sends it to GM for final approval in the same way a smartphone developer would submit his new application to Apple for approval and admittance to the Apple Appstore.

After initial checks for safety & security, adherence to coding standards for minimized driver distraction etc., the application is ready for real vehicle testing.

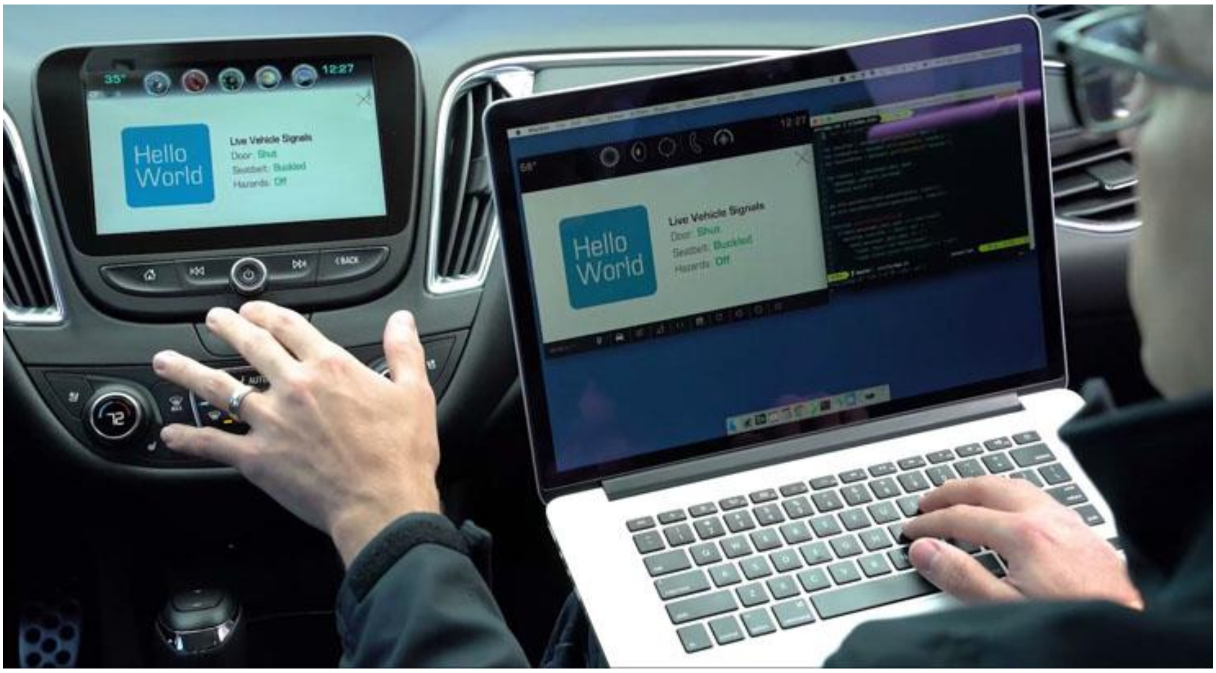

Figure 15: Testing a developed GM App on a real vehicle

As depicted in this Picture from GM, the app looks identical on both the simulated car and in the real car. After every acceptance test from GM is passed, the new application can be used by every GM customer.

Figure 16: First GM apps in productive use

In late 2017, GM – using over-the air-updates – prompted all GM NGI customers with a new marketplace functionality where the customers can find ready-to-use applications, predominantly related to travelling related services with the car (e.g. parking, fuel offers or restaurant services like Dunkin' Donuts).

Figure 17: Minimize Driver Distraction by preconfiguration

As an example, to counter the argument that driver distraction would be increased if drivers configure the morning coffee of their choice whilst driving with various versions of a cafe latte with shots and flavours, the application restricts the choice of the driver whilst driving to a set of preconfigured variants of coffee the driver has to pre-configure when he is not driving.

4.1.2 Access to Data

In total, GM at the time of this investigation, offered 401 data points, the most of any aftermarket solution analysed thus far. However, these are restricted to 'read-only' data points.

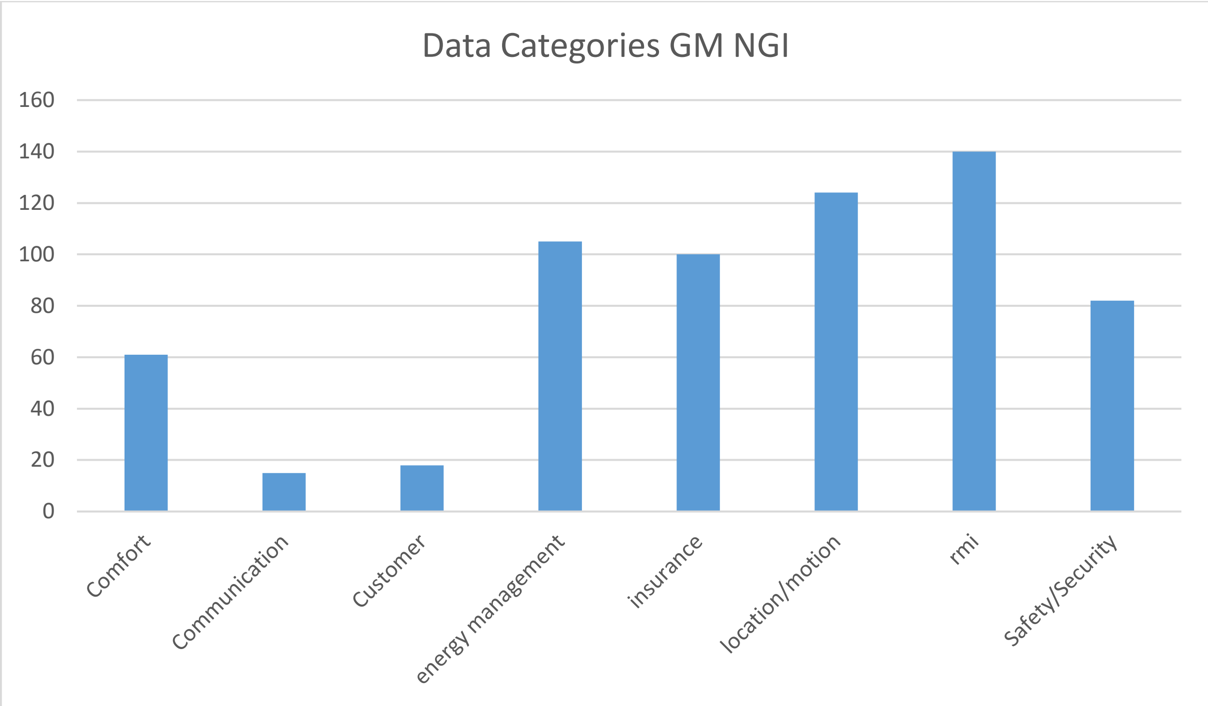

Figure 18: Data points by category of GM (Multiple assignment possible)

The data points are clustered in categories by GM. For the analysis, the clusters depicted in the figure above were used with a significant caveat: The very nature of data is that it can't be used solely for one use case or category.

A signal like "Brake Pad Overheated" e.g. can be used for RMI prognostics to determine the next likely brake bad replacement as well as for a driving style premium insurance use case. (so the numbers of the categories won't add up to the number of signals available in total, currently 401).

As for RMI data, the data points include for example information about wear & tear parts like brake fluid, brake pads or the need for a change of oil. What is missing though is service intervals for regular or PTI services.

To a certain extent that could be compensated by use of prognostics, because the driving style is very well documented, including speed and out of lane warnings, through to brake pad overheating.

Defective parts like bulbs are included, as well as a sound set of parameters to monitor the tyre state. However, what is not included is a full coverage of the EOBD identifiers and anything about diagnostic trouble codes. The full list of GM NGI data points can be found in this document link below.

GMRealTimeDataOve
rview.xlsx

4.1.3 Capabilities by Service

The key capabilities in terms of offering the services to the customer and controlling the service execution whilst driving in a safe & secure way are exactly the same for both the OEM and IAM providers and this is one of the most important requirements for IAMs to be able to provide effective competing services. Additionally, it supports speech recording and recognition by IAM Apps.

Thus, the differences between OEM and IAM service offers can be based mainly on the data points and the functionalities offered for the car.

Write access is very limited e.g. only to the entertainment system so that apps can play music lists or set the destination for the car's navigation system. Re-coding replacement components, initiating actuators in the diagnostic process or resetting DTCs is not possible.

Service: RMI

Good support for wear & tear parts (Brake pads, light bulbs, brake fluid etc.), missing support for DTCs or service intervals. No possibility to initiate actuators or reset DTCs or update an ECU software. Reasonable abilities for prognostics due to coverage of driving style data points.

Other Services: Music Players, Location based services, Insurance

The abilities to interact with the driver using in-car controls as well as speech control together with the possibility to control the music player and the navigation system make GM NGI a solution for the developers of Music players as well as for every service provider who just wants to propose to the customer to use their service at a given location (but this is 'location-reactive', rather than 'location-predictive', so has limitations:

- Parking service,

- Fuel service,
- Restaurant service
- Etc…

These types of service don't need much information from inside the car once the vehicle is at a certain location (e.g. the fuel service provider just needs the fuel level of GM NGI, the other two don't need any information from the vehicle).

For any insurer who is interested in driving style premiums, the solution is good. GM NGI supports locations, road types, weather conditions, speed, acceleration, speed limits, lane departures, distance to the vehicles in front etc, pp.

4.2 Technical Capabilities for OEM

In terms of access to the driver, the IAMs makes use of exactly the same technologies as the OEMs. However, in terms of data access and functionalities used within the car, the OEM (GM) has a distinct advantage with their access to much more in-vehicle data and 'write' abilities.

4.2.1 Description Solution

The package for GM customers is called 'On-Star'. As is the case for Mercedes, the customer can use the use GM services via his dashboard or via an On-Star App.

- Monitor oil life, tire pressure, remaining fuel, fuel efficiency and more.
- Schedule maintenance with your preferred Dealer.
- Lock and unlock your doors* or activate the horn and lights.
- Remotely start or stop your engine (if factory-equipped).
- Receive rewarding offers on everyday purchases with Marketplace.*
- Get Roadside Assistance* if you're stranded, have a flat tire or need a tow.
- Remember where you parked and set a timer to alert you when your meter is expiring.
- Access your vehicle's Owner's Manual.
- Manage in-vehicle Wi-Fi® hotspot* settings (if equipped).
- Search for destinations and send directions to your OnStar Turn-by-Turn Navigation* system, or send destinations to your vehicle's in-dash navigation system (if equipped).
- Contact an OnStar Advisor.

Figure 19: Functionalities of the On Star App (Source: GM)

As shown, the On-Star app allows the door control (a feature which is not accessible via GM NGI as of now).

4.2.2 Access to Data

The number of data points used by GM aftermarket services is not documented. However, a list of the services offered by GM reveals what is needed in terms of data to offer these services:

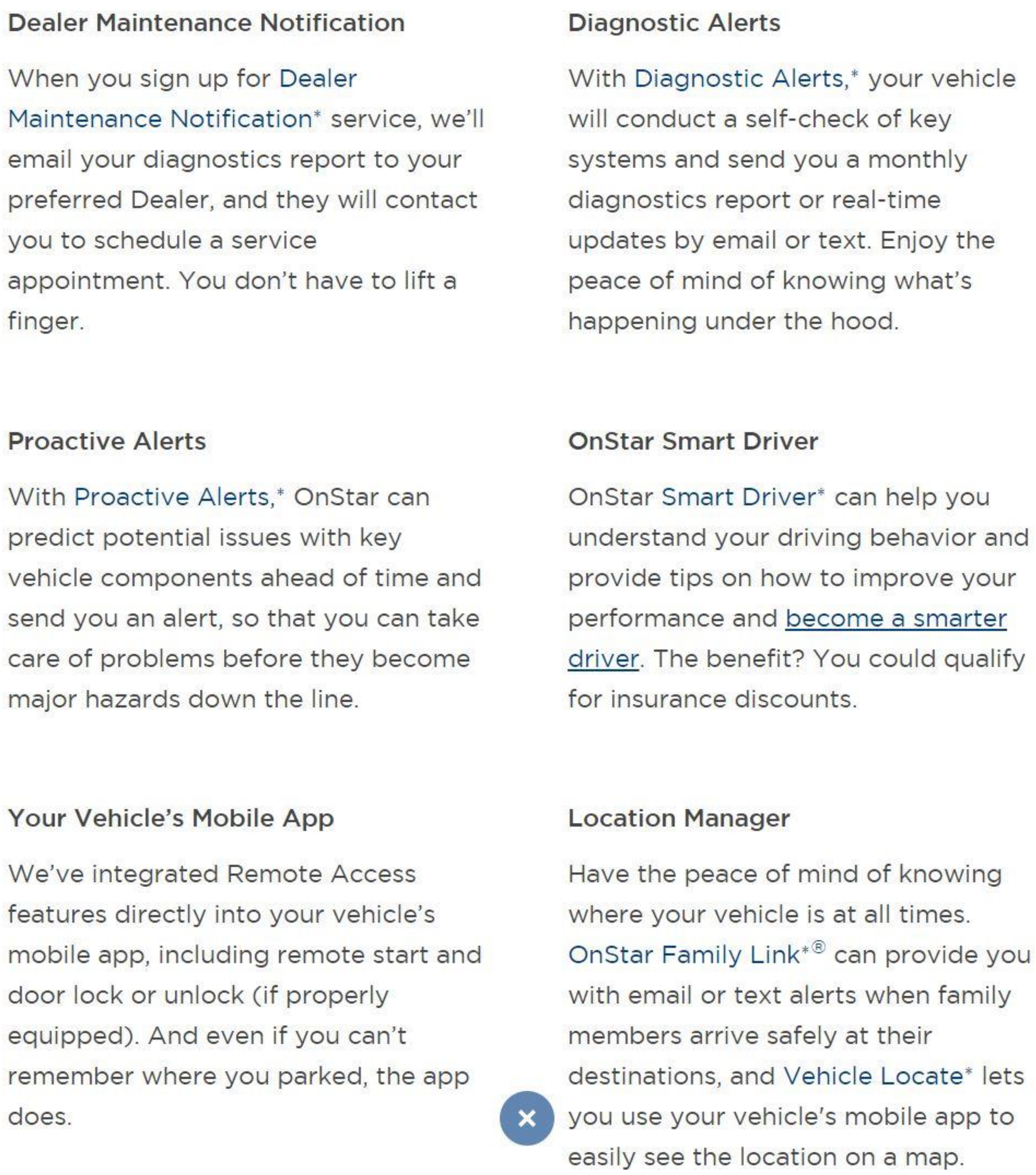

Figure 20: The On Star services of GM (Source:GM)

Of special interest are the diagnostic and repair and maintenance services (where obviously information about service intervals is needed) as well as the proactive alerts for key vehicle components. Only a detailed field study could verify what key components are affected, but it is highly likely (due to the field tests done with BMW and Mercedes for in-car diagnostics) that there are many more data points available for GM than are currently included in GM NGI.

4.2.3 Capabilities by Service

Service RMI:

GM has in addition to NGI significantly enhanced possibilities for maintenance services, diagnostics and prognostics.

Other services:

By opening the GM NGI for services like fuel service, parking, restaurant etc. as well as for potential driving style insurers, GM seems to want to enlarge its service ecosystem, but by attracting service developer partners that develop for NGI, rather than trying to be a full service provider by using just its own resources.

4.3 Comparison and Rating

In terms of driver access, GM has decided to compete or to partner with IAM offers on equal technical terms and capabilities. They protect some service areas (e.g. RMI) by narrowing down the car sided aspects of telematics: Data extent and access to car functionalities.

4.3.1 Capability to offer a service to the customer

VM capabilities:

In-Car apps and controls, Voice recognition plus Smartphone:

IAM capabilities:

In-Car apps and controls, Voice recognition plus Smartphone - IAM as well as OEM use the same methods:

Abilities to offer a service	VM	IAM
In-car Apps	✓	✓
In-car controls	✓	✓
Voice recognition	✓	✓
Smartphone	✓	✓

IAM: 100%

OEM: 100%

4.3.2 Capability to conduct a service with a customer

VM capabilities:

Both the VM and the IAM have equal technical possibilities.

IAM capabilities:

Both the VM and the IAM have equal technical possibilities.

Abilities to conduct a service	VM	IAM
Implement in-vehicle service	✓	✓

IAM: 100%

OEM: 100%

4.3.3 Capability to monitor the need of the thing (the car) for a specific service

VM capabilities:

The OEM claims that his ‘On-star’ proactive diagnostics service includes wider and deeper abilities to detect developing or actual vehicle faults.

IAM capabilities:

The IAM is still restricted in terms of monitoring needs for services. (e.g. the DTC handling is completely left out in NGI).

Abilities identify a specific service	VM	IAM
Identify all in-vehicle service needs	✓	X
Identify specific in-vehicle service needs	✓	✓

IAM: 50%

OEM: 100%

4.3.4 Capability to actually perform the service on the thing (the car)

VM capabilities:

GM can control in vehicle functions, actuate in-vehicle components and install new software versions over the air.

IAM capabilities:

Write access for the IAM is only possible for the music player and the navigation system. There is no possibility for an IAM to re-code a replacement part, reset a DTC, use diagnostic functions to control RMI actuators or update an ECU software with a newer version to fix a software problem.

Abilities to perform a service in-vehicle	VM	IAM
Perform an in-vehicle service	✓	X

IAM: 0%

OEM: 100%

4.3.5 Rating

Two things stand out from a technical as well as development approach of the solution GM NGI.

1.) It is the first, and up to now only, solution that allows IAMs to compete on equal technical terms with the OEM for some capabilities – e.g. access to the customer using

In-car apps, controls and even in-car speech recognition. Apps of different suppliers allow fair competition in the dashboard of a GM vehicle.

2.) The software development relies on open standards like HTML5, node.js etc. and is in terms of development tools, guidelines and acceptance test criteria, identical for OEM as well as IAM service providers. As a logical consequence, apps from both groups share the same level of safety & security.

The major downside for RMI service providers is the imbalance in terms of RMI data points and diagnostic or RMI functionality. So, in total, the solution is rated:
3 out of 5 stars (i.e. 60% capabilities in comparison to the VM).

5 Analysis OEM PSA

PSA has released its version of an Extended Vehicle solution already in 2016, so it can be seen as the first Extended Vehicle solution of a significant OEM in the market. While it is in terms of data points and data sampling frequency superior to the BMW CarData solution that was released months later in 2017, nevertheless the solution as of now has apparently not attracted much interest from the market. As a proof: the latest blog entries on the solution's website are dated December 2016, a developer innovation competition ended January 2017 and checks for news on the subject returned no results at all.

5.1 Technical Capabilities for IAM

As for every Extended Vehicle solution, the IAMs can't deploy their own applications into the vehicle, thus can't access real time data and are limited to aggregated and delayed information on the PSA server. A write access to the car is not possible, a communication with the driver using in car display and controls is also missing.

5.1.1 Description Solution

The solution can be found at:
https://developer.psa-peugeot-citroen.com/inc/node/2633

From a development viewpoint, the solution is well documented, tool supported and aided by community efforts like a developer forum.

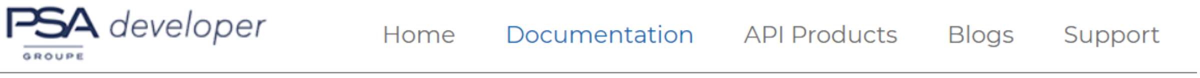

Figure 21: Titles from the API-website

Unfortunately for PSA, the solution seems to have attracted little attention from the external developers.

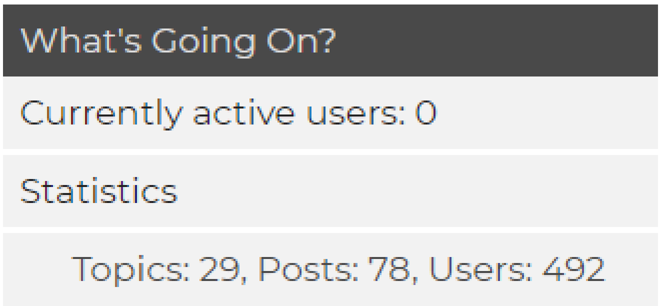

Figure 22: Current Activities in the Developer Foum

With just 78 Posts in total as of now, the interest seems to be minimal.

5.1.2 Access to Data

In total, at the time of this investigation, the API offered 89 data points. However, these are restricted to 'read-only' data points.

Technically, the data points are – with respect to sampling frequency – divided into two message types.

56 data points are collected by the OEM software in the car over the timespan of one minute and then this piece of information is sent to the PSA server in one message block every minute. Some data points in this data set are sampled every second, some every 6 seconds (e.g. the GPS Location of the car), some every 20 seconds and most of the data points are sampled only once every minute.

Assuming the best case for a signal with the highest sampling frequency of once per second, the recipient gets a history of 60 values (one per second) in the message that is sent every minute, but can't still react to it in a timely manner because he has to wait whilst the message for the corresponding minute is sent to the ExVe. A navigation application e.g. would be impossible to be built upon this data access level because with this approach the app could only in retrospective inform the driver "20 seconds ago you should have turned left."

