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Controller Area Networks (Can) Evolution, Response Time Analysis and Applications

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Abstract:Initially designed as a new mean in providing communication network between control units in automotive industries, the controller area network (CAN) has shown a great surge of interest due to its vast advantages. Since then it is widely used in various automation industries including military, aviation, electronics, factories and many others. CAN was designed to allow microcontrollers and devices to communicate with each other without the presence of a host computer and avoiding extensive load to the main controller. It is a high performance and high reliable advanced serial communication protocol which effectively supports distributed real- time control. Ideally, CAN is suitable in application requiring a large number of short messages with high reliability in rugged environment. These characteristics along with many others, allows wide opportunity in development of intelligent ubiquitous sensor network and controller system. This paper presents a brief introduction on CAN operating principles, its architecture and protocols. Also, various applications of CAN are introduced and surveyed.

Keywords—Controller Area Network, Scheduling, Time analysis.

I. INTRODUCTION

In the past, devices and sensors in automotive industries are connected in a point to point wiring system which in turn causes the overall network system to be complicated, bulky, heavy and expensive. In the early 1980s, Robert Bosch GmbH company has developed a new network controller in the automotive industries with the intention of replacing and simplifying the wiring system. This development gave rise to a new network system, called the controller area network (CAN). The CAN system was developed as a serial bus with high speed, high reliability, and low cost for distributed real time control applications.

CAN is becoming a de facto standard for data transmission in automotive applications. Slowly, CAN begins to gain wide appreciation in various industrial automation due to its high immunity towards electrical interference and the ability to self-diagnose and repair data errors. With its low cost, high performances, upgradeability, and providing flexibility, researchers begin implementing CAN in military, aviation, electronics, factories and many other industries.

This paper provides a comprehensive overview of CAN, its architecture, protocols, standards and some of itsimplementation in various industries. In Section 2, the CAN basics such as message format, message identifiers and bit-wise arbitration are explained. The following few sections will introduce CAN implementation in various automation fields such as automotive industries.

II. CONTROLLER AREA NETWORK (CAN) PROTOCOL

The CAN was defined in International Standardization Organization (ISO) as a serial communication bus to replace the complex wiring harness with a two-wire bus. Additionally, it is a multi-master serial bus that broadcast messages to all nodes in the network system. The CAN system offers a transmission speed of up to 1 Mbit/s with reliable and error detection method for effective transmission.

CAN uses carrier sense multiple access protocol with collision detection (CSMA/CD) and arbitration on message priority as its communication protocol. This communication protocol allows every node in CAN to monitor the bus

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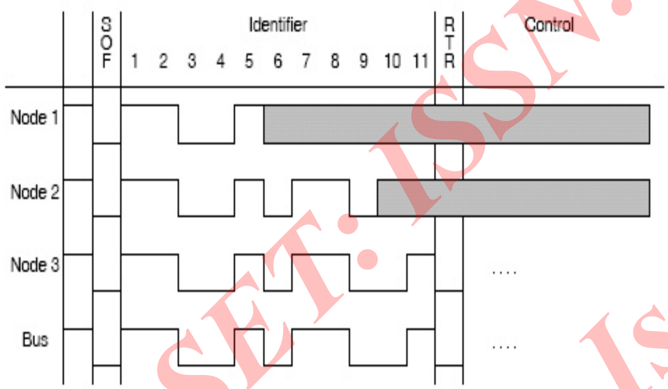
network in advance before attempting to transmit a message. When no activity occurs in the network, each node has the same opportunity to transmit a message. Additionally, this communication protocol allows collision to be solved using bit-wise arbitration, based on a pre-programmed priority of each message in the identifier field of a message. This configuration allows messages to remain intact after arbitration is completed even if collisions are detected. In order for the arbitration process to be successful, the logic states need to be defined as dominant or recessive. CAN defines the logic bit '0' as the dominant bit where as the logic bit '1' as the recessive bit. An example of CAN arbitration can be seen in Figure 1 when three nodes are assumed to be transmitting simultaneously. This figure is illustrating CAN arbitration when three nodes start transmitting their start of frame (SOF) bits simultaneously. Nodes 1 and 2 stop transmitting as soon as they transmit bit ‘1’ (recessive level), and Node 3 is transmitting bit ‘0’ (dominant level). At these instances, Nodes 1 and 2 enter the receiver mode, indicated in grey. When the identifier has been transmitted, the bus belongs to Node 3 which thus continues transmitting.



