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Architectural Decisions as the Basis for Sustainable Mobility

New developments in passenger-car technology involve a multitude of special challenges that have to be met in terms of system complexity as well as cost, time and innovation pressure. The coordination with additional technology sectors also plays a major role, according to fka. The particular relevance of all these factors and architectures for achieving climate targets must be taken into account, and they must be subordinated to the topic of sustainable mobility.

What architectures of next-generation vehicle systems will look like is often and strongly discussed. Different understandings, terminologies, contexts and associations complicate the discussion. In addition, there are specific challenges based on established structures of business and industry [1]. Overall, there is a broad spectrum of diverse views and perspectives, rich in detail, with accompanying strategies, solutions and measures.

With regard to the concept of sustainability, which, like the concept of archi-

tecture, is a broad and difficult one to grasp, it must be stated that a sustainable mobility technology is more than the question of energy efficiency and direct or indirect emissions. Consideration must go beyond a linear life cycle of design and development, production and operation, and subsequent recycling. Resource inputs and utilization rates at multiple levels, across subsystems and life-cycle phases, and interactions among them play a critical role. A paradigm shift in the concept of the automobile (passenger car and commer-

cial vehicle), of its actors (in terms of architecture, system and component design and use, operational strategies) and of integration scenarios is necessary, as exemplified by scenarios from fka's current concept developments.

The virus illness Covid-19 was not yet relevant to the conceptual design phase of the architectural approaches presented. In many respects, this disease has become an accelerator for changes to established structures and solutions. The question of how these changes are now being addressed and shaped – also raised by

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the European Commission [2] – is therefore perhaps more topical than ever.

SYSTEM AND ARCHITECTURE LEVELS

fka has been pursuing the development and design of architectures since 2012. With the Automotive Service-oriented Architecture (Asoa) approach [3], a new method for intra- and inter-vehicle networks was developed as early as 2014 – with influence on function strategies, development and integration as well as Electronic Control Unit (ECU) structures. With a view to future developments, fka already expanded its considerations in 2015, moving away from an initial focus on logical function and ECU layers.

fka's architecture development strategy is dedicated to technical challenges within the vehicle and extends to other technology sectors – such as Information and Communications Technology (ICT) or its infrastructure. Non-direct technical aspects are also covered, for example the sustainability of innovations and approaches. This works because the vari-

ous aspects are not considered alongside one another, but rather in direct interaction with one another [4].

There are often several architectural options. In order to evaluate these, quality attributes are used; in the area of sustainability, for example, the aspect of recyclability or the achievable benefit of the resources used, **FIGURE 1**. In order to approach the architectural decisions and then assess them with quality attributes, system layers are defined in advance, **FIGURE 2**. In addition to a structural layer, which primarily addresses questions of mechanics and packages, a distinction is also made between an energetic layer, which encompasses all forms of energy sources and transport variants including the distribution and storage network, an ICT infrastructure layer with communication networks and high-performance computing systems, and a logical function layer. In addition, each form of mobile and stationary systems can be grouped into a mobility layer.

The layers describe partial aspects of the overall system. In real systems, they interact and depend on each other and

change/influence each other. For example, a change of location on the mobility layer means a change or dependency on the energy layer or the ICT infrastructure layer.

SCENARIOS FOR VEHICLE AND INFRASTRUCTURE

Scenarios based on vehicle and infrastructure can be used to illustrate architecture action options. The following scenarios extend the context from local to system-wide intra-vehicle aspects to overall applications that cross vehicle boundaries and use case boundaries. Consideration of zone and central ECU architectures are included. In this way, approaches for improving the sustainability and resilience of systems and infrastructure can be identified at an early stage.

ECU NETWORK AND POWER GRID

Today, ECUs are developed for individual vehicle systems or vehicle system generations. Here, there is a close link to suppli-

FIGURE 1 Qualities for architecture assessment: This can be done with the help of the Architecture Trade-off Analysis Method (Atam) process or in a simplified way with exemplary scenarios (© fka)

FIGURE 2 The structuring of the layers of vehicle and mobility helps to identify common connecting points and strategies (© fka)

ers. The same applies to function. The package, connectors and interfaces change continuously and are mostly also manufacturer-specific rather than generic or standardized. Even if building block principles are used, the overall strategy is not true modularity; interchangeability and reusability are limited.

The introduction of true modularization and the adoption of uniform standards, preferably applied across system generations, enables interesting application scenarios, especially with respect to component interchange and reuse [5]. In this context, a stringent separation of hardware and software is also advanta-

geous, as is a modified tailoring of the functional components, including in conjunction with middleware and smart sensor and actuator systems.

This enables strategies for Redundant Assembly of Interoperating Devices (Raid) – both at the ECU layer and at the energetic layer. These show their strength in the interconnection and help to compensate failures with low performance restrictions. In addition, system layers, such as the power grid, become more scalable. These strategies have been proven to be effective for highly available ICT infrastructure. This can be supported by a zone architecture with

powerful zone computers and central computer system(s), **FIGURE 3**.

DYNAMIC AND SYSTEM-WIDE SAFETY

Automation and the use of mechatronic by-wire applications are just two examples of future safety-relevant systems. High demands of functional and operational safety come into play, as considered by ISO 26262, Sotif or the like.

