Real-time Analysis of dynamic priority of CAN Bus protocol

Tan Xiao-peng, Li Xiao-bing, Xiao Ti-liang
School of Mechatronics Engineering
University of Electronic Science and Technology of China
Chengdu, China
e-mail: tanxiaopeng@gmail.com

***Abstract*—Based on the static scheduling algorithm, the arcticle, which introduced a dynamic priority promotion mechanism for CAN, proposed a scheduling algorithm with the advantages of both static scheduling algorithm and dynamic scheduling algorithm. The algorithm can improve the real-time transmission of data; especially data with low priority and the utilization rate of CAN network bandwidth being very high. The simulating results show that the transmission of data with different priorities can be remarkably improved, which verify the design concept.**

Keywords-CAN bus; static priority; dynamic priority; real-time

I. INTRODUCTION

The Controller Area Network (CAN) belongs to the category of field bus. It is a serial communications protocol supporting distributed realtime control efficiently with a very high communication rate and performance-cost, and is a reliable and convenient choice for users. Its applications range from high speed networks to low cost multiplex wiring[1].

The version 2.0 of protocol of CAN bus was released in 1991. It has defined the standards of the data link layer and the physical layer, but without the protocol of application layer. As a result, CAN bus can be widely adapted to different application conditions. However, when users want to achieve the normal communication of system, the protocol of application layer must be defined.

At present, there are several popular protocols of application layer, such as CANOpen, J1939, DeviceNet. These protocols give a complete and detailed definition on the application layer. Sometimes if a simple protocol can fufill the demands, the use of complicated protocols would cause the waste of resources and limit the flexibility of CAN bus. Therefore, users must design appropriate CAN protocol in accordance with the actual demands.

II. DATA FRAME STRUCTURE OF CAN FIELDBUS

In the system of CAN, there are four types of frame that manifeste and controlle message transfer. The data frame carries data from a transmitter to the receivers. The remote frame is transmitted by a bus unit to request the transmission of the data frame with the same identifier. The error frame is transmitted by any unit on detecting a bus error. The overload frame provides an extra delay between the preceding and the succeeding data or remote frames.

A data frame is composed of seven different bit fields: start of frame, arbitration field, Control Field, Data Field, CRC Field, ACK Field, End of Frame. The data frame length can be zero[1]. Fig.1 illustrates the composition of data frame.

III. ANALYSIS AND DESIGN OF APPLICATION LAYER PROTOCOL

A. Access Control Protocol of CAN bus

Network of CAN is a shared media bus-network. All nodes are connected with a pair of CAN_L and CAN_H wires. In CAN protocol, CSMA[2]—Carrier Sense Multiple Access describes as follows: transmitter detects the state of bus before trying to send information, if the bus is idle, the nodes would start sending data; if the bus is busy, the nodes would continue to detect until the bus was idle. If multi-nodes start simultaneous transmission while the bus is idle, the access would conflict arise.

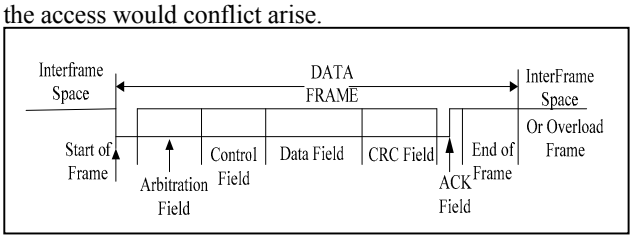

Figure 1. The Composition of Data Frame

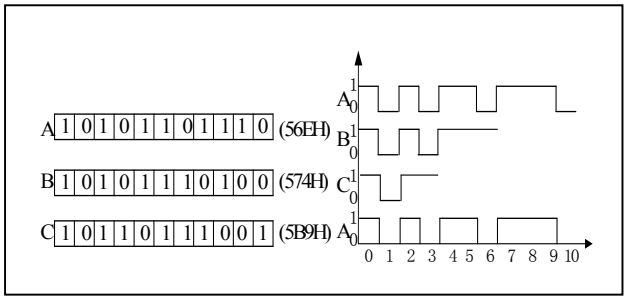

Figure 2. The Identification Field of Three Nodes and The Arbitration Process

The non-destructive arbitration mechanism, which based on the competition of priority, applied to CAN bus to resolve the conflict. During the arbitration, higher priority is

determined by the smaller identifier. When two different priority nodes competing the right of access to the bus, with the identifier field from high to low and bit by bit, the arbitration mechanism would determine which node would hold the right. When there is a bit of which priority is different, the bit display itself "0" and get the access. As can be seen in Fig.2, the higher-priority node A, get the access to bus the three nodes are competing.

