

Research and Implementation of AUTOSAR NM Mechanism in FlexRay Network on Electronic Vehicle Motor Drive Control System

^{1,2} An Yu Cheng, ² Rong Gang Wang, ² Yong Fu Li, ³ Min Wei

¹ School of Electronic Information of Wu Han University, Wu Han, 430074, China

² Chongqing University of Posts and Telecommunications, Chong Qing 400065, China

³ Dept. of Computer Science and Engineering, Konkuk University, Seoul, Korea 143-701

Tel.: 86-13594087351

E-mail: chengay@cqupt.edu.cn

Received: 16 September 2013 / Accepted: 15 October 2013 / Published: 23 December 2013

Abstract: This paper has mainly analyzed the characteristic of AUTOSAR NM (Network Management) mechanism, and combined with the FlexRay communication network's requirements of vehicle motor drive system, Designed the FlexRay NM control strategy, NM message, time parameters, and built a simulation and hardware in the loop platform to verify these design, the results show it can meet with the network nodes of electric vehicle motor drive system control's requirements. *Copyright* © 2013 IFSA.

Keyword: Network management, FlexRay, Four-wheel drive control system.

1. Introduction

Recently, with the development of electronic technology, the electronic control unit (ECU) has been applied to vehicle distributed control system widely, and it becomes more and more complex, the information that exchanged between the ECUs has become huge. The vehicle networks (such as CAN, LIN, MOST) have been applied to vehicle electronic control system widely. Nowadays, the networks that mentioned above cannot satisfy the demand of the complex vehicle electronic control system.

Therefore, many universities and research institutions have studied new vehicle network and control strategies, such as the TTCAN enhances the periodic signal processing capability [1], the Time-Triggered Protocol (TTP) [2], the wireless sensor networks instead of the other network [3, 4], which

cannot resolve all the automotive network management problems.

Finally, the FlexRay network protocol that formulated by FlexRay Union established by many automobile companies is recognized by the automotive industry, and then become the next generation main control network of vehicles, to meet the requirements of vehicle control.

FlexRay standard [5] defines the basic protocol, such as frame structure, the frame synchronization and other requirements, including the FlexRay static state feature [6] and dynamic feature [7] in the transmit processing. But there are few papers about the nodes' network management (NM) in the FlexRay network. Only few suggestions we can get from several papers about the OSEK/VDX NM protocol [8], implemented on dynamic segment of the FlexRay communication cycle.

FlexRay communication protocol is triggered based on time, a communication cycle period includes static section, dynamic section, symbol window, network idle time. Its static segment uses TDMA (Time Division Multiple Access) access method, every node in the network occupies specified static slot to transmit the message, to guarantee each node send message in static segment which has a certain time. The dynamic segment takes the FTDMA (Flexible Time Division Multiple Access) method to visit, non-periodicity signal is sent in dynamic segment. While the node inquires to send message, it occupies one or more mini slot to send dynamic message.

The OSEK/VDX NM standard is a widely vehicle network management protocol[9], it suits for event trigger network, the NM statement transform is based on the timer in the node, the NM messages are sent with uncertainty, it mainly applies to the CAN (Controller Area Network), doesn't suit for the FlexRay network which is based on the time trigger. In the FlexRay communication network, the network communication cycle, static frame, dynamic frame are associated with NM messages and NM states, these are not well achieved on the OSEK/VDX NM.

AUTOSAR (Automobile Open System Architecture) alliance published AUTOSAR FlexRay NM in 2008. AUTOSAR FlexRay NM [10] fully is considered the characteristics of the FlexRay network, and it can reach the demand of high speed and deterministic communication needs.

This paper's research focuses on the FlexRay communication NM, which is mainly based on the AUTOSAR NM protocol.

2. FlexRay Network Management Principle

AUTOSAR FlexRay NM is implemented by the periodicity NM message, network state transform is based on the node's inquire network state and periodicity NMPDU (Network Management Protocol Data Unit), NM cycle synchronizes the FlexRay communication cycle periodicity.

