Study on next generation of in-vehicle network protocol for passenger vehicles based on CAN FD

Qijin Cai*, Yong Xu

School of Electronic Engineering and Automation of Guilin University of Electronic Technology, Guilin, Guangxi, China, 541004

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Abstract

Aiming at the next generation of in-vehicle network protocol system for conventional passenger vehicles and new energy passenger vehicles, an in-vehicle network protocol named as IOCAN is proposed using information-oriented idea based on CAN FD. By using longer ID field of extended frame and concepts of PDU, PGN, SPN in SAE J1939 protocols, the information management-oriented protocol frame are designed. With variable and higher bit rate of CAN FD and its maximum 64 bytes of data field, a data segment transmission strategy is put forward. Then the practicality of the system is demonstrated with the analysis of the application. Finally described is the framework of the in-vehicle network protocol of passenger vehicles with universal, normative and greater information capacity.

Keywords: CAN FD, passenger vehicles, network protocol, SAE J1939

1 Introduction

To meet the increasing demands for road safety, driver comfort, vehicle intelligence and energy efficiency and environmental considerations, there are two long-term trends in vehicle technology development: (1) With high-level vehicle intelligence, more and more electronic equipments and ECU are installed in automobiles [1]. (2) Various new energy technologies are applied to vehicles, and the application and control of high-power electrical appliances is the core of vehicle technology.

How to solve the communication problem of electronic equipments in vehicles is the key issue of automobile industry. Commercial vehicles use SAE J1939 system based on CAN 2.0B. Featured with high normalization and integrity, J1939 has high data utilization rate because of using more bit of ID. However, it is o not used in passenger vehicles, which commonly use communication network system based on CAN 2.0A. In passenger car manufactures, where no unified application layer protocol standard exists, they formulate their own application protocols, and hence the specifications of information exchange is deficient, use and management of information is not easy.

As the development direction of automobile industry, new energy vehicles (including hybrid vehicles) developed rapidly. The present networking systems, based on tradetional protocol, is not appropriate in terms of bandwidth and size of messages to be exchanged within the network. With the new times and challenges of communication technology [7], BOSCH Company launches a new generation of local area network control protocol-CAN FD, and the main objective is to promote transmission bandwidth. Based on basic protocol of CAN FD, a network communication transmission application protocol for the next generation of passenger vehicles is proposed. The basic idea is information-oriented, combining long data field and variable transmission rate of CAN FD, and integrity and normalization of J1939. For the application requirement of passenger vehicles and communication requirement of new energy vehicles, the paper proposes the next generation of in-vehicle network communication protocol based on CAN FD, namely IOCAN (Information- oriented Controller Area Network).

2 Introduction of CAN FD

Compared with conventional Can bus, CAN FD has the following characteristics. Firstly, a frame of data use different bit rates. Data field (from BRS bit of control field to ACK bit) uses variable rate. The bit rate can be higher than 1Mbit/s, and the other fields use the original standard bit rate, and two sections use different bit time management mechanism. Secondly, the maximal data length of data field is 64 bytes, which in the conventional Can is less than or equal to 8 bytes.

2.1 CAN FD FRAME FORMAT

New bits including EDL, BRS and ESI are added to data frame. EDL is the reserved bit r1 in the original standard CAN data frame. When the bit is invisible, it means that the data frame is CAN FD, and when it is visible, it means that the data frame is CAN frame. When BRS bit is invisible, it means to transform data field rate, and when it is visible, it means not to transform rate. When EST is invisible, it means passive error, and when it is visible, it means active error.

