Ethernet as Future Automotive Communication Backbone

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I. INTRODUCTION

The automotive network architecture is currently facing the limits of established technology. Traditional protocols such as CAN, Flexray and LIN do not meet the bandwidth and scalability requirements of next-generation Advanced Driver Assistance Systems (ADAS). Automotive niche solutions such as the MOST-Bus are simply too expensive and the launch of CAN-FD as a successor to CAN can only be seen as a transition technology as it will not stand the pace in the long term.

Ethernet is the emerging technology in the automotive domain. It is capable to address bandwidth demands of tomorrow’s advanced driver assistance systems (i.e. HD video, LIDAR) and it offers superior interoperability with consumer multimedia products such as smartphones and tablets. Due to its superior bandwidth and flexibility and the promise of sharing cost of ownership with other industrial segments, Ethernet appears ideal to address the high demands of new functions in infotainment and advanced driver assistance systems (stereo camera, surround view) or to reduce ECU flashing and updating cost. While the first generation of cars will use Ethernet as additional communication medium, it is also considered as a powerful future backbone technology also carrying traffic originating in CAN (-FD) or other bus subsystems (cf. Figure 1).

Being able to analyze architecture concepts, load, performance and real-time capabilities of such Ethernet networks is one of the top-priority requirements. Such analyses are established standards for CAN and FlexRay networks already today, and we will need them more urgently for Ethernet-based E/E architectures because the real-time behavior will become more complex. At present, first solutions exist but there is only little experience with Ethernet-in-the-car, and the existing standards do not cover all relevant aspects.

Through extensive fine-tuning of the available parameters, today’s pioneers manage getting the first high-bandwidth Ethernet on the road without violating the standards. This is spectacular and deserves high respect. In the longer term, we will need standardized solutions in order to reach our objectives, in particular in terms of cost and flexibility. The authors cooperate with leading volume and premium car manufacturers on the configuration, evaluation and real-time analysis of Ethernet architectures. In our contribution, we compare fundamental architectural options and upcoming standards (such as Ethernet AVB) with respect to their real-time capabilities. Papers resulting from this collaboration (i.e. [1]) summarize the findings and raise awareness and stimulate the discussions among experts and in particular among decision makers at the car manufacturers world-wide.

The trend towards Ethernet-based E/E architectures has already been observed in the avionics and industrial domains, there leading to domain specific standards, which are mostly incompatible with standard Ethernet devices. While automotive electronics can learn from those domains, vastly different requirements, cost targets, safety requirements, and design processes suggest to rethink Ethernet usage and stay as close as possible to existing high volume solutions. This is no easy task since Ethernet has been developed for applications which are neither time nor safety critical, but focus on bandwidth. Cars have a far richer set of real-time requirements including quality-of-service (QoS), guaranteed end-to-end timing (i.e. latency), guaranteed delivery, guaranteed bandwidth, or best-effort.

Furthermore - and different from all technologies used in a car so far - Ethernet is a packet-switched network with point-to-point links introducing a new layer of complexity over traditional busses. With traditional busses (e.g. CAN, FlexRay), the access to the shared bus was the only point of arbitration, and it was in total control of the ECUs. In packet-switched networks, each switch adds delay on the end-to-end latency. The Ethernet protocol allows dropping frames if switch buffers are full (often without any ECU noticing it), or stalling communication to prevent buffer overflow, even if critical traffic is delayed. Ethernet has a maximum of 8 priority levels which requires merging the fine grain priority structure of CAN onto few separate communication streams. This entails a lot of potential real-time effects (e.g. latency) that must be
taken into account.

But let us start with the situation currently faced by automotive network architects. They have to: select the network topology (line, star, hybrid), configure the switches (priorities, buffers, etc.), including a technology selection (VLAN, AVB, TTE, etc.), and finally connect the higher-level applications (control, AV, software updates) through appropriate mechanisms (e.g. multiplexing, marshaling, etc.). We will look at this design space, explain key mechanisms (that are relevant for timing), their options, the possible pitfalls, and their influence on the overall performance.

II. Outlook

Leading OEMs such as Volkswagen, Daimler, BMW and others have made clear that Ethernet is on its way into automotive electronics. While first applications will, for the most part, use Ethernet as an add-on to existing network structures, Ethernet is also a hot candidate as future backbone technology. There are many good arguments, such as cost sharing with other industries, high bandwidth and new protocol functions for Internet access. Ethernet has a proven record of picking up new technological developments towards permanently increasing bandwidth, and Internet and wireless communication compatibility with the promise of a long lasting backbone standard that the automotive industry has been looking for. However, the way is rough as Ethernet is conceptually different from legacy automotive networks in various aspects.

We show different flavors of Ethernet with their unique strengths and weaknesses, underlined with experimental data, and with a whole chain of further questions: What is the best topology, switch architecture, and signal packing rule as well as higher level protocols? Here, a strategy must be planned well ahead, as decisions have far-reaching cost and productivity implications for the entire automotive supply chain, from the OEMs through the tier-1 suppliers down to the device and communication stack suppliers, as well as associated tool providers. The necessary research into real-time and performance analysis generates valuable results, which we will continue on the open questions. First solutions exist but we need “deeper” standards as soon as possible. Otherwise, we will find us lost in a zoo of manufacturer-specific solutions; expensive and inflexible.

REFERENCES