Dynamic Message Id Allocation And Arbitration In Can Architecture

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***Abstract* - On board communication on FPGA is an issue of interest for many researchers in recent years. Various protocols have been proposed in the literature to provide communication between central unit and peripherals. Control Area Network is also an on board protocol for communication of FPGA or microcontrollers with different peripherals. Traditionally, the message id allocation in CAN is static which means only one id is given to each application and it remains same throughout the communication. This leads to biasness for various applications while others always access the bus at the time of arbitration. In this paper Dynamic approach of message id allocation from the message id window is proposed which increases the randomness and thereby decreases the biasness. The results discussed in the coming sections also prove the same.**

***Keywords* - CAN, Bus Arbitration, Dynamic Message Scheduling.**

INTRODUCTION

The Controller area Network may be a serial bus prescript developed by Bosch within the early Eighties [1]. It defines a regular for economical and reliable communication between detector, controller, actuator and different nodes in period of time applications. It is the de facto customary during a giant form of networked embedded management systems. The first development was primarily supported by the vehicle industry: which is found during the form of cars, trucks, boats, spacecraft, and different kinds of vehicles [2]. The protocol is additionally wide used these days in industrial automation and different areas of networked embedded management, with applications in numerous products like production machinery, medical instrumentality, building automation, weaving machines, and wheelchairs [1].

The will protocol standardizes the physical and electric circuit layers, that square measure the 2 lowest layers of the open systems interconnect communication model. For many systems, higher-layer protocols square measure required to modify economic development and operation [3]. Such protocols square measure required for outlining. However, protocol ought to be employed in applications, as an example, a way to talk to the configuration of identifiers with relation to application messages, a way to package application messages into frames, and the way to affect start-up and fault handling.

Description

A bus can manage data field and overhead, like symbol and management fields [4]. Since the appliance processes generally square measure asynchronous, the bus features a mechanism for resolution conflicts. For CAN, it's supported a non-destructive arbitration method. The will protocol thus belongs to the category of protocols denoted as carrier sense multiple access/collision shunning, which implies that the protocol listens to the network so as to avoid collisions [5]. CSMA/CD protocols like local area network have instead a mechanism to affect collisions once they're detected. It can also include numerous strategies for error detection and error handling. The communication rate of a network supported will depends on the physical distances between the nodes [5]. If the gap is a smaller amount than forty m, the speed is up to one Mbps.

Application	
Presentation	
Session	
Transport	
Network	
Data link	CAN
Physical	CAN

Figure: 1: Vehicle Applications of Controller Area Network

Message formats

CAN distinguishes four message formats: information, remote, error, and overload frames. Here we tend to limit the discussion to info frame. The knowledge frame begins with the start-of-frame bit. It's followed by associate eleven-bit symbol and also the remote transmission request bit. The symbol and also the RTR bit kind the arbitration field [6]. The management field consists of six bits and indicates what percentage bytes of information follow within the data field. The info field is zero to eight bytes. The info field is followed by the cyclic redundancy verification field that permits the receiver to envision if the received bit sequence was corrupted [7]. The two-bit acknowledgment field is employed by the transmitter to receive associate acknowledgment of a legitimate frame from any receiver.

SOF	Identifier	RTR	Control	Data	CRC	ACK	EOF

Figure 2: CAN bus

Arbitration

Arbitration is that the mechanism that handles bus access conflicts. Whenever the will bus is free, any unit will begin to transmit a message [8]. Attainable conflicts, as a result of quite more than one unit getting down transmitting at the same time, square measure resolved by bit-wise arbitration victimisation the symbol of every unit [8]. Throughout the arbitration section, every transmission unit transmits its symbol and compares it with the extent monitored on the bus [9]. If these levels square measure equal, the unit continues to transmit. If the unit detects a dominant level on the bus, whereas it had been attempting to transmit a recessive level, then it equal transmission.

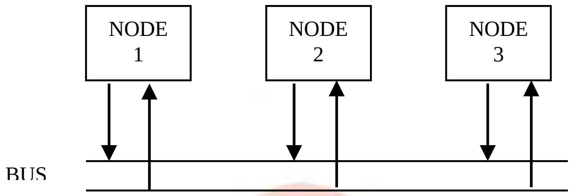


Figure 3: CAN message frame

PROPOSED METHODOLOGY

The problem of message scheduling in Control Area Network can be solved by simply making the ids correspond to every message dynamic. This simply means that with every message the id window changes with every message. These message ids selected from a pre-defined message id window. The selection of message ids from that window is also dynamic, means there is no fixed order of selection. So that any id can request the bus access any time can have random id, if they are not a part of emergency messages. Besides this if any message belongs to emergency message category then it must be given access as soon as it is available or enabled. Moreover, emergency messages fall under priority base scheduling and messages which rather than emergency messages would fall under random based scheduling. This method would help to remove the biasness among messages.

Id1	Id2	Id3	Id4	Id5	Id6

Figure 4: Message Id Window

Figure 4 shows the message id window from where the ids are fetched randomly and are different for every type of applications for arbitration.

