Backbone Network Design of Multi-target Automotive Ethernet

Yi-Nan Xu, Yi-Hu Xu, Yu-Jing Wu, and Hua-Yang

***Abstract*—With the increasing number of electronic control systems on the car and the increasing number of in-vehicle electronic control units (ECUs), the real-time, safety and reliability requirements of the vehicle-mounted bus network are gradually increasing. This paper focuses on the backbone network design of automotive Ethernet, and proposes a scheme for multimedia information and control information to communicate through the vehicle Ethernet system. The network topology architecture was built by the CANoe tool and the proposed solution was verified. The experimental results show that the proposed scheme completes the communication of video information and control information simultaneously without delay time. Therefore, it breaks through the traditional bus network design concept of independently building multimedia network and bus control network, and lays a solid foundation for the bus network architecture design field of the next generation intelligent car.**

***Index Terms*—Automotive ethernet, multimedia information, control information, network topology architecture, CANoe.**

I. Introduction

With the continuous development of technology, intelligence and networking of automobiles, the number of electronic products in the car continues to increase, the electronic control system in the car becomes more and more complex, and the number of ECUs (Electronic Control Units) is also increasing [1]. At the same time, new technologies such as ADAS (automobile assisted driving system), high-definition car entertainment system, car networking system, cloud service, and big data are applied to automobiles, so the requirements for the bandwidth of automobile networks are getting higher and higher. For a long time, the vehicle bus network system is mainly divided into two major categories: control network and multimedia network. Among them, LIN, CAN, FlexRay bus to build control network,automotive Ethernet, MOST network to build multimedia network [2]. Because the car Ethernet system has the advantages of data transfer rate of up to 500 Mbps and strong compatibility, it can replace the bus network system such as CAN and FlexRay and become the backbone network of the next-generation vehicle bus network system [3].

Literature [4] developed a simulator called SEtSim to evaluate architectures and protocols based on switched Ethernet. SEtSim is based on Simulink simulation and currently supports different network topologies for FTT-SE protocol and Ethernet AVB protocol, and SEtSim's core design can add and integrate other Ethernet-based switching protocols. Literature [5] proposed a novel vehicle network simulation method. The purpose of this project is to design a cost-effective and flexible vehicle network suitable for multi-camera, high-bandwidth environments. The simulation platform uses a hybrid simulation approach and allows for the coexistence of actual network traffic flow and simulated network traffic. Literature [6] proposed a gateway between the vehicle Ethernet and the MOST bus network to ensure that the video information between the MOST bus network and the vehicle Ethernet communicate with each other. Reference [7] proposed an in-vehicle network gateway structure based on CAN, FlexRay and Ethernet. The gateway features reprogramming, diagnostic routing, network management, dynamic routing updates, multi-route configuration, and security. In summary, the main research content of vehicle Ethernet is to use the gateway system to build an in-vehicle network and transmit multimedia information.

When each car is equipped with a bus system such as LIN, CAN, FlexRay, car Ethernet, and gateway to build a network topology, it will bring a series of problems such as real-time, compatibility, and high cost. This paper proposes a scheme for transmitting multimedia information and control information simultaneously using the vehicle Ethernet system.

The organizational structure of this paper is as follows. The second chapter gives an overview of the car Ethernet system and analyzes the network characteristics and technical specifications of the car Ethernet. The third chapter proposes a network topology structure based on automotive Ethernet, and proposes an information scheduling scheme for simultaneously transmitting multimedia information and control information. The fourth chapter uses CANoe.Ethernet simulation platform to verify the proposed scheme. Finally, the fifth chapter summarizes and forecasts the full text.

II. Introduction to Automotive Ethernet

At present, the vehicle Ethernet system is applied in the field of communication of in-vehicle multimedia information. Broadcom's Broad R-Reach single-pair unshielded twisted pair cable and standard Ethernet PHY components have been standardized by the IEEE802.3bw working group and are named after 100BASE-T1. High-level protocols Ethernet AVB, SOME/IP (Scalable Service-Oriented Middlewar E on IP) and ISO17215 are also relatively well-established as standards. The Ethernet AVB technology inherits and extends the traditional Ethernet function, and adds the Precise Time Protocol (PTP) and the Resource Resvervation Protocol (RSVP) to enhance the real-time performance of traditional Ethernet audio and video transmission. The communication medium of the vehicle Ethernet can use the differential signal

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line or the plastic optical fiber, and adopts the Time-Sensitive Networking (TSN). The TSN improves and expands the AVB protocol, and introduces the technology of the time-triggered Ethernet TTE [9].

A. Data Frame Structure

Fig. 1 shows the data frame format of the automotive Ethernet. Includes preamble, start of frame destination address, source address, 802.1Q tag, Ethernet type, data and padding, frame check code.

