Challenges in the Design of Automotive Software

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Abstract—**Since the foundation of AUTomotive Open System ARchitecture (AUTOSAR), the AUTOSAR Core Partners and more than 65 Premium and Development Members have been working on the standardization of vehicles' software architecture. As a result of its joint development activities AUTOSAR has already provided several Releases, which comprise a set of specifications describing software architecture components and defining their interfaces. With Release 2.1 and Release 3.0/3.1 the majority of partners and members started their series roll-out of AUTOSAR. When introducing the AUTOSAR standard in series products dedicated migration scenarios need to be applied.**

BMW is migrating to AUTOSAR Basic Software in its current and upcoming product lines. This includes also common functionality that is today already realized as AUTOSAR compliant extensions to the basic software. Further on BMW's strategy on providing application software as ready-to-integrate AUTOSAR software components is described. *(Abstract)*

I. INTRODUCTION

Software development for automotive applications is gaining more and more importance. In the 70ties, mechanical systems dominated car development. In the 80ties, we saw electronic support mainly in the area of chassis and engine control. Infotainment functions gave software dedicated meaning in the automotive domain of the 90ties. Today, software controls a large number of functions, which make use of linked networks. Interactions of functions in a linked network contribute to an increasing complexity, which require a strong controllability of the complexity.

II. INCREASING COMPLEXITY

Modern vehicles have a large number of Electronic Control Units (ECUs) inside that realize a huge number of functions. Those functions may be distributed among several ECUs. Premium cars for example have up to 70 ECUs, connected to 5 system busses, realizing over 800 functions.

The ECUs are comparable to small „computers" that control aspects of the vehicle, such as air conditioning, seats, engine, or transmissions. They are connected to each other by various bus systems (CAN, FlexRay, etc.) and thus form a distributed system inside the vehicle. The software is primarily written in the programming language C, running on dedicated embedded operating systems like OSEK.

Meanwhile 90% of all innovations are driven by electronics and software. Furthermore, up to 40% of a vehicle's development costs are determined by electronics and software. 50 - 70% of the development costs for an ECU (Electronic Control Unit) are related to software. The results:

- Growing system complexity

- Increasing number of dependencies

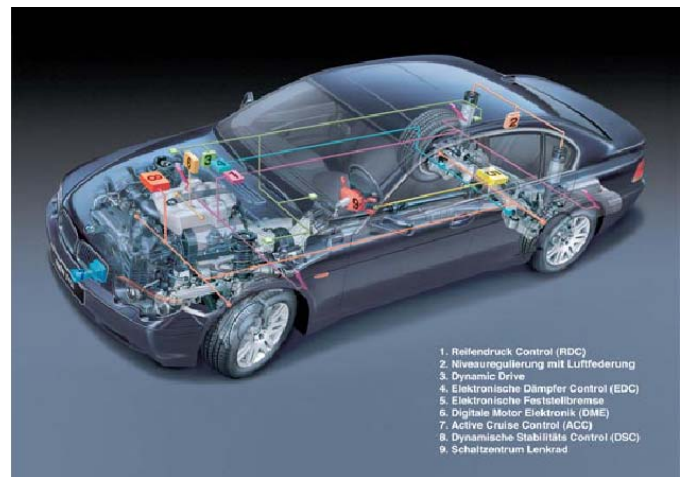- Costs play a significant role

Figure 1.   E/E-architecture network

Future E/E-architectures will consist of highly integrated domain-controllers, which will be interconnected via high-speed bus-systems. Sub-busses with CAN, FlexRay and LIN will provide connectivity to intelligent satellites within the car's network. For that highly interconnected architecture powerful domain controllers are required. They will provide very high functional integration and maximum availability.

III. FUNCTIONAL INTEGRATION

High integration of for example central body architecture with an integrated gateway results into a cost reduction due to

- reduced number of parts,

- optimized wiring,

- reduced number of ECUs,

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- shared use of common resources like micro controller,

- reduced physical busload, and

- reduced weight.

Where does it lead us? Future E/E-architectures will have a common basis across OEMs. In order to manage the growing system complexity and to keep the costs feasible, the basic software and the interfaces to applications and bus-systems have to be standardized in a future proof way. AUTOSAR provides this standard.