Pseudo Code:

1: Start
2: Assign each application a unique message id from id window
3: Emergency messages are assigned with minimum id (decimal value)
4: Enable 2 or 3 applications to check bus arbitration
(Assigned ids act as weights to the equation
$\text{access grant} = \sum_{i=1}^{N} w_i * \text{application}_i$
5: Check for weights for the selected enables
6: if $(w_i < w_{i+1})$ $i \in N\{..\}$ (covers both normal and emergency messages)
w_i is granted the permission to access the bus
7: end if
8: End

Worst case response time: Process is said to be schedulable only when it meet its deadline or message reach at its destination before deadline it mean there is no chance when it violate its deadline. However, in physical application there are many processes which ended up very close to their deadline. Response time of the system defines the weather system is scheduled or unscheduled. Basic idea of this work to consider additional interference that can block the transmission of message M. Such interference can describe by the function E(α,ω,i). Whereby α represent the scaling factor, ω describe the time interval over which interference occur and i is priority level affected by interference.

Robust priority order

The priority assignment produced by the RPA algorithm using the additional interference function which is α that is maximizes the number of faults that the system can tolerate without any message missing its deadline. Furthermore, value of interference depend upon interference factor α and interference function can be derived through E $(\alpha, \omega, !)$. α is interference factor, ω is scaling factor and ! is priority level which going to be affected.

Robust Priority Assignment Algorithm:
for each priority level m, lowest first
{
for each unassigned message M
{
binary search for the largest value of α for which message M is
Schedulable at priority m
}
if no messages are schedulable at priority m
return unschedulable
else
assign the schedulable message that tolerates the max α at priority m to priority m
}
return schedulable

α is represented by maximum number of error that bus can tolerate of particular frame that being transmitted on bus. In other words we can say α is maximum number of error bits one particular message can tolerate before the transection of message being completed. Tα is a transmission time for α.

RESULTS AND DISCUSSIONS

The proposed methodology is simulated using the Xilinx Virtex4 FPGA in Xilinx ISim and the coding is done in Xilinx ISE environment using VHDL language. Figure 6 shows the top module implementation of the proposed methodology and figure 7 shows the simulation of the top module.

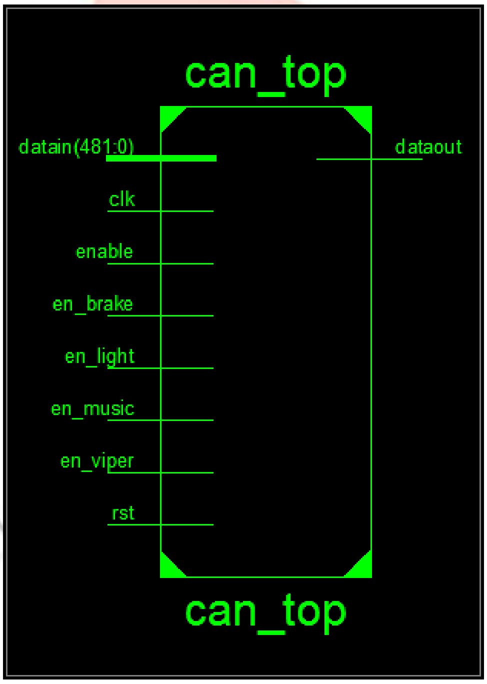


Figure 5: CAN Top Module

The worst case response time of the system to each message is given by

$$W_M^{n+1} = \min(\alpha, \text{Fixed Id}) + \sum \frac{W_M^n + \tau_{bit} + D_M}{T_M} \quad (1)$$

$$R_M = W_M^{n+1} + C_M \quad (2)$$

Here R_M is the worst case response time. α Is the number of bits error, τ_{bit} is the time required to transfer 1 bit, D_M is the deadline time and T_M is the period of the message, W_M is the step value for Message M and C_M is maximum transmission time of frame.
Table 1 to Table 5 shows the actual order of processing of all messages. Dead line time frame has been considered on the basis of assumption by studying previous work on Controller Area Network.
Simulation has been done through ISE Design suite 14.2. It has shown all parameters which require to show the arbitration between the messages based on their priorities.