In just three events, the vehicle transmits another message type, the event message:

1. In the event of starting the ignition.
2. In the event of shutting down the ignition
3. In the event of a crash

The "event message" is also a one minute block of data that at best is sampled every second. In total 77 data points are transmitted within this message type.

Most of the data points are present in both message types, some unfortunately only in the rarely sent event message type. The information about upcoming maintenance (300km to your next maintenance) e.g. is only present in the event messages at startup, shutdown or crash.

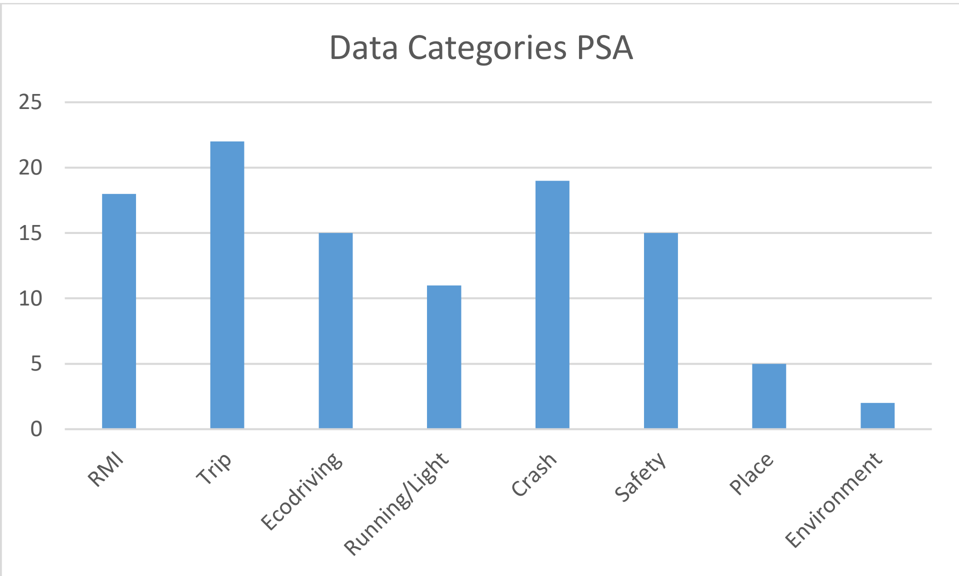

Figure 23: Data Categories suggested by PSA

The categories for the data points above are suggested by PSA. Some data points like "Engine speed" or "Fuel level" appear multiple times, so the sum of 107 over all categories is slightly misleading. PSA talks about "more than 89 signals" in a constantly evolving API. (Although apparently the API hasn't evolved much since 2017.)

5.1.3 Capabilities by Service

In general, the PSA solution lacks every possibility to offer a service to and conduct the service with the customer in the vehicle using in-vehicle displays and controls. Communication has to rely on smartphones.
Furthermore, there is absolutely no write access to the vehicle possible, so resetting a DTC as a typical first try to resolve a problem is not possible.

Service: RMI
In the area of RMI, a fuel service could be offered because data points like fuel level or fuel consumption allow the determination of the next necessary fuel stop.
For maintenance services, the days and or miles up to next scheduled maintenance are included.
The most interesting feature is the handling of alerts signalled to the driver. Within an event message at startup or shutdown – unfortunately not whilst driving! - the alerts displayed to the driver in the cockpit are transmitted ("excessive engine temperature", "insufficient coolant level"). However, it is unclear due to lack of documentation on the website and in the forums if this feature covers a significant portion of the DTCs usually needed for a solid Aftermarket RMI service.

Other services:
Other services that might be possible with the PSA approach are:

1. e-Call
2. Driving style insurance
3. Crash analysis

But, as stated above, apparently the solution has as of now not attracted many developers and not led to many working solutions.

5.2 Technical Capabilities for OEM

PSA has as an OEM an unlimited access to the real-time signals and sensors/actors in the car. So, the only On-Board-Diagnostics software as of now is the one from PSA which generates all the alerts about vehicle needs and malfunctions and displays them to the driver via in-car displays. In so far that is neither astonishing nor technologically very advanced (in terms of communicating with the driver), the quality of the Diagnosis itself can't be judged in the scope of this study. For unknown reasons however, PSA misses out on the chance to make better use of its driver communication privilege, e.g. it's Applications myPeugeot/myCitroen have neither Android Auto nor Apple Carplay abilities. Thus, they can't be safely operated whilst driving, although newer models of PSA have "MirrorScreen" aboard, a technology that encompasses AppleCarplay, Android Auto and MirrorLink.

5.2.1 Description Solution

The English version of the myPeugeot app can be found on:
https://www.peugeot.co.uk/lp-mypeugeot-app/
The version for Citroen offers the same functionalities and is labelled myCitroen.

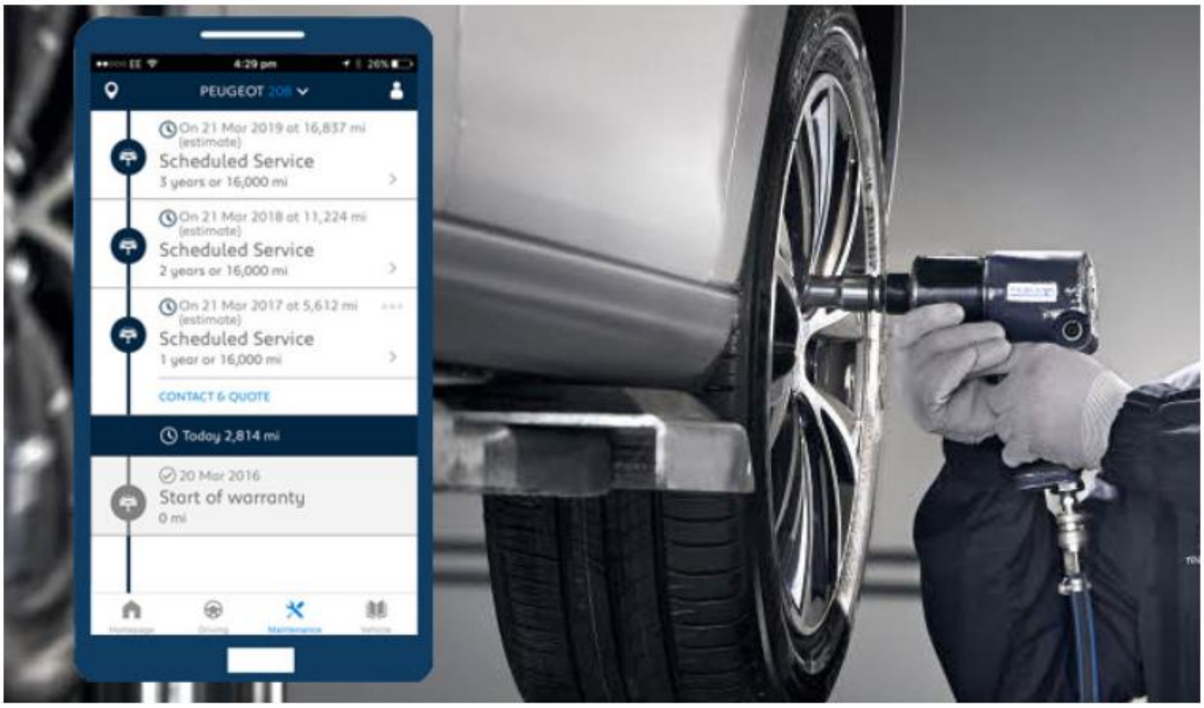

Figure 24: the RMI section of the myPeugeot app

Technically the solution is available for both Android and IOS-systems, as mentioned above, the apps lack support for the car versions of Apple's and Google's operating systems.

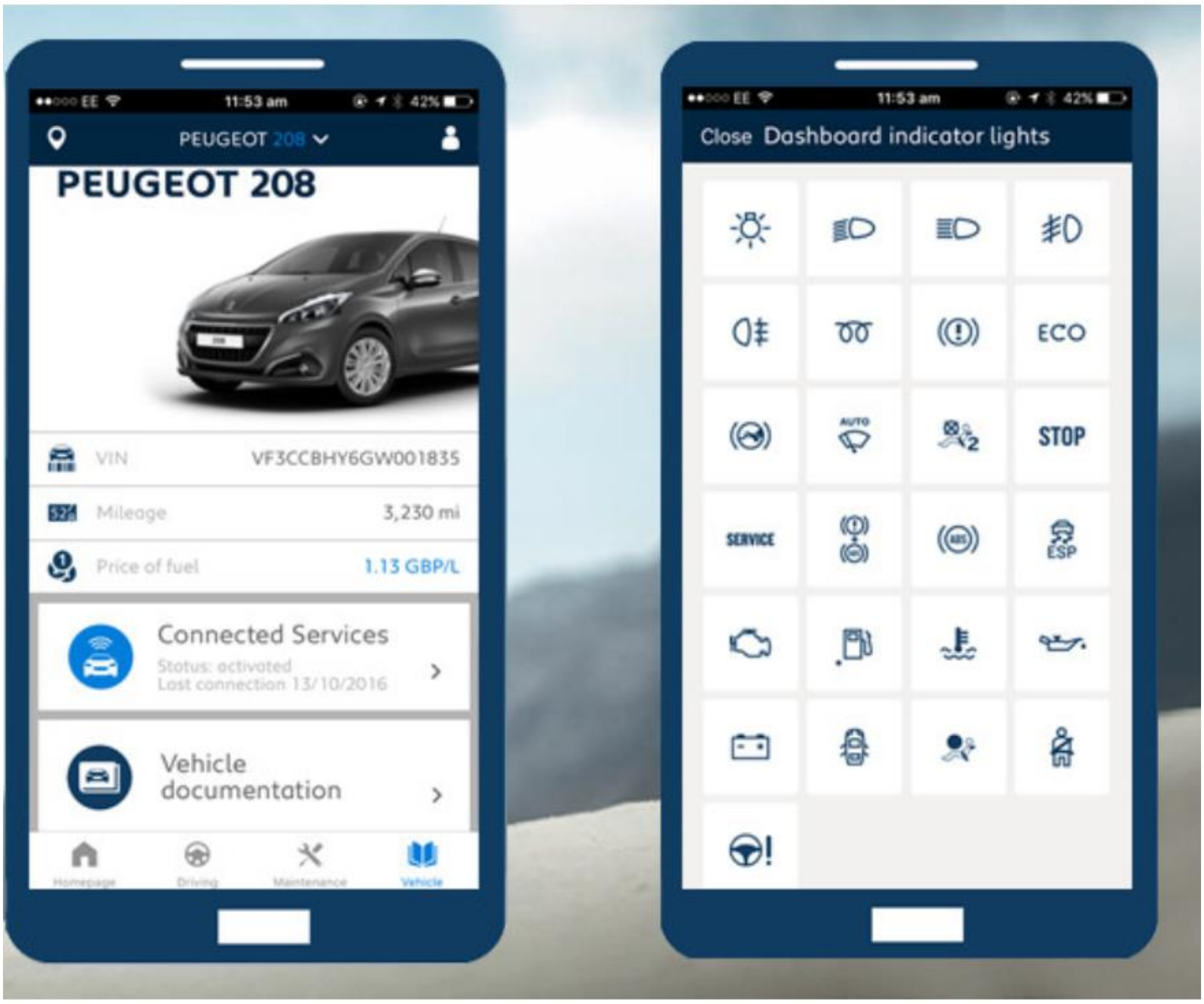

Figure 25: The services and alert section of the myPeugeot App

Apart from the RMI services above, the app offers:

- Vehicle tracking
- Driver's log
- Fuel handling
- Peugeot News service

Summing up, there are no real-time services involved and there is as of now no possibility to trigger actions in the car, e.g. to lock/unlock doors remotely as displayed by various other OEM proprietary apps.

When comparing the functionalities offered by the App with the PSA ExVe, it really looks as if the PSA app is based just on the data offered to 3rd-parties via the ExVe whilst of course the PSA diagnosis software in the car has access to the full extent of signals, sensors and actors in the car.

5.2.2 Access to Data

When it comes to telematics, PSA seems to have developed three parallel systems:

1.) The PSA diagnosis software in the car
2.) The myPeugeot/myCitroen Apps
3.) The MirrorScreen technology

The PSA diagnosis software in the car will of course have unrestricted and unlimited access to all data points, signals, ECUs, sensors and actors in the car to come up with an OEM diagnosis result, e.g. an alert on the driver's screen. The full extent of signals is not documented in a publicly available format.

The myPeugeot/myCitroen apps however seem to really access just the PSA ExVe. So, in terms of RMI they can't do a diagnosis on their own, but just display the result of the Peugeot Diagnosis (e.g. the determined alert) on the driver's smartphone.

The third technology, MirrorScreen, would offer just a very limited set of in car data points, but could be used for a better interface to the driver. For unknown reasons, PSA doesn't make use of this technology for its myPeugeot/myCitroen-app.

5.2.3 Capabilities by Service

Service RMI:

PSA has the full access to the in-car signals, thus is the only party who can up to now provide in-car diagnostics. Prognostic support seems to be very limited when the myPeugeot-App and the ExVe data points only offer support for fixed date, fixed mileage maintenance.

Other services:

As already stated, PSA offers:

- Vehicle tracking
- Driver's log
- Fuel handling
- PSA News service

5.3 Comparison and Rating

The IAM-offer of the PSA ExVe seems to be the technological basis for the myPeugeot-App as well, so in this perspective IAMs could theoretically compete on equal terms at first sight.

In reality however, the foundation for every aftermarket activity, the independent diagnosis inside the vehicle, remains in the exclusive access by PSA, as does the access to the driver via in car displays and controls.

5.3.1 Capability to offer a service to the customer

VM capabilities:

In-Car apps and controls, Smartphone:

IAM capabilities:

Restricted to Smartphone

Abilities to offer a service	VM	IAM
In-car Apps	✓	
In-car controls	✓	
Voice recognition		
Smartphone	✓	✓

IAM: 33%

OEM: 100%

5.3.2 Capability to conduct a service with a customer

Abilities to conduct a service	VM	IAM
In-car-Apps	✓	
In-car controls	✓	
Voice recognition		
Smartphone	✓	✓

IAM: 33%

OEM: 100%

5.3.3 Capability to monitor the need of the thing (the car) for a specific service

VM capabilities:

Only the in-vehicle OEM software can currently monitor DTCs and alerts.

Maintenance however is currently based on fixed mileage/fixed data and equally offered to IAMs via the PSA ExVe.

IAM capabilities:

IAM can’t come up with independent diagnosis, can only display OEM diagnostic results.

Abilities to monitor a service need	VM	IAM
Check for DTCs, alerts	✓	
Check fixed mileage service	✓	✓
Prognostics		

Currently the OEM doesn’t offer prognostics (although technically he is likely in a position to do so), the IAM can’t offer prognostics because the technical abilities of the PSA ExVe are too limited for this task.

IAM: 50%

OEM: 100%

5.3.4 Capability to actually perform the service on the thing (the car)

Within the scope of the study, the extent to what PSA is really able to do could not be evaluated.

Abilities to perform RMI in the vehicle	VM	IAM
Full diagnostics		
Delete DTCs		
Reprogram Over the Air		

Thus, the rating for this aspect could not be determined.

5.3.5 Rating

The PSA ExVe was the first ExVe to enter the market in 2016.

In comparison to other Extended Vehicle solutions, it still scores pretty high:

a.) It offers more data points than the BMW CarData and the (experimental Mercedes ExVe)

b.) It's sampling frequencies (sample some signals internally every second, transmit a subset of the signals in one block from the car to the server every minute) are far better than the "Just one transmission after ignition off"-approach of BMW.

The only disadvantage in comparison to the -admittedly experimental – Mercedes ExVe would be the lack of any write access to the car as demonstrated by the door lock/unlock feature of Mercedes. Although this feature still has to make it into a production environment.

However, as a typical ExVe and thus server based solution, it lacks by technical design every ability for independent real time in car diagnostics and it has zero support for safe & secure driver interaction because the user interface will always be restricted to a smartphone.

The interesting aspect of the PSA ExVe for this study is the market reception of the solution because it has now been available for more than 18 months.

Judged by the internet, the interest is nearly zero. (see e.g. the very few developers in the support forum, lack of any Google News around the topic in the current year).

A possible analysis that will likely uphold for other ExVe based solutions is the following:

a.) The classical users and companies of the core aftermarket (e.g. Diagnostic Tool suppliers) miss vital technical elements like in-car apps, driver interaction and real time support). For them, retrofit OBD-Dongles are not perfect, but are still a better fit than the possibilities offered by ExVes. This may explain the low interest amongst this group.

b.) For Non-aftermarket developers, the customer base is too small. No one will spend time and effort for solutions that are just useful for some rare owners of new PSA models, when with a similar effort, the developer can reach billions of Android or Apple users.

6 Analysis OEM Volkswagen

Volkswagen has not yet presented a solution for independent access to the car, but an approach proposed to the world-wide web consortium (W3C) at the end of 2016 is led by Volkswagen.

It is an in-vehicle solution based on web services and thus from a technology viewpoint more comparable with the GM NGI approach than to the Extended Vehicle Solutions developed by PSA or Mercedes. The original solution was called ViWi - Volkswagen Infotainment Web Interface.

Because the solution is still under development, all findings within this study have to be regarded as preliminary results. Nevertheless, at first sight the concept looks sound and shows that like the already in-use GM NGI example, it shows that once more, safe and secure in-vehicle solutions are possible. The submission at the W3C for a worldwide standardization exemplifies that the idea of a standardized Open Telematics Platform obviously must have its merits for OEMs as well.

6.1 Technical Capabilities for IAM

The solution is aimed at giving applications running in the in-vehicle infotainment system as well as every other device connected via TCP/IP a unified, safe and secure access to in-vehicle resources and functionality, enabling reading as well as write access to the car to trigger functionalities on the system's resources.

6.1.1 Description Solution

The original submission request can be found at:

https://www.w3.org/Submission/2016/01/

The general architecture resembles a typical web service approach.

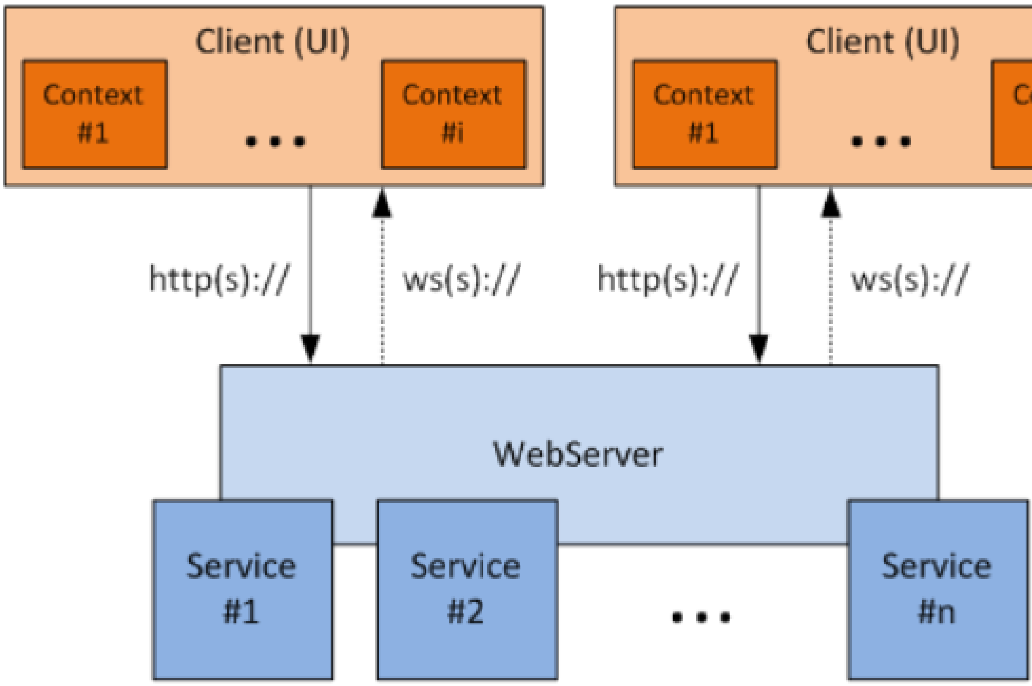

Figure 26: ViWi-Architecture

The elements in blue represent the in-car abstraction layer of the car's systems, resources and functionalities. Every request for a specific signal and every command to trigger a specific functionality is transferred via the web service protocol.

Because these elements are in the vehicle, real time access to the car is possible with ViWi.

An application running inside the vehicle would in this drawing be presented by a web service Client (Orange Box) and the application is responsible to render its user interface for the user during the operation of the service.

In the current state of discussion, a user interface using pure HTML5 applications seems to be favoured. This is exactly the approach of the GM NGI and like in this case, the need to develop two applications for the user interface (One for Android Auto, the other for Apple Carplay) would be eliminated.

It would be sufficient to write this code only once and have it deployed on every vehicle of every brand that supports ViWi. (Same approach as in OTP)

As for the extent of data available, the original ViWi document identifies different Services.

