An Efficient Method of Reselecting Grand Master in IEEE 802.1AS

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Abstract*—Recently, IEEE 802.3 Ethernet network is not limited to be used as the sub-network of a vehicle but also can be used as backbone network of a vehicle. Audio/Video Bridge (AVB) standard is about the Ethernet technology that can be used as a backbone network in a vehicle. AVB provides time-synchronized low latency streaming service through the Ethernet. 802.1 AS protocol in AVB can synchronize the time between different nodes through Grand Master (GM) which is selected by the Best Master Clock Algorithm (BMCA). If the synchronization message of GM is not received by another node within timeout interval, the protocol selects a new GM in the network through BMCA. This method can occur the bunching error because of consecutive exchange of messages. This paper proposes an efficient method to re-synchronize GM's time. This proposed method is to use a table which indicates a pre-defined sequence of GM to reconfigure GM. As a result, the reconfiguration procedure of GM with the sequence table can decrease generated traffic and a time when operating an existing BMCA procedure. In addition, this proposed method reduces the residence time of the bridge to prevent bunching of consecutive messages. Therefore, this paper proposes more efficient method of reselecting the GM than the BMCA.

Keywords—GM Sequence Table, Static Announce, BMCA, Reconfiguration

I. INTRODUCTION

Along with some constraints, the internal network of the vehicle combines different bus systems such as CAN, FlexRay, LIN and MOST which can provide various applications. As the ADAS (Advanced Driver Assistance System) is getting popular, the desire for integrating portable consumer electronics with ADAS within the network is increasing. Since the vehicle network is becoming more and more complicated, the vehicle applications in the future will need wide bandwidth.

The IEEE 802.1 AVB can provide low-latency streaming service through the switch networks that are synchronized. And this standard has a promising QoS mechanism to process data of all bridges by using the priority of different traffics. For streaming frames in an Ethernet switch, AVB guarantees a latency of 2ms in 7 hops. Within the guaranteed latency it is possible to use the application of ADAS system in the vehicle network.

IEEE 802.1AS is one of the standards of AVB which provides time synchronization that support only the profile of the OSI layer 2 based on IEEE 1588. In the case of applying the IEEE 802.1AS standard to Layer 2 devices such as switches and bridges, it is possible to configure the time synchronization of the network in Layer 2 using BMCA procedure for selecting a bridge for providing a reference time. Bridge that provides this reference time is defined as the GM. The method synchronizes the time of the sender and the receiver using timestamp of event messages such as synchronization(Sync) message, Follow-up message and P2P message. If the bridge which provides the reference time is not running, all bridges should exchange Announce message again to select another bridge to provide the reference time via the BMCA.

When configuring a network environment for time synchronization in a limited space like a car, we use a time source in common because the number of the devices in the network is small. Because these vehicles can use a single source time, we simplify the format of the Announce message used in the comparison procedure of selecting GM. And the sequence table is constructed through BMCA procedure. Therefore, we can make up the sequence table faster because the BMCA process is reduced. In this paper, we focus on reducing the delay caused by message exchange used in BMCA by using the sequence table in 802.1AS protocol when reconfiguring GM.

This paper is organized as follows. In section II, we introduce BMCA process of selecting a bridge that provides reference time from 802.1AS. In section III, we propose the algorithm for constructing sequence table of the GM and describe the procedure of GM reconfiguration without BMCA using the table. Section IV finishes with summarizing our result and conclusion.

II. RELATED WORK

In this section, 802.1 AS explains to select the GM and to decide port role through BMCA. For time synchronization of networks, IEEE 802.1AS selects GM to provide a reference time information using the Announce message and defines the procedure of BMCA that assigns the role of each port in the bridge, to determine the spanning tree for synchronization.

Figure 1 defines the field of Announce messages of IEEE 802.1AS standard. The field of this message consists of priority, the time information of the bridge (time source, currentutcfoffset, clockquality), grandmasteridentity, steps-

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removed and path trace TLV, to be used in the comparison items of BMCA procedure.

Bits (8 7 6 5 4 3 2 1)	Octets	Offset
header	34	0
reserved	10	34
currentUtcOffset	2	44
reserved	1	46
grandmasterPriority1	1	47
grandmasterClockQuality	4	48
grandmasterPriority2	1	52
grandmasterIdentity	8	53
stepsRemoved	2	61
timeSource	1	63
path trace TLV	4+8N	64

Fig. 1. The Announce message field of IEEE 802.1AS

The grandmasteridentity is formed by mapping the information of the MAC address of the bridge. stepsremoved, based on the transmitting bridge, means the number of hops that the message has passed, and path trace TLV has information of clockIdentity of the bridge which the message has passed. In order to select a bridge for providing reference time information in the network, all bridges perform the BMCA to compare the time information of their own and the received message. Each device is transferred to any other devices that are within 7 hops by generating Announce message with the reference time information in the message fields. According to the procedure shown in Fig. 2, all devices that receive the Announce message compare their time information with the time information of the device that sent the message.