B. Arbitration Field of Data Frame

The arbitration field in data frames, which is compose of an identifier and the RTR bit, shown in Fig.3, is firstly concerned when a proctrol is made. In addition, it is used for resolving the competition of bus in MAC layer. Meanwhile, it provides the basis of arbitration and filtering services of information frame for the receiving node in the data link layer.

Static priority algorithm, which is applied to distribute the priority of message in the standard protocol of CAN, is simple, easily to manage and of schedulability judgment. But a determinate priority of a frame will not change until terminated. Data can be reliably transmitted when the utilization rate of bus is very low. The static priority mechanism leading to uneven distribution of the bandwidth, the delay time of low priority frame will augment as the utilization rate increasing caused by the number of retransmission growing. In particular, data may be lost when the utilization rate of bus is very high.

C. Analysis and Design of the Dynamic Priority Protocol

In order to solve the issue caused by the static priority, pormotion mechanism of priority is applied to design protocol[5]. The basic idea described as follows: each node has its own different priorities on initial conditions, and send data comply with the initial fixed priority when there is no conflict occur on the bus. In case of conflict, the node holding high priority gains the right of the access to the bus on the competition, and starts sending data. In order to make low priority frame to have more great probabilty to clinch victory on the next time, the failed nodes improve priority for next competition, and continue to promoting when failed again. Even though failure continues, the priority of the failed node will become very high and hold high probability to win. The waiting time of service is preferentially considered on this mechanism to reduce the information congestion and to ensure the real time of this system on communication.

The indentifier, as shown in Table 1, is divided into two parts in the vision of CAN 2.0A. ID.10 ~ ID.x is Characterization of priority of the information frame, which plays a master role in the arbitration. ID.x-1 ~ ID.0 is identity of the information frame, which represents the physical address of each node in the CAN network to sure that the network does not exist two same address.

TABLE I. THE IDENTIFIER OF STANDARD FRAME

ID.10	……	ID.x	ID.x-1	……	ID.0

Priority(m bit)	the physical address of the node(11-m bit)

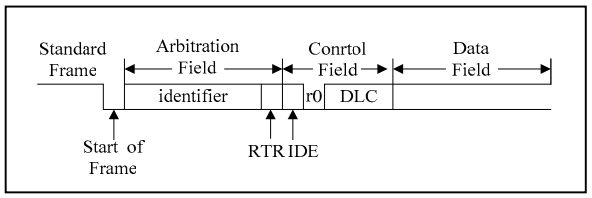

Figure 3. The struction of arbitration Field of the standard data frame.

The priority field in Identify, which consist of m-bits can be expressed as 2^m priority level, is denoted by PRI. In accordance with the CSMA / CD protocol, the nodes comply with determined priorities when sending data at the same time. The smaller PRI has higher priority than the greater one, so is sent in advance. With the increasing of the send wait time(t), the priority of node(i) is promoting[2], mathematical writter as:

$$PRI_i = INIT_i - f(t) \quad (1)$$

PRI_i represents the priority of Information frame(i). According to the different requirements of the real-time system, $INIT_i$ indicated the initial priority value of node(i), and assigned different priority between 0 and 2^m-1. The real-time data assign higher priority than the non-real-time data in system. Based on significance, the real-time data assign different priorities. e.g. the alerts data hold higher priority than the general monitoring data.