According to the AUTOSAR FlexRay network manage state transfer, the FlexRay communication network and FlexRay NM state transfer, show in Fig. 1.

2.1 NM Algorithm

AUTOSAR NM takes the distributed directly NM mechanism [11], each node can receive and send message by independent NM, the network state transfer is based on the node require network state and periodicity NMPDU is received. A node that receives a broadcast NMPDU indicates that the node which sends message is intention to keep network wakeup state. If one node prepares to enter the bus

sleep state, then it stop to send NMPDU, but if it receives NMPDU from others, it can postpone network sleep state transfer. If the node can not receive the NMPDU, the preset time (FlexRay communication period counter) would be overflowed, therefore the node can enter the bus sleep state. If the node needs to communicate with others, it should send NMPDU to wake up network from the sleep state to normal state.

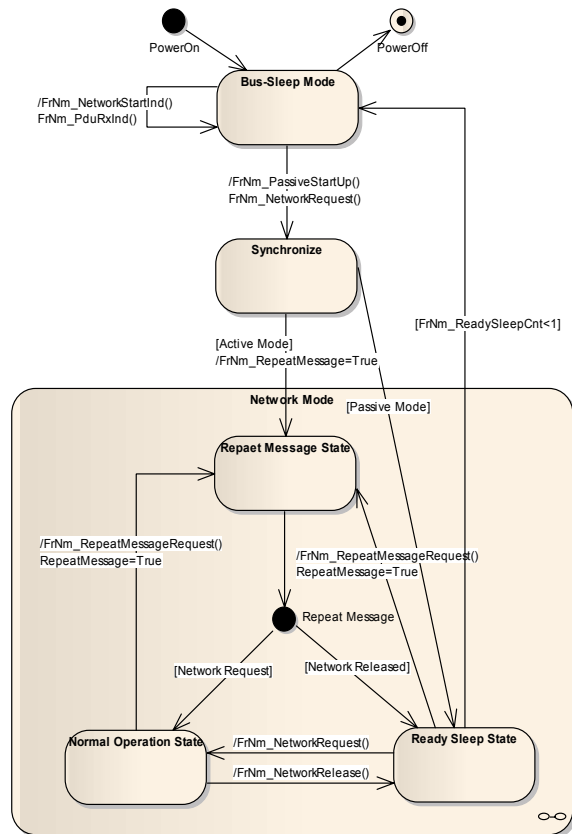


Fig. 1. State transfer and condition.

2.2. NM State and Transition

AUTOSAR NM protocol has defined three modes: Bus-Sleep, Synchronize and Network mode, the NM is implemented by transferring among the three modes. The network mode has three sub-state: Repeat Message, Normal Operation, Ready Sleep.

FlexRayNM algorithm does not depend on the timer which in the controller, it depends on the network cycle period. For the FlexRay network use the period communication, the FlexRay node's NM must be implemented in the interval FrNMMainfunction which in the communication cycle period. The start time of FrNMMainfunction is that when all nodes' MN-Vote message becomes valid, in other words, all the nodes in the network have sent a MN-Vote message. The end time of FrNMMainfunction is that the moment of the next FlexRay Cycle when the node needs to send the NM message.

2.3. The Node Online Monitor

When some node needs to monitor other node which is online or not (generally the node can generate a RepeatMessage requirement), this node's network state will transfer to Ready-Sleep mode, and then send the RptMsgRequest. If the receive node NM state is Normal Operation or Ready-Sleep, when it received RptMsgRequest this node NM state will transfer to RepeatMessage mode and send NM message periodically. Sending the "periodical NM message (RptMsgRequest)" by read the NM-Data from other node in the network to judge which node is online.

Some nodes monitor other node which is online in the network, the algorithm show in Fig. 2.

