Performance Comparison of Zonal and Domain-based In-Vehicle Network Architectures

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Abstract

In recent years, vehicles have been adopting a domain-based in-vehicle network (IVN) architecture (DIA). Simultaneously, zonal-based IVN architecture (ZIA), which is emerging as the next generation architecture, is being researched. In this paper, we compare the performance in terms of end-to-end (E2E) delay to investigate the difference between DIA and ZIA. We developed IVN simulators using the network simulator OMNeT++ to measure the E2E delay. DIA shows 1.47 times better performance than ZIA in the case of traffic generated within the same domain. ZIA shows 1.64 times better performance than DIA in the case of traffic generated in different domains.

Ⅰ. Introduction

An in-vehicle network (IVN) was developed for effective vehicle control and management, facilitating data exchange between electronic control units (ECUs). However, as vehicles become more sophisticated, the increase in ECUs requires an increase in the wiring harnesses to connect them. This led to an increase in the length and weight of the wiring harnesses as well as the complexity of the network. Research on IVN architecture is essential to efficiently reduce the length and weight of the wiring harnesses and the complexity of the network. The IVN architecture can generally be classified into three types: central gateway-based IVN architecture (CGIA), domain-based IVN architecture (DIA), and zonal-based IVN architecture (ZIA) [1]. Currently, most original equipment manufacturers (OEMs) are adopting DIA in vehicles. They also are researching ZIA, which is emerging as the next-generation IVN architecture. In this paper, we examine the configuration methods and features of DIA and ZIA. Moreover, we compare the performance of the two IVN architectures in terms of end-to-end (E2E) delay using developed IVN simulators through network simulator OMNeT++.

Ⅱ. In-Vehicle Network Architecture

A. Domain-based IVN Architecture

DIA is an architecture in which ECUs with similar functions are grouped into a domain. There can be several domains for each major function of the vehicles. ECUs are controlled by the domain controller to which they belong. DIA provides fault tolerance because even if one domain controller has a problem, it does not greatly affect other domain controllers. Moreover, it reduces the load on the central gateway as data transmission and reception are primarily performed within the domain.

B. Zonal-based IVN Architecture

ZIA is an architecture in which ECUs in similar locations are grouped into a zone. The vehicle can be divided into several zones and ECUs located close to each zone are included in the respective zone. ECUs are connected to the controller of the zone to which they belong, and each controller is managed by a high-performance central computing unit (CCU). ZIA has the potential to reduce the length and weight of wiring harnesses as well as network complexity. As the wiring harnesses decrease, the total cost and weight of vehicles can be reduced. Moreover, since centralized control is performed through the CCU, ZIA has an advantage in implementing functions such as advanced driver assistance systems (ADAS) and over-the-air (OTA) that use integrated vehicle data.

Ⅲ. Performance Evaluation

We evaluated the performance of both the DIA and ZIA using OMNeT++ and CoRE4INET. The performance was evaluated considering the network aspect, and the performance was compared to the E2E delays of DIA and ZIA. We developed simulators while endeavoring to meet constraints described in IEEE 802.1Q as much as possible. The link speed between controllers and a gateway was set to 1 Gbps, and the link speed between controllers and ECUs was set to 100 Mbps. Fig. 1 shows the DIA and ZIA simulator structures, which are based on information supplied by OEMs. Table 1 shows the traffic information transmitted between ECUs [2]. For each type of traffic in Fig. 1, the data source, destination, and payload size are specified. Control data traffic (CDT) has the highest priority for vehicle control, which must be transmitted within 100 ㎲ through a maximum of 5 hops, and the transmission period is generally 500 ㎲. AVB is used for transmitting entertainment data, such as audio and video. SR Class A has a higher priority than SR Class B and must be transmitted within 2 ㎳ through a maximum of 7 hops, and the transmission period is generally 125 us. SR Class B must be transmitted within 50 ㎳ through a maximum of 7, and the transmission period is generally 250 us [3]. Based on Fig. 1 and Table 1, we developed two simulators for DIA and ZIA.