Figure 2 is a data set comparison algorithm used to select the GM bridges to provide a more accurate reference time in the network. Once GM is selected through the algorithm, the bridge must be assigned with a port role to configure the time synchronization spanning tree. All ports on the bridge that is selected to be the GM play a role in transmitting the reference time to other devices, and these ports are defined as the Master port. If a port on the bridge of non-GM forwards a reference time, the port is also defined as the Master port. And one port of the bridge which is the closest to the root of the spanning tree set to Slave port. any port of the bridge which is neither Master port or Slave port nor a Disabled port set to Passive port. The synchronization tree is the spanning tree and synchronization information is only transmitted from the Master port to the Slave port. After BMCA procedure is done, all bridges synchronized to reference time which is sent by Sync message of the GM.

If the bridge in current GM which provide reference time in the network does not support the message, all devices in the network send to the port that are connected another bridge by generating an Announce message again. Therefore, the same comparison procedure like the initial synchronization needs to be executed again, which may cause latency when operating in the network of a vehicle.

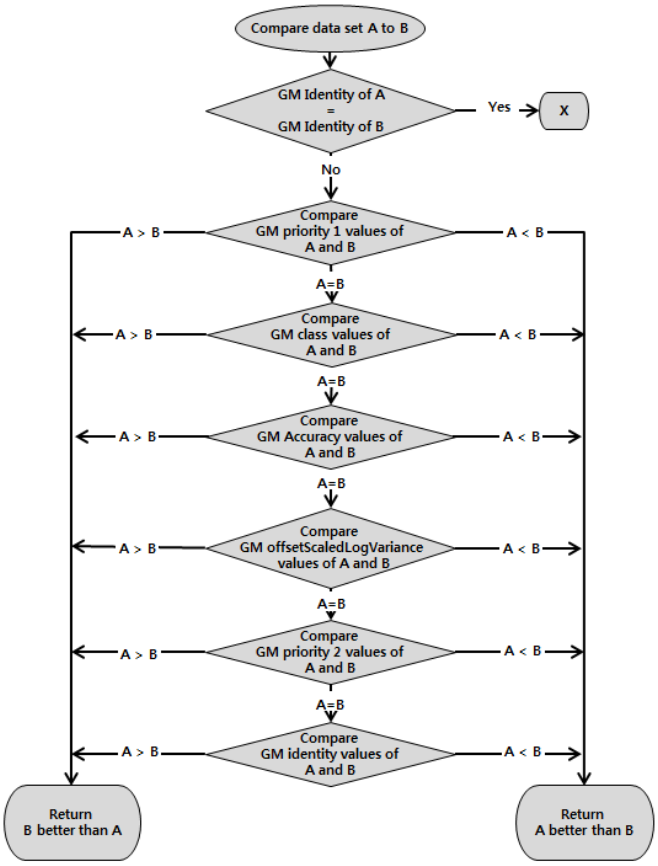

Fig. 2. Data set comparison algorithm

III. Procedure for Reconstruction of GM through the Improved BMCA by Using a Predefined GM Sequence Table

In the 802.1AS, if the bridge in the existing GM is not running, all bridges will select another GM by performing the BMCA again. In this paper, prior to synchronization, all bridges in the network generate a table showing the order of the bridges that operate the GM by running repeatedly BMCA procedures. When selecting GM again, the generated sequence table indicates the bridges to operate, and it has state information for the port of each bridge associated to GM. When the established GM does not operate, a new GM is chosen by the information in the table without BMCA procedure. For example, if the Sync message of GM is not transferred to the port of each bridge within the time out period, it is assumed that the current GM does not work. According to the information of the GM listed in the table, the port of all bridges except the GM changes their status, and the bridge selected in the GM sends a Sync message to all the other bridges. If the information in the GM listed in the table matches the sender of the received message, the bridge receives the message and transfers the message to other bridges.

A. *Algorithm for setting the GM sequence table*

To construct a sequence table, at first each bridge and terminal device select the bridge of GM to provide a reference time through exchange of the Static Announce message.