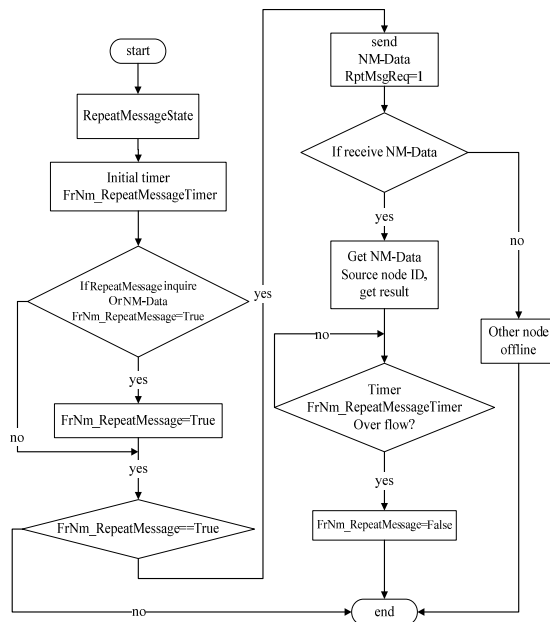


Fig. 2. The algorithm that the node online monitor

2.4 Node Synergy Sleep

The node transfers the state from the Ready-Sleep to Sleep mode, it can initialize Sleep counter FrNmReadySleepCnt, meanwhile the counter will decrease progressively with the FlexRay communication cycles. When it detected other node send the NM-Vote message in order to keep network waking up, the value of FrNmReadySleepCnt will be re-initialized. When the NM period is end, if FrNmReadySleepCnt < 1, then NM mode will transfer to Bus-Sleep mode. If FrNmReadySleepCnt is not overflowed all along, the node is continuing to send NM message, NM state will transfer to Normal Operation state.

The time that the node is entering the Sleep state can be calculated by the formula 1:

$$T = \text{FrNmReadySleepCnt} * \text{Repetition Cycle} * \text{Vote Cycle} * \text{FlexRay Cycle} \quad (1)$$

For instance:

FrNmReadySleepCnt = 3

Repetition Cycle = 4 vote Cycle

Vote Cycle = 1 FlexRay Cycle

FlexRay Cycle = 5 msec

Then it can be calculated that the time is $3 * 4 * 1 * 5 \text{ msec} = 60 \text{ msec}$

3. FlexRay Communications Network Management Design

Four-wheel independently drive as a high transmission efficiency way has begun to apply in the electric vehicle, There is five nodes in this FlexRay network, which includes the vehicle control unit, Front Left motor control unit, Front right motor controller unit, Rear Left motor controller unit, Rear right motor control unit. The VCU (vehicle control unit) is the network hub. The network topology shows by Fig. 3.

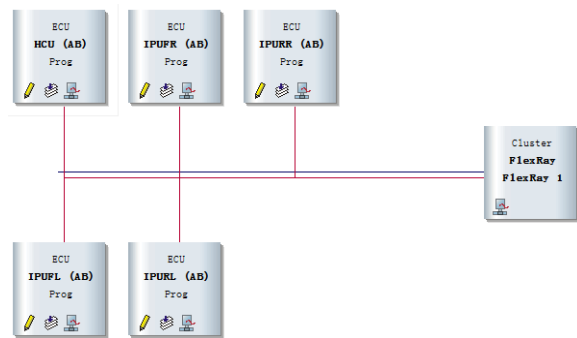


Fig. 3. Network topology.

According to the FlexRay communication network requirements, the network system mainly design includes: network topology, clustering protocol parameters and communications matrix design.

3.1. Network Management Data Format Definition of FlexRay

The node can transmit the NM-Vote message and NM-Data message individually in the NM mode, it can also transmit the NMPDU message which combined complete with NM-Vote and NM-Data, which provides a great convenience for the network management data schedule, the NMPDU format shows by Table 1.

3.2. Network Management Message and Network Schedule Design

The network data unit is generally sent in the message through static frame or dynamic frame. The form of NMPDU mapped into the message shows by Table 2.

Table 1. NMPDU format.

N M P D U	NM-Data							
	...							
	NM-Data							
	Source Node ID							
	Vote	R	R	R	R	R	R	R

Table 2. Message mapping.