The wait time is caused by the delay of continuing conflict in the process of queuing. $f(t)$ can be expressed as:

$$f(t) = \lfloor k * n \rfloor \quad (2)$$

Where K, which can be expressed as $k = w/l$, is the weight factor for $f(t)$. l is the length of DLC(data length code) of information frame. The value of w is determined by the length of data and the importance of node in the whole system, so it ranges from 0 to l. Smaller l results greater k, which achieve The Earliest Deadline First to ensure the short data can be send firstly when w 's value is fixed. To adjusting the value of w can carry out the strategy of Highest Value First when frame have the same length of l. By (1), (2), the priority function is written as:

$$PRI_i = INIT_i - \lfloor w * n / l \rfloor \quad (3)$$

Firstly, the priority fields are defined as static priority, and then different promotion functions are chosen. In this way, different priorities on the promotion rate are adopted. In other words, different priorities are pre-arranged. The static

priority achieves a predetermined priority categories. Meanwhile, dynamic priority ensures the real time frame to avoid the occurrence of deadlock priority.

D. the algorithm of Dynamic priority

the dynamic process of PRI described as algorithm 1: algorithm 1:

a) Node generates a new frame, n=0 , $PRI = INIT - f(0) = INIT$.

b) The new frame access channels with the CSMA and the priority of non-destructive arbitration. Once the bus being idle, the new frame send immediately.

c) The new fram sends successfully when no conflict happens.

d) If there is conflict, illuminating some higher priority frames are senting, the frame would wait the next. If PRI *is less than the highest priority the system allowed,* $PRI = INIT - \left\lfloor \frac{1}{l} * w * (n++) \right\rfloor$ *,the frame promote the priority, or hlod and Turn to (b).*

e) When waiting for the bus, node receives a frame. The same as with (d).

The flowchart of algorithm 1 shown in Fig.4.

E. Real-time analysis of dynamic priority

In the model of the queuing theory that the probability density of the frame generation/ frame transmitted /the number of frame can be transmitted at the same time, the situation of priority allocation and change can be regard as a M/M/1 queuing model which is based on the hypothesis that the generation is Poisson process. The transmission line with exponential distribution and the network of bus can only transmit one frame at the same time [2,3]. In this queuing model, the frame transfer rate(μ) is equal to the bandwidth(B) of CAN bus, which is a reciprocal of the transmission time(t) of a single frame. Namely: $\mu = B = 1/t$.

The generated rate of data in the node of network is λ_i , the frame generation rate of the entire network is described as:

$$\lambda = \sum_1^n \lambda_i = n\lambda_i \tag{4}$$

The network load has the form:

$$\rho = \frac{\lambda}{\mu} = \lambda\tau \tag{5}$$

Obviously, it is an unstable situation in any random queuing system where the queue is infinite when $\rho > 1$, so pass. When the system reaches equilibrium, the condition of $\rho \le 1$ can be met in the network of CAN. The average availability of the network frame($\overline{N}$) is known by the mathematical expectation, and is described as $1/(1-\rho)$.

According to Little's law, when a frame was sent to the destination node and just left the system, the average number of frames should be equal to the number of the arrived farme during the average frame transmission delay time($\overline{W}$) of this frame in the system. That is $\overline{N} = \overline{W}\lambda$.

The average delay of frames describe as:

$$\overline{W} = \frac{\overline{N}}{\lambda} = \frac{1}{\lambda}\frac{\rho}{1-\rho} = \frac{1}{B(1-\rho)} \tag{6}$$

According to the equation above, it can be concluded that ρ is very small when the network load is low. The average delay of frames approximately is expressed as the function of the bandwidth of network, which only depends on the network bandwidth, is unrelated with the load of network.

As the network load increasing, the utilization rate and the network throughput are significantly decreased under the static scheduling. The dynamic priority promotion mechanism can handle the problem of collisions on the network to ensure the network throughput and utilization rate is almost not affected. In addition, it solves the priority problems caused by the static priority of the data transmission process which can not change dynamically [3,7]. It optimizes the utilization rate of network bandwidth and improves the real time in network.

