Design of AVB Node Based on R-Car T2

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ABSTRACT

With the proliferation of various types of automotive electronic equipment, the existing in-car network can not meet the growing demand. FlexRay, CAN, LVDS and FlexRay are widely used in premium car, but these network are not compatible, we need gateway to connect each other to communicate. So the wiring in car is complicated and quiet heavy. The next generation car network demands larger bandwidth, lower latency and more equipment access. Therefore, high bandwidth, low cost, low latency and easy-deploy network is under study. In last decade, IEEE802.1 Audio Video Bridging(AVB) has been proved to be an option solution. AVB use accurate time synchronization, bandwidth reservation and Credit based Shaping(CBS) algorithm to guarantee high rate and low latency transmission for AVB traffic. R-car T2 is the first car-film SoC support AVB protocol and will be used in future ADAS. In this paper, we analyzed AVB protocol and designed a video capture device using R-car T2 to test the AVB performance.

CCS Concepts

Hardware → Digital signal processing

Keywords

In-vehicle; AVB; ADAS; R-car T2

1. INTRODUCTION

the car is almost an information station with four wheels, many electronic device are connected together to serve for the driver and passenger. The Advanced Driver Assistant System can notify the road condition to driver to avoid danger; The entertainment System can provide HIFI music and high definition video to the passengers; The control System controls the power system. But different System has different demand of transmission time delay and data rate, to satisfy these requirement, different bus type are adopt in car industry[1]. But different standard means wiring is complicated, inter-connection is difficult and cost is high. So a unified connection standard is necessary for car industry[2].

The switch Ethernet is easy to deploy, support different data rate and have low cost. Therefore, the technology was widely used in last decades. But when consider the demand of in-car network, legacy Ethernet can not work well. In some application, especially some time critical application like control system, the latency of legacy Ethernet can not meet the demand. To conquer the short of legacy Ethernet, The AVB technology has been proposed. AVB is based on legacy Ethernet and compatible with it.

The AVB is set of protocols, contains IEEE 802.1BA (Audio Video Bridging), IEEE 802.1AS (Time Synchronization for Time Sensitive Application), IEEE 802.1Qat (Stream Reservation Protocol) and IEEE 802.1Qav (Forward and Queuing for Time Sensitive Streams)[3]. These protocols ensure that AVB can satisfy the both requirement of high bandwidth and low latency.

2. AUDIO/VIDEO BRIDGING

An "Audio Video Bridging"(AVB) is a set of protocols developed by IEEE 802.1 Audio/Video Bridging Task Group(AVBTG)[4]. This task group was named to Time-Sensitive Networking Task Group in November 2012 to reflect the expanded scope of work. This protocol aims to support low latency and high reliable service in automotive, consumer and professional audio and video market. The figure 1 shows the overview of Ethernet AVB and the relationship with legacy Ethernet.

As shown in figure 1, the AVB protocol is an extension of legacy Ethernet. This ensure AVB can be used in existing network without modification. If all device in network are AVB compatible, it can transmit both AVB message and legacy message; If not, it still can transmit traditional traffic.

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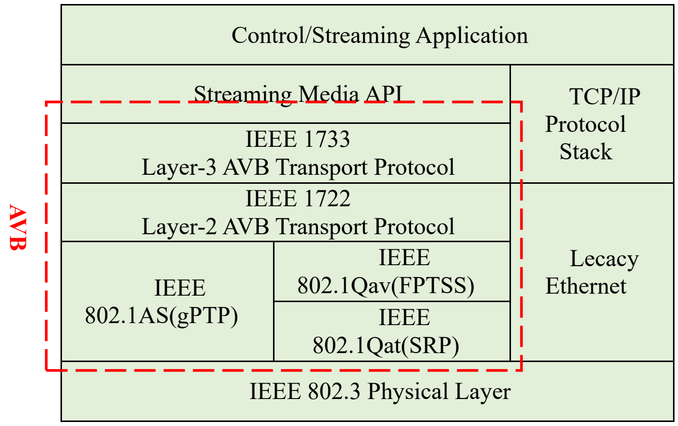

Figure 1. Over View of AVB Protocol

2.1 IEEE 802.1AS

The accuracy time synchronization is the base of time sensitive network. In AVB network, 802.11AS enables a synchronization of participating nodes in switched Ethernet with accuracy of less or equal than 1us between maximum 7 hops. This make an time critical application becomes possible[5].