The most interesting for the IAMs is likely to be the "car"-web service, encompassing the resources (Name, Number of data points/ typical data points):

- /car/info/ 6 (vehicle type, VIN..)
- /car/environments/ 5 (darkness, rain level..)
- /car/drivingstates/ 16 (accelerators, engine speed..),
- /car/engines/20 (oil temperature, Power output..)
- /car/consumptions/ 4 (current consumption in e.g. km/kwh or mpg..)
- /car/batteries/ 7 (capacity, charging state..)
- /car/fueltanks/ 7 (Level, capacity..)
- /car/gastanks/ 7 (Level, capacity..)
- /car/gearboxes/ 9 (e.g. recommended gear..)
- /car/distances/ 10 (distance trip, avg speed etc...)
- /car/ranges/ 4 (range..)
- /car/services/ 5 (Type of Service, due Date..)
- /car/times/ 7 (time, UTC offset..)
- /car/units/ 14 (units for distance, consumption..)
- /car/doors/ 3 (status for all doors and windows)

Adding up these data points for just the service "Car" up, totals 124 Data points.

This is just an estimate, because e.g. the resource "doors" looks in detail:

name	description	type	format	unit(s)	value(s)
id	identifier	string	uuid		-
name	name	string			-
uri	object uri	string	uri		-
position	the vehicle door position	string			bonnet front_left front_right rear_left rear_right boot
isDoorOpen	the door state; set to 'true' if the door is open	boolean			-
isWindowOpen	the window state of this door; set to 'true' if window is open; set to JSON-undefined if window state is unknown or invalid	boolean			-

Figure 27: Resource details for "door"

The detailed design reveals that in fact at best the status for 4 windows and 6 “doors” (including 4 doors plus bonnet and boot) can be determined, so in terms of data points this resource offers 10 data points and not just 3.

On the other hand, static information is included like in “units” (14 Datapoints) which is by definition not so useful to query whilst driving as a dynamic data point like the current fuel level.

In total the picture for data points per subcategory/resource of service “Car” looks like this:

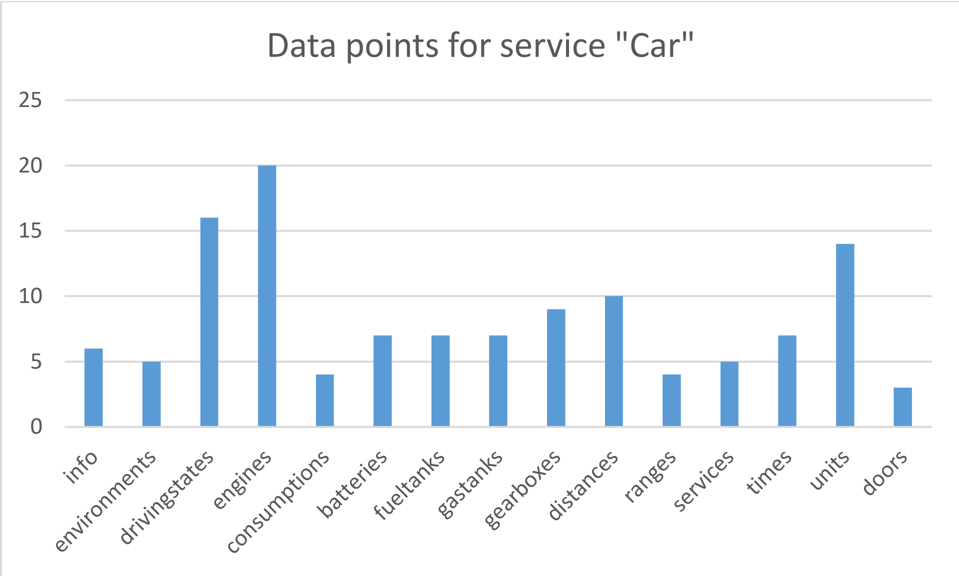

Figure 28: Overview for data points per resource within the service "car"

Without going too much into detail, it can be seen that services like:

- Driving style based insurance
- Door-Lock/unlock for Parcel Delivery
- Refueling/Charging optimisation

Would be easily possible given the information above.

As for RMI, the information available is sufficient for fixed mileage/ fixed time maintenance.

However, prognostics, real time diagnostics or even the transmission of current DTCs determined by an OEM on-board-diagnosis are currently not included.

As an example, find below the information available for the resource “services” (Service needs):

typeOfService	The service data are related either to inspection service or to oil service.	string			inspection oil airFilter oilFilter
distance	The distance in miles or kilometers when the service is due or since the service is overdue. If the service is overdue, then distance < 0. If the service is due today, the distance == 0. If the service is due in <x> km or mls, then distance == x.	integer			[-204700..204700]
distanceunit	the variable unit belonging to the property 'distance'	string	distance		-
time	The time in days when the service is due or overdue. If the service is overdue, then time < 0. If the service is due today, the time == 0. If the service is due in <x> days, the time == x.	integer		d	[-2048..2048]
intervalReset	the interval to be or being reset in a comma separated list	array			distance time

Figure 29: Information available for the resource "services"

6.1.2 Capabilities by Service

When the ViWi is implemented, the IAM providers would – like in the GM NGI example – have the possibility to access the car’s signals, resources and functionalities in real time. As for the access to the driver: how applications of IAMs can enter the in-vehicle infotainment system is not described within the scope of this document. Other discussions within the group that are publicly available reveal that a similar approach to GM is envisioned – write Applications in HTML5, have them deployed over an OEM app store after certification.

Service: RMI

In the current state of the ongoing development, the approach could be a viable solution to offer competitive IAM-proposals for service and maintenance needs to the customer along the OEM proposals for a 'fair customer choice'.

Although technically possible because of the real-time access, the solution does – as of now – not allow the ability to query ECUs in real time for a truly independent IAM on-board-diagnosis.

Based on the extensive coverage of the driving style information, initial tryouts for a sort of prognostics in terms of assumed tyre or break pad wear are possible.

Other services:

Just taking into account the service "car", ViWi indicates that:

- Driving style based insurance
- Door-Lock/unlock for Parcel Delivery
- Refueling/Charging optimisation

Would be possible IAM services.

Other services within ViWi deal with typical entertainment resources like images, videos, music, radio stations etc and would likely offer the possibility to create independent media players or similar entertainment applications.

6.2 Technical Capabilities for OEM

Volkswagen's answer today (ViWI is a proposed future solution) for the connected car is called Car-Net.

It is a closed system, so every Service offered is developed by Volkswagen or it's chosen development partners. There is no open "API" available at this moment, although parts of the interface can be found on GitHub, so that there are already tryouts out there to use the interface with unauthorized software.

6.2.1 Description Solution

The solution can be found on:

http://www.vwcarnetconnect.com/

The first part is the universal smartphone interface.

The solution is called "App-Connect" and offers exactly the same functionality as PSA's "MirrorScreen"-solution.

The smartphone of the user can be handled via Apple Carplay, Android Auto and MirrorLink.

In the same way as for PSA however, the VW Car-Net-application for Android and Apple lacks the respective functionality for Android Auto and Apple Carplay, thus it also misses out on the chance to make the app usable in a safe & secure way whilst driving.

The service "Guide & Inform" offers real time traffic information and fuel pricing during the trip.

With "Security & Service", Volkswagen covers eCall, as well as service handling based on fixed mileage/usage data and some remote control features for the car.

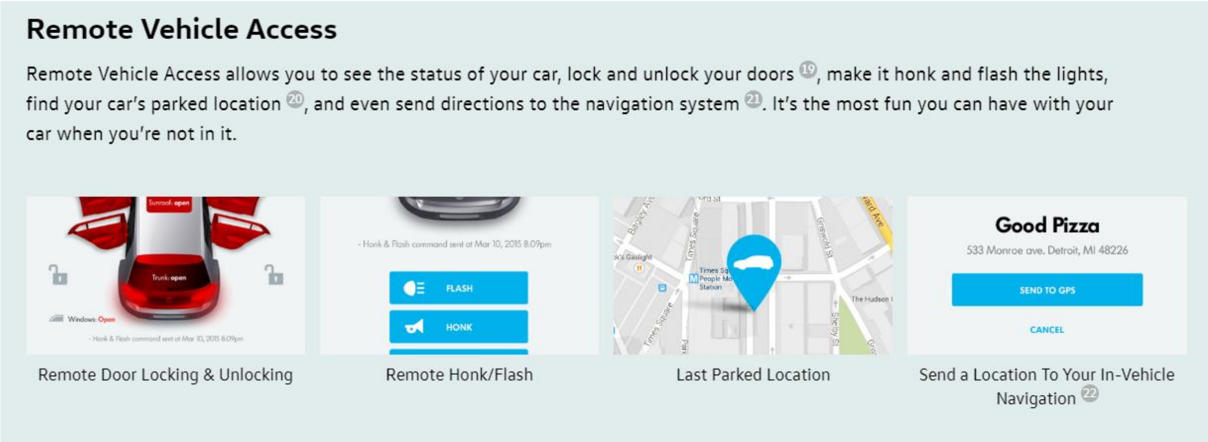

Figure 30: Remote Vehicle Access feature according to vwcarnetconnect.com

In terms of real time access to the car, Volkswagen seems to rely on the Volkswagen diagnosis software in the car, the app itself can only request data and issue commands to the car (Flash the lights, honk the horn, send destinations for navigations, lock/unlock doors) via the Volkswagen server backend.

6.2.2 Access to Data

Like for PSA, Volkswagen seems to have developed three parallel systems:

4.) The Volkswagen diagnosis software in the car

5.) The Car-Net App

6.) The App-connect (equals PSA's MirrorScreen) -technology

Thus, the Volkswagen diagnosis software in the car will of course have unrestricted and unlimited access to all data points, signals, ECUs, sensors and actors in the car to come up with an OEM diagnosis result, e.g. an alert on the driver's screen. The full extent of signals is not documented in a publicly available format.

The Volkswagen app however seem to only access the Volkswagen server. So, in terms of RMI they can't do a diagnosis on their own, but just display the result of the Volkswagen Diagnosis (e.g. the determined alert) on the driver's smartphone.

The third technology, MirrorScreen, would offer just a very limited set of in-car data points, but could be used for a better interface to the driver. For unknown reasons, Volkswagen doesn't make use of this technology for its Car-Net-app.

6.2.3 Capabilities by Service

Service RMI:
Volkswagen has the full access to the in-car signals, thus is the only party who can up to now provide in-car diagnostics.

6.2.3.1 General annotation for Prognostics

As for prognostics however, the usage is restricted for the customer to fixed mileage/fixed time intervals. Given the extent of information available now in a modern car, technically far superior solutions would be possible.

Most OEMs (Volkswagen here being just one out of many OEMs) stick with the fixed intervals in time or mileage. One possible explanation for this is the current business model for servicing.

Today a great part of the revenue with the car is made with service and maintenance.

The customer owns the car and is charged for the respective service by the OEM. The more frequently the customer has to service his car, the better the revenue for the service provider, in this case the revenues in the first years are likely to remain with the OEM.

Prognostics prevail however in business models "Mobility as a service", one simple example being the railroad companies. They sell "mobility" via tickets to customers and they only have to refund them if due to failures (e.g. due to missed services) the transport system is not available. These mobility service providers have to carry the service costs for the mobility system, so for them Prognostics makes perfect sense.

If in the future these "mobility service"-business models expand to car fleets (one example out of many would be Car2Go), it is likely that prognostics will see an increase in the volume of implementations, but for private vehicle owners today, prognostics may reduce the servicing requirements – so would not be a benefit to the OEM.

Other services:

The amount of other services available via the Volkswagen app is very limited.

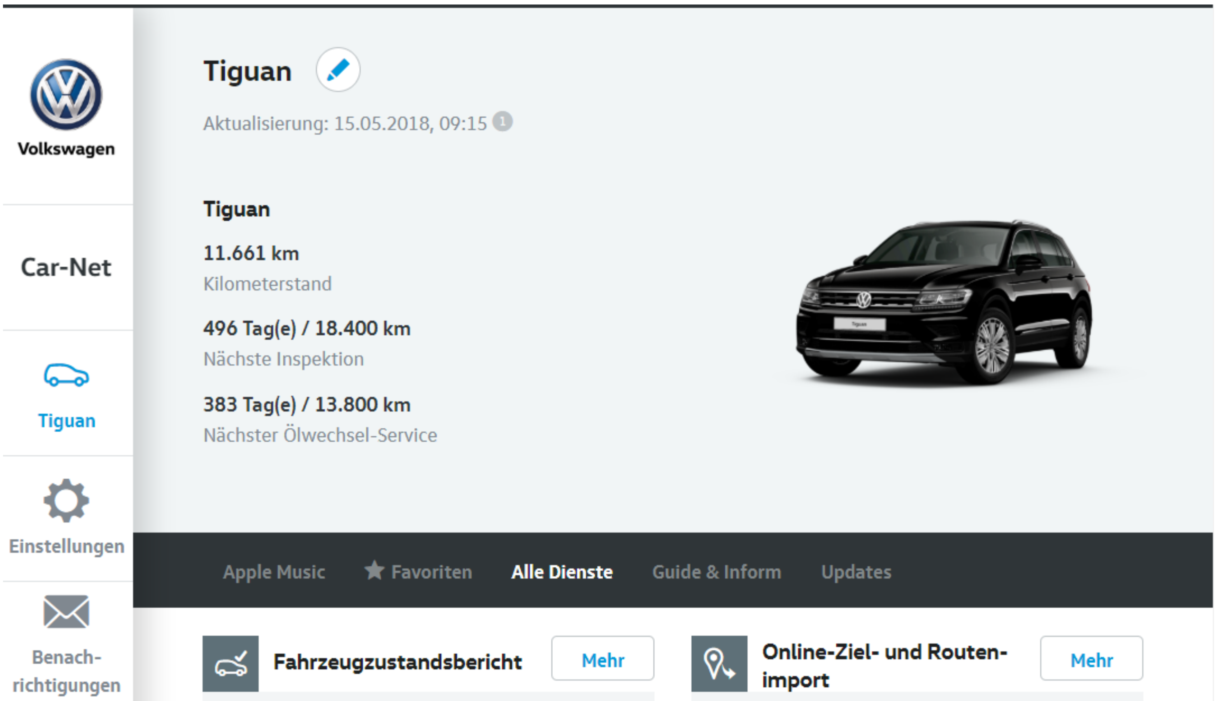

Figure 31; Main Screen of Car-Net website

As of now, it is limited to the sole ability to send navigation destinations to the car.

That explains, why most users in the Google play store are quite disappointed from the app and just assign 1,8 out of 5 stars as a rating.

6.2.3.2 Security concerns

In the past, the solution seemed to have severe security problems. A developer on GitHub (https://github.com/bisho/carnet) discovered and reported the following issues:

"I must confess that the findings are not very encouraging:

- Authentication is done with a sequencial account id and a 4-digit pin, which is totally insufficient for any decent security.
- Authentication seems to be done via IP. After authenticating, you can call to status with totally different transaction_ids and it works.

- There is a pairing mechanism that seems to be used for the more sensible operations (like unlock the car, turn lights, claxon…) BUT there is access to a lot of information without the pairing, including phone and email of the owner, location of the car and much more, which opens the door to social attacks.

I have already contacted the company that runs this service and will let them know about my findings and suggestions."

6.3 Comparison and Rating

Because ViWi is as of now just a proposal to W3C and thus is not realized and ready for use, the IAM comparison is put in brackets together with the overall rating. A proposed system (ViWi) is compared with a currently used system (Car-Net). It is assumed that the process of developing applications for ViWi and hosting it in the Infotainment system would be conducted in a similar way to the GM NGI system which is from the architectural viewpoint very comparable.

6.3.1 Capability to offer a service to the customer

VM capabilities:

In-Car apps and controls, Smartphone.

IAM capabilities:

In car apps and controls, Smartphone

Abilities to offer a service	VM	IAM
In-car Apps	✓	(✓)
In-car controls	✓	(✓)
Voice recognition	✓	
Smartphone	✓	(✓)

IAM: (75%)

OEM: 100%

6.3.2 Capability to conduct a service with a customer

Both the VM and the IAM have equal technical possibilities.

Abilities to conduct a service	VM	IAM
In-car-Apps	✓	(✓)
In-car controls	✓	(✓)
Voice recognition	✓	
Smartphone	✓	(✓)

IAM: (75%)

OEM: 100%

6.3.3 Capability to monitor the need of the thing (the car) for a specific service

VM capabilities:

Only the in-vehicle OEM software can currently monitor DTCs and alerts.

Maintenance however is currently based on fixed mileage/fixed data and would equally be offered to IAMs via VIWI.

IAM capabilities:

IAM can't come up with independent diagnosis, can only display OEM diagnostic results.

Abilities to monitor a service need	VM	IAM
Check for DTCs, alerts	✓	
Check fixed mileage service	✓	(✓)
Prognostics		

IAM: 50%

OEM: 100%

6.3.4 Capability to actually perform the service on the thing (the car)

Within the scope of the study, the extent to what Volkswagen is really able to do could not be evaluated.

Abilities to perform RMI in the vehicle	VM	IAM
Full diagnostics		
Delete DTCs		
Reprogram Over the Air		

Thus, the rating for this aspect could not be determined.

6.3.5 Rating

The ViWi proposal that was sent to the W3C by Volkswagen et.al. is a very promising step towards the development of a unified Open Telematics platform. Though limited in terms of diagnostics depth it relies on open standards (in this matter close to the GM approach with their NGI-system), but by submitting it to the W3C, Volkswagen took the idea of standardization one step further. Thus, it is not the case that just IAM service providers are pushing for an open telematics platform inside the vehicle, at least one OEM (Volkswagen) shows great support for the idea with the ViWi-approach.

Unfortunately, as of now there is no existing system that sticks to the ViWi standard ready to test. So, the rating for ViWi can only be a best guess, but taking into account what it is trying to accomplish, it is the closest approximation today towards a standardized open telematics platform governed by a standards body (in this case W3C).

With the only drawback that the amount of real time data for diagnostics and access to actors is limited, a rating today of 4 out of 5 stars can be granted.

7 Analysis OEM Ford

Ford had in the past developed a technology called Ford Sync that should allow mobile apps from Smartphones to run safely and securely on the car's HMI and that could be controlled by the car's controls. The idea was comparable to the approach taken by Apple and Google for their in-car technologies Apple CarPlay and Google Android Auto.

A developer that would like his app to run inside a Ford had to add Ford Sync specific code to his Android or Apple-application. Once connected to the car, the in-vehicle component of the Ford Sync system queried the phone, to verify which app in the smartphone had this additional Ford Sync code and abilities then rendered them in the car's HMI and made them controllable via in-car controls.

While the technical approach is similar, because of the sheer market power of Apple and Google, Ford-Sync apparently only convinced a few developers to add additional code just for Ford vehicles. A developer that has to choose between adding Android Auto code for his Google App to reach all customers in vehicles equipped with Android Auto, Apple CarPlay Code for his Apple App to reach all customers in vehicles equipped with Apple CarPlay or Ford Sync Code to his Google or Apple App to reach just all Fords equipped with Ford-Sync is always likely to develop for the far greater customer base in the widely used platforms Android Auto and Apple CarPlay.

Below is a picture of the full list of Android apps available for the latest Ford Sync version.

