Development of Vehicle Domain Controller Based on Ethernet

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Abstract. The ‘new four modernizations’ of automobiles with the trend of electrification, intelligence, network connection and sharing has brought new challenges to the electrical/electronic architecture of vehicles. The topology of the vehicle has changed from distributed ECU development to the centralized oriented domain controllers and central computers; the function of the whole vehicle has been changed from decentralized software development to the development of a unified software architecture for aggregation. This paper studies the Ethernet-based on-board domain controller and expounds the research method for the unified architecture platform. Based on the SOA model, it discusses the definition of services based on SOME/IP, the software architecture, the hardware topology, and communication layer parameters; and builds a domain controller hardware platform, and simulates the development content in the later stage to form a complete Development process of Ethernet-based on-board domain controller.

Key words. Ethernet, domain controller, SOME/IP.

1. Introduction

With the development of "new four modernizations" of automobiles, which are electric, intelligent, network connected and shared, the design of backbone network and subnet based on vehicle Ethernet is gradually increasing. The whole vehicle network topology changes from can bus to Ethernet. This paper studies the vehicular gateway controller based on Ethernet. Firstly, through the architecture design tool PREEvision of Vector Company, the design requirements of vehicular Ethernet are built, including the service definition of some / IP, the definition of software architecture, the definition of hardware topology and the definition of communication layer parameters. Through Davinci, a protocol stack design tool, the domain controller meeting the AUTOSAR architecture is constructed finally, through the bus simulation software canoe of Vector Company, the design content is simulated and verified [1].

2. Ethernet Gateway domain controller software architecture

Service interface definition: According to the function of vehicle architecture, the service included in gateway controller is designed in PREEvision tool. The service includes service provider and service consumer. The main job of service provider is to provide service, and service consumer sends service request to service provider to obtain service function [2]. The application information of vehicle
gateway controller information is defined in the form of service interface, mainly including method, event and properties [2]. In the preview tool, according to the service content, the service interface is established and its methods and events are defined. For the method, its input and output parameters need to be defined. In this design process, the interface of service is realized by AUTOSAR software architecture, and the service provider and consumer are realized by AUTOSAR software component (SWC), which is assigned to ECU component later [3].

Figure 1. Service Interface.

Figure 2. Define service interface.

Figure 3. Autosar design process.
SWCS transmit information through ports, and service interfaces are encapsulated into ports. Ports can be divided into "send / receive data" and "send / receive services". SWC is located on the top of the RTE, through which the underlying protocol interface is called to complete the data transmission. In SWC, service provider confirms service availability and service consumer confirms service request status; basic software pattern Manager (bswm) is used to manage service model and forward service availability and request status to software component or service discovery; service discovery confirms service availability and request status and sends corresponding SD message (such as SD provides service message) according to receiving The SD message to is converted to the basic software mode manager mode. Service discovery configures the sending and receiving events and methods through socket adapter. Socket adapter can flexibly allocate PDU to realize multi-client reception, that is, one PDU sends dynamically on multiple socket connections, while service discovery and some / IP complete information interaction through socket adapter. In the preview tool, establish the corresponding SWC and corresponding interface. After the service software component is designed, the gateway controller can publish the availability and location of the service to other ECU through service discovery. The service message types include search service, provide / stop service, stop / subscribe event group and subscribe event group feedback[4].
Figure 5. Service interaction.

Figure 6. Ethernet communication protocol.

Software architecture: the underlying communication protocol of vehicular gateway controller is shown in Figure 6, and the SWC components of its application layer operate on the real-time operating environment (RTE). In the underlying communication protocol of gateway controller, it is necessary to define the routing mode of Ethernet message, and instantiate the transmission of service into specific signals and messages. Through Davinci tool, the communication layer design configuration of Ethernet bottom domain controller is as shown in Figure 7.
3. Hardware implementation of Ethernet Gateway domain controller

This scheme is equipped with dual MCU, in which Freescale i.mx6q processor is used for algorithm processing under complex working conditions, and s32k148 processor of NXP company is used for vehicle signal routing; Ethernet gateway includes can / FD and Ethernet communication module, and Ethernet communication module circuit is composed of MAC control and PHY interface of physical layer. The Ethernet system structure includes 5-channel can (4-channel can FD support), 1-way Lin, 4-channel digital switch acquisition, 5-channel 100base-t1, 1-channel 100base-tx, and 2-way power input.