802.1AS get the best and unique root clock using Best Master Clock Algorithm, then build a spanning tree to synchronize the rest nodes. The BMCA basic steps are as follows[6]:

(1) Collect the clock information of whole network;
(2) After collection, best clock will be chosen from the network and other clock will synchronize to it;
(3) Judge node port will be based on the time source of the selected results to synchronize the working state and generate the spanning tree as show in Figure 2.

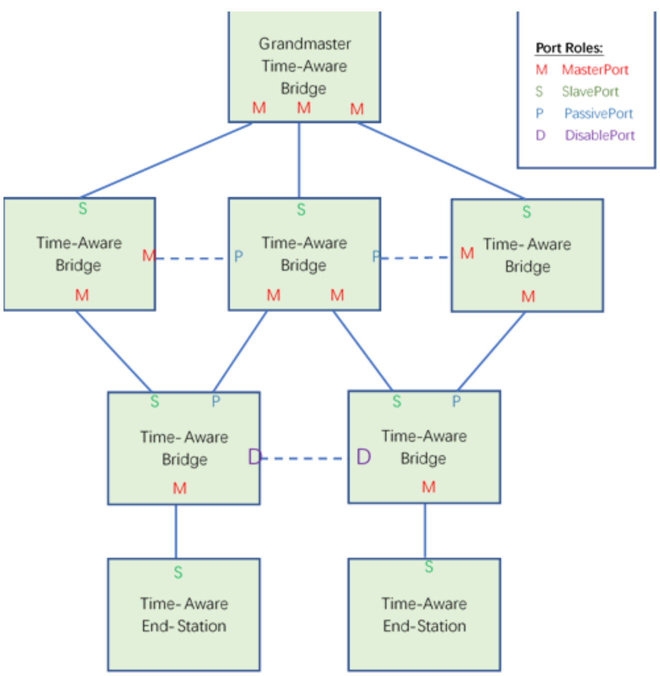

Figure 2. Spanning Tree By BMCA

2.2 IEEE 802.1Qav

AVB defines queuing and forwarding method for time sensitive applications in IEEE 802.1Qav. IEEE 802.1Qav includes traffic shaping, priority portioning and queue management[7]. There has two different AVB class traffic: Stream reservation(SR) class-A(maximum 2ms latency),Stream Reservation(SR) class B(maximum 50ms latency). Besides, There is a best-effort class which stands the legacy Ethernet traffic.

Different class traffic selection are control by a credit base shaper(CBS) algorithm. AVB traffic are allowed only when the amounts of credits is greater or equal than 0[8]. An example CBS operation is depicted in Figure 3. A single AVB Frame arrived and is queued because there is conflicting frames. The credits are increase by a rate of idleSlope and the Frame A is selected to transmit when the conflicting frames are transmitted complete. The credits are set to 0 when the credits is positive but there is no message to send. When next AVB frames arrived, the Frame send immediately due the credits is greater than 0 and there is no transmitting message. The credits decreased by a rate of sendSlope. The credits is lower than 0 when frame B transmitted. Then the Frame C arrived has to queued because the credits is lower than 0. The credits will increase with rate of idleSlope and when credits is 0 the Frame C will transmit immediately.