N M P D U	CRC								
	NM-Data								
	...								
	NM-Data								
	Source Node ID								
H E A D E R	Vote	R	R	R	R	R	R	R	RptMSgReq
	Head CRC								
	Frame ID (8Bit)								
	R	P	N	S	S	Frame ID (3Bit)			

The FlexRay network management achieves by the periodic network management messages, so it is necessary to design a schedule list for periodical communication.

According to the FlexRay communication protocol, each first slot of dynamic segment can also ensure that messages should be sent periodically in the FlexRay communication cycle. If it is multiple nodes that need to send messages periodically in the first slot of the dynamic segment, we need to set the same dynamic frame ID, but the communication cycle count must be different. Base on this way, the FlexRay network management messages will be sent in the dynamic segment, the other application messages in four independent driver control system are sent in the static segment to ensure that these transmit deterministically. The other large amount of application messages is not described in this paper. Communication schedule shows in Table 3. Application messages are sent in static slots 1-50, the network management messages sent on the first slot (51) of dynamic segment. The communication cycle of the five network management message is 0-4.

Table 3. Communication schedule.

Message type	Message name	Message ID	cycle
Application Message		1-50	0-63
Network Management Message	VCU_NMdyn	51	0
	FL_NMdyn	51	1
	FR_NMdyn	51	2
	RL_NMdyn	51	3
	RR_NMdyn	51	4

4. Design of Simulation System

According to the design of the previous section FlexRay communication network and network management, Network database is established by the FlexRay Network design tool designed by Vector company. The database is imported into the CANoe.FlexRay, network parameters of the network, node, message, signal, etc is identified by the tool, then the network can work in the simulation state.

4.1. Design of Test Panel

The test panel is human-computer interaction interface, it can simulate external IO of a node, display the node status information. The test Panel is shown in Fig. 5. The left three lights indicate the current state of network management of a node, the switch is used to simulate the network request of a node. If a lost node of network was found by other nodes, the flashing red light will indicate that one node is lost.

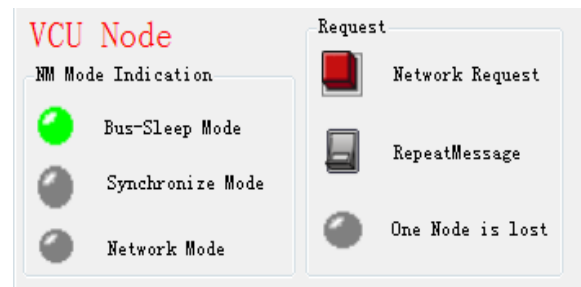


Fig. 5. Test panel.

4.2. Design of Network Management Function

The network management messages are sent and received by running function program. The functions are shown in Table 4.

Table 4. Design of API function.

Categories	Functions
Network management and control	long FrNm_NetworkRequest(); long FrNm_NetworkRelease(); long FrNm_PassiveStartUp(); long FrNm_RepeatMessageRequest();
Network management state	long FrNm_GetState(); LongFrNm_GetPduData(BYTEpduOut [], DWORD bufferLen); FrNm_GetNodeIdentifier();
Network packet receive and transmit	void FrNm_PduRxInd(DWORD slotId, DWORD identifier, long bRepeatMessageBit, BYTE data[]) Void FrNm_PreSendInd(WORD dlcInOut[], BYTE data[])

4.3. Sending of Network Management Message

All nodes in the network should send network management messages to keep the network awake in network mode. It can be traced the network management messages each node sends in the Trace window of CANoe. FlexRay as shown in Fig. 6. The ID of network Management messages are 51, but the cycle of them are different.

Time	Time	Channel	Name	Identifier	Cycle
198.423278	FR 1 A	RR_NMdyn_Ch_A	RRVote	51 [4, 64]	4
198.403278	FR 1 A	HCU_NMdyn_Ch_A	HCUVote	51 [0, 64]	0
198.408278	FR 1 A	FL_NMdyn_Ch_A	FLVote	51 [1, 64]	1
198.413278	FR 1 A	FR_NMdyn_Ch_A	FRVote	51 [2, 64]	2
198.418278	FR 1 A	RL_NMdyn_Ch_A	RLVote	51 [3, 64]	3

Fig. 6. Network management message.

