In search of the best migration strategy from CAN to FlexRay

For the migration from CAN to FlexRay, the research and advanced engineering department of Daimler is extending the design process for its future E/E architecture with performance evaluations. This enhancement raises the productivity and provides a systematic and efficient evaluation base for the dimensioning and configuration of network architectures for the next generation.

FlexRay is alive and components are available: Transceiver hardware and AUTOSAR FlexRay stack, lab equipment and configuration tools. Already, cars with FlexRay have hit the road. First application areas are predominantly in the chassis domain. On the one hand, FlexRay is expected to replace CAN in other areas and might – when component prices drop for instance – become attractive for lower-cost car segments. On the other hand, migrating from CAN to FlexRay is still costly and extensive.

While setting the protocol parameters like cycle time, inter frame space etc. is well understood, other questions remain and new ones arise. When will we reach the extensibility limit of CAN? How about flexibility of FlexRay configurations despite its quite static time-triggered behavior? How to derive a platform strategy across variants? And finally: How to reach a consolidated view?

In fact, we are asking for nothing less than an optimal migration strategy for FlexRay with inherent impact on E/E architecture design and the entire design process. New technological and conceptual challenges add to this situation, e.g. coupling event- and time-triggered communication in heterogeneous networks, CAN-FlexRay-gateways, synchronous and asynchronous ECUs. And finally, there is always the trade-off between flexibility and cost reduction.

1. The situation

Architecture design is complex. The system architects must handle the high amount of new innovations while existing systems are to carry over. Fortunately, new network architectures are hardly designed from scratch but mostly result from an evolutionary process based on existing ones (from previous platforms and existing modules). Furthermore, the migration to FlexRay is typically bound to specific domains such as chassis control. Nevertheless, a huge number of options to dimension and configure the new buses and gateways remains. This requires systematic decision processes for reliable and cost-efficient designs.

In this situation, the research and advanced engineering department of Daimler is working with two key steps during the design process of E/E-Architectures (see **figure 1**): (a) the design of architecture alternatives, and (b) the seamless evaluation of these alternatives following the most relevant criteria. This raises the productivity and provides a systematic and efficient evaluation base for dimensioning and configuring future network architectures.

2. Architecture Process

This is the major challenge of the architecture design: the focus on the key high-level decisions and support detailed design steps to the maximum possible extent. Next, the detailed configurations have to comply with specific criteria, e.g. predefined signal grouping rules. For the design and evaluation of E/E architectures the research and advanced engineering department of Daimler is using the E/E-concept tool PREEvision of aquintos ([1] and [4]). For extended performance evaluations, Daimler uses the timing tool suite SymTA/S of Symtavision ([2] and [5])

Architecture Design

The function-oriented view of PREEvision supports deriving communication configurations for existing network topologies as well as for future concept alternatives. Feasibility forecasts of these alternatives support comparisons. As an important property for the productivity, PREEvision can automatically generate large parts of the detailed communication configurations (needed for the implementation), e.g. automatic signal routing and frame synthesis. Therefore the legacy of signal-to-frame mapping can be assured for re-used components, in conjunction with enhancing or restructuring other parts of the communication design when integrating new functionality. This way, similarities among all variants and alternatives are considered to maximize the re-use of I-PDU layouts, frame IDs etc. In the end, the system architect selects from a manageable number of architecture alternatives. PREEvision offers several metrics for initial comparisons, e.g. static busload or network expansion. Customer specific metrics can be integrated over the open interfaces.

Architecture Evaluation

One additional criterion is predicting the performance and timing, i.e. the resource consumption, message timing, buffer delays, etc. of each architecture alternative. The timing analysis tool suite SymTA/S enhances this step significantly.
SymTA/S takes the topology, network configuration (number and parameters of frames), signal-to-frame mapping etc. as input – this data is exported from PREEvision. SymTA/S then analyzes the timing behavior of the architecture and determines the average and peak bus load, the

EVALUATION EXAMPLE

An example illustrates the approach (see **figure 2**). ECU_A sends data to ECU_B which then sends information to ECU_C. Alternative (1) on the left side could be considered as favorable in terms of the busload for CAN_1 as this bus only includes the communication from ECU_B to ECU_C. Architecture alternative (2) on the right side yields a higher bus load on CAN_1 but has one gateway hop less. In terms of optimal signal timing, alternative (2) with only one gateway hop and no CAN-FlexRay and FlexRay-CAN transition is favorable, despite its higher bus load.
Designed in PREEvision, the communication parameters of both alternatives are derived and exported as a base for the timing analysis with SymTA/S. Using this integrated approach the architecture decision could take into account both, busload and timing evaluation results.

message delays, and the end-to-end signal delays for single buses as well as gated networks incl. transitions between time-triggered and event-triggered domains. The result is a compact "performance report" for each architecture alternative, which eases the comparison.