TABLE I Traffic Information Transmitted Between ECUs

Traffic Name	Traffic Type	Source	Destination	Payload [Bytes]
CDT_1	CDT (ST) Class	ADAS Sensor Fusion	ESC	625
CDT_2	CDT (ST) Class	ADAS Sensor Fusion	MDPS	625
AVB_A1	SR Class A	Forward CAM	ADAS Sensor Fusion	490
AVB_A2	SR Class A	ADAS Sensor Fusion	Cluster / HUD	2
AVB_B1	SR Class B	AMP	Rear Seet Entertainment	1250
AVB_B2	SR Class B	Infotainment System	AMP	11

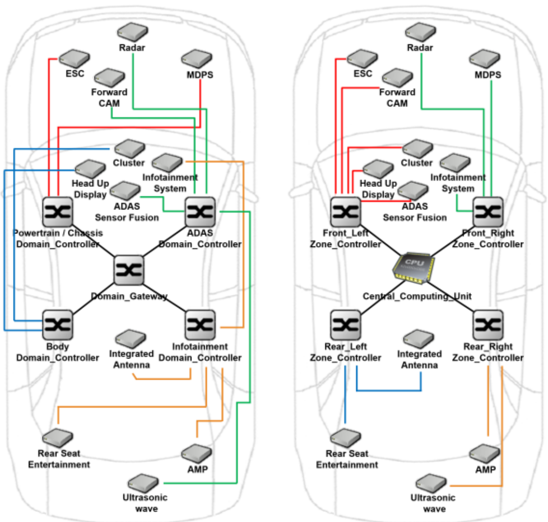

Fig. 1. Structure of DIA and ZIA simulators

IV. Results

Fig. 2 shows the result of measuring the E2E delays for each traffic. It shows that for most traffic, ZIA has decreased E2E delays compared to DIA. However, it shows that for certain traffic, ZIA has slightly increased E2E delays compared to DIA.

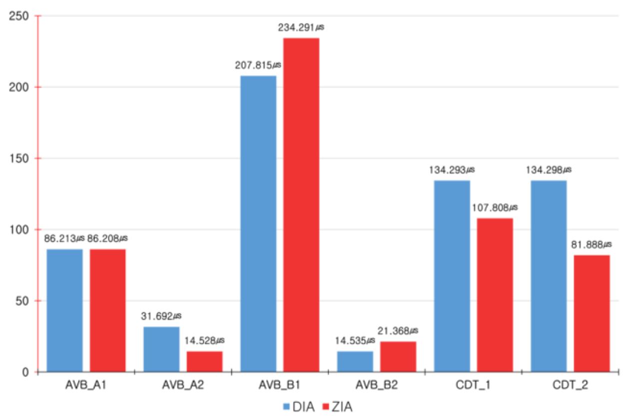

Fig. 2. Result of E2E delays for each traffic

However, this slight increase in delay of ZIA doesn't necessarily imply inferior performance since it still complies with the acceptable delay thresholds for the respective traffic types. Based on the results, DIA is more efficient in scenarios where data exchange is mainly between ECUs with similar functions. ZIA is more efficient in scenarios that require merging data from ECUs with different functions, such as complex data processing applications for advanced vehicle technologies.

Ⅴ. Conclusion

We present each feature through the performance comparison of DIA and ZIA, which are IVN architectures. For performance comparison, we developed IVN simulators through network simulator OMNeT++ based on actual vehicle data provided by OEMs. The E2E delays of DIA and ZIA were compared through the developed simulator. DIA shows 1.47 times better performance than ZIA in the case of traffic generated within the same domain. ZIA shows 1.64 times better performance than DIA in the case of traffic generated in different domains. Based on the results, we expect that an IVN architecture with excellent performance can be designed when DIA and ZIA are used in an appropriate combination, rather than using a single architecture of DIA and ZIA.

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