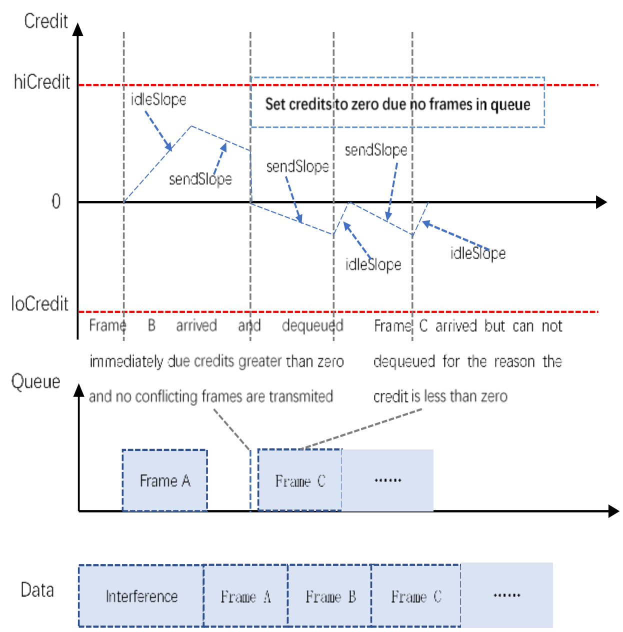

Figure 3. CBS Operation

Non-AVB traffic are re-mapped to the priority of best effort traffic class. This ensure the AVB class traffic has higher priority than traditional traffic. Therefore, AVB traffic can preferentially transmitted.

2.3 IEEE 802.1Qat

IEEE 802.1Qat ensures AVB frames have required resource on the whole path between source endpoint to the destination where maximum 75% of the total bandwidth will be reserved[9]. The resources left will allocated to best effort traffic.

Figure 4 and Figure 5 show the registration procedure. All AVB intermediate bridges receiving a "talker advertise" message check for bandwidth availability on their output ports. When the bridge has sufficient resources, then the "talker advertise" is propagated to the next AVB station. When resources are not available, the bridge will send a "talker failed" message. An intermediate bridge receiving a "talker failed" should pass on the message towards the listener. When listener receives a "talker advertise" message, it should know whether the resource are available, and if so, it respond with a "listener ready" message that is forward back to talker. Intermediate bridges use the "listener ready" message to reserve requested resources. When the talker receives the "ready" message, it can transmitting the stream.

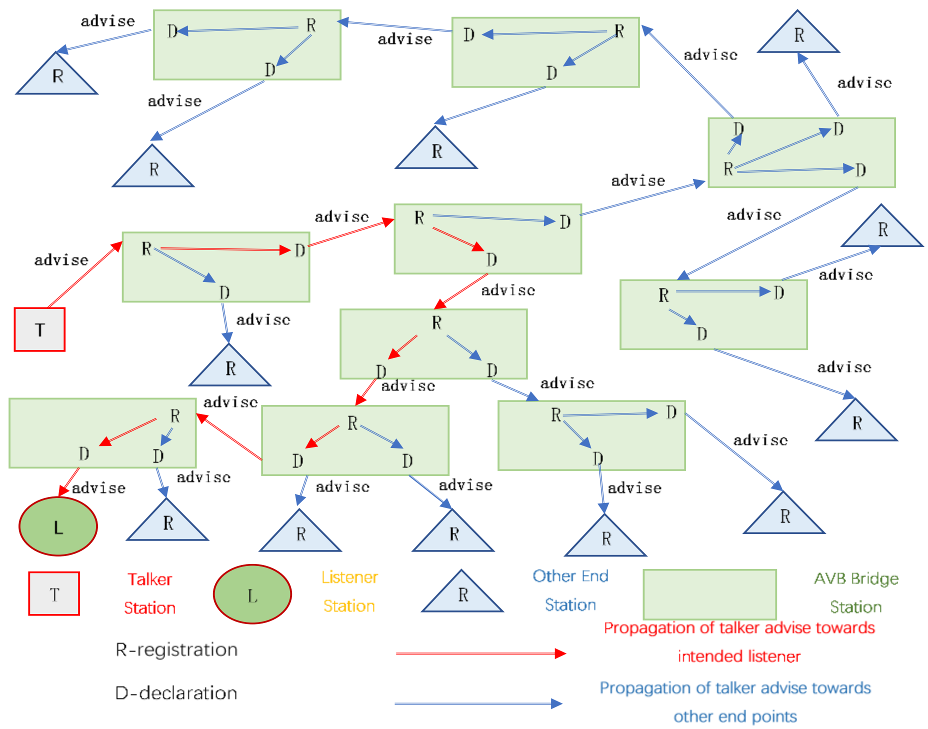

Figure 4. Successful Reservation(talker advertise)