In the process of Ethernet bus transmission, the loss of transmission cable itself and all the load on the bus channel will be more or less, including circuit consumption, filter circuit, circuit converter, connector of each component, etc. The signal frequency also has a great influence on attenuation. Based on this consideration, the design scheme adopts 8-storey high-density board, and the layout and wiring are strictly set in rules to optimize the signal integrity design.
4. Ethernet Gateway domain controller function test

In the preview tool, the topological connection relationship between components is established. In this case, the function of the Ethernet gateway controller is tested through camera module, radar module, gateway and ADAS. Each node is found in canoe simulation model, and the node is designed and programmed. Then global variables, event process instructions and function bodies are defined. The canoe simulation model is tested to obtain the simulation data results. The message information, protocol type, message sending node and receiving node can be obtained from the experimental results. According to the detailed business flow requirements, we select specific experimental scenarios for simulation. The following table shows the parameters of a simulation scenario. The two inputs are video stream camera 1 (Camera1) and camera 2 (Camera2) are transmitted to ADAS module through gateway controller. The flow size is 1500b per channel, with low priority. Periodic transmission is adopted, once every 200us and transmission time is 50us; the other input is radar data (radar), with flow size of 500B, high optimization First stage, periodic transmission, once every 100US, sending duration of 10us. Based on the scene function, the experimental bench is built, as shown in Figure 11 below.

![Figure 9. Hardware board design](image)

![Figure 10. Hardware Topology Design](image)
Figure 11. Experimental bench

Table 1. Experimental scenarios

| Parts       | Usage                    | Cycle/us | Size/B |
|-------------|--------------------------|----------|--------|
| Camera1     | image data               | 200      | 1500   |
| Camera2     | image data               | 200      | 1500   |
| Radar       | Distance data            | 100      | 500    |
| Gateway     | Information forwarding   |          |        |
| ADAS        | data processing          |          |        |

Through the real-time analysis of on-board Ethernet system to ensure that the system can communicate normally, the longest delay time of the system is calculated according to the system configuration attribute parameters to ensure the system communication time synchronization. Service communication is defined in service discovery protocol, which can be divided into three phases: initial waiting phase, repeating phase and main phase. According to the distribution of service provider and service consumer, it can be divided into client delay analysis and server delay analysis. In view of this situation, the data of the three stages of communication between the client and the server are analyzed.

\[
t_{S_{j,\text{init}}}= (\text{SvcBootDel}_{n,j} + \text{SvcInitDel}_{n,j})
\]

\[
t_{C_{i,\text{init}}}= (\text{CltBootDel}_{t_{i,j}} + \text{CltInitDel}_{t_{i,j}})
\]

\[
t_{S_{j}}= |t_{S_{j,\text{init}}}-t_{C_{i,\text{init}}}|\]

\[
t_{C}= |t_{C_{t_{i,j}}}-t_{S_{j,\text{init}}}|\]

Through the analysis of on-board Ethernet system, the longest delay time of the system is calculated according to the system configuration attribute parameters to ensure the system communication time synchronization. Service communication is defined in service discovery protocol, which can be divided into three phases: initial waiting phase, repeating phase and main phase. According to the distribution of service provider and service consumer, it can be divided into client delay analysis and server delay analysis. In view of this situation, the data of the three stages of communication between the client and the server are analyzed.

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\[
t_{C}= |t_{C_{t_{i,j}}}-t_{S_{j,\text{init}}}|\]

\[
t_{W_{i,j}}\]

is used to describe the time interval required for clients running on node i to find the service J that they want to subscribe to:
In the repeat phase, the basic interval time for service J to send the provided message; $SvcRepDel_{n,j}$—In the main phase, service J provides service message interval; After the system is running, the camera data is captured by canoe, as shown in Figure 12 below. Based on canoe tool, the time delay of acquisition signal is analyzed. The experimental results show that the delay of vehicle gateway controller meets the system design requirements, as shown in Figure 13.

$$t_{ij}^{R} = \max \left\{ SvcRepDel_{n,j} (2^x + 1) + 2 SvcCycDel_{n,j} + t_e(n,i) + e_{c} \right\}$$

$CltInitDel_{ij} + 2 \times t_e(n,i) + SvcAnsDel_{n,j}$

**Figure 12. Test validity**

**Figure 13. Signal delay analysis**
5. Conclusion
In the future, the E/E architecture based on domain controller and vehicular Ethernet will be the research focus in the future [3]. From the requirement design to the hardware implementation, this paper introduces the development process of the vehicle gateway domain controller based on Ethernet in detail, and introduces the development concept based on model. In the design, the design parameters are fully considered, which greatly improves the correctness and efficiency of the design.

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