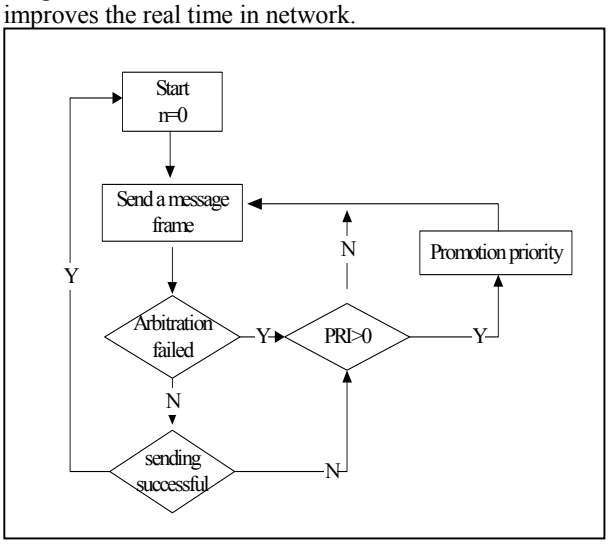

Figure 4. The Flowchart of Algorithm 1.

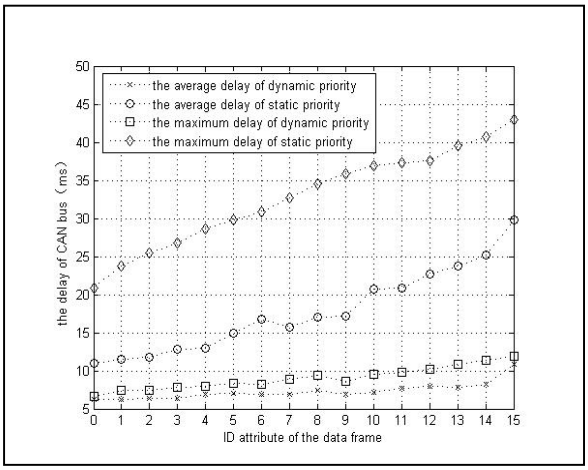

Figure 5. The Delay Time of The Different Priority Strategies In Network.

IV. SIMULATION

The model of simulation system was established by virtue MATLAB and CANoe. It simulates the network wire production monitoring system. The static priority and the dynamic priority mechanism are applied to this model[4,6]. The value of parameters in promotion machine is that m=4, $l=6$, $w=1$, the speed of bus is 25Kbps and the rate of network load is 80%. This experiment platform is composed of 20 nodes in a single segment network. The different strategy is applied to research the real-time of CAN bus. The delay of each node transmition is monitored and recorded. The results are obtained by virtue computer simulation, which is shown in Fig.5.

According to the Fig.5, the delay time of CAN bus has been improved significantly when the dynamic promotion mechanism was applied. The delay of network using dynamic priority strategy is better than that of static priority. The dynamic priority strategy improves the system's real-time property within a certain range. This design was proved after the experiment.

V. CONCLUSION

The algorithm using the function of dynamic priority promotion, can improve the utilization rate of CAN bus to content the requirements of real-time and reduce the network the transmission delay of lower-priority frame. There is no conflict, when the network load of CAN bus is low, and the arbitration of non-destructive method apply to transmit message frames. As the network load increasing, the system frames of auto promote priority guarantee high realtimeness of the network.

REFERENCES

[1] Robert Bosch GmbH, CAN Specification 2.0, sep.1991.

[2] XUE Lei, LI De-Hua, and GUAN Jing-Huo, “Adjustable real-time MAC protocol based on distributed dynamic priority queue,” Journal of China Institute of Communications(May 2003), PP64-71.

[3] TANG Hong-wei, Study and Improvement On The Real Time Communications of CAN Bus, XI’AN: Xidian University, 2006.

[4] SHI Jiu-gen, LIU Peng, and ZHANG Pei-ren, “On the Real-time Performance of CAN Data Transfer and Its Applications”, Information and Control(June,2004) , PP342-346.

[5] Zhou Shi-ying, Intelligent Scheduling of CAN Networked Control System, JILIN:Jilin university ,2009.

[6] SHI Jiu-gen,ZHANG Pei-ren,”The Study of CAN Network s Application in Real-time System,” Journal of University of Science and Technology of China(Apr.2005), PP195 -201.

[7] WANG Li-ming, SHAO Ying, and SHAN Yong, “The Research of Improving Dynamic Scheduling Algorithm Based on CAN Bus,” Computing Technology and Automation (Mar.2008), PP65-69.