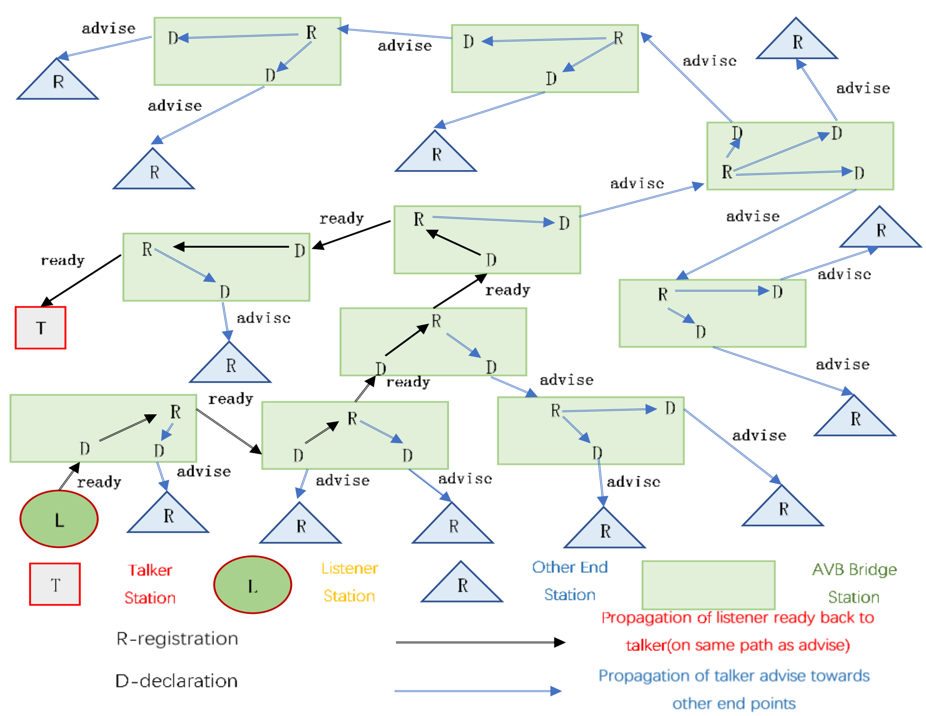

Figure 5. Reservation acknowledge(listener ready)

When registration is successful, the resources between talker and listener will be used exclusively. This means that AVB traffic can transmit in time even in heavy network jammed with non-AVB traffic.

3. OMNET++ SIMULATION

OMNeT++ is an extensible, modular, component-based C++ simulation library and framework, primarily for building network simulators. "Network" is meant in a broader sense that includes wired and wireless communication networks, on-chip networks, queueing networks, and so on. Domain-specific functionality such as support for sensor networks, wireless ad-hoc networks, Internet protocols, performance modeling, photonic networks, etc., is provided by model frameworks, developed as independent projects. OMNeT++ offers an Eclipse-based IDE, a graphical runtime environment, and a host of other tools. There are extensions for real-time simulation, network emulation, database integration, System integration, and several other functions[10].

In this paper, we use the Core4INET simulation module to simulate the AVB network. CoRE4INET is an extension to the INET-Framework for the event-based simulation of real-time Ethernet in the OMNEST/OMNeT++ simulation system. Currently CoRE4INET supports:TTEthernet (AS6802),IEEE 802.1 Audio Video Bridging (AVB) Time-Sensitive Networking (TSN),IEEE 802.1Q / IEEE P802.1p VLANs and Priorities[11].

In the simulation network, there has four endpoint(two of them are AVB endpoint and others are non-AVB endpoint) and 2 AVB switches. The diagram is shown in Figure 6.

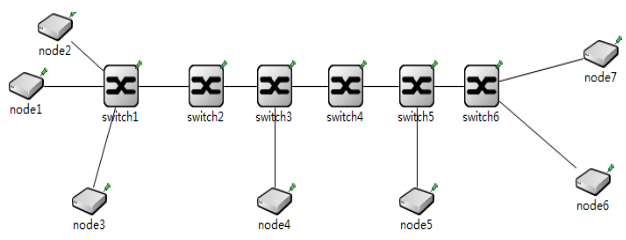

Figure 6. Omnet++ Simulation Diagram

As shown in Figure 6, The network is simple. All switches are AVB compatible, and node1, node7 are AVB endpoints, the other nodes are legacy endpoints. The links between endpoint and switch are 100Mbps.

