Chapter 16
Hybrid FlexRay/CAN Automotive Networks

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ABSTRACT

In recent years, the automotive industry has witnessed an exponential growth in the number of vehicular embedded applications, leading to the adoption of distributed implementations for systems in the powertrain and chassis domains. The Controller Area Network (CAN) protocol has been a de facto standard for intra-vehicular communications, while the FlexRay Communication System is being promoted as the future de facto standard for network interconnections of applications related to X-by-wire systems. Due to the characteristics of CAN and FlexRay, the coexistence of both protocols in the same vehicle is expected, leading to the use of gateways to manage the information exchange between electronic control units connected to different network segments. This chapter describes the main characteristics of CAN and FlexRay protocols, surveying the literature addressing schedulability and time analysis in both FlexRay and CAN protocols. The chapter also outlines the state-of-the-art in research about gateways for intra-vehicular communication networks.

1. INTRODUCTION

In recent years, the automotive industry has witnessed an exponential growth in the number of vehicular embedded applications, leading to the adoption of distributed implementations for electronic systems in the various vehicular domains.

Among other factors, this growth is stimulated by new requirements for safety and performance defined by several countries in the last years, by the evolution of systems related to the user comfort and experience, and by the crescent adoption of X-by-wire systems (Navet & Simonot-Lion, 2008; Zurawski, 2005).

The diversification of performance, cost and dependability requirements for automotive systems has resulted in the development of different communication protocols to be used throughout the car. These protocols can be as simple as communication systems for the interconnection of sensors and actuators at low speed rate such as LIN (LIN Consortium, 2012). They can also be sophisticated high-speed networks oriented for multimedia or safety critical applications such as MOST (MOST Cooperation, 2011) or FlexRay (FlexRay, 2011).

For network communications within powertrain and chassis domains, the Controller Area Network (CAN) (ISO11898-1, 2003), a network protocol developed by Robert Bosch GmbH, is today the *de facto* protocol standard. But according to several authors, CAN is not suitable for the projected demands for performance, hard real-time and dependability constraints in systems such as those related to X-by-wire applications. Due to this fact, an alliance of manufacturers including BMW, Bosch and DaimlerChrysler has developed the FlexRay protocol to meet the expected requirements. FlexRay has been heavily promoted as the future *de facto* standard for in-vehicular communications.

However, since CAN is still suitable for several applications and has a relatively low cost, in the near future it is expected the coexistence of CAN and FlexRay in the same car. In this scheme, FlexRay may be used in new high-speed functionalities and/or as a high-speed backbone between network segments that use different network protocols. It is easy to see that this kind of network architecture imposes the existence of gateways to allow the communication between ECUs connected to different network segments (Figure 1).

Although the work in (Steinbach, Korf, & Schmidt, 2010) suggests that time triggered Ethernet (TTEthernet) (TTTech Computertechnik AG, 2011) is a suitable replacement for FlexRay,

in (Lo Bello, 2011) it is stated that FlexRay will likely to continue being used in the powertrain and vehicle dynamics management. Therefore, FlexRay/CAN gateways have a key role in future in-vehicular network systems, and its design must consider the characteristics of both FlexRay and CAN protocols (Alkan, 2010; Lorenz, 2008) (Lorenz 2008; Alkan 2010). There are gateway-related commercial products (for instance, Vector's Network Design toolset (Vector, 2012)), but despite the number of researches addressing CAN and FlexRay protocols, just a few works in the literature deal with the design and timing analysis of FlexRay/CAN gateways.

The objective of this work is to survey the literature related to the design and implementation of FlexRay/CAN gateways. To a better understanding of the problems related to the design of FlexRay and CAN networks, we will first present the main characteristics of FlexRay and CAN, also surveying the existing works about scheduling and timing analysis of both protocols.

The remaining of this chapter is organized as follows. In Section 2 we present the basics of the FlexRay Communication System, including a survey of works related to scheduling and timing analysis of this protocol. Similarly, in Section 3 are presented the basics of CAN protocol. In Section 3 are also summarized works related to CAN's scheduling and timing analysis. Section

Figure 1. Example of car network with gateways (based on Navet & Simonot-Lion, 2008)
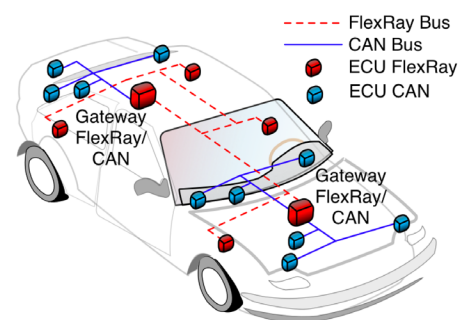
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