* ***Corresponding author*** e-mail: caiaaaaa@126.com

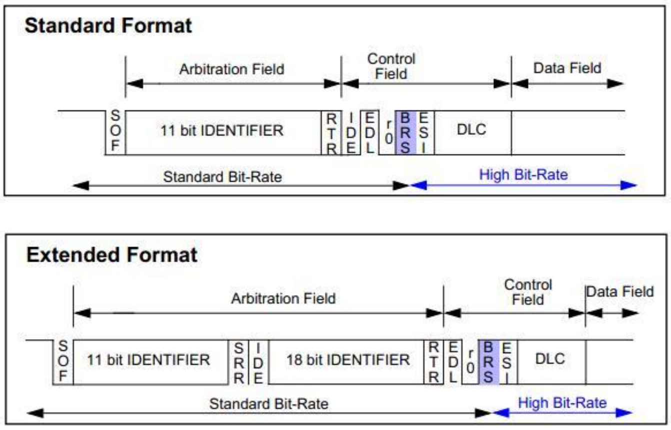

FIGURE 1 CAN FD frame format

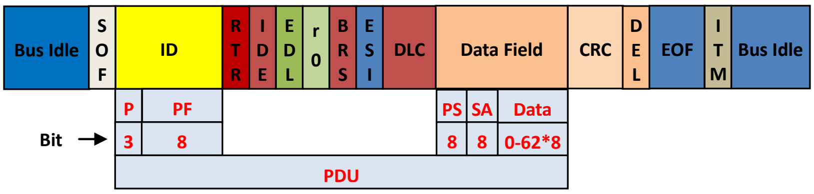

FIGURE 2 CANFD standard frame format

2.2 NEW FEATURES

CAN FD uses new CRC algorithm and DLC code. CRC algorithm computation includes bit stream filled with bits. A bit is filled from the first bit of bit stream after every four bits, and the padding is radix-minus-one complement. And format examination tests if the bit is radix-minus-one complement. DLC code uses nonlinear encoded scheme, as shown in Table 1. And the original DLC encoded scheme is for the data field which is less than or equal to 8 bytes.

TABLE 1 DLC encoded table

DLC	**1001**	**1010**	**1011**	**1100**	**1101**	**1110**	**1111**
byte	12	16	20	24	32	48	64

3 Protocol framework

Protocol framework of IOCAN is established based on OSI. For the actual requirements of in-vehicle network, the framework involves physical layer, data link layer, network layer and application layer. And it includes IOCAN 1.0A for CAN FD standard frame and IOCAN 1.0B for CAN FD extended frame. The paper describes the basic idea and important content of new protocol, and the significance of its application and development is explained.

3.1 PHYSICAL LAYER

Physical layer considers transmission media, transceiver and supporting degree of communication controller for CAN FD. For CAN FD, transmission media can continue to use the original system, and can use the original transceiver of CAN. But it needs to support the maximum rate of CAN FD, or it can use specialized transceiver. The controller needs to support CAN FD protocol, and it can change over between CAN and CAN FD to ensure that the bit rate supported by data field can achieve the desired effect.

3.2 DATA LINK LAYER

Based on information-oriented idea, IOCAN allocates ID in ID field based on transmitted information. Data link layer of IOCAN 1.0B refers to SAE J1939-21. CAN FD extended frame with 29 bits is based on ID field, which is different from CAN 2.0 A with 11 bits of passenger vehicles, which makes IOCAN 1.0B have large data utilization and information content. J1939 system is completed and reliable [9], the design of IOCAN refers to J1939 terms as PDU (Protocol Data Unit), PGN (Parameter Group Number) and SPN (Suspect Parameter Number).

3.2.1 Message format

For IOCAN 1.0A, as shown in Figure 2, the top three bits of ID field are priority P, the latter eight bits are PF (PDU Format), the first byte of data field is PS (PDU Specific), and the second byte is SA (Source Address). According to applications of message, P is distributed, which mainly considers the conventional communication message, diagnosis message and network management message. And the conventional communication message can be subdivided according to real-time requirements. The specific distribution is shown in Table 2. The information can be control information, state information or some data frames. If the message requires great instantaneity, it can be classed as important message. The distribution of diagnosis message is compatible with OBD requirements. And network management message considers direct network management based on OSEK/VDX.