IV. WAYS OF WORKING

The use of a standard for software development changes business and working models. The role of a supplier changes from providing customized functions changes to offering an application portfolio applicable to more than one OEM. On the other hand software development at OEM side will concentrate on the key functions, which differentiate one from the other OEM.

A. Working without a standard

1) Applications

Up to now, suppliers mostly provide E/E functionality as a black box. OEMs are only taking care of the kind of application and of the configuration of the functionality and/or software. In addition, BMW develops certain unique functionalities within the chassis and power-train domain on its own.

The supplier is overall responsible of the software. Furthermore, suppliers are doing the integration of the system. Re-use of application software is impossible in most of the cases. A change of the supplier typically requires a complete re-development of the application software. Efforts for verification and integration testing do never decrease.

2) Basic Software

The situation is different at the basic software development. To face the raising complexity and to increase efficiency and maintainability, BMW developed early a basic ECU software stack – called "Standard Core" – to be used across BMW models. The "Standard Core" is provided to suppliers for basing their applications on it. The main objectives are to supply, distribute, support and maintain basic- and system software for (all) ECUs in BMW vehicles. Moreover, BMW provides support to "Standard Core" users by a hotline and makes updates available via its business partner portal in the Internet.

B. Working with AUTOSAR

1) Applications and Basic Software

With the introduction of a standardized basic software stack, we see a paradigm change in business and working models.

A new approach is set-up to exchange software specifications as executable model instead of software documents. This leads to a new interface with the supplier. BMW still influences the software-architecture of an ECU and adapts quality control to software specification by models. Pre-condition for a successful software integration is a precise description of the software interfaces. The supplier remains responsible for the ECU.

BMW will no longer provide the "Standard Core", instead μC manufacturer or 1st tier or 3rd party software suppliers develop and test their implementation of AUTOSAR basic software.

The applications communicate with the basic software by standardized APIs (Application Interfaces). By that, a lot of applications will become common for several OEMs. The supplier does not develop customized software applications anymore, but addresses with the same function several customers. These software applications become reusable.

Specific key functions will remain OEM specific. However, thanks to standardization, also these applications will be reusable for all models.
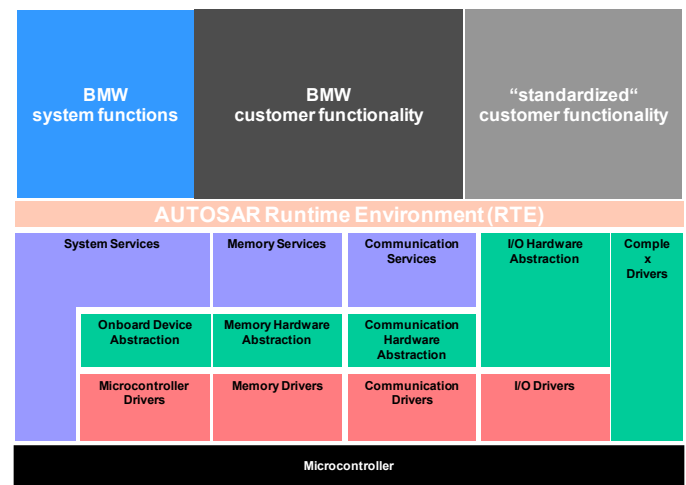

Figure 2. Different kinds of application on top of AUTOSAR basic software

2) Integration of functionality

Another great advantage of the AUTOSAR standard is the possibility to integrate a high amount of functionality into one ECU in a controlled way. Such development projects involve multiple suppliers and address many cross-domain interfaces. To handle this project complexity, extensive multilateral discussions and negotiations are needed in order to clarify the technical interfaces between deliverables and the project related interface between suppliers.

The standardized basic software stack of AUTOSAR greatly simplifies this complexity. Due to the defined modules and the standardized APIs, scope and interworking is preset.

BMW is working on a complex body domain ECU consisting of 3 microcontrollers, including a dual core 32Bit μC and a dedicated μC for safety-related applications. AUTOSAR will be used to integrate numerous functions into one ECU. Four ECUs of the current 7 series will be replaced by two in the next 3 series. AUTOSAR is the key technology to control this complexity.

V. MIGRATION

The roll-out of AUTOSAR in vehicles does not happen like a big bang. Instead, every car maker is applying various migration scenarios depending on what kind of products are suitable at the developing phase of the specific models. On the other side, product suppliers' offerings depend of course on their internal product plans and ability with respect to AUTOSAR. BMW already started migration by applying a network and an ECU migration process.