Bits 8 7 6 5 4 3 2 1	Octets	Offset
header	34	0
clockIdentity	8	34
stepsRemoved	2	42
time Source	1	44
Path trace TLV	4+8N	45

Fig. 3. Message field of the Static Announce

Clock Identity							
MAC address						*Static GM Number*	
Octet[0]	**Octet[1]**	**Octet[2]**	**Octet[3]**	**Octet[4]**	**Octet[5]**	**Octet[6]**	**Octet[7]**
0xAC	**0xDE**	**0x48**	**0x23**	**0x45**	**0x67**	**0xFF**	**0x01**

Fig. 4. Structure of Clock Identity used to the comparison procedure

Because all the bridges in the network use the same time source, the method to use the sequence table defines that all values except grandmaster-Identity which is used in the steps of comparison in BMCA are the same. Thus, Fig. 3 shows the format of Static Announce message in which the same values of all bridges in conventional Announce message are omitted. The MAC address included in the grandmasteridentity field in a message is used to determine the order of the GM in the table. The grandmasteridentity used in the procedure of the comparison means clockidentity (i.e. 6byte MAC address +2byte GM Number) of bridge that sends the message shown in Fig. 4, and the Static GM Number can determine the order by using GM comparison procedure of Static Announce message when constructing the network in a constrained environment.

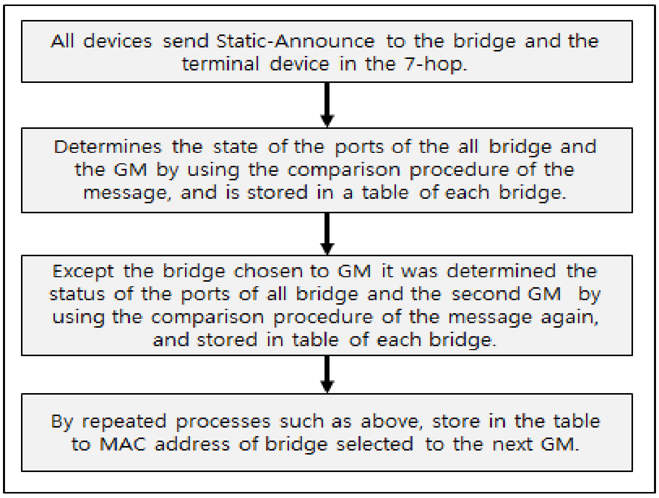

Fig. 5. Configuration steps of the table to use when reconstructing GM

Figure 5 shows the setup procedure of the GM sequence table to be used to reconstruct the GM with a Static Announce message. At First, all devices send Static Announce message to all devices within 7 hops. Each port of the device checks the value of the Static GM Number of the received message. If the number is not zero, the device which sent the message is recognized as a GM candidate. If the Static GM Number is zero, the device that sent the message is recognized as the terminal device, the port of the device receiving the message is set as the Master port.

TABLE I.COMPONENTS OF THE PRIORITY VECTOR USED IN THE PROCEDURE OF COMPARISON

Item	Description
ClockIdentitiy	Sequence information including the MAC address of the bridge that sent the message
StepsRemoved	Bridge hops passed from the bridge that sent the message
Source PortIdentity	Clock Indentity of the bridge that is connected to a port that is received
Port Number	Number assigned sequentially to each port of the bridge

Message priority vector and port priority vector which are used to determine the status of the ports and the GM is configured as shown in Table 1. Each bridge compares the ClockIdentity of the port which received Static Announce message with that of the received Static Announce message and sets the GM path priority vector of the port to the smaller one of the two ClockIdentity values. Then, the bridge received the Announce message considers the bridge which has a lower priority vector as the GM. Through the comparison procedure, all ports of the bridge that is selected as the GM are set as the Master port. If a single port of a bridge excluding the GM received the Static Announce message of the GM, the port is set as a Slave port, and if the Static Announce of the GM is received by more than one port, the port which has lowest Stepsremoved is set as a Slave port. The enabled ports except the Slave port compare their Master priority vector with the port priority vector of the received message. If the priority vector of a enabled port is smaller than the mater priority vector, that port is set as the Master port, otherwise it is set as a Passive port. The states of the ports of all bridges including the bridge of GM are set in the procedure of BMCA. A table of each bridge can be stored in the bridge's port setting which is associated the GM and in the MAC address of the GM. And except the bridge which was selected as the GM, all bridges execute the same comparison procedure as above again and select a bridge as the next GM and save the port setting of all bridges which are operating the next GM