TABLE 2 Priority distribution table

message type		priority (P)
conventional communication	important information	0
	high-speed control information	1
	important state information	2
	low-speed control information	3
	secondary state information	4
	secondary information	5
network management message		6
diagnosis message		7

For IOCAN 1.0A, PF is PGN. ID field is short, the mediation function is reserved for ID distributed by information. The deficiency of mediation function and uniqueness of data frame ID makes the ID field of IOCAN 1.0A not consider destination address and source address. But address definition is included in the definition of PGN, which defines the dispatcher and receiver of PGN. The paper focuses on introducing IOCAN 1.0B.

For IOCAN 1.0B, as shown in Figure 3, the top three bits of ID field are priority level P, the fourth bit is reserved bit R, the fifth and sixth bit is data page, the seventh-ninth bit is DT, the tenth-twenty-first bit is PF, the twenty-second to twenty-ninth bit is SA, and the first byte of data field is PS. PDU includes ID field with 29 bits and data field with 64 bytes.

IOCAN 1.0B is compatible with traditional ICE vehicle, hybrid electric vehicle and blade electric vehicle. The difference of internal control structure and power transmission system makes the vehicles great different in network structure, communication content and communication mode. Information-oriented idea is used based on this consideration and ID field is allocated. The difference between three types of vehicles is manifested by the difference of the transmitted information. Considering P, the priority level, in view of requirements of OBD, diagnosis message and network management message uses priority 6 and priority 7 as reservation, and the others continue to use the definition of IOCAN 1.0A. R is reserved bit, which can be extension of P or DP. DP is data page, which can be used as cluster management of information. DT is data type for data classification of conventional communication, which is subdivision of priority P, and the division is shown in Table 3. The security system means the system relating to active and passive security. PF is used to distribute information. PF not only can be used to differentiate information content, but also can be used to differentiate message type such as order, request, broadcast and response message. When PF<=239, it means that the message format is PDU1. As destination address, PS means the address to be transmitted by message. When PF>239, the message type is PDU2. PS is the data in data field. Or when P>5, PS is the data in data field, which differentiates from J1939.

TABLE 3 DT distribution table

system type	data type (DT)	corresponding DT (H)
reserved important system	0	0
power transmission system	1	1
braking system	2	2
chassis control system	3	3
body control system	4	4
security system	5	5
comfort system	6	6
reserved secondary system	7	7

The difference from J1939 includes increasing bit width of DP, which mainly considers huge information content of compatible object, and DP can be used to manage the information. It also includes increasing DT. And DT is used for detailed management to promote the compatibility of protocol. PS is placed in data field, and SA is reserved in ID field. Destination address is not added to mediation, and PS is not the part of PGN, which increases the content of PGN. When priority and PGN is the same, the message, which is transmitted by the nodes with little address occupy bus in priority. Most PGN includes the function of goal orientation, and the information has the feature of uniqueness, which means that the information of PGN is subordinated to an ECU, and the mediation requirement of destination address is lower than that of source address. And the mediation function of SA is reserved. The same ECU only can send a frame of message, so the broadcasting message, destination address message or the message with the same PGN have mediation function and can ensure the uniqueness of ID of data frame on bus, which meets the requirements of passenger vehicles.