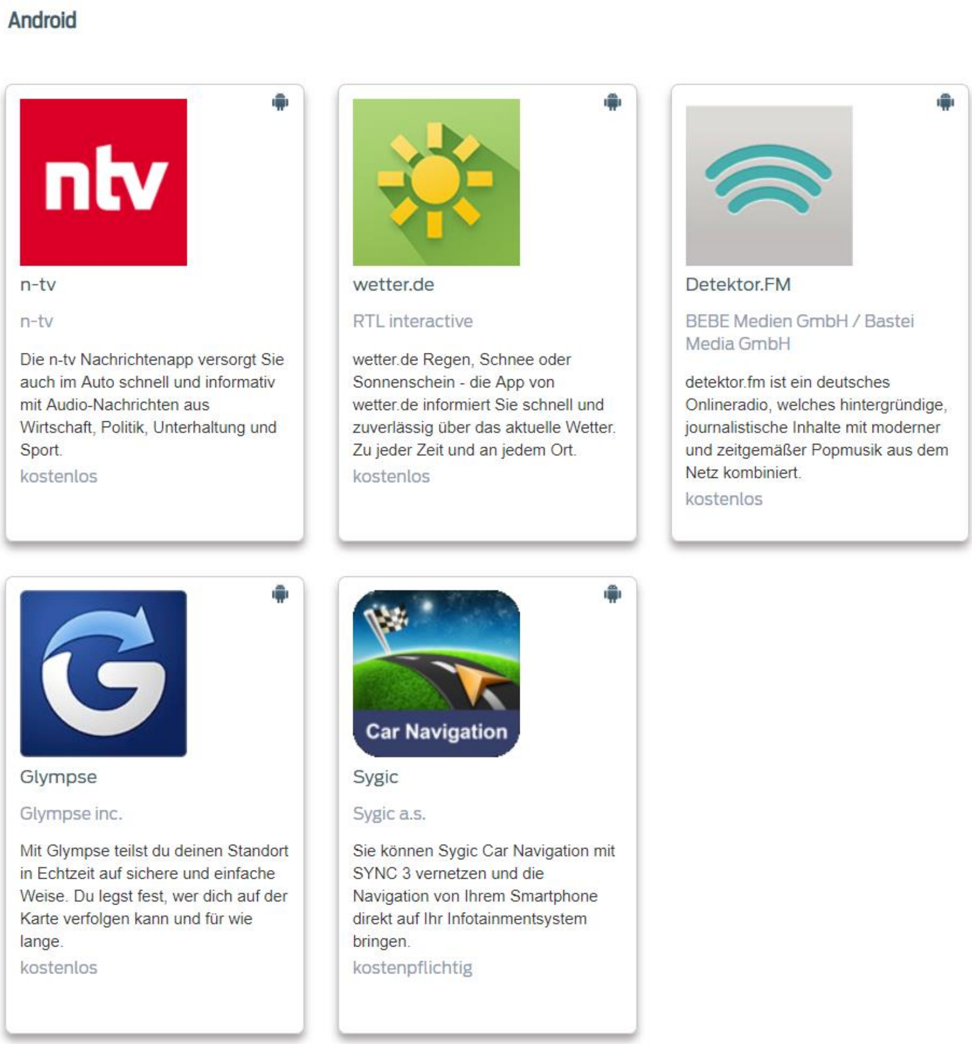

Figure 32: List of all Sync Apps available for Android on Ford (For IOS the total is 7) https://secure.ford.de/Rund-um-den-Service/Ford-SYNC/App-Katalog/

This limited success is due to the fact that Apple Carplay and Android Auto are becoming available in more and more cars of different brands, make and models. When the effort to make an application ready to use inside the car is comparable between two technologies (say Ford Sync or Android Auto), a developer is likely to code for the platform on which he can reach more customer and sell more apps or services. So, most developers code for either Apple Carplay and/or Android Auto and only few opt for the support for Ford Sync.

This market response has led Ford to the idea of opening their former proprietary solution to other OEMs.

The new solution is called Smart Device Link (SDL) and is run by a consortium:

https://www.smartdevicelink.com/members/

Amongst the OEMs, Ford, Suzuki and Toyota expressed the greatest interest (Diamond Members), followed by Mazda, Subaru (Platinum), Isuzu, Nissan, PSA (Gold) and Daihatsu, Mitsubishi (Silver).

Technically it is another in-vehicle solution and thus comparable to the other in-vehicle platforms, from the approach (Add additional code to smartphone apps for Google and Apple) it can be best compared to the Apple Carplay and Google Android Auto solutions.

7.1 Technical Capabilities for IAM

With SDL, the IAMs get another possibility aside CarPlay and Android Auto to reach the driver in the car. As a bonus, the functionality is not just limited to HMI and phone interaction, but offers more information about the car (On top of very basic vehicle information like Fuel Level it is e.g. possible to request Diagnostic Trouble Codes from a car.) Write access however is limited to the entertainment system (Playing music, setting navigation destinations, making calls) and subject to consensus of individual OEMs.

https://www.smartdevicelink.com/en/guides/android/setting-the-navigation-destination/

7.1.1 Description Solution

The solution can be found on:

https://www.smartdevicelink.com/

While the solution is open source it still needs group of core Project Managers and Project maintainers. Thus, Ford purchased the company Livio and tasked them with moderating and hosting the SDL development. The following pictures are screenshots from a presentation that Livio's CTO, Joey Grover, published on the SDL website (https://d83tozu1c8tt6.cloudfront.net/media/resources/sdl_overview_and_update.pdf).

The first picture show that different OEMs (Ford just being one of them who can incorporate SDL technology in their respective entertainments systems in branded form. Ford assigned its own implementation of SDL the name "AppLink" while other OEMs might call their implementations "MYAPPS" or "Connect Link 9000".

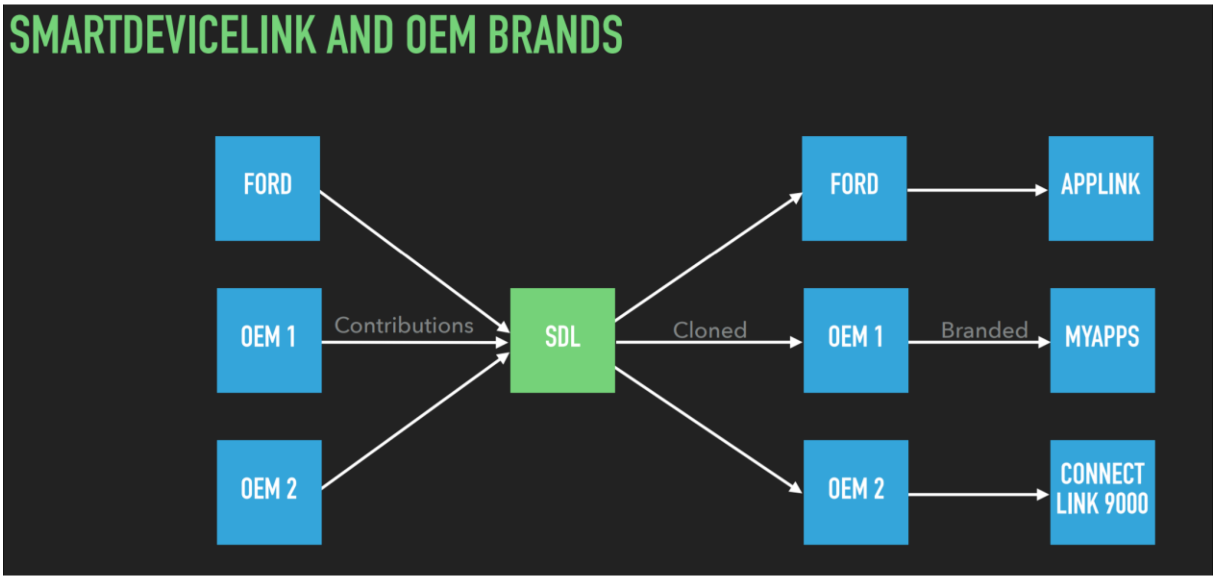

Figure 33: Different OEMs can implement SDL in branded format.

Technically SDL has one component (Software library) on the phone of the user and one in-vehicle component.

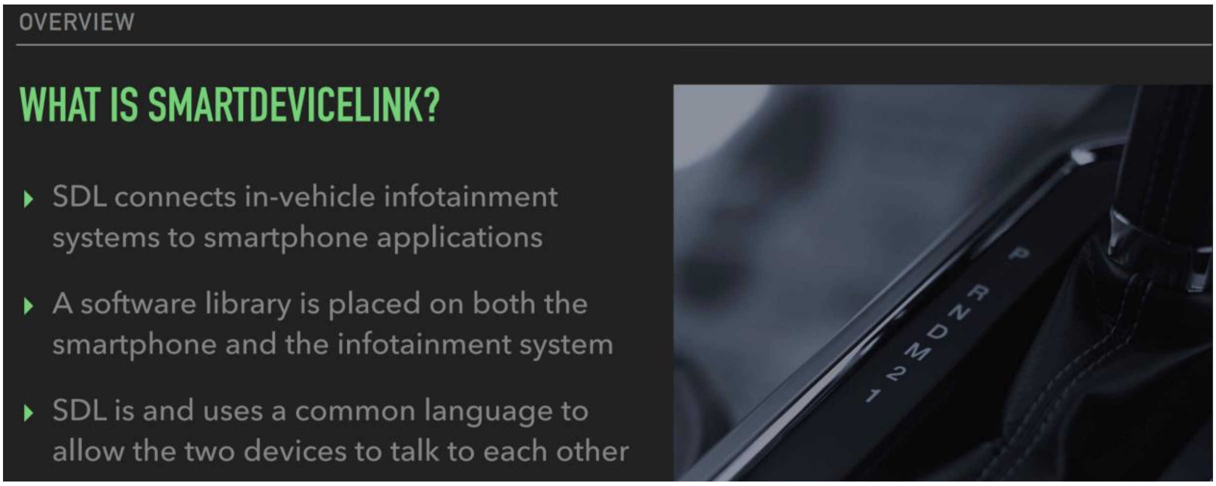

Figure 34: Definition of SDL

The general idea of this standardization approach is "Write Once, run anywhere".

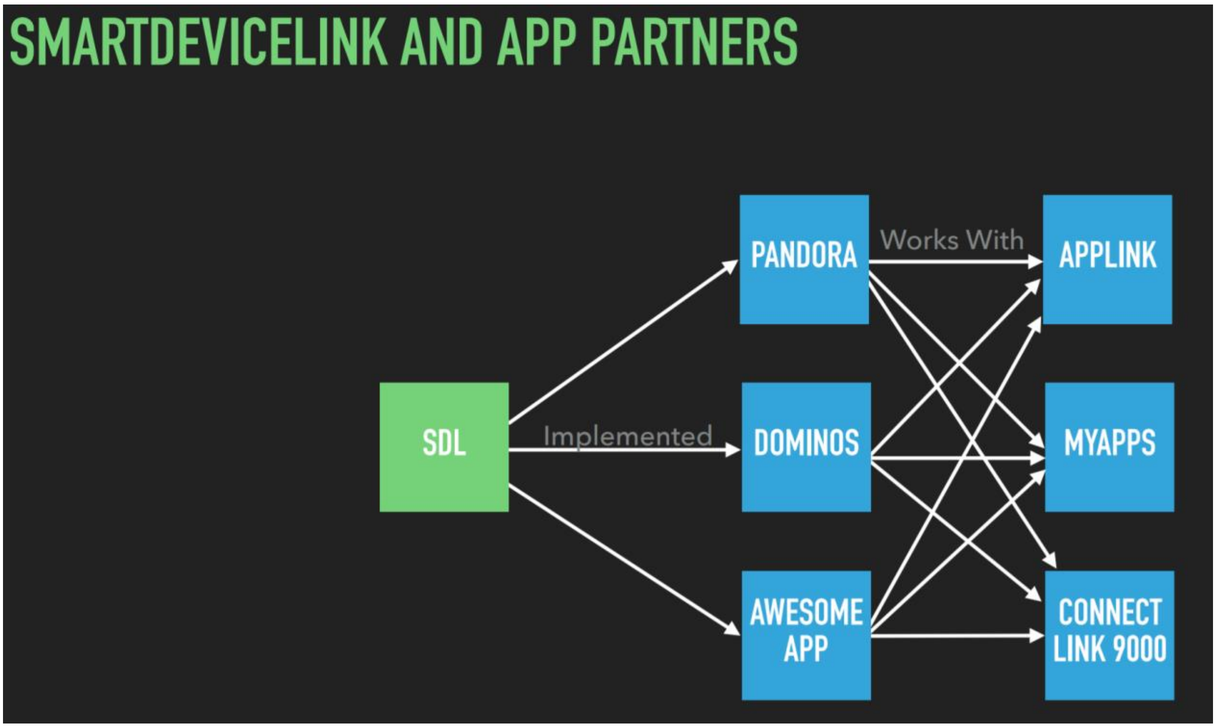

Figure 35: An SDL app will run on any OEM-platform that has implemented SDL

As it is the case for Apple CarPlay and Android Auto, a developer should have to add the additional code of SDL only once to his mobile phone application and have it enabled for usage in all vehicle of all OEMs that support SDL.

Data points available

In comparison to CarPlay and Android Auto, SDL offers a deeper access to the vehicle.

As of now, the following data points are available according to the API-documentation:

gps	GPS data. See GPSData for details
speed	The vehicle speed in kilometers per hour
rpm	The number of revolutions per minute of the engine
fuelLevel	The fuel level in the tank (percentage)
fuelLevel_State	The fuel level state
instantFuelConsumption	The instantaneous fuel consumption in microlitres
externalTemperature	The external temperature in degrees celsius
prndl	Currently selected gear.
tirePressure	Tire pressure status
odometer	Odometer in km
beltStatus	The status of the seat belts
bodyInformation	The body information including ignition status and internal temp
deviceStatus	The device status including signal and battery strength
driverBraking	The status of the brake pedal
wiperStatus	The status of the wipers

headLampStatus	Status of the head lamps
engineTorque	Torque value for engine (in Nm) on non-diesel variants
accPedalPosition	Accelerator pedal position (percentage depressed)
steeringWheelAngle	Current angle of the steering wheel (in deg)
eCallInfo	Emergency Call notification and confirmation data.
airbagStatus	The status of the air bags.
emergencyEvent	Information related to an emergency event (and if it occurred).
clusterModeStatus	The status modes of the instrument panel cluster.
myKey	Information related to the MyKey feature.

Figure 36: Data Points available in SDL

In total 24 data points are available in the sense that a developer can query the data point and subscribe to it so that his application gets informed once a data point changed its value.
The sampling frequency and access speed is not prescribed by the SDL standard, this depends on the respective OEM's implementation of the standard.

Diagnostic abilities of SDL

A strong point is made by SDL when it comes to diagnostic support.
Two functions within SDL are responsible for that: ReadDID and GetDTC.

###ReadDID###

Non-periodic vehicle data read request. This is an RPC to get diagnostics data from certain vehicle modules. DIDs of a certain module might differ from vehicle type to vehicle type.

HMI Status Requirements

HMILevel needs to be FULL, LIMITED, or BACKGROUND.

Request

Param Name	Type	Description	Req.	Notes	Version Available
ecuName	Integer	Name of ECU.	Y	Minvalue: 0 Maxvalue: 65535	SmartDeviceLink 2.0
didLocation	Integer	Get raw data from vehicle data DID location(s).	Y	Minvalue: 0 Maxvalue: 65535	SmartDeviceLink 2.0
appID	Integer	ID of the application that requested this RPC.	Y		SmartDeviceLink 2.0

Figure 37: Description of the ReadDID function within SDL. https://github.com/smartdevicelink/sdl_android/wiki/API-Reference

While there is no standardization available for ECU-numbering in the sense that “ecuName = 1” would always refer to the Airbag-ECU and so the app developer still has to know the detailed numbering of a respective vehicle, he nevertheless has the ability for an in-depth access to the car’s ECUs.

The same holds true for the other function, “GetDTCS”.

GetDTCs

This RPC allows you to request diagnostic module trouble codes from a vehicle module. HMI Status Requirements

HMILevel needs to be FULL, LIMITED, or BACKGROUND.

Request

Name	Type	Description	Reg.	Notes	Version
ecuName	Integer	Name of ECU.	Y	Min Value: 0 Max Value: 65535	SmartDeviceLink 2.0
dtcMask	Integer	DTC Mask Byte to be sent in diagnostic request to module.	N	Min Value: 0 Max Value: 255	SmartDeviceLink 2.0

Figure 38: Description of the GetDTCs-Function within SDL

These two functions really separate SDL as of now from all other solutions that are currently on the market.

7.1.2 Capabilities by Service

It has to be noted that the access to some functions of SDL depends on the consensus of the respective OEM. Within the scope of this study a registration as a Ford and as an SDL developer was conducted to get access to all of the development information presented in this study. However, it was out of scope to develop a real application and have it tested on a real SDL-compliant vehicle. So, the following assessments are based on the technical features described in the SDL documentation.

Service: RMI

For unknown reasons SDL offers no functions to determine the next scheduled service (Neither based on fixed mileage/duration), nor any type of prognostics.

However, their in-depth functions Read DIDs and GetDTCs would render it an ideal solution to transfer the Know-how from Diagnostic Tool companies from the cable-bound OBD-era to the Digital future where this information can be retrieved remotely via Application.

Other Services

Just taking into account the supplied data set two service types are likely:

- Driving style based insurance
- Refueling optimisation

Other services within SDL deal with exactly the main services of its competitors Android Auto and Apple CarPlay: Navigation, Phone, Entertainment.

Outlook

Currently the access to in car actors is limited to the HMI system (Media, Phone).

In the future, SDL is aiming at enhancing the set of accessible actors.

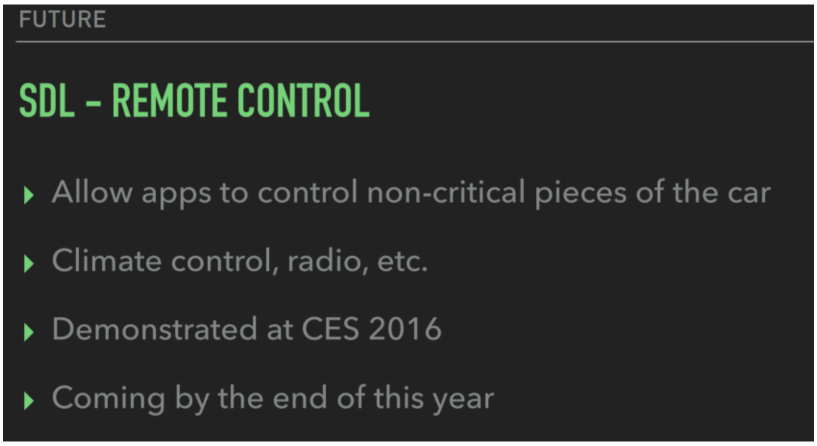

Figure 39: Intended write access in the future

To allow for a safe & secure access just for tested applications, each and every SDL-application gets a unique ID by which it can be identified.

Only certified apps will get access to the more sensitive actors of the car.

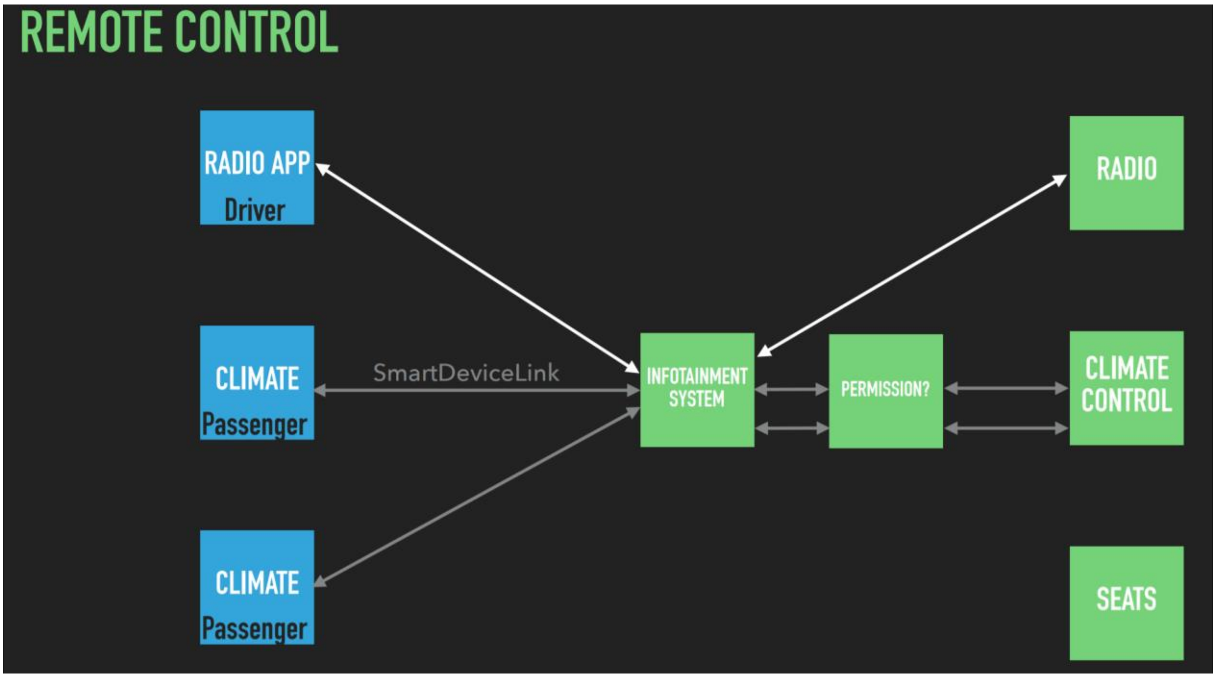

Figure 40: Future access control for apps to actors

7.2 Technical Capabilities for OEM

The technical abilities for Ford are very similar to those of the other OEMs in this study.

For this reason, the description in this chapter is kept short.

7.2.1 Description Solution

The technology used inside the vehicle is the aforementioned Applink (Ford's branded implementation of SDL).

For the convenient control of the vehicle via smartphone, Ford has developed the Applications:

- Ford Pass
- Ford Pass connect

The latter one is the technically more advanced solution with access to car controls (Start/stop engine, Lock/unlock doors) and apparently only available in the United States. The German app store for android just contains the more basic version Ford Pass.