To simulate an ADAS Camera, The node1 generate 1825Mbps rate SR-B traffic and route to node 7. The node2 will generate 18-25Mbps rate legacy traffic and also route to node 7. Node3, node4 and node5 will generate 6-10Mbps and route to node6. The node3 is used to generate jammed traffic, the type is best-effort traffic and will route to node6 and node7 randomly. In order to test the AVB performance, The rate of node3 will grow from 20Mbps to 80Mbps.The simulation result is shown in table 1.

When the bandwidth is enough for both AVB traffic and non AVB traffic, The latency of two types traffic is almost equal and low. When node3 rate grow, the latency of both two nodes are going high, but the SR-B message latency is lower than best effort message. When node3 rate are greater than 60Mbps, the SR-B message still transmit in time but the best-effort message are choked and can not transmit immediately. This result prove that bandwidth reservation and stream shaper can ensure AVB traffic transmit in time.

Table 1. Omnet++ Simulation Result

Node3 traffic rate(Mbps)	Node1 Message latency(us)		Node2 Message latency(us)	
	Average	Max	Average	Max
20-40	116	430	200	500
40-60	126	492	692	1532
60-80	136	536	1224	2156

4. AVB NODE BASED ON R-CAR T2

R-car T2 is a new announced SoC produced by Renesas Electronics Corporation, the SoC dedicated for Ethernet AVB enabled vehicle camera networks. The R-Car T2 supports multiple standards (Note 1), including IEEE 802.1AS, IEEE802.1Qav, IEEE802.1Qat, and IEEE1722 standards. The R-Car T2 SoC features a built-in H.264 encoder developed exclusively by Renesas to provide low-latency compression while maintaining real-time high-quality HD video (1,280 × 960) transfer. Video can be compressed with extremely low latency of less than 1 msec (one-thousandth of a second) and delivered to multiple systems through the networks to vehicle systems. The high quality and real time transfer create a high level of safety, making it possible to rapidly share camera footage with the advanced driver assist systems. Previously, with the popularity of Ethernet as an easy-touse network standard that allows video to be transferred to multiple systems, video compression was necessary as the maximum bandwidth supported by UTP cable (Note 2) is 100 Mbps, and latency was an issue in applications such as driver safety assist systems. Now Renesas has succeeded in reducing the latency time to less than 1ms, which is equivalent to a movement distance of 2.8 cm when driving at 100 km/h. This enables nearly real-time data transfer, allowing use in driver safety assist systems and making it possible[11].

We designed a video capture device using R-car T2 SoC. The device support AVB protocol and can transmit high definition video in time. To test the performance of AVB device, we connect the device to the AVB switch and non-AVB switch, then inject high volume traffic with network analyzer. The camera resolution is 1280*720 and capture frame rate is 30fps. The test environment is described in Figure 7.

Figure 7. AVB Test Environment

We set the inject traffic from 60Mbps to 100Mbps gradually and observe the output video. The result is shown in TABLE 2.

Table 2. Result of AVB device Test

Injected traffic(Mbps)	AVB switch	Non-AVB switch
60Mbps	Video output smoothly	Video output smoothly
80Mbps	Video output smoothly	Video appears latency
100Mbps	Video output smoothly	Video appears high latency and has frame dropping

As shown in table 2, when network analyzer begin to jam the system, the AVB network can still output camera stream smoothly, but in non-AVB network, the output video has obvious latency and dropping frames. The result shows that in AVB network SR traffic can reserve available resource to ensure preferential transmission. This result proves that in a busy network, 802.11Qat and 802.11Qav can work great to transmit AVB traffic in high priority.

5. SUMMARY AND CONCLUSION

In this work, we analyzed the problem of in-car network and introduce the AVB protocol would be an option solution for the in-vehicle network. Then we simulate the simple AVB network and design an AVB node to test the AVB performance. Both the simulation and real hardware test show that AVB protocol can ensure SR traffic transmit in time with high data rate and is suitable for in-car network, at least in some none strict time critical applications like ADAS. But we just test the none time critical message due to equipment limitation. Our next goal is studying and testing the time latency of time critical traffic like powertrain domain messages to see whether or not the AVB protocol is suitable for in-vehicle interconnection. AVB is still under development, we believe that in the near future, AVB will be widely used in in-vehicle network to replace the complicate and expensive connection standards and unify the connections to a simple and single standard.

6. ACKNOWLEDGMENT

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