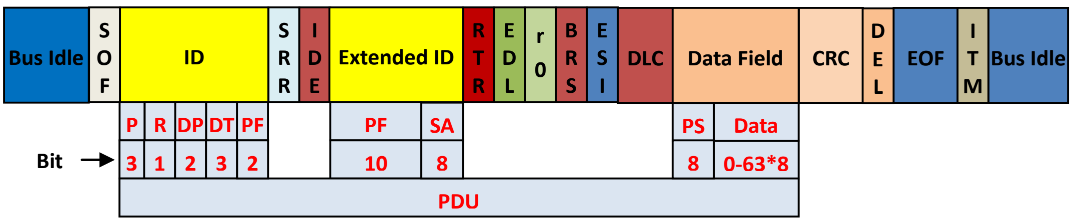

FIGURE 3 CANFD extension frame format

The constitution of IOCAN 1.0B, PGN is show in Table 4. PGN is a number with 24 bits, and the top 6 bit is 0, and then it corresponds to R, DP, DT and DF in PDU. And the content of PGN is that there are 240*32=7680 PGN with PDU1 format, there are (4096-240)*32=123392 PGN with PDU2 format. The content is more than 15 times of J1939, which is enough to meet the communication technique requirement of a new generation of vehicles, and can be compatible with traditional vehicles and new energy vehicles.

TABLE 4 PGN structure

PGN						
Byte1			*byte2*			*byte3*
bit8-3	*2*	*1*	*8*	*7-5*	*4-1*	
0	R	DP		DT	PF	

3.2.2 Message type

For IOCAN 1.0B, message type is classified as order, request and response messages. The message type is defined when PGN is defined. Response message is the message responding to order or request message, and it has concrete response information. Response message is a response to specific order and request, and it is sent in broadcast. Answer type is positive answer, negative answer and refusal access. The difference of response message and answer message is that response message has the required information, and answer message focuses on the answer type.

3.2.3 Transport protocol

The maximum transmission data of CAN FD is 64 bytes, and it can transmit the data with 12, 16, 20, 24, 32, 48 and 8 bytes. According to the data length of transmitted data, the corresponding data field is selected, which is determined when PGN is defined. When the transmitted data is greater than 64 bytes, the transmission of long data can be realized by increasing definition PGN. When the data filed is not filled, the omitted data is taken as 1.

3.3 NETWORK LAYER

Network layer is applied for diagnosis function to solve the problem that data needs to be split into multi-frame transmission. The system uses the solution based on ISO1565-2. Network layer only can be applied for diagnosis. Single frame can transmit 64 bytes, so the conventional communication do not involve network layer.

3.3.1 Addressing mode

Based on ISO1565-2, in diagnosis application, addressing mode is divided into physical addressing and function addressing. The distribution of address is based on ID field of CAN FD data frame. For IOCAN 1.0A, physical addressing range is 0x700~0x7FF, which includes physical request and response. The function addressing is 0x7FD. For IOCAN 1.0B, physical addressing range is 0x18DA0000~0x18DAFFFF, and function addressing range is 0x18DB0000～0x18DBFFFF.

3.3.2 PCI (Protocol Control Information) structure

As shown in Table 5, the size of data field based on CAN FD is different from the original CAN, and the definition of N_PCI is modified in ISO1565-2. When the single-frame data is less than 7 bytes, the low four bit of Byte 1 is used as SF_DL to indicate the data length of single frame. The data field after Byte2 is used as N_Data, and DLC is set as 8. When the single-frame data is greater than or equal to 7 bytes, and less than or equal to 62 bytes, that is, when 7<=SF_DL<=62, the low four bit of Byte is set as 1111, Byte2 is used as SF_DL, and that after Byte3 is set as N_Data. Proper DLC is configured according to the length of N_Data. CF uses the data frame of CAN F of data field with 64 bytes. FC uses he data frame of CAN F of data field with 8 bytes. The unfilled data bits in data fields are filled with 1.

3.4 APPLICATION LAYER

The design of application layer draws lessons from J1939-71 content. The message is defined as the set of parameters signal is defined as a parameter, and the set of parameters, parameter description methods have been standardized. Parameter set, parameters are assigned uniform number, are defined as PGN, SPN. By this standard definition, the content of communications management becomes clear, unified. The following paper suitable for routine communication PGN, SPN, not considering diagnosis, network management PGN, diagnosis, network management has its independent management mode.