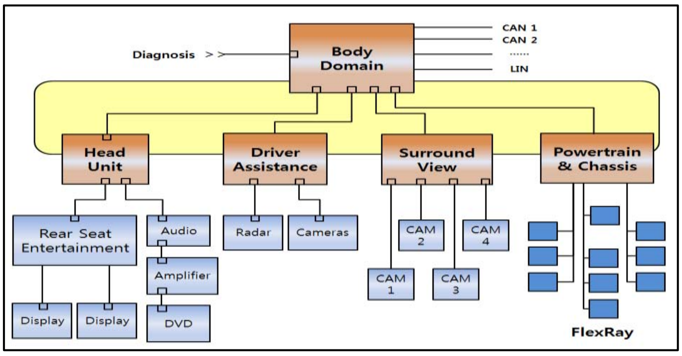

Fig. 6. The architecture of the domain in the Ethernet backbone network

The ECU serves as a bridge network of the vehicle when the Ethernet is used as the backbone network which is organized hierarchically as shown in Fig. 6. If the bridge of GM fails, in order to synchronize nodes in subnet, BMCA repeats 3 times to select 3GMs and the sequence table stores the 3GMs and the port role of each bridge according to each GM, then the GM sequence table configuration is done.

TABLE II. EXAMPLE OF THE SEQUENCE TABLE WHICH IS CREATED IN REPETITIVE BMCA

Table of Bridge 1				
The order of GM	***MAC address of GM bridge***	***Port status of bridge 1***		
		Port Number 1	***Port Number 2***	***Port Number 3***
1	Bridge1 (xx-xx-xx-xx-xx-1A)	Master	Master	Master
2	Bridge2 (xx-xx-xx-xx-xx-1B)	Disable	Disable	Disable

(a) The table of bridge1 that runs to the first GM

Table of Bridge 2				
The order of GM	***MAC address of GM bridge***	***Port status of bridge 2***		
		Port Number 1	***Port Number 2***	***Port Number 3***
1	Bridge1 (xx-xx-xx-xx-xx-1A)	Master	Master	Slave
2	Bridge2 (xx-xx-xx-xx-xx-1B)	Master	Master	Master
3	Bridge3 (xx-xx-xx-xx-xx-1C)	Disable	Disable	Disable

(b) the table of bridge 2 operating in the next GM

As an example, Table 2 shows the sequence table of bridge 1 which is the initial GM and the sequence table of bridge 2 which is the next GM after bridge1 fails. All bridges in the network are synchronized with the reference time of bridge 1. If faults occur in bridge 1, all bridges in the network are re-synchronized with the reference time of bridge 2 through the sequence table of each bridge. The next section will describe how to re-configure GM using the sequence table.

B. Reconfiguration procedure of GM using the sequence table

With the sequence table in each bridge, all bridges are synchronized to the reference time. Any bridge starts a timer whenever its port receives the Sync message and the Static Announce message of the GM are transmitted. If the message is not arrived within the timeout period, then the GM is considered to be failed and the network will be synchronized by the next GM in the sequence table.

Figure 7 shows GM reconfiguration procedure using the GM sequence table. All bridges confirm the order of GM that stored in the sequence table to synchronize to the next GM in the following steps. Based on the sequence table, the bridge compares the MAC address of the next GM with its own MAC address. Any bridge that has the same MAC address as that of the GM changes all of its ports to Master port and sends a Sync message with its time information to all bridges. The bridges whose MAC addresses do not equal the GM MAC address will change the port status specified in the table in accordance with the next GM. If the bridge of the next GM does not send a Sync message within timeout time, another bridge afterwards that does not operate becomes to GM. And all bridges in network change the status of all ports through information related to the GM in the table, and proceeds time synchronization procedure again.