$$I_1 = 11001101010,\quad I_2 = 11001011011,\quad I_3 = 11001011001.$$

Figure. 1 CAN arbitration

The ISO standard defined CAN with a standard 11-bit identifier that provides for signalling rates from 125 kbps to 1 Mbps. This standard is later improved to allow for larger number of bit, where the "extended" version with 29-bit identifier. The standard 11-bit identifier field provides for 211, or 2048 different message identifiers, whereas the extended 29-bit identifier provides for 229, or 537 million identifiers. The data format of both standards can be seen in Figure 2.

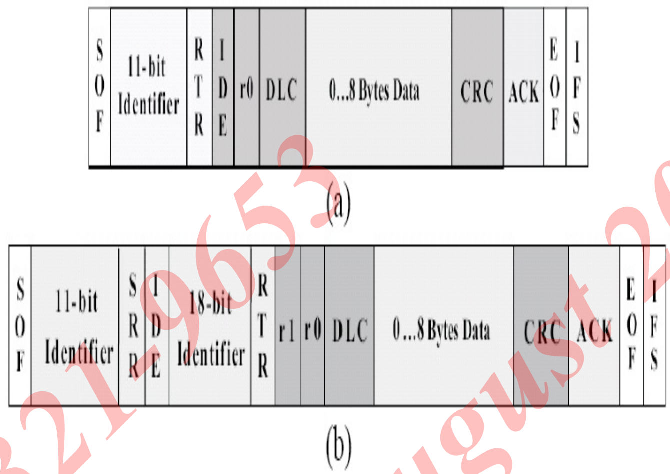


Figure .2 Frame format of (a) Standard CAN and (b) Extended CAN.

CAN protocol can be considered as a message-based protocol as messages are transmitted to all nodes in the network. Therefore, each node receives the messages and decides whether the message received is to be discarded or processed. Depending on the configuration of the network, a transmitted message can be destined to either one node or many nodes. This has several important consequences such as system flexibility, message routing and filtering, multicast, together with data consistency.

III. WORST CASE TIME ANALYSIS

The Response time analysis for CAN focus to offer a approach of measuring the worst-case response time of every message. These values can then be measured to the message deadlines to control if the network is schedulable**.** For structure abide by with the scheduling model the CAN has adhere to enact pre-determined priority nonpre-emptive scheduling of messages. Upcoming the inspection in the worst-case response time of a message can be estimated as being made up of three component:(i)one the queuingjitter *Jm*, communicate to the longest time connecting thestart ofoccurrence and the message being queued, prepared for imparting on the bus,(ii)the queuing waiting *Wm*, communicate to the longest time that the message can endure

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in the CAN controller slot or tool driver queue before begin successful transmission on the bus,(iii)the communication time *Cm*, communicate to the longest duration that the message can take to be transmitted.

The WCRT of message m is given by $Rm = Jm + Wm + Cm$

The message is said to be schedulable if and only if its worst-case response time is less than or equal to its time limit($Rm \leq Dm$). The structure is schedulable if and only if all of the messages in the structure are schedulable. Thequeuing waiting time consist of obstruct *Bm*, due to bottom prime concern messages which may be in the operation ofbeing communicated when message *m* is queued and intrusion due to higher prime concern messages which may win interposition and be transmitted in partiality to message *m.* The worst-case queuing waiting for message *m*occurs for some case of message *m* queued within a priority level- *m* busy period that initiates instantly after thelongest lower prime concern message begins transmission. Here maximal occupied session begins with a so-calledcensorious immediate where message *m* is queued concurrently with all higher prime concern messages, andthen every of these messages is afterwards queued again after the shortest viable time intervals. In the residue of thispaper a occupied duration means this uttermost length busy duration. If more than one case of message *m* istransmitted during a prime concern level-*m* busy period, then it is required to control the response time of every case inorder to find the overall worst-case response time of the message.