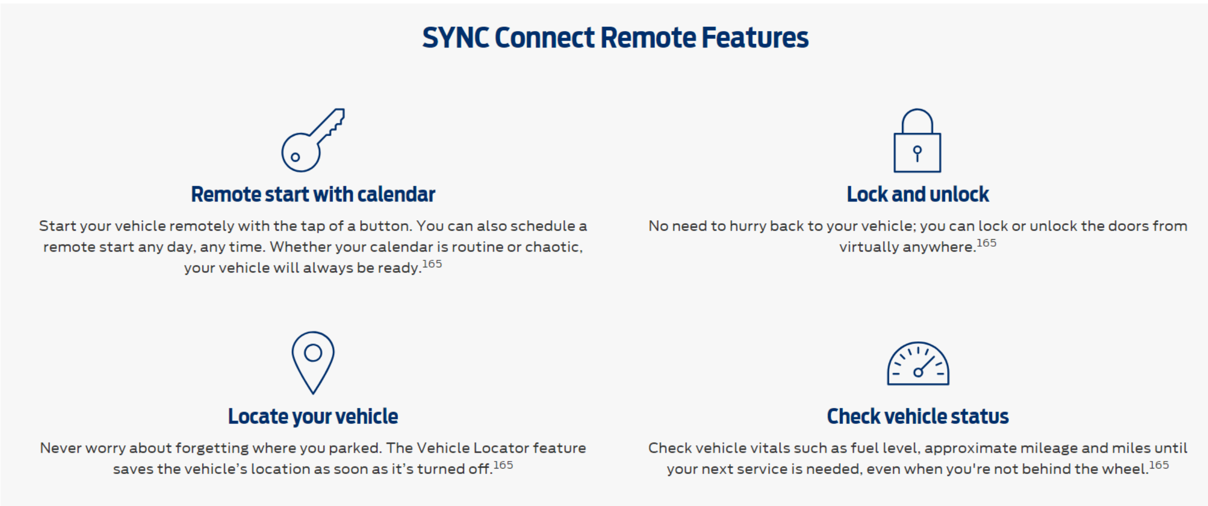

Figure 41: Sync-connect features. https://owner.ford.com/fordpass/fordpass-sync-connect.html

The basic functionalities for the Ford Pass app are:

Navigation using Live Traffic data

Basic car information like fuel level, tire pressure and next service appointments

Send navigation targets from the smartphone to the car

Find points of interests (From Café to fuel station and Ford Dealers).

7.2.2 Access to Data

As for most OEMs, Ford has the sole ability to deploy the diagnostic software in the car which determines on-board in real time the current Problems, Alerts and Diagnostic Trouble Codes. In addition, the Ford Pass Apps offer a very limited remote control and remote monitoring of the Ford cars.

As for PSA, Volkswagen and other OEMs, Ford has not developed Android Auto or Apple CarPlay versions of these apps, although these platforms are available for more and more Ford vehicles.

7.2.3 Capabilities by Service

Service RMI:

Ford has the full access to the in-car signals, thus is the only party who can up to now provide in-car diagnostics. Prognostics is not used publicly; the service intervals are up to now still based on mileage or time.

7.3 Comparison and Rating

A comparison and rating between Ford's own capabilities and that of an IAM developer using SDL is hard to determine because a practical tryout of SDL was out of the scope for this overview study. As of now, the authors of this study have registered themselves and the company as SDL developers but it is yet to determine, if an IAM app developed would make it into a car with the full set of functionalities offered via the API of SDL.

Two possible obstacles are:

The OEMs might disapprove the concept of an app as a whole.

The OEMs might refuse to grant access to a single technical feature of SDL that the app needs to fulfil its task.

If an app developer wants to write an SDL application, he has to specify his app, check all desired basic functionalities that might require an OEM grant and he has to select the OEMs for which he would like this app to work with.

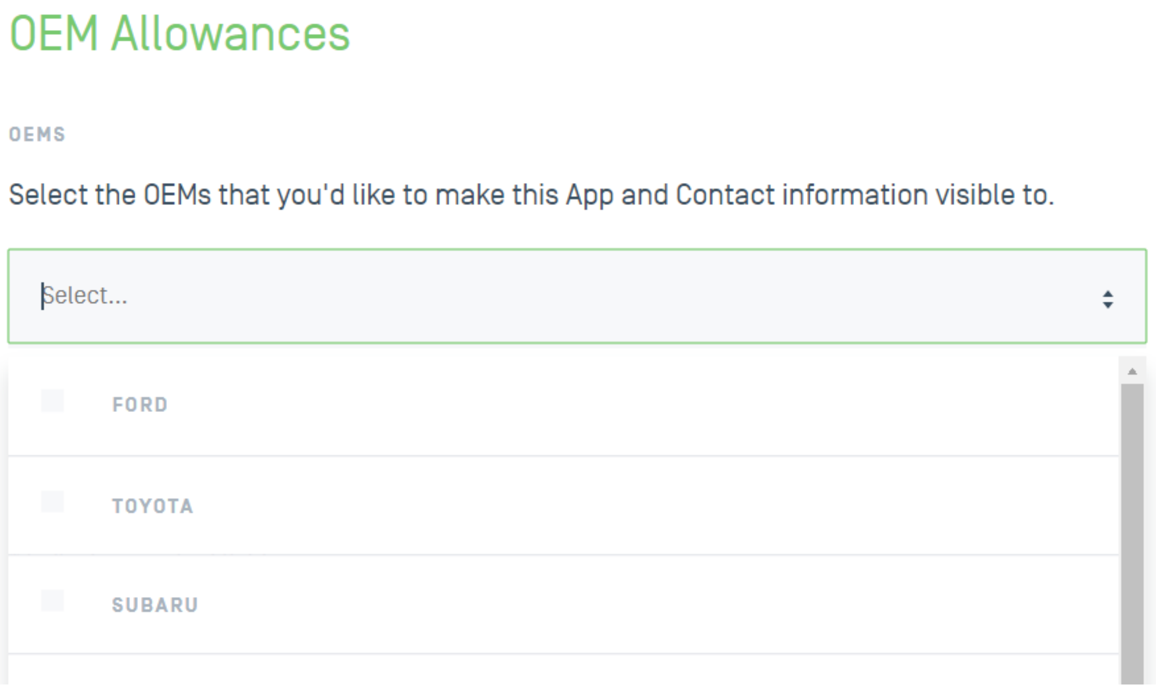

Figure 42: Selecting OEMs that need to accept the SDL app. https://www.smartdevicelink.com/profile/companies/182/app_id/new/

In addition to this, a long list of detail permissions needs to be checked.

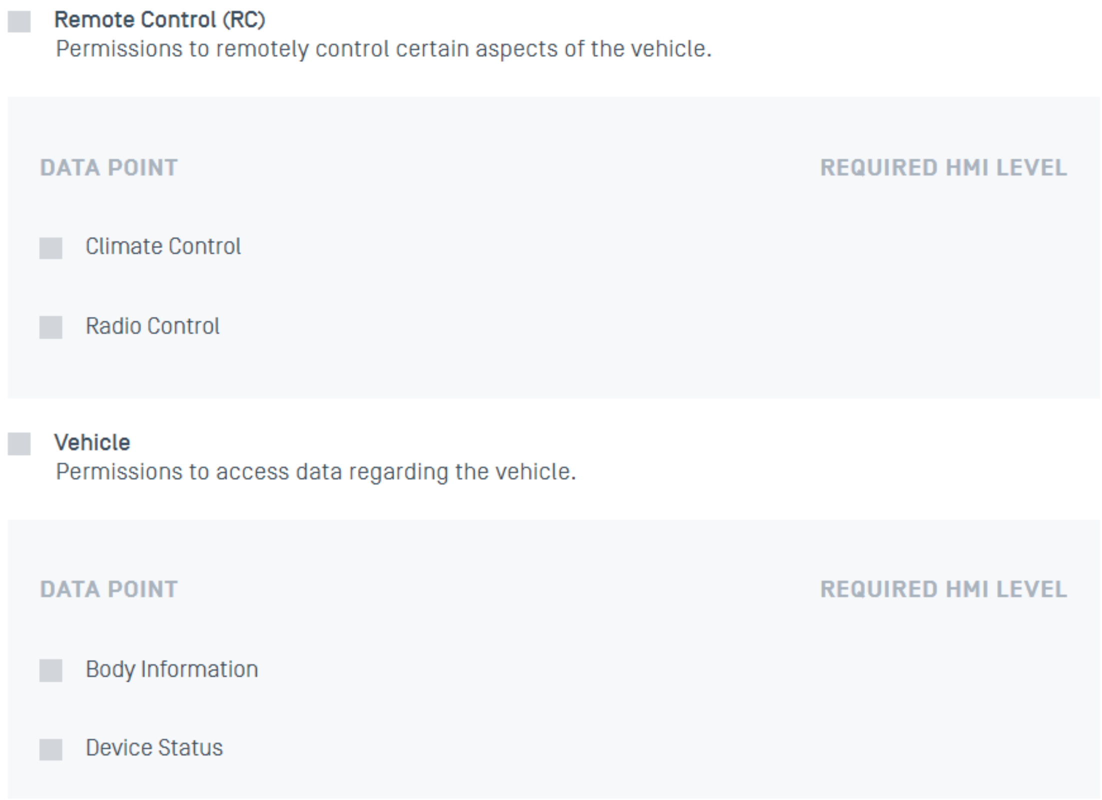

Figure 43: Specifying some detail permissions for certain technical capabilities

For the following assessment, it is assumed that every OEM always consents to all requested permissions, so that the full functional extent of SDL will be taken into account. Because this OEM behaviour can't be assured, the values for the IAM solutions are represented in brackets.

7.3.1 Capability to offer a service to the customer

VM capabilities:

In-Car apps and controls, Smartphone, Voice control

IAM capabilities:

In car apps and controls, Smartphone, Voice controls

Abilities to offer a service	VM	IAM
In-car Apps	✓	(✓)
In-car controls	✓	(✓)
Voice recognition	✓	(✓)
Smartphone	✓	(✓)

IAM: 100%

OEM: (100%)

7.3.2 Capability to conduct a service with a customer

Both the VM and the IAM have equal technical possibilities.

Abilities to conduct a service	VM	IAM
In-car-Apps	✓	(✓)
In-car controls	✓	(✓)
Voice recognition	✓	(✓)
Smartphone	✓	(✓)

IAM: 100%

OEM: 100%

7.3.3 Capability to monitor the need of the thing (the car) for a specific service

VM capabilities:

Only the in-vehicle OEM software can currently monitor Issues and trigger DTCs and Alerts.

IAM capabilities:

IAMs however have with the two function GetDTCs and ReadDIDs two very powerful methods to monitor DTCS and DIDs on a very low level. So, to a certain extent, IAMs could come up with different diagnosis results, if they take into account all DTCs and all DIDs from every ECU. For a level playing field in terms of diagnostics, SDL is up to now the most powerful solution.

Abilities to monitor a service need	VM	IAM
Check for DTCs, alerts	✓	(✓)
Check fixed mileage service	✓	(✓)
Prognostics		

(Prognostics is left out because the VM currently doesn't offer prognostics and the IAM won't be able to do prognostics with the functionality that SDL offers up to now)

IAM: 100%

OEM: 100%

7.3.4 Capability to actually perform the service on the thing (the car)

Within the scope of the study, the extent to what Ford is really able to do could not be evaluated.

Abilities to perform RMI in the vehicle	VM	IAM
Full diagnostics		
Delete DTCs		
Reprogram Over the Air		

Thus, the rating for this aspect could not be determined.

7.3.5 Rating

SDL is from a technical perspective an approach to counter the in-car technologies Android Auto and CarPlay from Google and Apple. SDL acknowledges the fact that most applications will be written in the first place for a user's smartphone, but they keep the aspect of access to in-car systems and controls under close control of the SDL consortium and the participating OEMs.

It is noteworthy that as of now, the SDL alliance represents the greatest number of OEMs that support a unified approach that is independent from the car versions of Google and Apple.

In comparison to ViWi, which relies purely on Web services and is thus independent from Google or Apple Smartphones, SDL assumes that every user has either an Apple or Android Smartphone to host the application.

What really separates SDL from other telematics systems on the market is it's direct, low level access to the DTCs and DIDs of the in-car ECUs. That would render it an ideal solution for independent Diagnostic tool providers, if the OEMs consent to grant permission to these features for the IAM apps.
In summary, with the limited drawbacks that the number of data points could be higher and triggering of actions is very limited as of now, the rating is 4 out of 5 stars.

8 Analysis of OEMs without an IAM offer

In the absence of legislation for access to telematics data is came as no surprise that some OEMs within the scope of this study don't offer at this point in time any IAM access method or access technology, instead handle telematics as a closed shop within the OEM's network.

For the following OEMs, no IAM access method could be found as of 31. July 2018:

1. Audi
2. Seat
3. Renault
4. Fiat
5. Chrysler
6. Toyota
7. Honda
8. Hyundai
9. KIA

8.1 Description Solutions

In general, the solutions of these OEMs look very similar in terms of the architectural approach.

- All of them host the real-time diagnostic software inside the vehicle.
- Most of them have developed a proprietary solution for their in-car infotainment systems (The only exception here would be Renault with their version of Android in the car).
- Most of them support the use of one or more Smartphone Solutions (Apple Carplay, Google Android Auto, MirrorLink).
- Most of them have developed a “normal” Smartphone application for remote control of the car that – with the lone exception of Seat – which cannot be run inside the car.

The typical set of functions covered by the remote applications are:

- Real time traffic Navigation
- Sending destinations to the navigation system of the car from the phone
- Car location finder
- Geofencing alerts
- eCall
- Basic car status information (Tyre pressure, Fuel, Oil, Ad-Blue-level, Control Alerts)
- Basic RMI service handling (Fixed Date, mileage scheduling)
- Basic car controls (Doors, Climate Control, Engine start/stop)

As an example, for the look & feel, find below some screenshots of the ‘myAudi’ app:

Figure 44: Service & Maintenance Screen Audi

The next inspection is due in 285 days or 28400 km, next oil exchange in 710 days or 28600 km, the AdBlue won't need a refill within the next 2400 km and the Oil level is nearly at max level.

Figure 45: Lock/Unlock-Screen of Audi App

Above an actor control screen is shown for the myAudi app. The user can view the status of the vehicle (Currently it is locked) and unlock it by a simple click on the button "Entriegeln" (Unlock) and entering of a 4-Digit PIN to verify that he can legitimately trigger this action.

8.2 Access to Data

All of these OEMs have full access to all in-vehicle signals, controls and actors and thus have the sole ability to deploy the diagnostic software in the car which determines on-board in real time the current Problems, Alerts and Diagnostic Trouble Codes.

It is up to the respective OEMs, how much of this information and access they make available for remote access via the respective applications.

8.3 Capabilities by Service

Service RMI:

All OEMs have the full access to the in-car signals, thus they are the only party who can up to now provide in-car diagnostics. Prognostics is not used publicly, the service intervals are up to now still based on mileage or time.

Other services:

(Examples)

- Navigation
- Travel services (Parking, Fuel)
- Entertainment (Amazon Music, Web Radio etc.)

8.4 Exception: Seat's Apple CarPlay app

Seat has been the first (and up to now) only OEM who has developed – already in 2016 a service app with Apple CarPlay support. (https://www.seat.com/corporate/news/corporate/seat-carplay-app.html) .

All other OEMs focus on standard Smartphone applications (Google or Apple) and handle the Driver Interaction for RMI with their proprietary systems inside the car.

Figure 46: The Seat app is located on the second screen together with 3rd party apps like Spotify

Figure 47: First Main item, the Vehicle status. All in vehicle sensors signal ok.

To get access to these in car signals, Seat has successfully implemented OEM specific extensions to the access level that the in-vehicle part of Apple CarPlay usually offers. (Access to the HMI, to the speaker, to the phone etc.)

OEMs are encouraged to do this by Apple (and by Google also). According to an Apple presentation, find below the general concept.

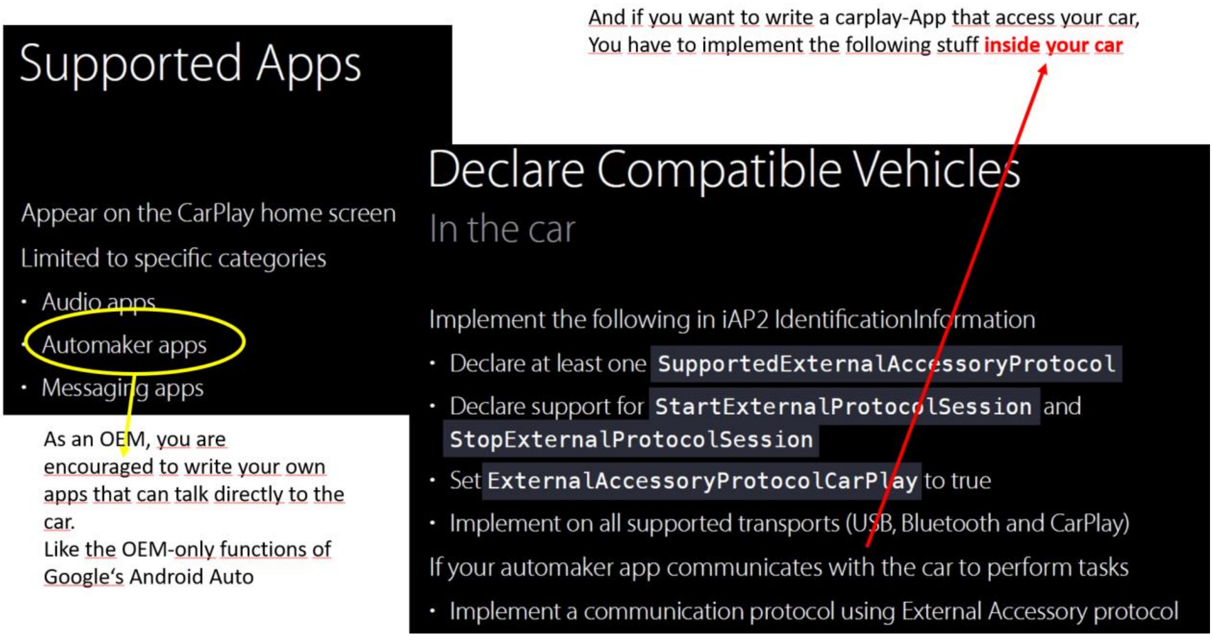

Figure 48: Concept from Apple how Automakers can enhance the CarPlay access level inside the car for their own OEM-apps.

While this would offer a convenient way for a driver that is used to handling his Android or Apple Phone to also control his car in the same way, OEMs seem to be reluctant to offer Apple and Google more insights into their cars:

https://www.theverge.com/2017/1/13/14268252/apple-carplay-google-android-auto-vs-carmakers

This is a possible explanation of why after the Seat app appeared in 2016 not more OEMs have developed deeper access solutions for CarPlay and Android Auto in the last years and has been one driver for the SDL approach described earlier in this report.

8.5 Exception: Renault's R-Link

Renault's R-Link is an in-vehicle infotainment operating system that is based on Google's Android and was released already in 2012. Google's own in-car technology, Android Auto, debuted two years later on the Google I/O in 2014.

Figure 49: R-Link in a 2017 Renault Clio

Besides the technical merits as a very early attempt to bring Android to the car, R-Link has since the arrival of Android Auto and Apple CarPlay in 2014 had significant problems to attract application developers for their own in-vehicle version of Android.

If a developer has to choose for which platform he develops, he is likely to code for the platform with the most possible customers. And of course the number of customers and cars ready to use CarPlay and Android Auto is now far greater than the number of possible R-Link users.

As a consequence, not too many applications have been developed for the R-Link system that could be downloaded to the car via the R-Link app store:
https://easyconnect.renault.co.uk/estore
Along with traffic information and maps, there are a number of gaming apps like Sudoku available (maybe for entertainment during traffic jams or for the kids on the rear view entertainment system?) and the author's favourite, the aquarium app:

Figure 50: The aquarium app for R-Link in a 2017 Espace.

As another drawback, the R-Link store offers a strange user experience when a user wants to download the app inside his car. To save costs and bandwidth, only very small applications can be downloaded directly from the app store into the car. For bigger applications (and already a simple mail client app qualified as a "bigger" application the user is forced to:

1. Visit the app store from his home laptop.
2. Download the app to his home laptop.
3. Transfer the app to an SD-Card or USB-Stick.
4. Install the app in his car by plugging in the USB-stick or SD-Card.

The limited number of application developers and apps together with the rather clumsy approach to download applications apparently have convinced Renault to offer for newer models the combination of Apple CarPlay, Android Auto and MirrorLink like most of its OEM competitors do. In that way, Renault users can also benefit from the greater number of apps and developers available for Google and Apple for consumer apps.

However, the approach to base the OEM's own operating system inside the car for in-car controls on a widespread technology like Android has its merits, because OEMs (or Tier 1 suppliers) don't have to start from scratch over and over again.

8.6 Outlook for deep Google integration in the future

The idea of Renault to use a popular system and a capable development partner like Google to build the OEM's own in-vehicle systems seemed to attract OEMs like Volvo and Audi.