4.4. Bus Sleep

When all the nodes in the network don't need the communication, all nodes are in sleep state. According to the protocol, the follow tests are done:

1) Some nodes need the network communication, and some nodes don't need the network communication. As shown in Fig. 7, network Request button of Node RR, FR, FL is pressed to indicate that the node need network communication, network Request button of Node RL is not pressed to indicated that the node doesn't need network communication. Network management state of every node is in network mode, none of them is in Bus-Sleep Mode.

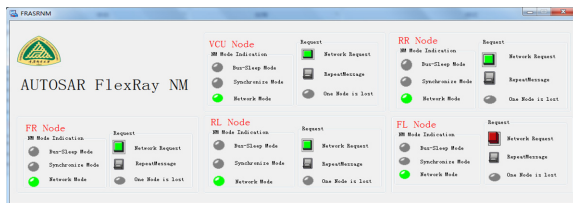


Fig. 7. A node request bus sleep.

2) All nodes in the network don't need network the communication. As shown in Fig. 8, all nodes in the network don't need the communication, the network management of all nodes are in Bus-Sleep Mode (Fig. 9).

The network management messages of all nodes as shown in CANoe.FlexRay Trace window indicate

that all nodes have stopped sending network management messages.

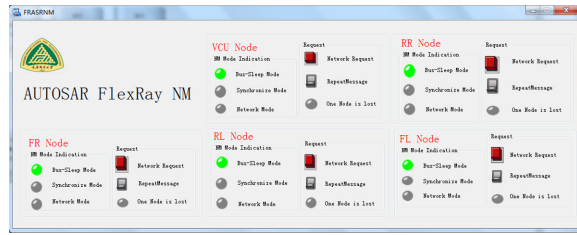


Fig. 8. All nodes turn off network communication.

Time	Channel	Name	Identifier	Cycle
27.538278	FR 1 A	RL_NMdyn_Ch_A	51 [3, 64]	3
26.248278	FR 1 A	FL_NMdyn_Ch_A	51 [1, 64]	1
25.623278	FR 1 A	RR_NMdyn_Ch_A	51 [4, 64]	4
28.493278	FR 1 A	FR_NMdyn_Ch_A	51 [2, 64]	2
24.323278	FR 1 A	HCU_NMdyn_Ch_A	51 [0, 64]	0

Fig. 9. Network management message in sleep progress.

4.5. Wake Up the Network

If any node in the NM-cluster requires network communication, then it can wake-up the node from the Bus-Sleep Mode by transmitting Network Management-Vote messages (Fig.10). Other node which received the wake-up message, the node was awaked. VCU node sent network management message in 106.883278 s to indicate network communication, other node was waked up after receiving the network management vote. And it started to send network management message, the state of network management changed into network mode.

Time	Channel	Name	Identifier	Cycle
106.883278	FR 1 A	HCU_NMdyn_Ch_A	51 [0, 64]	0
106.888278	FR 1 A	FL_NMdyn_Ch_A	51 [1, 64]	1
106.903278	FR 1 A	RR_NMdyn_Ch_A	51 [4, 64]	4
106.898278	FR 1 A	RL_NMdyn_Ch_A	51 [3, 64]	3
106.893278	FR 1 A	FR_NMdyn_Ch_A	51 [2, 64]	2

Fig. 10 .Trace window of wake up.

5. Simulation Results

Nodes' online monitoring is an important function of network management, requiring the other nodes to discover the dropping node on the network.

Showing in Fig. 11, to shield of the FR node and then running network on simulation condition. Now pressing the RR node's RepeatMessage button, to monitor whether there are nodes on the network have dropped. You can see that there are nodes dropped and the indicator turns red and starts flashing, indicating that the node found one node have dropped.