Integration

Based on the PREEvision and SymTA/S toolset, the essential building blocks are now available for a systematic and efficient decision process:

- a tool-based design of architecture alternatives,
- an automatic evaluation of each alternative with compact comparisons and guidance for the decision making.

This provides the system architects with a solid decision base that is compact and complete. It is compact because it is based on evaluation reports that hide the details of the vehicle architecture. And it is complete because the details are in fact part of the design step. Consequently, once the decision for one of the architecture alternatives is taken, the process immediately provides all the information needed for refinement and implementation including topology, communication matrices, COM layer configuration files, gateway routing tables etc.

As an important property for a wide applicability of this approach, the presented design and evaluation process is not OEM specific, but can be (and has to be) adjusted to the explicit manufacturer strategy, e.g. signal-to-frame grouping rules in the design and safety margin criteria in the evaluation. As a significant advantage over previous approaches, the system architect can evaluate several architecture and concept alternatives in parallel. Within Daimler this approach has been used extensively for the CAN FlexRay migration.

Lessons Learned and Conclusion

The major benefits have been generated by a seamless design and evaluation process. One critical factor for the efficiency of this approach is a seamless data exchange between the tools. Currently, this data exchange is file based using standard (FIBEX) and proprietary formats with

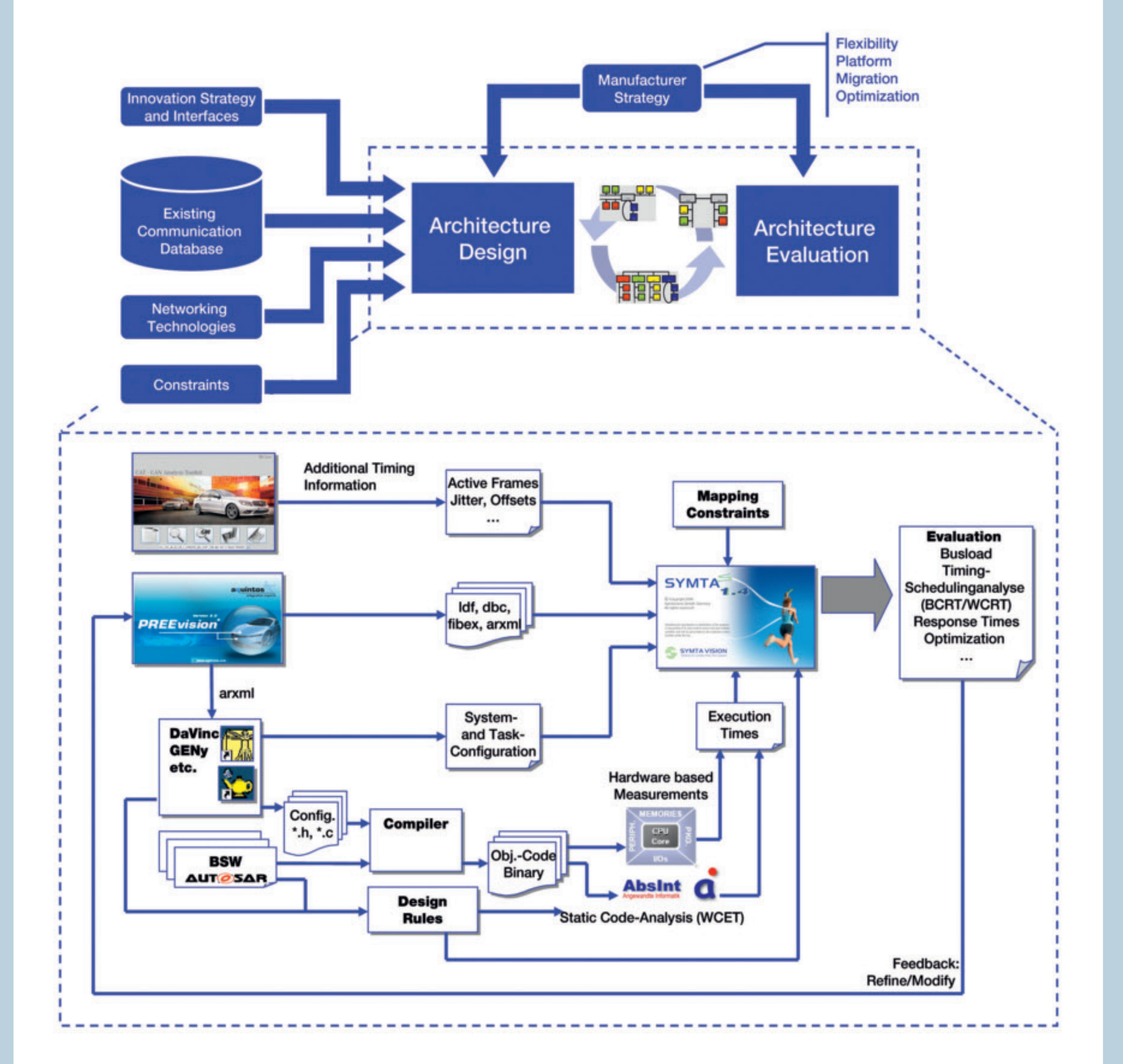

Figure 1: Seamless architecture design and evaluation.

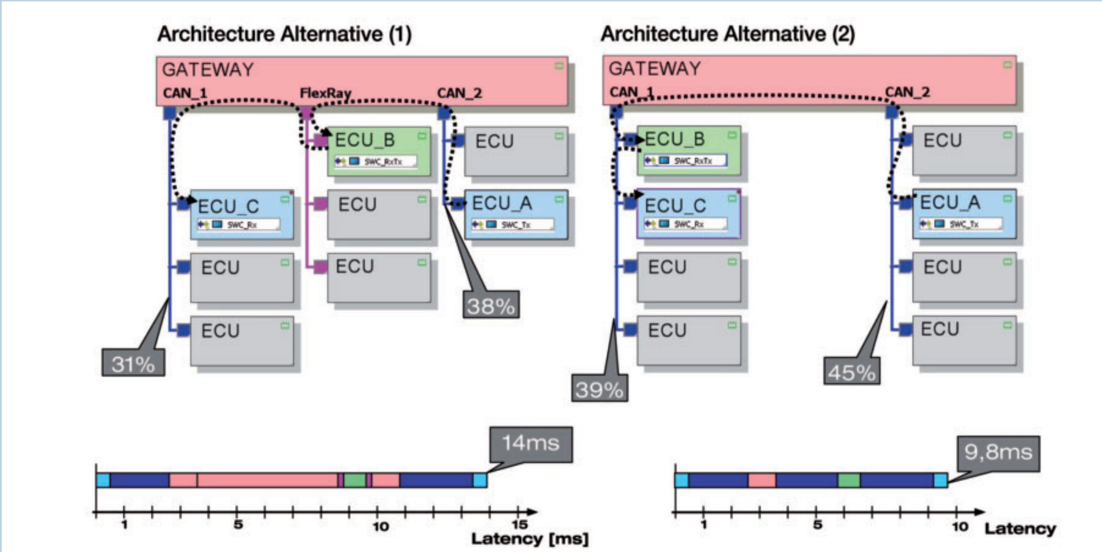

Figure 2: Evaluation example: busload optimized (left) –timing optimized (right).

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manual adaptation. In future, this will be supported by the timing specification of AUTOSAR Release 4.0 [3] including timing annotation and standardized data exchange.
Nevertheless, tools and methods are available to enhance the E/E-Architecture design process with timing evaluations in order to provide an efficient and more complete decision base for architecture design. This allows answering the key questions posed in the beginning of this article: If and what to migrate to FlexRay and how to do this most efficiently and at the right time. Daimler is using such extended design processes for dimensioning and configuring its future E/E architectures.

References

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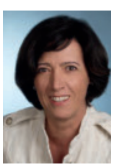

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