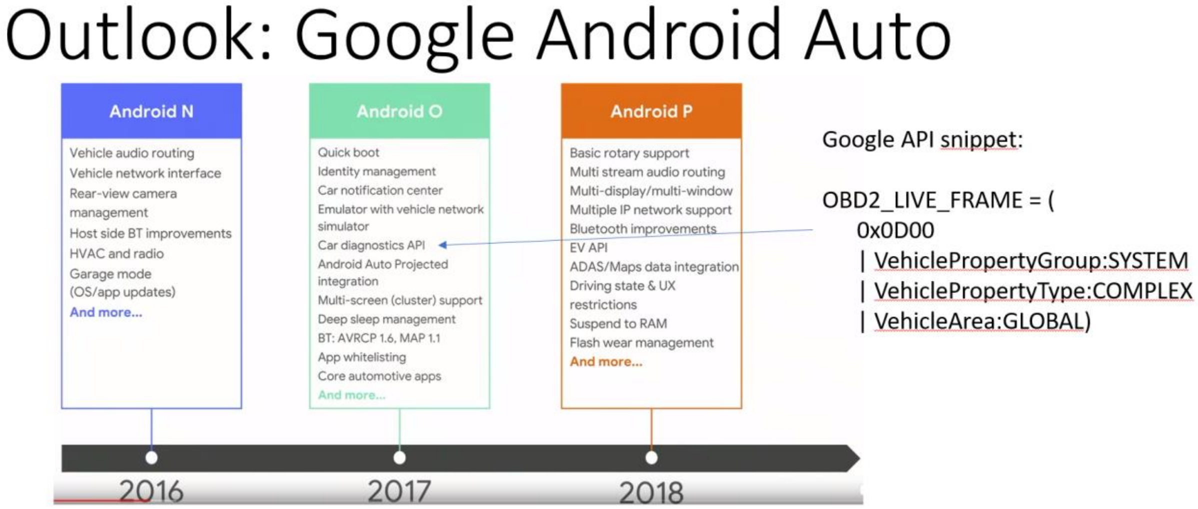

Figure 51: New in-car features for future Android versions

Already with Android Auto Version O in 2017 e.g. a full access to all the OBD2-information inside the vehicle is possible with an even deeper access in 2018 with the version "Android P".

A picture from a new Volvo shows one possible User Interface for this approach:

Figure 52: Google Play Store for a future Volvo

It is important to note that with these versions of Android the cars and the apps for the cars become independent from the phone. This is not (!) just a “simple mirroring” of apps on the phone inside the car. It can’t be, otherwise it would be hard to have an Apple CarPlay app run inside a Google Android O version. Google calls this technology Android Automotive:

https://source.android.com/devices/automotive

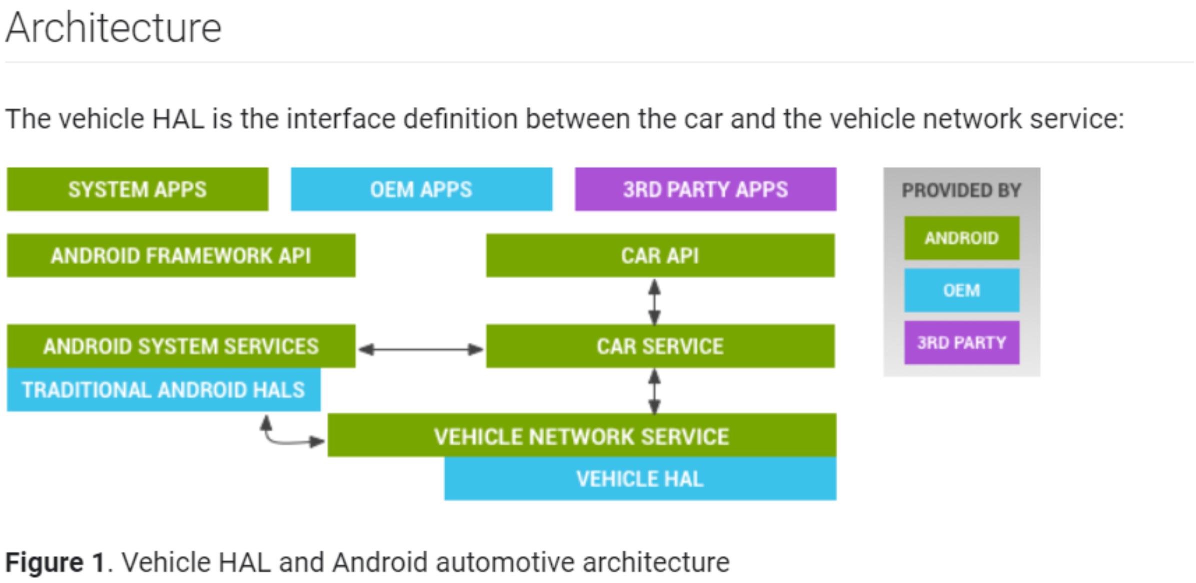

Figure 53: Android Automotive architecture

It becomes obvious that like for an open telematics platform in the vehicle the system is designed to host OEM APPs as well as 3rd Party Apps and Android Apps. Like for an open telematics platform it remains the responsibility of the implementing OEM to ensure a safe &Secure communication of the applications with the in-vehicle components via a Vehicle Hardware Abstraction Layer (Blue).

To preserve the brand identity of the respective OEMs, the future versions of Google's Android offer more options to customize the look and feel of the Android System.

Figure 54: New Audi systems are based on customized and branded versions of Android

This approach might be a reasonable attempt to benefit from the basic development efforts from Google whilst still preserving a brand identity when it comes to the look and feel of the in-car-systems.

8.7 The role of Telematics Suppliers

As it is the case in classic car engineering, in the field of telematics most components and subsystems are also not developed at the OEM internally, but are bought from external suppliers.

The Volkswagen Head Unit e.g. is developed by the same company that also develops Head Units for BMW, Harman. (www.harman.com).

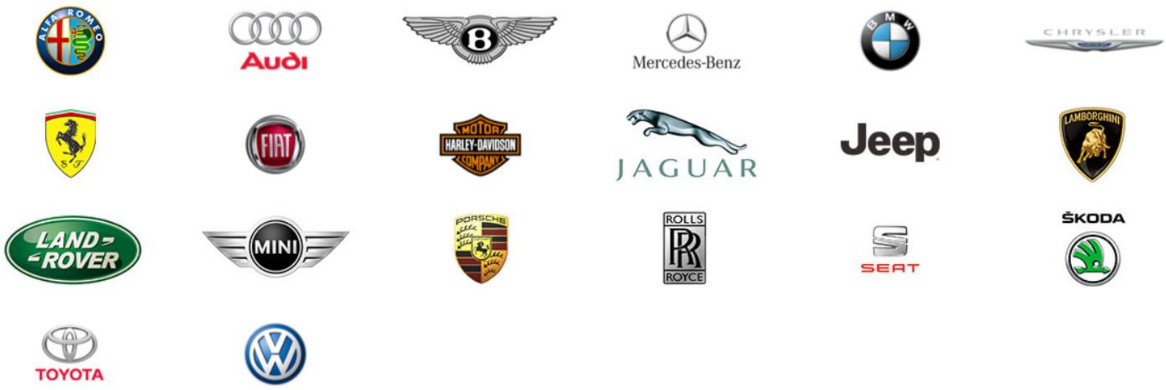

Figure 55: List of OEMs that Harman works for according to https://www.harman.com/connected-car

This is a possible explanation why some of the in-vehicle systems look similar in terms of functionality.

The same holds true for the suppliers for the smartphone applications.

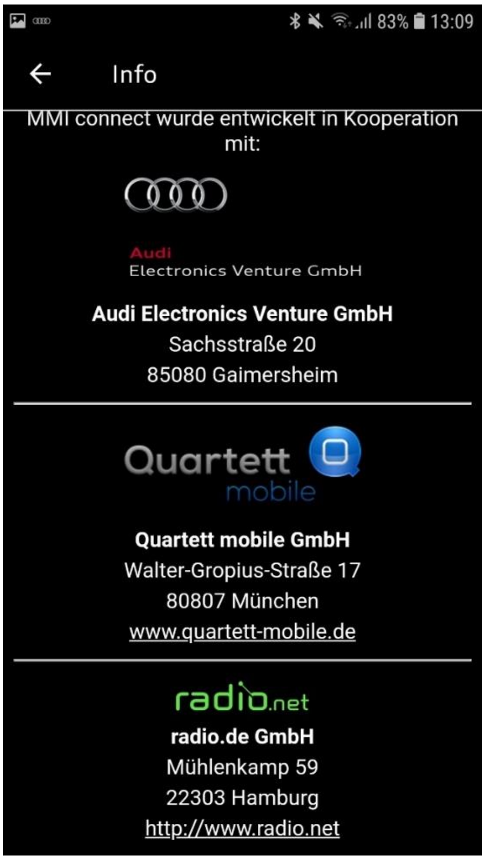

Figure 56: Developer Information of Audi App

As an example, the myAudi app is developed by the company Quartett-mobile GmbH. (www.quartett-mobile.de). According to their website, they also work for Porsche (PCM Connect) and Bentley (myBentley).

8.7.1 Effect on telematics know-how and spectrum of functionality

If OEMs use – like in classical engineering – the same suppliers to develop their telematics systems, it is understandable that some of the resulting systems are very similar in terms of offered functionality to the customer. In addition, the know how to develop these systems – which is IT-Know-How – resides within the respective supplier and it not an OEM domain.

8.7.2 Effect on security issues

Security is always a sensitive issue and this study is not a study about security. But from an outside perspective it is very likely that in case one supplier of a telematics unit has had security problems, not one, but all OEMs that use these supplier's telematics units are affected to a certain extent. How great the extent, depends on the layer and the usage of the subsystem that had the security issue. An issue in a very basic subcomponent that is thus used in nearly every OEM-specific adaption will affect more OEMs than an error in an OEM-specific part of the development.

This might (!) be the reason why e.g. three brands (Audi, Volkswagen and BMW) were affected by successful hacks from external companies. All of them used Harman systems.

Find below the report for the hacking of Audi and Volkswagen and for BMW:

1. https://www.bleepingcomputer.com/news/security/volkswagen-and-audi-cars-vulnerable-to-remote-hacking/ (Audi & Volkswagen)
2. https://thehackernews.com/2018/05/bmw-smart-car-hacking.html (BMW)

Caution: The full details of the security leaks have not been disclosed so it can't be confirmed that the security issues were caused within the Harman-System. But the outsourcing of the IT- and telematics know-how to suppliers could render such a scenario a likely one.

9 Summary

Today, the number of options for an IAM service provider to "Go Digital" with a third-party telematics solution is very limited.

9.1 Few ExVe solutions ready for production stage

Within the scope of this study, only the Extended Vehicle solution from PSA is ready for use. The only other option – outside of this study's scope – would be BMW Car Data as another ExVe solution.

Apparently, neither solution seems to have attracted much interest from the market. As indications for this:

- The developer forums for the PSA solution – who should be filled with discussions about applications and former extensions of the technology – count less than 100 posts in total since their release.
- A search for BMW CarData News returned not a single description of a user success story during the duration of this investigation.
- The last ExVe solution in this study, the Mercedes ExVe, is in Beta Stage since its release on 17.01.2018 and hasn't received any version updates or go-live information since then. If the other ExVe solutions of BMW and PSA would have been a great success on the market, Mercedes would likely put more effort into its own solution to benefit from this new business opportunity.

9.1.1 Technical limitations of the investigated ExVe solutions

By technical design all Extended Vehicles have to share the same shortcomings:

1. No real-time access to data and actors/sensors in the car.
2. No driver interface for in-car usage.

9.1.2 Missing real time access

The intended sampling rates for data was not revealed on the website of the experimental ExVe of Mercedes, so this solution could not be taken into consideration.

Proper timings are only described in the documentation of the PSA ExVe. At the very best and only for very few data points, data is collected every second inside the car over a period of one minute and then sent out in 1-minute chunks of data to the extended vehicle server.
All other data points are transferred in a far lower resolution in time (every 6 seconds, every 20 seconds and most data points are transferred only once per minute).
This is far below the timings needed to e.g. conduct a diagnosis with an ECU in the car (In this case the ECU usually requests a keep alive signal from the diagnosis tool in the range of every 50 msecs), to determine driving style behavior or to just develop an independent navigation application ("Judging your positions within the last minute, dear driver, and taking into account your target destination you should have turned left 20 seconds ago.").
To put this into context, the PSA timing is already excellent in comparison to:

- BMW CarData: Currently, data is just sent whenever the ignition is switched off.
- rFMS (Remote Fleet Management System for Trucks): This Extended Vehicle server can be queried every minute, but new values from the truck to the rFMS are only sent every 15 minutes at best (most data only once per hour), which makes a good advice for the refueling strategy in this time critical business a hard task.

9.1.3 Missing driver interface

The complete ExVe standard (20077/20078/20080) deals as of now just about the web service (ISO 20078) interface to a remote server. A standardization of the User Interface inside the car to make the ExVe services usable in a safe & secure manner is not part of the Extended Vehicle Standard. Thus, every IAM service provider has to develop a smartphone interface for the driver which is unsafe (driver distraction) whilst driving.

9.1.4 Commercial limitations of the ExVe solutions

The missing real-time ability can't be overcome with any server-based solution in the future, however, even with a slow server solution two commercial limitations could be eliminated:

1. Limitation of Data points available (PSA 89, Daimler 23)
2. Limitations of actor access (e.g. reset DTC)

It would be easily possible for the OEMs to deliver far more data points to the ExVe server than they currently do and allow for more control of actors inside the car as currently achievable with these solutions.

Currently, all OEMs are capable of determining a DTC and transferring it to their backend server, so that the respective OEM apps (myAudi etc.) can display the problem to the driver on their phone. The DTC itself is not time critical and could easily be transferred to an ExVe. However, neither Mercedes, BMW or PSA (to an unclear extent) choose to make this information available to IAMs via the Extended Vehicle, but instead keep the information in their network.

The same holds true for the access to actors. As a first fix for a problem, it is sometimes sufficient to just reset a DTC. The operation itself is also not time critical and could be triggered over the server. Unfortunately, no solution investigated exposes this functionality to IAM providers. This can't be a security issue, because e.g. Ford as well as Audi (to name just two) allow the locking and unlocking of doors remotely via their own app. Mercedes is featuring this functionality already in it's beta ExVe.

It can only be assumed that business interests to keep core RMI services within their network have motivated OEMs not to make these functions available.

9.2 Technically available In-Vehicle-Platforms today

In comparison to the just two productive ExVe solutions of BMW and PSA, there are already five in-vehicle platforms with real time access technically available today:

1. Apple CarPlay. Every major OEM as of now supports CarPlay https://www.apple.com/ios/carplay/
2. Google Android Auto: Nearly every major OEM supports Android Auto: https://www.android.com/auto/ (Prominent missing OEMs on this list are BMW, Porsche, Toyota.)
3. General Motors NGI (Supported by GM)
4. Smart Device Link (Supported by a consortium of 10 OEMs)
5. Renault's R-Link (Supported by Renault)

All of this in-vehicle platforms offer real time access to the car and a direct access to the driver via in-car controls and displays.

9.2.1 In vehicle Real Time Access

Each of the technologies is inside the car, thus can communicate with all the car's components, actors, sensors and ECUs in real time via the in-vehicle networks. The access level of both Android Auto and CarPlay is in the first place limited to the components responsible for driver interaction (Phone, Microphone, Entertainment system), although both systems can be enhanced by built in extension mechanisms to communicate directly with the car (Showcased e.g. in the SEAT CarPlay app).

With its plus 400 real time signals from the car GM's NGI tops the list in terms of data points available by far, although it omits information about DTCs and is restricted to read-only data for the most part (with the lone exception of write access to the media system and navigation system).

In this respect the SDL-approach is the clear leader with it's direct, low-level access functions to request DTCs and DIDs from every ECU in the car.

R-Link was not examined in technical detail because in 2017 Renault has started integrated the more popular platforms Android Auto and Apple CarPlay. But it was still the first Android based in-vehicle platform.

9.2.2 In-Vehicle Driver Access

With each of the five in-vehicle platforms it is possible to write applications that can communicate in a safe & secure way with the user using built in controls, displays and sometimes speech control.

9.2.3 Commercial limitations of the In-Vehicle platforms

Although technically available today, the current in-vehicle-platforms have two major drawbacks:

- Limitations in terms of data extent and access to actors
- Admission only upon approval of the OEM

For IAMs in the automotive aftermarket, some vital functions are missing especially for the most widespread technologies of Google and Apple: i.e. retrieving car status information (Alerts, DTCs, Fuel Level, Tire pressure, Next Service) and resetting DTCs.

This level is – as of today – only offered by the SDL-consortium.

Yet the even greater problem is the need to have each and every application pre-approved by the OEMs and/or Google and Apple. Attempts of the authors of this study to develop a sample application for Mercedes with Apple CarPlay were blocked and ignored by both Apple and Mercedes. Up to now all in-vehicle solutions lack a predefined pricing and admission regulation. Every app developer has to propose his idea upfront to Apple/Google and/or the OEMs (see SDL section) and can only hope for an approval and a moderate pricing.

9.2.4 Increasing trends towards standardization

IAMs, especially in the diagnostic tool business, are used to dealing with the problems of multi brand, multi-make, multi-model development.

It is therefore encouraging to see trends towards standardization and the use of standard technologies in the market. For user interfaces inside the car, the field seems to be divided between Carplay and Android Auto with the new challengers SDL and GM NGI, both relying on standard web technologies.

9.3 Technically available In-vehicle platforms in the future

In the future, the current trends point towards further standardization inside the vehicle and across vehicles:

The ViWi-approach is aimed at having a World Wide Web standard to communicate with the car (Proposed by Volkswagen et. Al to the World Wide Web Council (W3C))

Automakers like Volvo and Audi have started to integrate Google's Android as a de-facto standard more deeply into their cars.

With the aim of enabling autonomous driving at affordable costs, more and more OEMs and Tier-1 suppliers (e.g. Audi, Mercedes; Volkswagen, Bosch) team up with Silicon Valley companies like NVIDA.

https://www.rtinsights.com/volkswagen-bosch-nvidia-self-driving/

https://www.engadget.com/2018/07/10/daimler-bosch-nvidia-self-driving-taxis/

https://www.rdmag.com/article/2018/07/using-deep-learning-ai-supercomputing-nvidia-works-make-fully-self-driving-cars-reality

In the future, driven by increasing levels of system and vehicle automation, these in-vehicle supercomputers like NVidia's Xavier (https://blogs.nvidia.com/blog/2018/01/07/drive-xavier-processor/) will likely become a standardized in-vehicle-platform that can host multiple apps and thus render the old EE-architecture, where the software functionalities were distributed over different ECUs, obsolete.

9.4 Summary of the competitive differences between OEMS and IAMs

The competitive differences between the IAMs and OEMs will be assessed in three scenarios:

- Today with the available and offered technology to IAMs.
- Today, if the technical available solutions are opened for all IAMs and not just chosen app developers.
- Today, if also the OEM's proprietary systems would be opened.

9.4.1 Scenario 1: Today's situation

With just PSA's ExVe and BMW CarData available for productive use without additional consent of an OEM, the IAM cannot compete with the OEMs at all in the core field of RMI.

There is no access to the driver to offer or conduct a multi-step diagnosis, no real-time access to the car to come up with a different diagnosis other than the OEM result and with no possibility to solve an issue remotely by either resetting a DTC, resetting an ECU or patching an ECU.

9.4.2 Scenario 2: Today- if the predesigned app solutions are open for all IAMs

In this scenario, IAMs would have the right to write applications for today's technically available five in-vehicle-platforms:

- Apple CarPlay
- Android Auto
- SDL
- GM NGI
- R-Link

With this scenario – especially due to the nearly 100% market coverage for new cars for Apple and Google – IAMs would have the same abilities to interact with the driver in the dashboard as the new point of sale to offer and conduct IAM services.

In terms of access to the car, the IAM would still be at a significant disadvantage (e.g. most systems don't offer DTC handling or ECU resetting), the best technology here would be SDL with the restrictions that still every IAM app and every detailed access permission would be subject to an OEM approval

9.4.3 Scenario 3: Today- if the proprietary OEM solutions would be open for all IAMs

In terms of competitiveness, this scenario would really level the playing field between IAM and OEM service providers.

It would be possible for IAMs to develop apps e.g. for the new Mercedes Benz User Experience (MBUX)-infotainment system or with the system used by BMW, including integration of IAM services in the digital assistants like Alexa that come along with these systems.

Of course, this would require that the IAM partners develop exactly according to the same development and testing standards like the previously chosen development partners (like

Harman or Nvidia) do. With the same level of access to both the car and the driver and the same level of security (ensured by same development and testing standards), the competition success would really be determined by innovation and pricing.

9.4.4 Open issue: Legal basis for fair operating model

Technically, already the existing solutions for safe &secure in-vehicle platforms today demonstrate that a level technical playing field for IAM and OEM partners is possible. However, what is still missing is a legal mandate by which an IAM partner could claim a legitimate access to the existing systems to host his applications. Up to now, the respective OEMs can choose deliberately without further explanation or justification what applications from what IAM partner with what access level they allow in their platforms. Furthermore, they are not obliged to make all technical abilities that an OEM uses for his aftermarket services available for use by IAM applications.

This remaining competitive gap can likely only be closed by legislation.