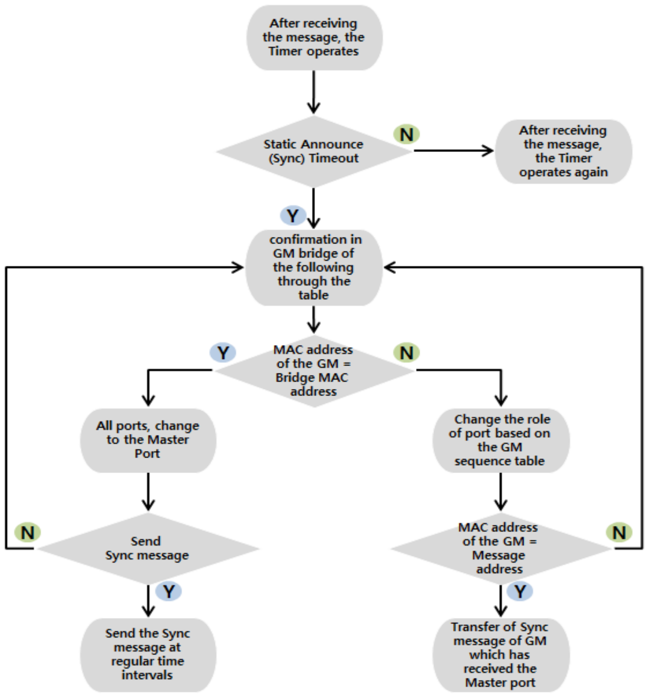

Fig. 7. Reconfiguration procedure of GM using the GM sequence table

TABLE III. PARAMETERS TO BE USED

WHEN CALCULATING THE CHANGE TIME OF GM

Item		**Value(s)**
Sync message transmission interval		125ms
Static Announce message transmission interval		1s
ANNOUNCE RECEIPT TIMEOUT ($Announce_{timeout}$)		375ms
SYNC RECEIPT TIMEOUT ($Announce_{timeout}$)		2s
Announce message delay time ($Announce_{delay}$)		0.25ms
Sync message delay (Sync delay)	Including Bunching error	62.63ms
	x	10.13ms

When receiving the message which the GM sent in regular time intervals, the Slave Port of all bridges excluding the GM operates the timer. The graph of Fig. 7 compares the GM changing time of the existing method with that of the proposed method. The timeout in the graph is SYNC_RECEIPT_ TIMEOUT because SYNC_RECEIPT_TIMEOUT is shorter than ANNOUNCE_ RECEIPT_TIMEOUT.

$$\text{Change time} = \text{Sync}_{\text{timeout}} + 7\times\text{Announce}_{\text{delay}} + 7\times\text{Sync}_{\text{delay}} \quad (1)$$

Equation (1) shows the time required to change the GM. The Announce delay in the equation is the time to transmit the Static Announce from one bridge to another bridge plus the BMCA procedure time. Sync delay is the time to transmit

Sync message to another bridge plus the residence time in the bridge.

Announce and Sync message must be transmitted to all bridges within 7 hops. Normally, a bridge sends Sync message to the Master port as soon as possible after receiving sync on a Slave port. However, in order to prevent burst and bunching of successive messages in comparison procedure of the existing BMCA, only one bridge in 7 hops will send sync after at least one-half sync interval has elapsed since last sync was sent. So, if the Bunching error in the bridge occurs, after a residence time of 62.5ms the bridge will send a Sync message. Instead of using the comparison procedure of messages in BMCA, changing GM using sequence table can reduce the delay time generated due to a bunching error.

Figure 8 shows the results of GM changing time when configuring GM again using the sequence table and the BMCA based on (1). When changing GM using BMCA, it takes about 500 ms, while using the sequence table, it takes about 446 ms.

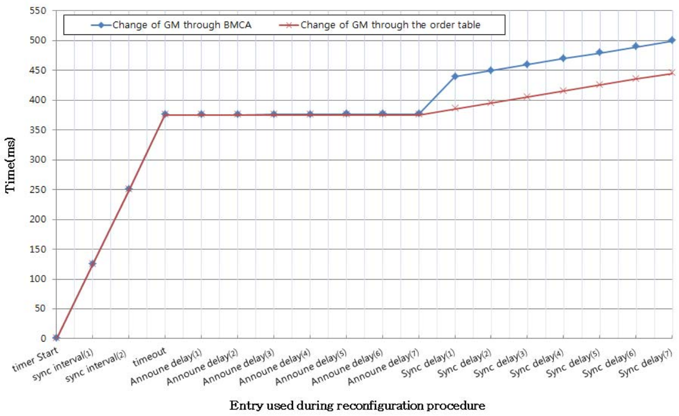

Fig. 8. Graph of the change time of GM that compares method of the sequence table with the conventional BMCA

IV. Conclusion and Future Work

In this paper, we propose a method for reselecting the GM with the sequence table of the predefined GM. Under the premise of using a common time, the comparison procedure to configure the sequence table of GM can be configured more simply than the existing BMCA. The proposed method of reselecting the GM can reduce a Sync message delay and Static Announce message delay occurring in Static Announce messages exchange between bridges. Furthermore, this proposed method has the effect of cutting the convergence time that is generated while comparing the message for selecting a GM in BMCA and assigning the role of ports. In conclusion, the proposed method can resynchronize the network faster than the existing BMCA. Consequently, the network can provide streaming services with low latency.

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