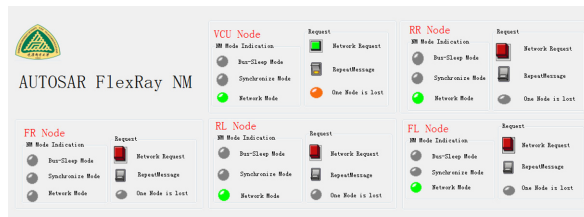


Fig. 11. Node Online detected.

We can see from the trace window, there are only four NM messages, the FR node which is shielded doesn't send the NM Message (Fig. 12).

Time	Channel	Name	Identifier	Cycle
238.403278	FR 1 A	HCU_NMdyn_Ch_A	51 [0, 64]	0
		HCUptMsgRequest	1	
		HCUVote	1	
238.418278	FR 1 A	RL_NMdyn_Ch_A	51 [3, 64]	3
		RLRptMsgRequest	0	
		RLVote	0	
238.408278	FR 1 A	FL_NMdyn_Ch_A	51 [1, 64]	1
		FLRptMsgRequest	0	
		FLVote	0	
238.423278	FR 1 A	RR_NMdyn_Ch_A	51 [4, 64]	4
		RRVote	0	
		RRRptMsgRequest	0	

Fig. 12. Trace window of online monitor.

6. Conclusions

This paper has analyzed FlexRay communication protocol and the AUTOSAR FlexRay Network Management Principle, designed the network management database parameters for the four wheels independent driver control system, simulated the system by the CANoe. FlexRay software tools, the simulation results show that can be achieved network management functions. This network

management has applied in the electric vehicle motor drive system by hardware in the loop system, which has also achieved good results.

Acknowledgment

This work was supported by Chongqing Science and Technology Projects Fund (NO:CSTC2013jcyjA40007) and National Natural Science Foundation of China (Grant No. 61304197).

References

- [1]. Road vehicles-controller Area Network (CAN) - Part 4: Time -Triggered communication, *International Organization for Standardization, ISO/DIS 11898-4*, 2002.
- [2]. H. Kopetz, G. Bauer, The time-triggered architecture, in *Proceedings of the IEEE*, 91, 1, 2003, pp. 112-116.
- [3]. Rajeev Ranjan and Shirshu Varma, Collision-Free Time Synchronization for Multi-Hop Wireless Sensor Networks, *Journal of Computational Intelligence and Electronic Systems*, Vol. 1, No. 2, December 2012, pp. 200-206.
- [4]. Irfan Ullah, Furqan Ullah, Qurban Ullah, and Seoyong Shin, Sensor-Based Robotic Model for Vehicle Accident Avoidance, *Journal of Computational Intelligence and Electronic Systems*, Vol. 1, No. 1, June 2012, pp. 57-62.
- [5]. FlexRay Consortium FlexRay Communications System Protocol Specification, Ver. 2.12005.
- [6]. Klaus S, Ece G S., Message scheduling for the FlexRay protocol: the static segment, *IEEE Trans Actions on Vehicular Technology*, 58, 5, 2009, pp. 2170-2179.
- [7]. Ece Guran Schmidt and Klaus Schmidt, Message Scheduling for the FlexRayProtocol: The Dynamic Segment, *IEEE Trans. Veh. Technol.*, 58, 5, 2009, pp. 2160-2169.
- [8]. Zhang Jianjun, Tian Xiao, Zhang Benhong, GuJianwei Research and implementation of OSEK NM mechanism in FlexRay network, *Journal of Electronic Measurement and Instrument*, 12, 2012, pp. 1037-1042.
- [9]. OSEK/VDX Network Management Concept and Application Programming Interface Version 2.5.3, <http://www.vector.com>.
- [10]. AUTOSAR Consortium, Specification of FlexRay Network Management, V4.0.0.2008.
- [11]. Yao, J. Y, Kong, F., Wu, F. Y., FlexRay vehicle network management control research. *Automationinstrument*, 12, 32, 2012, pp. 43-46.