9.4.5 A final annotation towards security

It is often quoted that opening the systems would bring along all sorts of security issues inside the car and that only the OEM is able to deal with security requirements.

To start with the latter: A close look at the suppliers for telematics reveals that the know-how about security already is on the side of the chosen development partners like NVidia, Harman or others and not with the OEM.

And openness means just that every IAM partner has the right to become a supplier and develop to exactly the same safety, security and development standards and pass exactly the same final acceptance tests by the OEM that were previously passed only by the OEM's chosen suppliers. So the security level will in no case decrease, but would rather increase, because more developments by different partners allow the detection of more possible security issues prior to the vehicle being sold or throughout its service life.

10 Table of Figures

11 Attachment A: Analysis of BMW CarData

11.1 Overview of the Analysis

In June 2017, BMW released their first implementation of an Extended Vehicle for third-party access to vehicle data, BMW Car Data[1], from the BMW fleet. BMW is the second player to join the market with a web service based approach, the first solution[2] was introduced by PSA in October 2016 already.

Upon demand from FIA, the general analysis will focus on the following important questions for after-market stakeholders:

1. How to register?
2. What data is available?
3. What use cases are available (read / write / delete Diagnostic Trouble Code (DTC), activate components, please see ISO 20080[2] as a reference)?
4. What function calls (API)[3] are possible?
5. What models are connected?
6. What effort is necessary for third-parties to create services for the BMW Car Data solution?

To complete the general overview, two more issues will be addressed:

1. Technical maturity of the solution (plays a role in development efforts as well as in reliability and stability in front of the customer).
2. Pricing models.

1

2

3 API means a set of functions and procedures that allow the creation of applications which access the features or data of an operating system, application, or other IT service

11.2 Management Summary

The functional extent of the BMW Car Data is only of very limited use for after-market stakeholders in the current state. There are only around 75 data points available from a vehicle, from which the two greatest categories are data for energy handling (electrical as well as fossil energy) and comfort (5 values for doors, 4 for windows,..). Although a data point can be used for various use cases, a separation of the data points in categories/use cases where the data point is likely to be predominantly used as done in this analysis reveals that RMI is covered by just around 10 data points and insurance by 4 data points.

To put this amount of data into context: currently a connected vehicle is estimated to produce around 25 GByte of data per hour that is available for analysis only to the OEM. BMW doesn't supply sample rates, but assuming they are in the usual range for other solutions (around 10 seconds at best), an hourly amount of approximately 100 (data points) * 6 (times per minute) *60 (minutes) * 100 (average length of data format for) = 3.6 Mbyte could be computed at best.

The competitive disadvantage for the after-market in terms of access to data can thus be computed as a ratio of 25Gbyte/3.6Mbyte ≈ 7000/1 as a pure ratio and even worse in the ability to use different data combinations/algorithms for different service offers.

Service due dates are available for fixed mileage as well as for usage based inspections. However, the data set lacks Diagnostic Trouble Code reports and even the emission related OBD-data. Writing into the vehicle's systems is not possible at all according to the process descriptions, e.g. resetting of DTCs is not possible. Because writing is not feasible, there is also no contact with the driver possible using in-car displays (Any display of a message would imply a write operation to the display device). Thus, any third-party solution will have to rely on smart phone apps for customer interaction.

Pricing for a single data point in a single call is extremely high (29 cents per data point per call), but is capped early at a flat rate for 5 Euros/Month/Car per container, where container describes the data set – the number of data points – a third-party developer needs for his use case. Additionally, the third-party service provider needs to show evidence of permission from the customer for this use case and the related container before he can start retrieving data from the BMW extended vehicle.

Documentation, API Guidelines and related resources and processes seem to be in a very early stage of maturity, allowing only slow data access in the first place and which will likely hamper the development of apps based on this data later on.

In a nutshell, the solution in its current state:

1. Data access around 7000 times less than OEM
2. Access to driver only via Smartphone instead of built-in HMI and controls
3. Access to resources (writing, resetting) is not possible, is therefore of little use to after market stakeholders, is not at all a replacement for the data accessible through the OBD-port and very costly and is far away from the full-fledged telematics solution that BMW markets.

In practical term, BMW CarData will restrict the ability of third-party service providers to compete – both in terms of being able to develop competing services and in terms of cost. The cost will also limit the ability to use the data for 'data trading' as a new business model for third-parties.

11.3 How to register?

The user/developer of a third-party application has to register at the BMW after-market portal:

The developer has to supply personal as well as company data to prove that they are a legitimate stakeholder. After a period of roughly 14 days according to the documentation, access to BMW Car Data should be granted, provided there are no concerns raised by BMW.

After a successful login, the developer will find BMW CarData in the list of available applications with the following start screen.

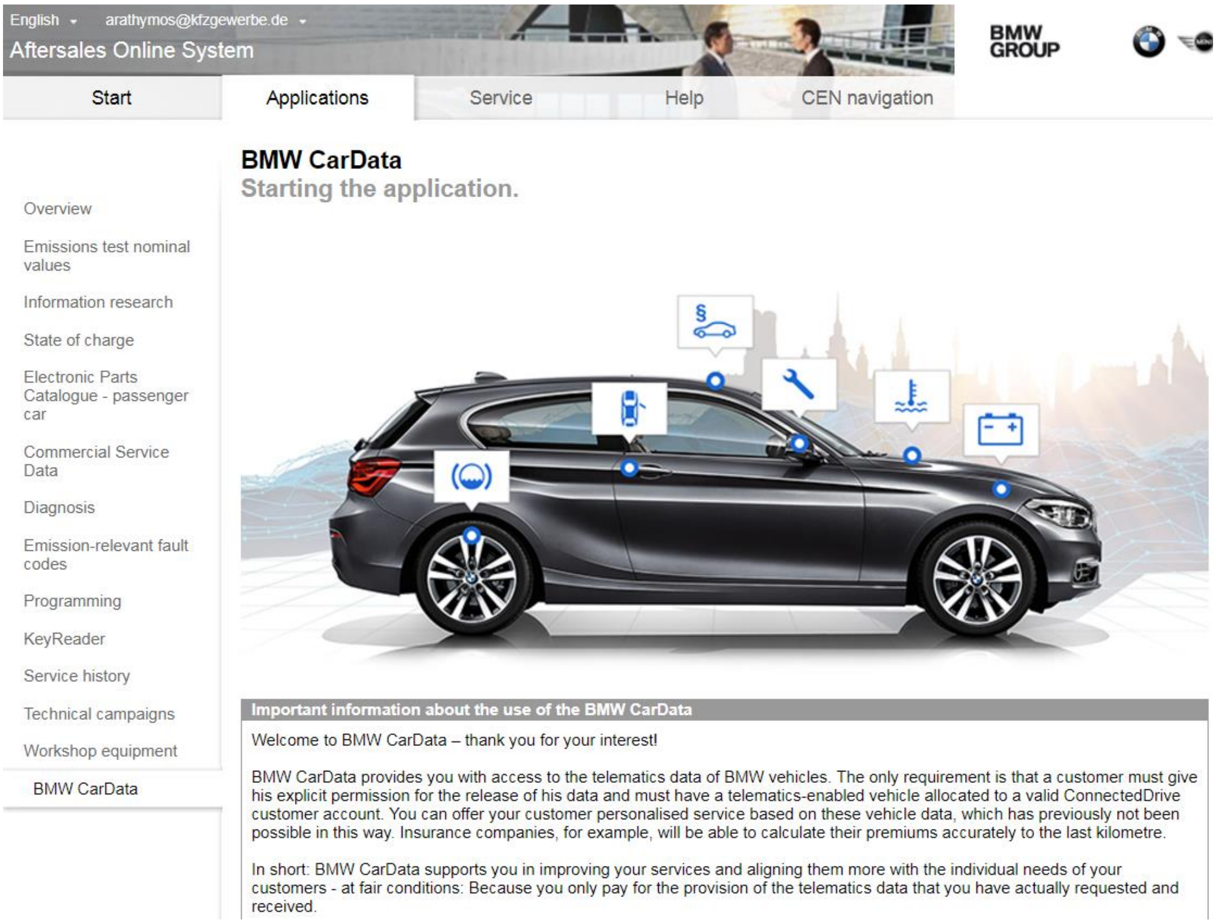

Figure 57: Start Screen of BMW CarData

Here one should find the necessary documentation about how to use the portal in terms of processes, billing and technical requirements. Some documents lack sufficient level of detail, and the whole developer data and information set is very limited.

11.4 What data is available?

The document BMWCarDataTelematicsDataCatlogue.pdf lists in its current version contains the data points listed below.

Please note: In the original document, the data points are not numbered, nor is a category assigned to them. Both elements have been introduced during this analysis to help identify data points and ease a first clustering in use cases/domains.

BMWCarData		
ID	**Data name**	**Data group**
1	Ambient temperature	Comfort
2	Vehicle altitude	Location
3	Battery voltage	RMI
4	Date for brake fluid replacement	RMI
5	Number of service reports and appointments	Customer
6	Air conditioning charging current	Energy
7	Air conditioning charging voltage	Energy
8	Charging method and plug Type	Energy
9	Charging profile	Energy
10	Charging status (state values..e.g. charging, charging paused..)	Energy
11	Check control messages	Customer
12	Time threshold for main and exhaust gas inspection	RMI
13	Condition Based Service	Customer
14	Status of convertible roof	Comfort
15	Coolant temperature	RMI
16	Display unit of instrumental panel in vehicle (Km/Miles)	Customer
17	Status front left door	Comfort
18	Status front right door	Comfort

BMWCarData		
ID	**Data name**	**Data group**
19	Status rear left door	Comfort
20	Status rear right door	Comfort
21	Status doors	Comfort
22	Vehicle position longitude	Location
23	Vehicle position latitude	Location
24	Orientation of the vehicle	Location
25	Status of hood	Comfort
26	Status of charging plug	Energy
27	Tank content range	Energy
28	Date of next inspection	RMI
29	Number of free POI[4] spaces in Nav-System	Customer
30	Maximum number of POIs in Nav System	Customer
31	Mileage	RMI
32	Time to the navigation destination	Location
33	Navigation destination	Location
34	Distance to navigation destination	Location
35	Date of next service (Month to next service)	RMI
36	Distance to the next service (Km before next service)	RMI
37	Charging profile(selected remotely via App)	Energy
38	Tank content	Energy
39	Remote service result (BMW remote App triggers command)	Communication
40	Remote Service Type: RemoteDoor(); Remote Climate Control, remoteVehicleFinder, remote360()	Communication

4 Point of interest

BMWCarData		
ID	Data name	Data group
41	Charging status high voltage battery	Energy
42	Availability of teleservices	Communication
43	Position sunroof	Comfort
44	Status sunroof	Comfort
45	Tilting status sunroof	Comfort
46	Status of boot lid (trunk)	Comfort
47	Status engine (on/off)	Energy
48	State of ignition	Energy
49	Status of lights	RMI
50	Low Voltage battery	Energy
51	Mobile phone connection	Communication
52	Motion status of vehicle (moving/stationary)	Location
53	Datetime shown in vehicle	Customer
54	Status front left window	Comfort
55	Status front right window	Comfort
56	Status rear left window	Comfort
57	Status rear right window	Comfort
58	Distance threshold for service information (to customer)	RMI
59	Time threshold for service information to customer(e.g. 4 weeks)	RMI
60	Charging window selection	Energy
61	Average distance per week	Energy
62	Average distance per week (2 month sample)	Energy
63	Driving style evaluation acceleration (0..5 stars)	Insurance
64	Driving style evaluation proactive driving (0..5 stars)	Insurance
65	Percentage Eco plus mode last drive	Insurance

BMWCarData		
ID	**Data name**	**Data group**
66	Percentage Eco mode last drive	Insurance
67	Electrical energy consumption in comfort mode last drive	Energy
68	Electrical energy consumption last drive	Energy
69	Fuel consumption last drive	Energy
70	MileageAfterlastLoggedDrive	Location
71	Distance driven electrically last drive	Energy
72	Energy recuperated last drive	Energy
73	Charging status battery (Percentage Value)	Energy
74	Timestamp most recent drive	Location

The original document adds a technical name and a short description for every data point, but for most data points not even a unit or a range is specified. No sampling rates (every second, every week?) or accuracies are specified. That's why the documentation is labelled as an early version in this analysis. Typical API descriptions would have contained these missing features and usually even come with a sample source code.

Some other observations:

BMW text:

"Vehicle position – degree of latitude

The GPS position is transferred independently of whether the GPS positioning has been activated or deactivated in your vehicle via the settings menu. "

Comment: If this is true – that the GPS position is transmitted even if the customer has deselected the GPS positioning - it would be highly disrespectful for the selection made by the motoring customer in his vehicle and a direct data privacy issue.

BMW text:

“*Mileage data statistics*

The value indicates the current mileage at the time of data collection. This value is redundant and is only determined when the regular mileage is not available on the speedometer. The values range from 0 to 999999. Note: It is recommended to use only the regular mileage instead of this value“.

Comment: it seems a little odd to provide data and then recommend that it should be ignored.

Door status

This value indicates the status of the doors, but is only sporadically recorded and transmitted. Note: It is recommended to use only the individual door status instead of this value.”

Comment: For a first release of an API where the set of data points should be comprehensive, it is unusual that already in the first version the programmer is encouraged not to use two of the data points. Technically, it would have been preferable to remove these two data points from the list, even if this would decrease the number of transmitted data points.

11.5 What use cases are available?

In general it is not possible to determine that a data point belongs to exactly one use case or use case category. Instead, one data point can be used in many use cases and reversely a single use case makes use of many data points. That's why in general a clustering of data points into use cases can only be a rough estimation.

But for an initial assessment the exercise of clustering the BMW CarData into data groups/use cases/domains is helpful.

Thus, within this study, the total amount of 75 data points can be clustered as follows:

DataGroupClusters

Data group	Number
Energy	22
Comfort	16
RMI	11
Location	10
Customer	7
Insurance	4
Communication	4

Note: The category names (Energy, comfort..) and assignments of data points to the respective categories were defined in this study, it is not(!) a categorization by BMW.

As discussed in the previous chapter, two data points are already obsolete and at least the 4 data points of the category "communication" are of very limited use for after-market applications.

(See detailed discussion in respective subchapter)

Displayed in descending order:

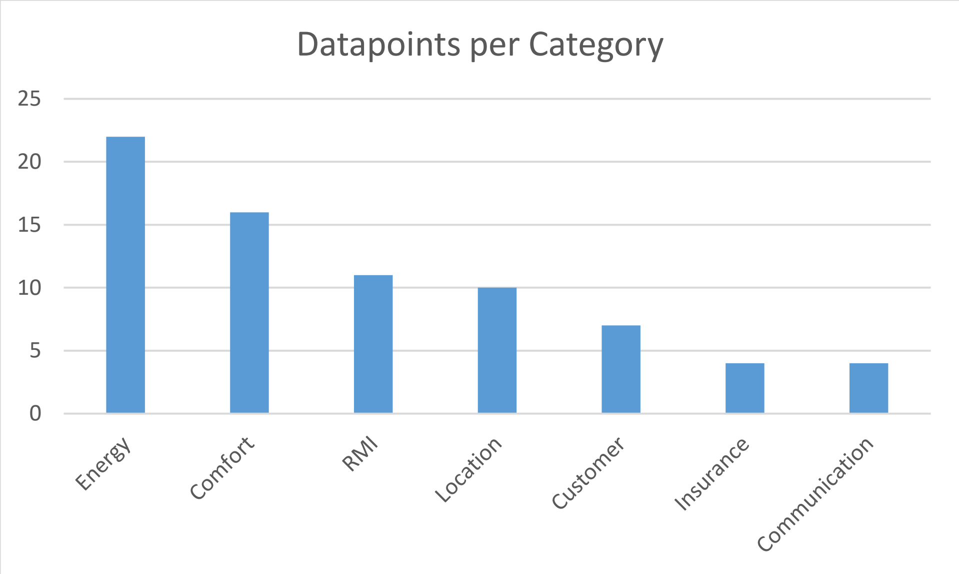

Figure 58: Data points per category/use case/domain

In the following subchapters, a first assessment of the possible use cases will be given together with the list of available data points in the respective cluster.

11.5.1 Data Category Comfort

BMWCarData		
ID	**Data name**	**Data group**
43	Position sunroof	Comfort
14	Status of convertible roof	Comfort
17	Status front left door	Comfort
18	Status front right door	Comfort
19	Status rear left door	Comfort
20	Status rear right door	Comfort
1	Ambient temperature	Comfort
25	Status of hood	Comfort
57	Status rear right window	Comfort

BMWCarData		
ID	**Data name**	**Data group**
44	Status sunroof	Comfort
45	Tilting status sunroof	Comfort
46	Status of boot lid (trunk)	Comfort
54	Status front left window	Comfort
55	status front right window	Comfort
56	Status rear left window	Comfort
21	Status doors	Comfort

This group of data can be used to display the lock status of every vehicle access possibility to the customer on his smartphone. Because remote opening or closing is not possible, the customer can only be informed that he/she has forgotten to close some door/window.

11.5.2 Data category communication

BMWCarData		
ID	**Data name**	**Data group**
51	Mobile phone connection	Communication
42	Availability of teleservices	Communication
40	Remote Service Type: RemoteDoor(); RemoteClimateControl(), remoteVehicleFinder(), remote360()	Communication
39	Remote service result (BMW remote App triggers command)	Communication

"Mobile phone connection" only reports if the customer has established a connection with his phone at the very moment when the data set was retrieved from the car. "Availability of teleservices" indicates if the selected vehicle has enabled telematics services or not. If the value is “No”, it is not clear how an application would ever get this information via a telematics call in BMW CarData. This is one of the elements that need clarification in a subsequent and more detailed analysis.

RemoteServiceType does not offer to actuate devices through the commands RemoteDoor(); RemoteClimateControl(), remoteVehicleFinder(), remote360(). Instead, a call to the BMW CarData platform only detects that the last write command from the BMW connected Drive Application has been one of the above four commands and that it has resulted in the value reported in the data field Remote Service result.

Please be reminded that third-party apps are prohibited to write into the vehicle but at the same time OEM telematics solutions, like BMW Connected Drive App writes and interacts with the car remotely and directly. This clearly shows the ‘uneven level playing field’ between independent operator and OEM.

11.5.3 Data category customer

BMWCarData		
ID	**Data name**	**Data group**
53	Datetime shown in vehicle	Customer
30	Maximum number of POIs in navigation system	Customer
29	Number of free POI spaces in navigation system	Customer
16	Display unit of instrumental panel in vehicle (Km/Miles)	Customer
13	Condition Based Services	Customer
11	Check control messages	Customer
5	Number of Service Reports and Appointments	Customer

Number 11 „Check control messages“ could be useful for RMI but – because the documentation is vague – it is not clear if single messages and indicator light status will be reported or if this is only a 0/1 flag that is activated if any of the available check control messages is present, it is not possible to know what data or information is provided.

The original description reads:

"*Check control monitors functions in the vehicle and notifies the user when there is a fault in the monitored system. A check control message is displayed as a combination of indicator lights or warning lights and text messages on the dashboard, and on the head-up display, if applicable.* "

Only a detailed analysis in source code and example calls will reveal the extent of possibilities for RMI in this case.
The same statement holds true for Condition Based Services (CBS):
"*Sensors and special algorithms take into account the operating conditions of the vehicle. CBS uses this to determine the required service. The system hereby adapts the scope of the service to the individual usage profile.* "

It is hard to determine why this functionality is proposed at all when there are data points in the RMI category that reveal the distance in km or the time to the next service. A sound implementation would simply expose these points and hide, if these next service needs have been determined using fixed mileage service intervals or usage based intervals (prognostics).

11.5.4 Data category energy management

BMWCarData		
ID	**Data name**	**Data group**
48	State of ignition	Energy
7	Air conditioning charging voltage	Energy
8	Charging method and plug Type	Energy
9	Charging Profile	Energy
10	Charging status (state values, e.g. Charging, charging paused)	Energy
26	Status of charging plug	Energy
27	Tank content range	Energy

BMWCarData		
ID	**Data name**	**Data group**
37	Charging profile (selected profile via remote app)	Energy
38	Tank content	Energy
6	AC Charging current	Energy
47	Status engine (on/off)	Energy
73	Charging status battery	Energy
50	Low Voltage battery	Energy
60	Charging window selection	Energy
61	Average distance per week	Energy
62	Average distance per week (2 month sample)	Energy
67	Electrical energy consumption in comfort mode last drive	Energy
68	Electrical energy consumption last drive	Energy
69	Fuel consumption last drive	Energy
71	Distance driven electrically last drive	Energy
72	Energy recuperated last drive	Energy
41	Charging status high voltage battery (percentage value)	Energy

These data points could be useful for oil companies or energy companies to offer their charging/refuelling services to the customers.

11.5.5 Data Category insurance

BMWCarData		
ID	**Data name**	**Data group**
66	Percentage Eco mode last drive	Insurance
65	Percentage Eco plus mode last drive	Insurance
64	Driving style evaluation pro active driving (0..5 stars)	Insurance
63	Driving style evaluation acceleration (0..5 stars)	Insurance

For insurers only these limited, aggregated and computed values that are based on an OEM algorithm are available to assess the driving style on which premium calculations could be made. Access to real time data is not possible (e.g. pay how you drive). Deployment of the insurer's own algorithms into the car in the format of apps that collect the real-time data is also not possible.