TABLE 5 PCI structure

N_PDU type	11/29 bit CAN FD identifier	N_PCI			
		byte 1		*byte2*	*byte 3*
		bit 7-4	*bit 3-0*		
single frame (SF)	CAN FD ID	00b	SF_DL	SF_DL /N_Data	N_Data
first frame(FF)	CAN FD ID	01b	7<FF_DL<=4095		N_Data
continuous frame(CF)	CAN FD ID	10b	SN(0~F cycle count)	N_Data	
flow control frame(FC)	CAN FD ID	11b	FS	BS	stmin

3.4.1 Definition of parameter group

For IOCAN 1.0B, parameter group defines the number and name of parameter group, transmission mode, DLC size, data length, data page (DP), data type (DT), PDU format (PF), PDU specific (PS), default priority and parameter list. For IOCAN 1.0A, the definition is similar, but without descriptions of DP, DT and PS. The name of parameter group is used to express the common features and functions of all parameters in the group. Transmission mode defines the transmission mode of parameter group such as periodic transmission and frequency, event driven transmission, event periodic mixture. DLC size is defined according to encoded mode of DLC and the required data length, which is used to configure data filed length of CAN FD. And the data length is the data length of all parameters in parameter group. The size of data length should be less than or equal to that of DLC code. The undetermined CAN FD data bit is filled with 1. Parameter list defines the storage place of parameters in data filed. Parameters are distributed in parameter group according to functions, and all parameters are from the same ECU and have the same transmission mode.

3.4.2 Definition of parameters

Parameters are used to describe signals. Each parameter is allocated a number, SPN (Suspicious Parameter Number). The description of parameters include parameter name, SPN, transmission function, parameter type, arrangement format, data type, data length, accuracy, data range, unit, initial value, ineffective value and PGN.

Parameter name is used to describe the function, content and applications of signals, and the naming rule can be defined according to specific requirements. Transmission function is used to analyze parameter functions. Parameter type can be state type and measurement type. State type parameter reflects the state of functions, but it can determine if the function realizes. Measurement type parameter reflects the actual measurement results. Arrangement type describes the filing mode of data in data filed. The first item selects Motorola LSB format. Data type describes the data format of the original data, and the first type selects no-signal format. Parameter length is the data length of parameters, and the least length is 1 bit. Accuracy defines the mapping relationship of data value and physical value, which means proportional coefficient and offset. Data range is the value range of physical value. The unit is the unit of physical value. And initial value and ineffective value is the original data value.

3.4.3 Transmission strategy of data segment

CAN FD data filed can be 64 bytes, and the transmission rate is fast. The information content of a frame of message can be 8 times of traditional CAN message, and the transmission rate is 4Mbit/s. The transmission efficiency improves 8 times. Non-periodic message is undetermined, and there are many undetermined factors in network design and applications, which reduces the reliability of network. It requires that the period of message should be small to meet the transmission requirements of non-periodic message. Or several non-periodic messages can be integrated to be a message to reduce the type of non-periodic messages. The paper proposes a transmission strategy, which means to divided into several data segments in CAN FD data field, as shown in Table 6. The original transmission modes of each data field are different. According to the actual requirements, the size of DLC is set. The data length is adjusted, but the place of data segment is fixed.

TABLE 6 Data segment distribution table

data filed of data frame			
data segment 1	data segment 2	data segment 3	data segment …

3.4.4 PGN and SPN

For IOCAN 1.0A, PGN used 8-bit number. For IOCAN 1.0B, PGN uses 24-bit number. The distribution should consider the factors including priority, transmission mode, data importance and data length. PDU2 format has no need to consider the specific destination address, and PDU1 needs to consider the specific destination address. SPN uses 19-bit number. For the parameters of the same parameter group, it considers the correlations of SPN distribution. SPN may not be PGN, and all PGN may not include SPN, and PGN and SPN has reservation for other purposes.