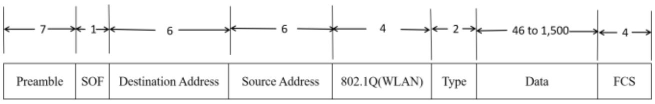

Fig. 1. Automotive Ethernet data frame structure.

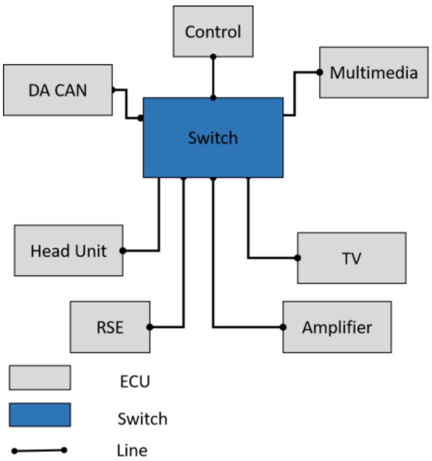

Fig. 2. Star topology.

The following is a brief description of each field.

1) Preamble

The frame header is a 7-byte binary number indicating the start of the frame for synchronization between the sender and the receiver.

2) Start of frame (SOF)

The frame start character is represented by 1 byte. When the last 0 is changed to 1 and finally 10101011, the boot code sent to the receiver is ending, followed by the actual Ethernet frame.

3) Destination address and source address

The destination address and source address are the addressing mechanisms of the in-vehicle Ethernet. Each address consists of 6 bytes each, which is divided into a 3-byte organization number and a 3-byte device number. The data frame of the car Ethernet has a source address and one or more destinations.

4) 802.1Q (WLAN / Frame Priority) tag

802.1Q is composed of 4 bytes and is used to implement virtual local area network (WLAN) functions and specify the priority of frames. It is widely used in audio video bridging (AVB) applications in automotive Ethernet.

5) Type and data (payload)

The 2-byte Type field, commonly referred to as Ethertype, describes the type of data carried in the data (or payload) field.

6) Frame check code

The 4-byte frame check code is to check the correctness of the data frame at the receiving end.

B. Network Topology

The topology of the automotive Ethernet is divided into a star structure, a daisy chain structure and a tree structure [10], as shown in Figure 2-4. The star structure is the main switch to connect multiple ECUs; the daisy chain structure is connected by the main switch and the sub-switch, and the branches are connected, the main switch and each sub-switch are connected to the ECU; the tree topology is a total The switch connects all the sub-switches, and each sub-switch is connected to other switches and ECUs.

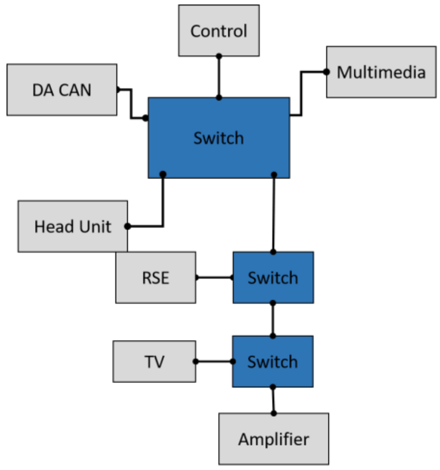

Fig. 3. Daisy chain topology.

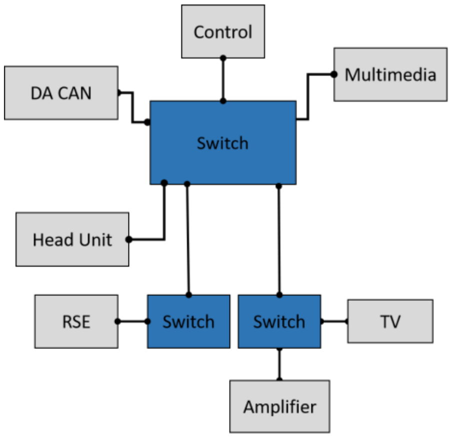

Fig. 4. Tree topology.

III. Automotive Ethernet Backbone Network Design

This paper uses the modular network architecture design method of vehicle Ethernet to realize the vehicle backbone network. In our in-vehicle backbone network, there are mainly control information (such as steering, braking, lighting, etc.) and video information (such as entertainment video and driving images). The vehicle backbone network must ensure the priority transmission of important information. Fig. 5 is our design.

In this paper, the vehicle topology information is constructed with the purpose of car control information and multimedia information using the vehicle Ethernet at the same time.

