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Message scheduling with reduced matrix cycle and evenly distributed sparse allocation for time-triggered CAN

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ABSTRACT

Controller Area Network (CAN) was initially developed as an in-vehicle real-time communication bus. Due to its low cost and high reliability, it has also become a widely accepted standard in industrial distributed control applications. The CAN protocol has an event-triggered architecture. Although its priority based medium access mechanism provides guaranteed immediate access for the highest priority messages, it may cause unpredictability in communication media for the lower priority messages. In order to address the problems caused by the event-triggered architecture, different time-triggered network architectures, such as TTP, Byteflight, and Flexray, have been introduced.

This paper focuses on time-triggered CAN (TTCAN), which is built on the existing CAN standard with the addition of time division multiple access (TDMA). In order to combine the advantages of the event-triggered and time-triggered communication to meet the requirements of the distributed real-time systems, it is crucial to construct feasible message schedules. In this study, a schedule construction method, based on the reduced matrix cycle and evenly distributed sparse allocation, is introduced to produce the best optimum message schedules possible in terms of the message delay performance. The simulation results show that the method introduced in this study provides significant performance improvement not only for the time-triggered messages but also for the event-triggered messages.

1. Introduction

Modern upper class vehicles may have up to 70 electronic control units (ECU) exchanging up to 2500 signals using in-vehicle communication networks (Albert, 2004). Controller Area Network (CAN) is a widely accepted real-time communication bus for in-vehicle applications. CAN provides a robust communication environment for ECUs, comprised of microcontrollers, sensors, and actuators.

Real-time networks provide communication for both sporadic and periodic messages with deadlines, which describe the latest transmission time. The CAN protocol employs a mechanism called Carrier Sense Multiple Access with Collision Detection (CSMA/CD) with non-destructive bit-wise arbitration as the medium access method (Lawrenz, 1997; CAN Specification, 1991). Although this mechanism provides a guaranteed response time for the highest priority message, there is no guaranteed upper bound for delays encountered by the lower priority messages, especially under the high bus-load and fault conditions. However, it is an important issue to meet deadlines in safety-critical hard real-time applications, such as X-by-wire systems, which require deterministic behavior and high performance. As the arbitration mechanism of the event-triggered CAN does not meet these requirements, the time-triggered CAN (TTCAN) concept has been developed (Leen and Heffernan, 2002). Several other time-triggered networks (Gena et al., 2005; Paret, 2007) such as time-triggered protocol (TTP) (Kopetz and Bauer, 2003), Byteflight (Byteflight Specifications), and Flexray (FlexRay Specifications) have also been introduced. This paper focuses on TTCAN, which provides a deterministic behavior by imposing a TDMA structure over the existing CAN standard. TTCAN has been standardized and described in ISO 11898-4 (2004).

According to the medium access method applied, the real-time networks can be classified as event-triggered and time-triggered. Hybrid networks also constitute another class combining features of both types. In the event-triggered networks, messages are produced according to the occurrence of events and the medium access is provided in a dynamic way for messages. In the time-triggered networks, messages are produced at regular time intervals and the medium access is arranged in pre-defined time-windows in a TDMA manner.

The time-triggered systems have the advantage of deterministic behavior, whereas the event-triggered systems have the ability to react fast to asynchronous external events (Albert and Hugel, 2005; Albert and Gerth, 2003). As a hybrid system, TTCAN is expected to combine the features of both systems. Real-time

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