IV. RESULTS & SIMULATION

Response time analysis for CAN bus in worst case scenario is discussed here. The Software simulator is typically used to run Verilog HDL-based designs. The Software simulator sprint on a generic computer. I loadthe Verilog HDL code and simulate the behaviour. Software simulation work done on Modelsim. Coding work is done on Verilog HDL language. The simulation result shows the remote frame and data frame transmission and extraction of data from the data frame, all processes are done under the fixed scheduling of messages, controlled bya CAN controller. My mainfocus to reduce response time by using less clock frequency.

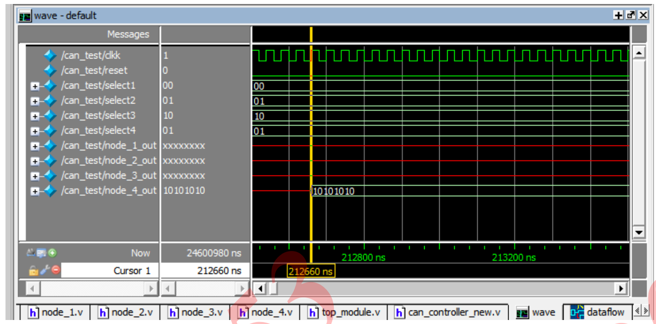

Figure .3 Data transmission.

V. APPLICATION OF CAN

In the automobile industry, it has been successfully realize the data communication between inner control system and test actuator on many famous vehicle maker using CAN. CAN is applied in the function of communication controllers that can transmit electric signals to different controllers in a vehicle system such as signal lamp, audio, air conditioner, communication, electronic ignition, engine fuel injection, etc. Not only that, CAN has been proven to reduce and simplify the amount of signal lines and additionally solve many complex and difficult control problems of modern vehicles such as Automatic Stability Control (ASC) and Automatic Braking System (ABS).

The popularity of CAN due to its many advantages can be seen in its implementation in various automation applications. Researches uses CAN in home automation, robotics, medical, military, structural monitoring and many others. CAN was introduced in the application of direct load control programs for residential automation. This system was intended to allow users to monitor and control the heating and cooling individual loadsof their homes offering flexibility in demand-side participation in deregulated electricity markets.

Kyung et. al proposed a fire detection system found in most home and offices which is designedutilizing CAN as itsbackbone network as shown in Figure 4. By redefining the message identifier of Extended CAN, it has been determined that the enhanced system surpasses the conventional one. This is because conventional method perceives a fire based on the increase of current as the fire causes analog line to short-circuit. However, using CAN, the system can synthetically judge a fire occurrence by directly receiving fire detection data from multiple fire detectors.

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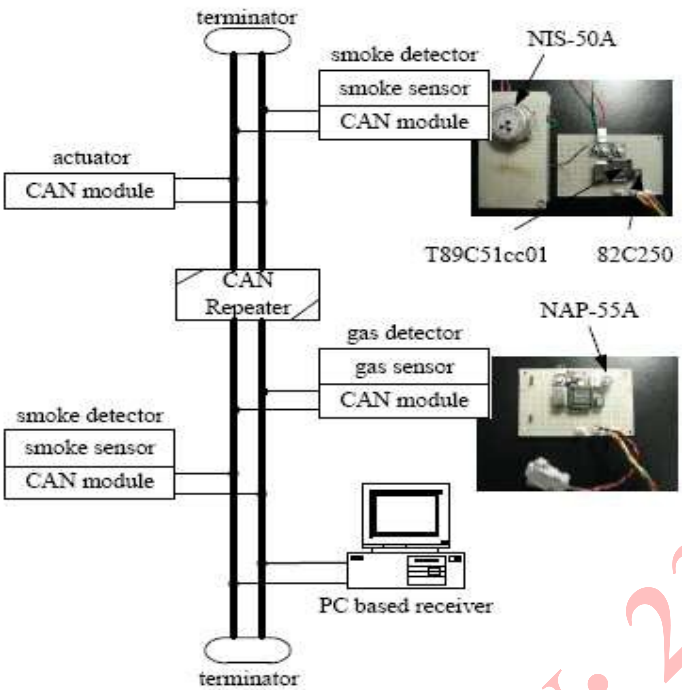

Figure. 4 CAN based fire detection system

VI. CONCLUSION

This paper presents a brief overview of CAN and response time analysis in worst case scenario. This network is emerging and gaining high ground in many applications from automobile industry to automation and factory industries. CAN is a multi-master serial bus that allows an efficient transmission of data between different nodes. With its flexibility and robustness against electrical interference, CAN have become one of the main choices in many researches as the ideal network system.