The paper proposes the definition of parameter group, parameters, and the allocation method of PGN and SPN. Actual situation requires standardized and clear parameter group and parameters. Targeting different application objects such as electric and hybrid power systems, PGN and SPN are defined. In IOCAN protocol system, the user can add in own definitions according to requirements based on standardized PGN and SPN.

4 Application analysis

Based on the above protocol system, from the perspective of conventional communication, network management and diagnosis, the paper analyses application in passenger vehicles, which includes in-vehicle network functions.

4.1 COMMUNICATION FUNCTION

Based on the communication requirements and the definition of common parameter group and parameters, the communication database is formed with IDs including PGN, SPN and ECU (for IOCAN 1.0B), also the relationship between the sender and receiver. The conventional communication function realizes based on the database.

4.2 NETWORK MANAGEMENT

Network management function applies direct network management based on OSEK/VDX. PDU structure of network management consists of address field and data field of network management field, as shown in Figure 4. Network management address filed is divided into source address and destination address. The source address is located in ID field of CAN FD data frame, and it can be dissolved into base address and ECU address. Destination address is located in the first byte of CAN FD data frame data filed. The network management control field is located in the second byte of CAN FD data frame data filed. The network management data is located in the third~eight byte of data field of CAN FD data frame.

For IOCAN 1.0A, the base address is 0x600, and the range of ECU address is 0x00~0xFF. For IOCAN 1.0B, the base address is 0x18FFA000, and the range of ECU address is 0x00~0xFF, which means that the range of source address is 0x18FFA000~0x18FFA0FF and that of destination address is 0x00~0xFF. According to ECU of network management, ECU address is allocated and network management structure is determined.

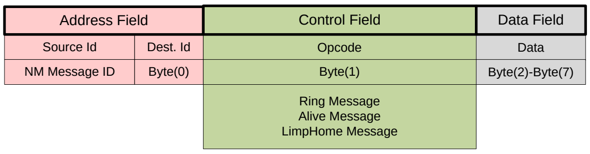

FIGURE 4 NMPDU structure

4.3 DIAGNOSIS

The paper discusses the enhanced diagnosis of vehicle manufactures. Diagnosis protocol system has physical layer, data link layer, network layer, session layer and application layer. Physical layer, data link layer and network layer is based on the above establishment, the session layer uses ISO15765-3, and application layer applies ISO15765-3/ISO14229-1.

According to the vehicle program, the distribution of ID, DID and DTC is diagnosed, the supported diagnosis service and the limitation of diagnosis service for session mode, security access and addressing mode is determined, and the diagnosis database is established.

5 Conclusion

By referring to the concept of SAE J1939, based on standard frame and extension frame of CAN FD and information-oriented idea, proposed in the paper is the next generation of in-vehicle protocol framework with great bandwidth capability, great compatibility and large information content, which standardize traditional protocol system of passenger vehicles and adapt to new communication requirements of new energy vehicles. The application on in-vehicle communication protocol of passenger vehicles is analyzed. In addition, the paper makes clear and effective observation on unification, standardization and promoting integrity and flexibility of in-vehicle network protocol of the next generation of passenger vehicles.

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Authors

Qijin Cai, 1986.10, Guilin, Guangxi, P.R. China

Current position, grades: Currently occupied in his M.S. degree in control science and engineering at Guilin University of Electronic Technology in China.
Scientific interest: His research interest fields include automobile electronic technology, field bus technology.
Publications: more than 2 papers published in various journals.
Experience: He has completed more than 2 scientific research projects.

Yong Xu, 1955.6, Guilin, Guangxi, P.R. China

Current position, grades: Full Professor of School of Electronic Engineering and Automation, Guilin University of Electronic Technology, China.
Scientific interest: His research interest fields include automobile electronic technology and automatic control technology
Publications: more than 40 papers published in various journals.
Experience: He has teaching experience of 20 years, has completed more than twenty scientific research projects.