11.5.6 Data category location

BMWCarData		
ID	**Data name**	**Data group**
74	Timestamp most recent drive	Location
70	MileageAfterlastLoggedDrive	Location
52	Motion status of vehicle (moving/stationary)	Location
34	Distance to navigation destination	Location
33	Navigation destination	Location
32	Time to the navigation destination	Location
24	Orientation of the vehicle	Location
23	Vehicle position latitude	Location
22	Vehicle position longitude	Location
2	Vehicle Altitude	Location

The list above summarises BMW report on the car's location and destination.

11.5.7 Data category RMI

BMWCarData		
ID	**Data name**	**Data group**
59	Time threshold for service information to customer(e.g. 4 weeks)	RMI
58	Distance threshold for service information (to customer)	RMI
49	Status of lights	RMI
36	Distance to the next service (Km before next service)	RMI
35	Date of next service (Month to next service)	RMI
31	Mileage	RMI
28	Date of next inspection	RMI
15	Coolant temperature	RMI
12	Time threshold for main and exhaust gas inspection	RMI
4	Date for Brake fluid replacement	RMI
3	Battery Voltage	RMI

The transmission of next service dates and intervals together with the thresholds BMW uses internally to inform the customer of the upcoming service needs is also useable for repair and maintenance. However, the OEM can notify the owner / driver through the in-vehicle display whereas the independent operator can only do so via the owner's mobile phone, again demonstrating that there is no level playing field between OEM and independent operator.

11.6 What function calls are possible?

The API is limited. There is no writing of data possible to the vehicle.

The app developer can only request to read values from the extended vehicle (ExVe)[5].

In addition, the developer can be notified when a specified event occurs so there is no need to include routines for updates.

Side note for software developers: With a possibility for both communication partners (third-party application as well as BMW CarData ExVe) to trigger the communication, it deviates from common practice that in the category of asynchronous calls – where a request is sent and the answer is not immediately returned, but is sent out to a so called callback function after it is computed – the ExVe instead that the answer is not yet ready but will be ready after e.g. 300 seconds and will be available for 300 seconds after that for retrieval.
So the third-party app is expected to call back at a later time.

In summary:

BMW CarData – like every other ExVe system planned or released so far – is only about reading a few values in (too) slow sampling rates remotely.

Not possible are:

- writing to the vehicle;
- resetting of DTCs;
- access to in-vehicle displays;
- access to in-vehicle resources (sensors/actuators)
- deployment of own algorithms into the car that could collect real-time data and to send this data out later in aggregated format.

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5 ow the creation of applications which access the

11.7 What models are connected?

The extent of connectivity of the BMW fleet in circulation is not known up to this point of the analysis.

For testing purposes, for a new BMW X50d vehicle the collected data up to now have been requested and the resulting XML file snapshot is shown below.


```
- <telematicValueList dataCategory="VEHICLE_STATUS">
  - <telematicValue>
      <name>Position des Fahrzeugs – geographische Breite</name>
      <value>51.58468</value>
      <unit>WGS84</unit>
      <fetchTimestamp>24.06.2017 12:16:02.127</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:12.198</valueTimestamp>
    </telematicValue>
  - <telematicValue>
      <name>Position des Fahrzeugs – geographische Länge</name>
      <value>8.340968</value>
      <unit>WGS84</unit>
      <fetchTimestamp>24.06.2017 12:16:02.127</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:12.198</valueTimestamp>
    </telematicValue>
  - <telematicValue>
      <name>Remote Service Typ</name>
      <value>POSITION_ON</value>
      <unit>-</unit>
      <fetchTimestamp>24.06.2017 12:16:02.128</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:08.534</valueTimestamp>
    </telematicValue>
  - <telematicValue>
      <name>Remote Service Ergebnis</name>
      <value>true</value>
      <unit>-</unit>
      <fetchTimestamp>24.06.2017 12:16:02.127</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:08.534</valueTimestamp>
    </telematicValue>
  - <telematicValue>
      <name>Zustand der Türen</name>
      <value>oldDoorStatus:ASN_locked,newDoorStatus:ASN_locked,allDoorsLocked:ASN_isTrue,trunkLocked:ASN_isTrue</value>
      <unit>-</unit>
      <fetchTimestamp>24.06.2017 12:16:02.128</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:08.534</valueTimestamp>
    </telematicValue>
  - <telematicValue>
      <name>Zustand des Motors (an/aus)</name>
      <value>ASN_isTrue</value>
      <unit>-</unit>
      <fetchTimestamp>24.06.2017 12:16:02.127</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:08.534</valueTimestamp>
    </telematicValue>
  - <telematicValue>
      <name>Zustand der Zündung</name>
      <value>ASN_isTrue</value>
      <unit>-</unit>
      <fetchTimestamp>24.06.2017 12:16:02.127</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:08.534</valueTimestamp>
    </telematicValue>
  - <telematicValue>
      <name>Zustand der Lichter</name>
      <value>ASN_isTrue</value>
      <unit>-</unit>
      <fetchTimestamp>24.06.2017 12:16:02.127</fetchTimestamp>
      <valueTimestamp>09.06.2017 15:21:08.534</valueTimestamp>
    </telematicValue>
```


Figure 59: Screenshot from a customer data archive

Although the snapshot is not complete, there are already a few signs that BMW CarData is in its early stages of development only.

The naming in the XML-File is in German, the API description supplied English technical names. (Might be caused by an XSLT transformation, but likely is due to early "language confusion". However, the list of values seems far shorter than the extent of values described in the API. There are roughly 15 days between the timestamp of the fetch (when the data was obtained from the ExVe) and the timestamp of the values in the XML File (when the data was sent from the car to the ExVe). Given BMWs status in connectivity of its fleet it is hard to believe that a top of the line X5 only communicates once per two weeks with the ExVe. Instead, it is likely that they are currently transposing make after make, model after model to BMW's implementation of ExVe.

Summary: The coverage of BMW CarData can only be determined in detailed analysis at a later point in time, model by model.

11.8 How much development effort is necessary?

To develop a third-party application requires the development of at least two technical components:

a.) A third-party server which communicates with the ExVe, stores values even if no smartphone is currently requesting values, provides callback URI[6]s for the BMW ExVe for notification messages and standardizes the communication to the smartphone apps.

b.) One or more smartphone applications (e.g. one for Google, one for Android) that communicate(s) with the third-party server to retrieve the data, display(s) the status information to the customers and present them with the third-party service offers.

Set up this way, the development effort for the smartphone apps is known and relatively easy to determine depending on the desired functionality and design of the app.

Given the relatively small functional extent of BMW CarData, development efforts are in the range of 50,000 Euro for an app developed for one platform (e.g. Google) and then around 25% effort to convert the app to the other platform.

It is harder to determine the effort to develop the server part for the BMW CarData communication, because this system is obviously in an early stage, where frequent changes of protocol details and data formats will force the developer to adjust to and adopt every change BMW applies to its system.

In terms of developer cost, first assumptions would be around 30,000 Euro for the initial development and setup of the system plus 20,000 Euro for development changes in the first three months.

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6 Uniform Resource Identifier (URI) is a string of characters used to identify a resource. Such identification enables interaction with representations of the resource over a network, typically the World Wide Web, using specific protocols.

11.9 Technical maturity

BMW CarData is a new system that has been released in a very early stage of development.

Proof for this:

- **a.)** The admission process took longer and required more call-backs and retriggering from us than envisioned.
- **b.)** The set of accompanying documents lack details and is sometimes inconsistent. (E.g. dead links or a set of two json-files[7] where an API documentation should be found etc.)
- **c.)** Long waiting time for trouble tickets.
- **d.)** Already deprecated data points in the official documentation in the first release.
  E.g. for the value "Remaining Range" the explanation reads "This value indicates the remaining range of the fuel tank contents in kilometres at the time of data collection. Note: It is recommended to use the regularly transmitted fuel tank content range instead of this value."
- **e.)** Data Points of very limited use for third party developers. In the attempt to increase the number of available data points, data points like the ones in the "communication category" have been incorporated. After-market providers have no interest in these data points if there is a mobile phone connected to the car (there must be a phone, because it is the only way for an independent operator to display services to the customer).

If a single company wants to get really into end consumer business in this early stage they should be aware that they are likely to pay a high price in terms of development efforts due to frequent system changes on the BMW side for their technical leadership.

[7] JavaScript Object Notation or JSON is an open-standard file format that uses human-readable text to transmit data objects consisting of attribute–value pairs and array data types (or any other serializable value).

11.10 Pricing models

The pricing model in BMW CarData is based on two terms:

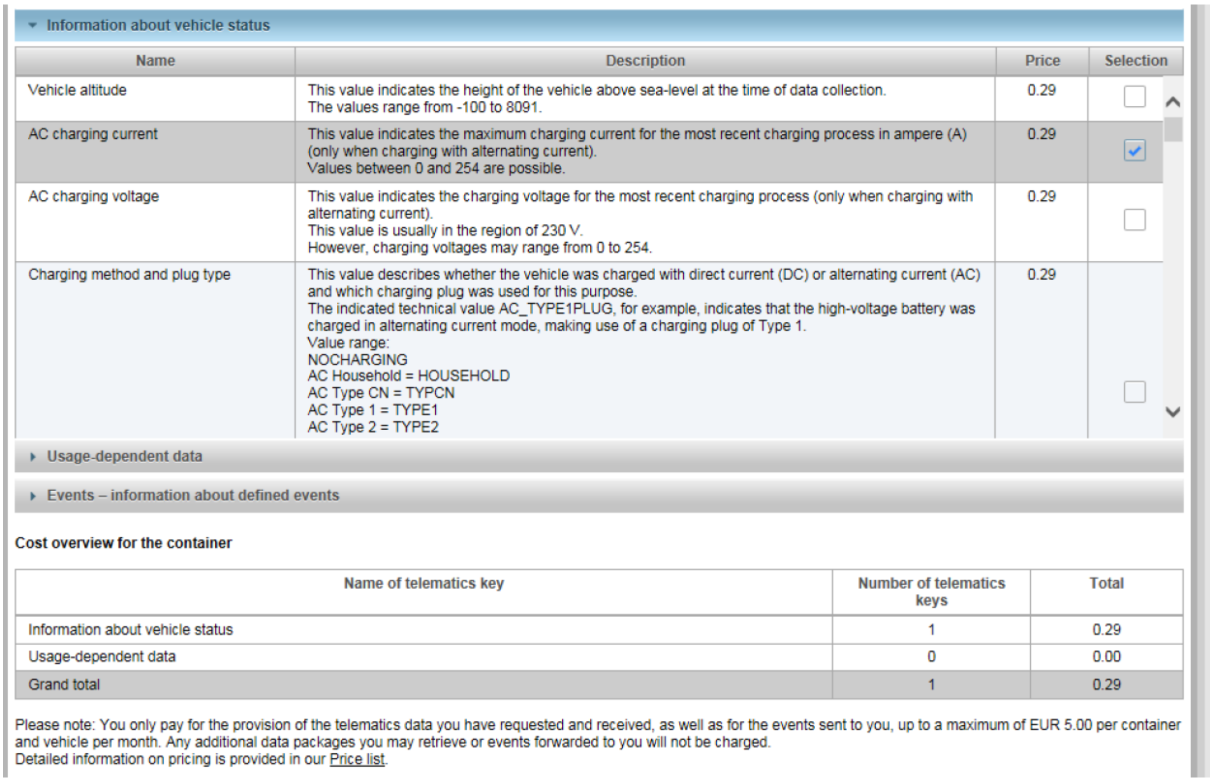
1. Keys
2. Containers

A key is a single data point from the data catalogue list discussed in the chapters above. A container is a set of keys (data points) used to conduct a use case for the customer. Customer acceptance is requested on the basis of a certain use case for the associated container.

11.10.1 Keys

Due to the current pricing list, a single key is billed with ***29 Euro cents*** per retrieval.

Keys can only be selected as part of a container and thus as part of a use case.



▾ Information about vehicle status

Name	Description	Price	Selection
Vehicle altitude	This value indicates the height of the vehicle above sea-level at the time of data collection. The values range from -100 to 8091.	0.29	☐
AC charging current	This value indicates the maximum charging current for the most recent charging process in ampere (A) (only when charging with alternating current). Values between 0 and 254 are possible.	0.29	☑
AC charging voltage	This value indicates the charging voltage for the most recent charging process (only when charging with alternating current). This value is usually in the region of 230 V. However, charging voltages may range from 0 to 254.	0.29	☐
Charging method and plug type	This value describes whether the vehicle was charged with direct current (DC) or alternating current (AC) and which charging plug was used for this purpose. The indicated technical value AC_TYPE1PLUG, for example, indicates that the high-voltage battery was charged in alternating current mode, making use of a charging plug of Type 1. Value range: NOCHARGING AC Household = HOUSEHOLD AC Type CN = TYPCN AC Type 1 = TYPE1 AC Type 2 = TYPE2	0.29	☐

▸ Usage-dependent data

▸ Events – information about defined events

Cost overview for the container

Name of telematics key	Number of telematics keys	Total
Information about vehicle status	1	0.29
Usage-dependent data	0	0.00
Grand total	1	0.29

Please note: You only pay for the provision of the telematics data you have requested and received, as well as for the events sent to you, up to a maximum of EUR 5.00 per container and vehicle per month. Any additional data packages you may retrieve or events forwarded to you will not be charged.
Detailed information on pricing is provided in our Price list.

Figure 60: Selection of keys for a container

In the picture above only the key (data point) “Air conditioning charging value” was selected, so the total amount for one call of the complete container would be just the 29 cents for exactly this key.

11.10.2 Containers

Containers are the technical, legal and commercial foundation of the BMW CarData ExVe.

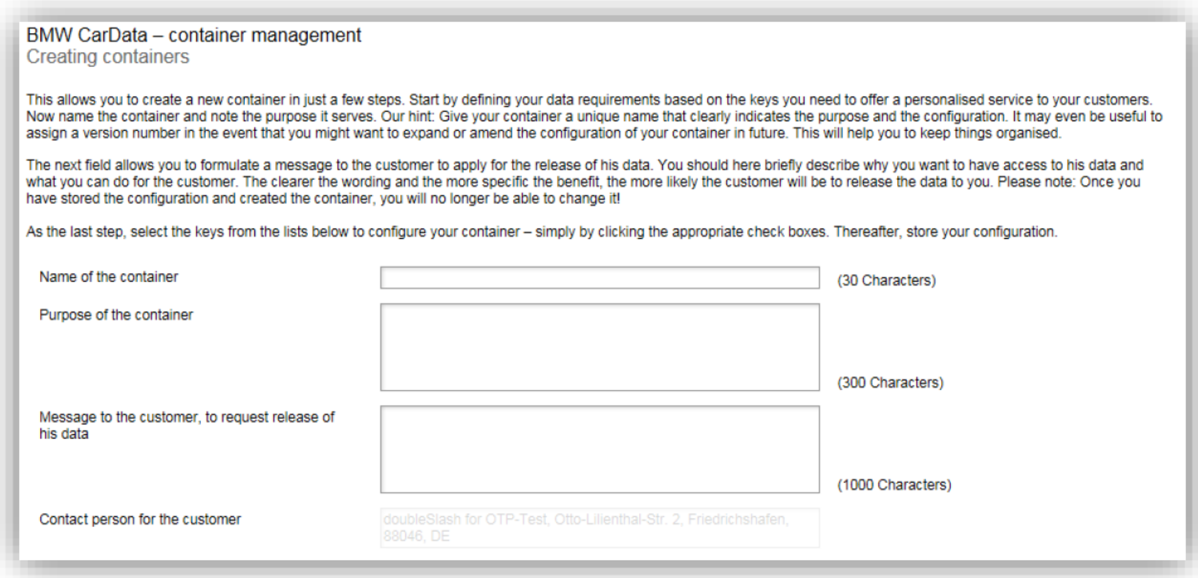


Figure 61: Naming and describing a container

If an insurer would want a BMW customer to subscribe to their pay-how-you-drive-offer, he would likely select all 4 data points (keys) of the insurance category.

A possible name for the container (use case) might be “FutureInsurancePHYD”.

Purpose of the container: ”Allow the calculation of a fair premium for PHYD-insurance”.

The message to the customer might read: ”Dear Customer, to enjoy the benefits of our new PHYD-offer we kindly request you to give us access to the needed data points”.

After the container is named, the insurer would select the four data points (which will total in 4 times 0.29 cent is 1,16 Euro per Call.) Therefore, the cost of a container is directly the aggregated costs of the individual data points it contains.

11.10.3 How to reach the customer via BMW Car Data?

The analysis has already determined that BMW CarData offers absolutely no possibility to interact with the customer during usage of a given service. (e.g. there is no possibility to access in-vehicle controls or HMIs). Furthermore, it is not an advertising tool to reach new customers. Technically, it would be easy to inform every BMW customer that the insurer in the example above has released the new premium "FutureInsurancePHYD" by displaying a list of newly available services.

Instead, the insurer has to convince customers via other media channels to sign an insurance contract. Then, the customer has to supply the vehicle's VIN to the third-party provider.

Identified by the VIN, the customer's vehicle is then prompted with the request to release vehicle data for the usage of the service.

In comparison, new offers for OEM services are made available directly via the HMI,
(See SEAT APP
while after-market stakeholders are forced to use nomadic solutions to identify and approach customers to use their services.

In the example of the insurance container, every call would cost the insurer ***1,16 Euro***, which is commercially uninteresting.

There are also bandwidth problems and the availability of real-time access to data.

Typical usage and access as envisaged by insurance companies for 'pay how you drive' would add up to 11,60 Euro per second and result roughly in 366 million Euros per year.

However, BMW has capped the billing cost at 5 Euro per month per container so the insurer would have to pay a maximum of 60 Euro per year.

How often the data in that case can be accessed could not been determined in this study. The Fleet Management System (rFMS ExVe) for trucks and the PSA-ExVe supplied these data access timing in their documentation

11.11BMW CarData and Mobility Clubs

11.11.1 Preconditions

BMW CarData and all related services are based on individual customer consent. A club needs the consent from each single member, based on the Vehicle Identification Number (VIN). Today, the Clubs do not possess the VIN of its members' vehicles. Such a service must be implemented first, before services based on BMW CarData can be offered at all. Moreover, Clubs must negotiate prices with BMW first, which may be not so easy for those in Member States with small membership numbers.

BMW CarData enables the manufacturer to monitor the Club services and the behaviour of the customers, which is in contradiction with the FIA Region I campaign MyCarMyData[8]

8 http://www.mycarmydata.eu/

11.11.3 Road side assistance

The low number of available RMI related data and the lack of use case based functions, such as read and delete DTCs, make BMW CarData almost irrelevant for roadside assistance services

Insurance

Insurance Services like PHYD would need significantly more data points to be able to offer a competitive product.

11.11.4 New Services

For the development of new Services for a connected device like the connected vehicle three elements are essential:

1. Data extent and Data accuracy to determine the status of the vehicle with respect to the service. (e.g. determine that a DTC is present)
2. Access to in-car controls and devices to perform the service on the vehicle. (e.g. reset an ECU, reset a DTC)
3. Access to the driver to offer the service and interact with the driver during service performance. (e.g. instructing driver to park the vehicle prior to the resetting of the ECU)

The Data extent of BMW is very small, it's sampling rate (how often is the data transmitted from the car to the server) is not specified in the API documentation. Internal tests indicate that data is only transmitted at the event "Ignition off" of the vehicle which would be a far inferior sample rate compared to existing solutions on the market that transfer data while the vehicle is driving and (e.g. in case of the PSA solution) transfer data every minute.

The small data extent, very low sample rate, no possibility to interact with the vehicle and no possibility to interact with the driver other than by smartphone make the development of innovative new services that can compete with service offers from OEM on equal terms for developers extremely difficult, if not impossible at all.

11.11.5 Conclusion

This proposal from BMW illustrates the key issues of restricted data, uneconomic costs, latencies and access conditions that preclude competitive services. The BMW Car Data does not support the ability to display third-party services in the vehicle and most importantly, the access to real-time data.

The quality (data available, aggregated data/information, latency and granularity etc.) all prevent the creation of alternative competing services and therefore consumer choice. Additionally, any competing service has inherent access costs which distort consumer choice, whilst increasing the cost of the service. This is a problem of both accessing in-vehicle information as well as developing and maintaining the web services interface that is required.

The ability to remotely access in-vehicle data and information to support a range of services (prognostics, diagnostics, predictive maintenance, insurance services etc.) that would really help to optimise the diagnostic, service, repair and maintenance process to reduce consumer costs, is not possible. The ability to use the data available from BMW CarData in the wider digital economy is also limited due to both the quality and cost of the data.

Thus, BMW CarData cannot be considered as a better basis for competitive third-party services that could provide viable consumer choice and is therefore not a beneficial development of the extended vehicle concept.