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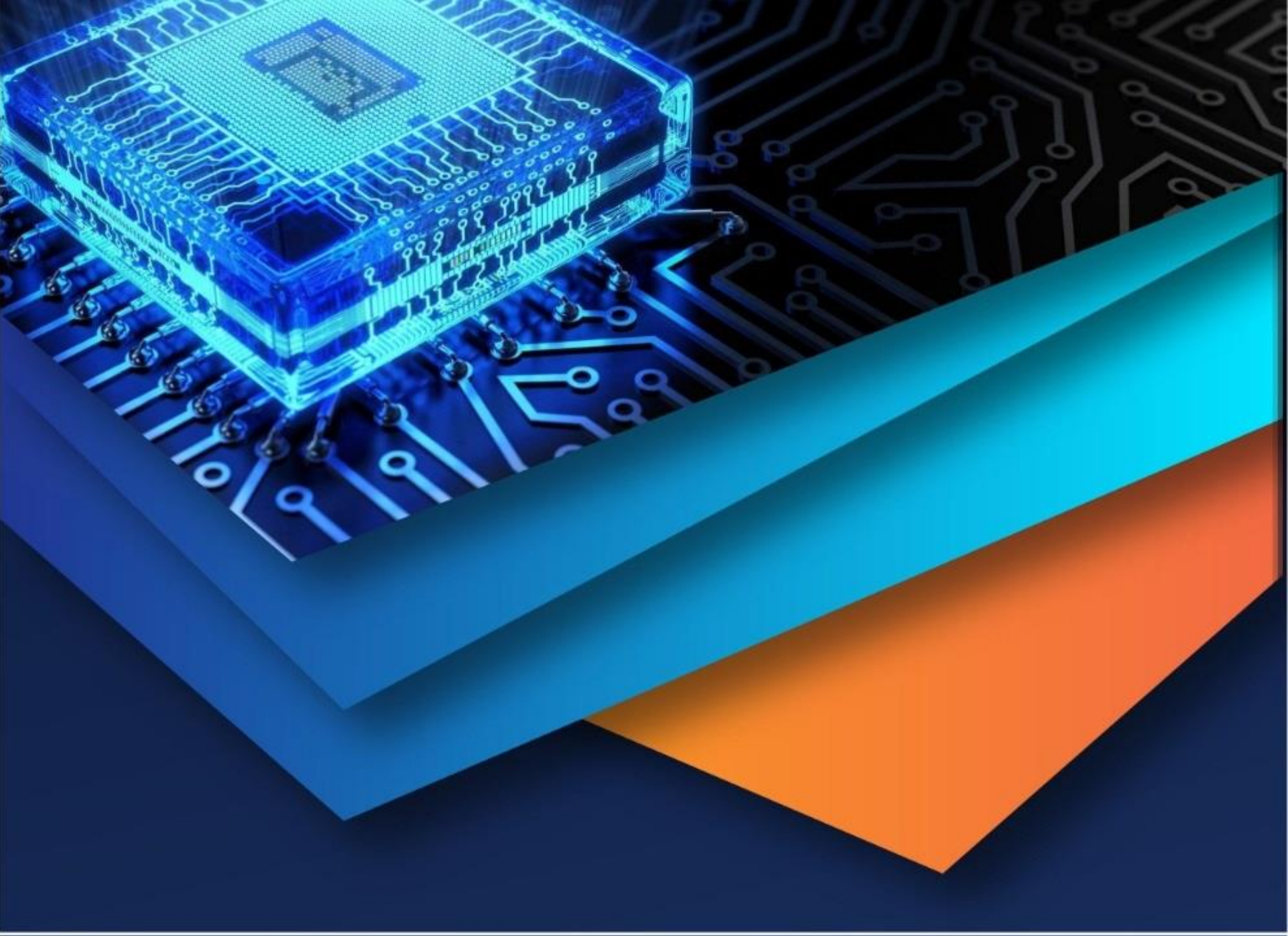

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