The migration of a vehicle's E/E-network to AUTOSAR will follow a step-by-step approach. Starting with a few ECUs, especially those with a new hardware platform, more and more ECUs will be migrated over time.

The ECU migration process considers the migration of the software architecture of one ECU. The AUTOSAR basic software Release 2.1 is the current base of the ECU software architecture. However, a number of BMW legacy functions cannot be realized with AUTOSAR Release 2.1. For this reason, BMW develops so-called compatibility modules to modify the functionality of the AUTOSAR basic software stack. Five compatibility modules are necessary for diagnostics, handling of service messages, and FlexRay.

On the one side, these proprietary compatibility modules ensure interworking to BMW functions, which cannot be migrated to AUTOSAR yet. On the other side, they enable an evolutionary migration to the AUTOSAR standard. At the same time, BMW is able to use additional standardized AUTOSAR functionality.
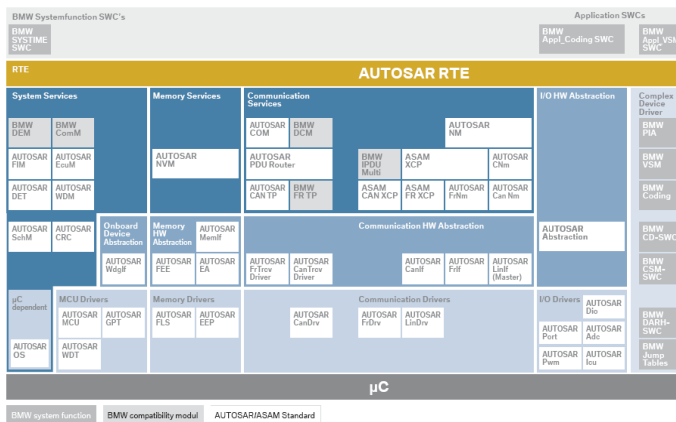

Figure 3. BMW AUTOSAR Core 2.1

AUTOSAR basic software stack and BMW compatibility modules form the BMW AUTOSAR Core. Basic principles during migration are to use as many AUTOSAR basic software modules as possible, modify AUTOSAR basic software modules only to ensure backward compatibility to BMW legacy functions, and to provide BMW specific system functions either as AUTOSAR software-components or as complex drivers.

Already the migration to AUTOSAR means a change in business relation. The μC manufacturer or 1st tier or 3rd party software supplier develops and tests the AUTOSAR basic software. Then, the 1st tier replaces defined AUTOSAR Modules by BMW compatibility modules. At last, 1st tier and BMW test the BMW AUTOSAR Core.

BMW provides the BMW AUTOSAR Core to application providers to base their application development on. Since the BMW AUTOSAR Core uses the standardized RTE for interfacing the applications, new applications will be based on AUTOSAR. Legacy application software will use wrapper code on top to interface AUTOSAR RTE.

Long term, the BMW specific compatibility modules will be replaced by standard AUTOSAR. AUTOSAR Release 4.0 will make it possible to realize a pure AUTOSAR basic software stack in series products of BMW.

The upcoming BMW 3 series will make widely use of the BMW AUTOSAR Core 2.1. Almost all new ECUs will be based on AUTOSAR basic software Release 2.1. Moreover, body and chassis systems will use AUTOSAR compliant functions.

Starting in 2010 BMW will also support AUTOSAR Release 3.0/1 in the basic software as this release is currently used by the majority of 1st tier.

VI. SUMMARY

Standardization of the ECU architecture is needed in order to handle increasing functional complexity in a cost efficient way. It enables a high amount of functional integration and the reusability of software applications.

Standardization also means a paradigm change of the working and business models. Suppliers will develop applications applicable to more than one OEM. OEMs will concentrate their development on key functions.

From BMW's perspective, AUTOSAR fulfills all requirements for an ECU basic software standard. BMW goes for AUTOSAR basic software now and is fully committed to AUTOSAR. The BMW "Standard Core" is replaced by AUTOSAR basic software. Application Interfaces including functional specifications are already used in series development. The current BMW 7 series and BMW 5 series Gran Turismo are using AUTOSAR components. AUTOSAR is on the road.