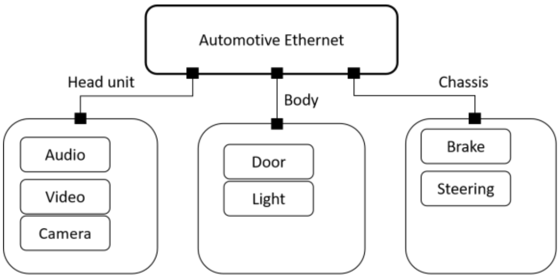

Fig. 5. Network topology of automotive ethernet.

Fig. 6 is a node connection model built on the CANoe.Ethernet tool. Among them, IC is the dashboard display node, CAMF is the analog camera node, LRR is the driving status node, ADAS is the auxiliary driving system node, AMP is the audio node, HU is the video display node, and Vehicle_E is the vehicle Ethernet bus.

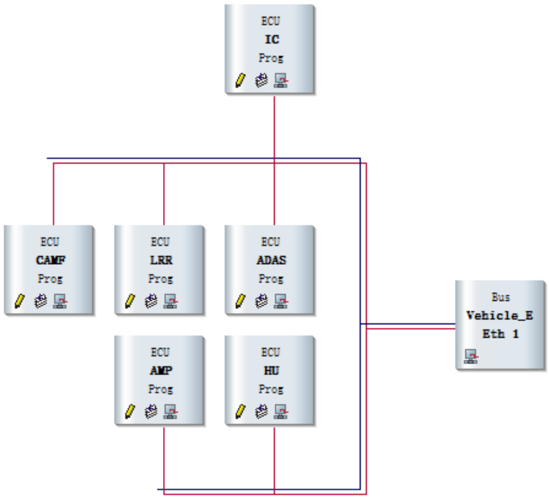

Fig. 6. Node connection model.

The transmission of control information is mainly through the environment variable as the carrier. The basic control information panel is designed by Pannel Designer. The buttons and the display panel respectively control and display the result of the control information. When the button is pressed, the value of the system variable changes, and The operation is transmitted to the CAPL program in the node, and the operation is transmitted to the display interface through the system variable to finally realize the control of the data, and the actual data transmission process is embodied by the message form.

The lamp signal is transmitted through the system variable Control related to the lamp. As shown in Fig. 7, the double flash is indicated by the system variable Hazard. The transmitted Head lights are transmitted by the system variable Light, the left turn to the right Turnleft, and the right turn is indicated by Turnright. A variable of 0 indicates that the light is off and a value of 1 indicates that the light is on. Runtime

Variable	Datatype	Initial Value	Unit	Min	Max
ConceptCar					
Control					
Hazard	Int32	0	-	0	1
Light	Int32	0	-	0	1
TurnLeft	Int32	0	-	0	1
TurnRight	Int32	0	-	0	1

Fig. 7. Headlight system variable.

The car's speed and direction light control signals are also under the system variable Control. The system variable of Start is Starstop, 0 means no open, 1 means open, the steering wheel system variable is Steering Wheel, -1 means the steering wheel turns left, 1 means the steering wheel turns right, the throttle system variable is represented by PedalPosition, from 0-100% Indicates the degree to which the pedal is depressed. The system variables for the brakes and throttle are shown in Fig. 8.

Variable	Datatype	Initial Value	Unit	Min	Max
ConceptCar					
Control					
BrakeActive	Int32	-	-	0	1
PedalPosition	Int32	0	%	0	100
StartStop	Int32	0	-	0	1
SteeringWheel	Double	0	-	-1	1

Fig. 8. Vehicle speed and direction control system variables.

During the transmission process, several signals are transmitted in a message. The specific information represented by the hexadecimal number at different positions of the data frame, the receiving end will also get the final display result according to this feature.

The transmission of video information based on the vehicle Ethernet requires the sender Talker and the receiver Listener node. In the network we designed, the sender is represented by CAMF and the receiver is represented by HU. The transmitting end includes entertainment video information and driving record video. Since the video captured by the camera that records the video in real time needs to be processed by hardware to be transmitted and stored, the AVB protocol is adopted for transmission. These two videos are stored in different locations and need to be switched and recalled by pressing the video playback panel when transferring.

The main part of the car video transmission is the design of the video display interface and the design of the playback function, which is represented by Head Unit (HU). The main function of HU is to accept and play the video information. At the same time, it should also have the basic functions of video playback, such as volume adjustment and video switching. The entertainment video adopts the playing mode, while the driving video adopts the video streaming mode because of the real-time performance, the entertainment video is transmitted by the UDP protocol, and the driving video adopts the AVB protocol. A toggle button was added during the design process to switch between the two video formats.

IV. Experimental Results and Analysis

This article uses the CANoe.Ethernet tool for simulation. Communication between the multimedia network and the control network is carried out simultaneously in a automotive Ethernet network.

The video information part of the data frame is shown in Table I. The video information frame includes a data ID, a destination address, a VLAN ID, a data size, a transmission priority, data, and the like.