For many of the strategies used today to realize the safety requirements, the focus is on subsystems only. Consequently, functional complementary

FIGURE 3 Automobile with ECUs: zone ECUs (black) as well as central ECU with uniform design (white) increase interchangeability and reuse and simplify the engineering process in the long term (© fka)

FIGURE 4 The vehicle as a “movable infrastructure component” enables dual-use scenarios of components and systems, but requires coordinated strategies (© fka)

potentials, which enable an efficient realization of a safe behavior in case of failure, remain unexploited. The safeguarding of subsystems is nevertheless – or precisely because of this – demanding and costly. The system behavior and the safeguarding strategy is statically defined at development time and can only be guaranteed by using components that were part of the system development process.

Another strategy is to introduce “self-awareness” at component and system level [3]. Here, dynamic information, abilities and operating condition variables of the components are respected and are mapped on a performance of the entire system. For example with runtime evidence checks, a decoupling between the characterization of the component or a subsystem and the functional orchestration is to be obtained. The focus of development thus shifts to two aspects: a better characterization of component performance (guarantees) and a better characterization of needs (requirements). The performance and safety reserve can be determined at runtime. The preceding approach can also be actively used here, such as through targeted wear-out shaping and the acceptance of the failure of subcomponents with the

goal of preventing oversizing and increasing reusability.

END-TO-END DIGITIZATION

Digitization in mobility and other parts of economic and social life leads to an increasing demand for resources for computer technologies and communication networks. This applies to the use of the components and systems, the design and the maintenance, as well as their energy demands. Added to this is the particular importance of their availability and reliability in order to operate a world based on digitization or to make its expansion scalable.

Whereas in a large number of digitization strategies, the resources used are thought of in isolation on specific applications, special opportunities open up in a cross-technology solution. This is because the high-performance control units with high computing power required in the context of automation remain unused for large parts of their life cycle. In this context, the computing power is available at the supposedly locally best possible position, the so-called Point of Presence (PoP).

In Vehicular Edge or Fog Computing, vehicles in two operating states become part of the cloud – both mobility use as

part of the mobility cloud and the vehicle, as well as in stationary times as part of the ICT infrastructure cloud, **FIGURE 4**. Thus, these architectures open up potential for synergies and optimum resource and energy utilization. In addition, computing and communications networks can be relieved and organized in a non-centralized manner. However, this requires complete infrastructure integrability.

ASPECTS OF THE ARCHITECTURE

The preceding scenarios are exemplary. They help to understand the derivation of the consequences of architectural decisions regarding and as a basis for the development of sustainable mobility technologies and to broaden the perspectives and thought spaces.

It can be seen that modularization and decoupling of individual aspects in particular show significant architectural advantages that have a relevant influence on sustainability. This requires a different component and system design philosophy. Cooperations within the automotive industry, but also in particular with other technologies (ICT and infrastructure), are necessary if the aim is to achieve consistency in the solution strategy. This is only possible at the

FIGURE 5 To ensure systematic sustainability, the requirements profile of the architecture must be defined from the entire life cycle (© fka)

expense of a supposedly believed flexibility, which is due to the fact of a lack of standards and agreements.

Better scaling effects in development and reuse, but also in particular the possibilities of increased reusability and reduction are the result. A distinction must be made between the reuse of components instead of recycling (upcycling, component lifetime utilization) and multiple usage (multi-purpose, multi-use). This makes it necessary to consider the entire life cycle in the design, even beyond system generations, **FIGURE 5**.

SUMMARY

The relevance of architectural decisions that can directly or indirectly contribute to an improved and more comprehensive sustainability in the development of the automobile but also of other technologies have been outlined by fka in this paper. In addition to the development and design of technical measures, this requires above all a willingness to cooperate and make joint efforts.

Above all, a broadly oriented, far-sighted and flexible architecture makes it possible to address an appreciable spectrum. It is important not to think in too small steps. The core challenge

is that the architecture decisions provide the means to simultaneously guarantee the long-term nature of the measures. This can ensure interoperability and compatibility of solutions across generations.

Only if the next architectures and their interplay in mobility technology are set for the long term and with ambition, a technological edge and, at the same time, a targeted focus on the challenges of our time can be ensured. Decisions in the architecture are thus essential guarantors – also for sustainable future viability.

REFERENCES

- [1] Conway, M. E.: How Do Committees Invent? In: Datamation magazine, F. D. Thompson Publications, April 1968, pp. 28-31
- [2] European Commission: Questions and Answers: Sustainable and Smart Mobility Strategy. Online: https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_2330, access: January 21, 2021
- [3] Woopen, T.; et al.: Unicaragil – Disruptive Modular Architectures for Agile, Automated Vehicle Concepts. 27th Aachen Colloquium Automobile and Engine Technology, October 2018
- [4] Parnas, D.: On the Criteria To Be Used in Decomposing Systems into Modules. In: Broy, M.; Denert, E. (ed.): Pioneers and Their Contributions to Software Engineering. Berlin, Heidelberg: Springer, 2001, pp. 479-498
- [5] Baldwin, C. Y.; Clark, K. B.: Design Rules. The Power of Modularity. Cambridge, MA, USA: The MIT Press, 2000

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