Dependable and Cost-Effective Electronic Platform Architecture for X-by-Wire Systems with Membership Middleware

Abstract

The advance in automotive electronics will enable more sophisticated vehicle control systems. Among these systems, X-by-Wire systems, where driving, steering and braking are electronically controlled, are expected to enhance the vehicle driving performance and safety. Because acceleration, steering and braking control have great influence on the vehicle safety operation, X-by-Wire systems are required to be dependable. On the other hand, cost for dependability cannot be so high to widely spread X-by-Wire systems in the future. Therefore, our goal is to balance these competing demands: dependability and cost-effectiveness.

To achieve this goal, we have so far proposed a network centric architecture based on a concept of autonomous decentralized systems. In our proposed architecture, all nodes related to the control including smart sensors and actuators share various data through the network, and each node autonomously gets/broadcasts the necessary data from/to the network. If a certain node stops operating because of some fault, the remaining normal nodes autonomously execute a backup control to maintain at least minimum necessary system function using the shared data. Therefore, the network centric architecture can tolerate the existence of the failed node and does not require high cost fail-operational nodes with triple or more redundant architecture.

As there is no master node for communication monitoring in this architecture, to execute the autonomous backup control, we have a technical challenge: how to identify the failed node accurately and ensure consistency of the information on which node has failed among all remaining normal nodes. Our novel approach to solve this challenge is a membership middleware which executes node status monitoring by a voting of the node status date exchanged among all nodes. We regard this functionality as one of the essential features of network management middleware for dependable distributed systems.

Consequently, we have designed the membership middleware and developed a FlexRay-based prototype brake-by-wire system based on the network centric architecture. Figure 1 shows a software architecture and process sequence of the

membership middleware synchronized to the FlexRay communication cycle as well as an overview of the prototype system. The middleware is implemented as a basic software module like communication stack and OSEK OS, and offers an API to provide the application program with the information on other ECUs status. In the brake ECU, the middleware has been implemented so as not to interfere with a three-phase brushless motor control task execution which has to satisfy a severe real-time requirement.

Following an introduction of our proposed network centric architecture and membership middleware, this paper will describe implementation details and result of performance evaluation, e.g. CPU execution time of the middleware, using the above-mentioned prototype system. We will also discuss improved features of the membership middleware to reduce CPU resource and communication bandwidth even in systems with large number of nodes and to manage communication reintegration nodes, which will be inevitable problems for practical X-by-Wire systems.

(474 words)

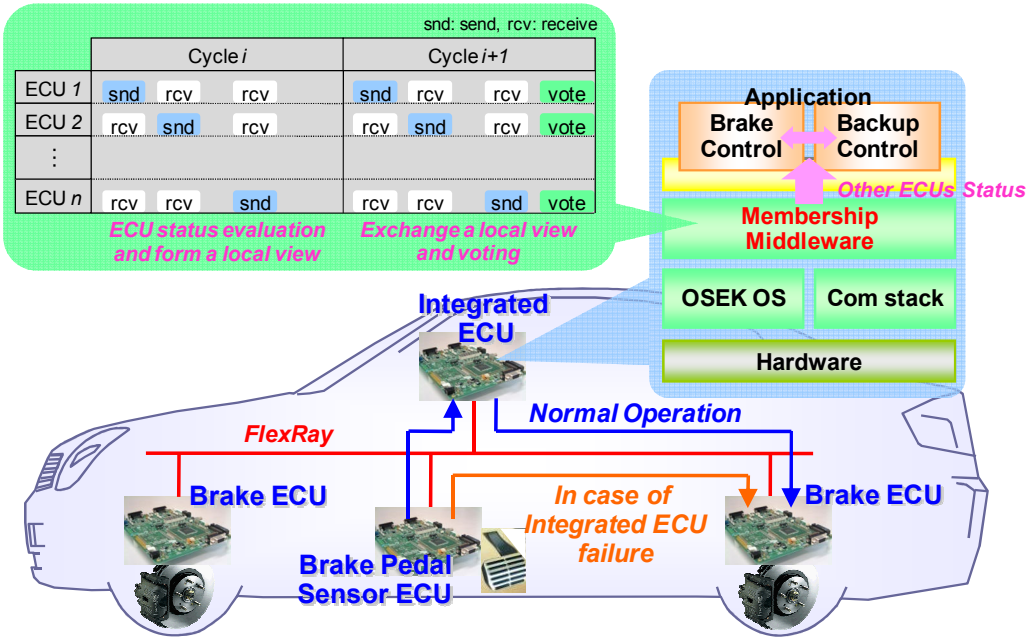

Figure 1. FlexRay-based prototype brake-by-wire system based on the network centric architecture