Fig. 9 and Fig. 10 are experimental results of driving video playback and entertainment video playback. From the CANoe simulation results, the designed multimedia network runs normally.

TABLE I: FRAME OF VIDEO MESSAGE

Data Name	Value（Hex）
Moving Record video	C0 00 00 00 00 00 00 30 07 00 00 00 03 E8 00 01 01 00 01 2C 00 00 00 01 07 00 00 00 03 E9 00 01 01 00 01 2C 00 00 00 01 07 00 00 00 03 EA 00 01 01 00 01 2C 00 00 00 01 00 00 00 00
Entertainment video	C0 00 00 00 00 00 00 10 06 00 00 10 03 E8 00 01 01 00 01 2C 00 00 00 01 00 00 00 0C 00 09 04 00 C0 A8 03 04 00 11 9C 41 01 2C 00 00 00 01 00 00 00 0C 00 09 04 00 C0 A8 02 02 00 11

Fig. 9. Driving video playback results.

Fig. 10. Entertainment video playback results.

The data frame of the control network is shown in Table II. It mainly includes information such as speed, light, distance and fuel quantity.

TABLE II: FRAME OF CONTROL MESSAGE

Data Name	Value（Hex）
Speed	D3 01 01 FF
Light	38 0B 9F 0C B0 D6 0F 00 A0 7D 0F 00
Distance	5A D7 98 00 16 3E A8 00
Oil	5F 0B

Fig. 11 is a result of data analysis of control information. The first is the analysis of the basic data. When starting the operation, the speed will continue to rise and finally reach the same speed position as the speed control lever. At the same time, the engine temperature, the battery temperature will rise, and the remaining oil will decrease. As the car continues to travel, the exhausted vehicle will become zero, and the corresponding waveform represents the change value of each data, as shown in Fig. 12.

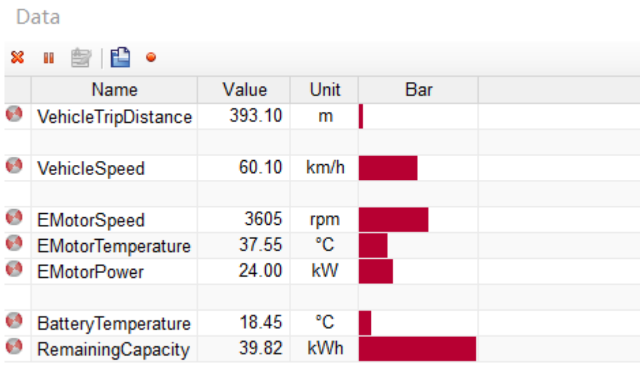

Fig. 11. Data analysis result.

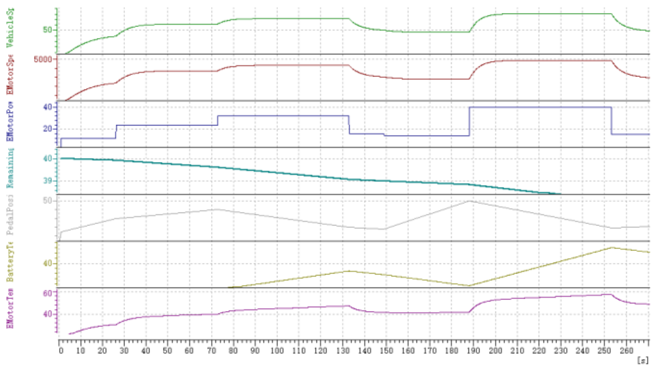
Fig. 12. Data running waveform.

Fig. 13 is a simulation result diagram of a data frame. From left to right, the running time, transport channel, VLAN ID, transmission or acceptance mode, transmission protocol, transmission module, receiving module, protocol information, payload length and data are described in sequence. From the simulation results, the proposed scheme simultaneously realizes the communication of communication multimedia information and vehicle control information.

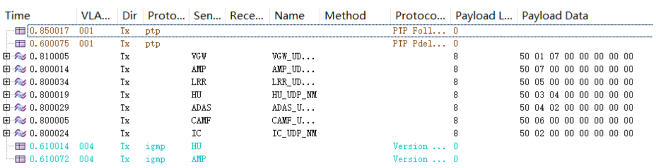

Fig. 13. Data frame simulation result.

V. CONCLUSION

Under the rapid development of the automotive intelligent process, the vehicle Ethernet has the advantages of low cost, high reliability and strong compatibility with traditional Ethernet, which fully meets the requirements of the future automotive bus network. In this paper, the CAN topology. Ethernet tool is used to build the network topology architecture, and an in-vehicle Ethernet backbone network capable of transmitting control information and video information at the same time is designed. The experimental results show that the communication function of communication multimedia communication function and vehicle control information can be realized simultaneously by using a vehicle Ethernet network system.

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