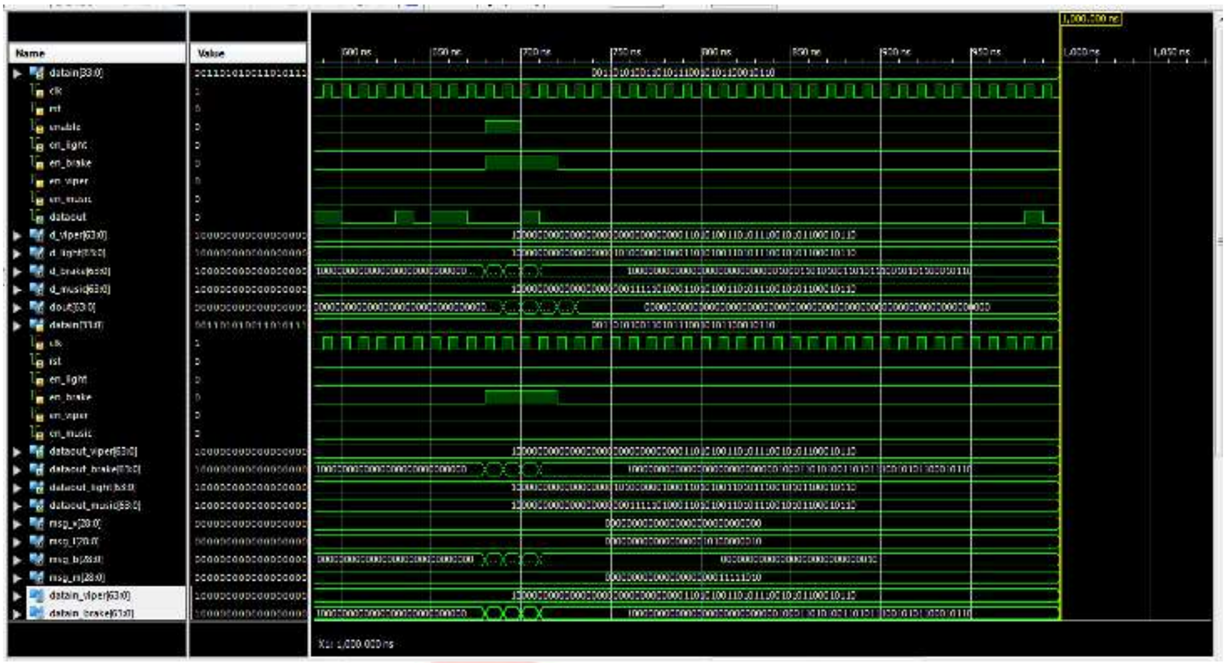


Figure 6: Simulation of Top Module

However, arbitration bit value would decide the priority level of each ECU. Each and every sensor or ECU having its own priority level or arbitration bit value. It is very important to note that binary bit value at arbitration level would decide the priority level among ECUs. In above figure there are four ECUs considered which controls lights, break, wiper, music. Control of bus to any particular ECU shall be provided through arbitration mechanism. The ECU which having lower binary or decimal value would win the arbitration.

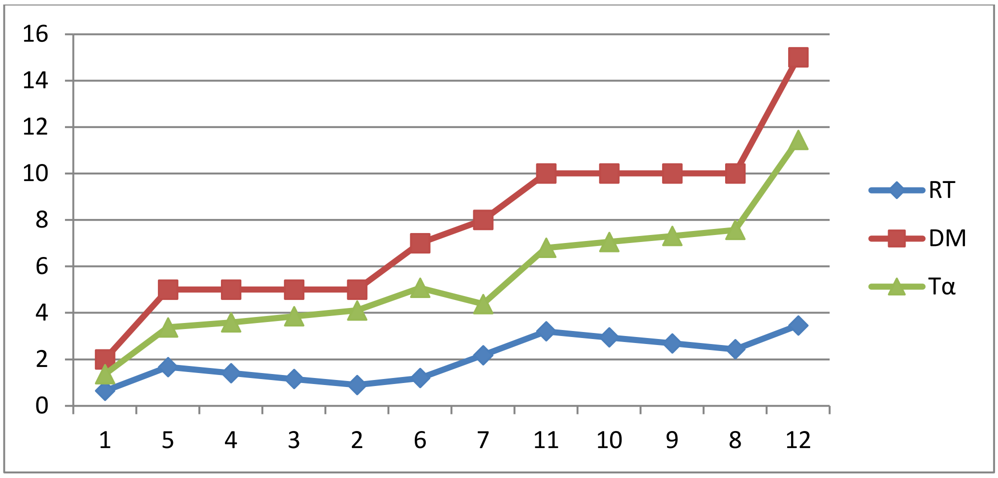
Response time Calculation with full frame: Full frame comprise with 128 bits and below result has been calculated by the transfer of 128 bits on CAN bus with 500Kbit/s. Moreover, it has been assumed that no error occur during the full communication.

OM	Message	α	Tα	RTB	RT	DM	DMB
1	M1	680	1.36	320	0.64	2	1000
5	M2	1688	3.376	832	1.664	5	2500
4	M3	1796	3.592	704	1.408	5	2500
3	M4	1924	3.898	576	1.152	5	2500
2	M5	2052	4.104	448	0.896	5	2500
6	M6	2540	5.08	960	1.192	7	3500
7	M7	2192	4.384	1088	2.176	8	4000
11	M8	3400	6.8	1600	3.2	10	5000
10	M9	3528	7.056	1472	2.944	10	5000
9	M10	3656	7.312	1344	2.688	10	5000
8	M11	3784	7.568	1216	2.432	10	5000
12	M12	5722	11.444	1728	3.456	15	7500

Table 1: Response Time calculation with full frame

We have illustrated above results in form of lines in Graph-1. Line graph clearly shows that system is schedulable accord with above results due to fact that response time of all messages with in the deadline or with in stipulated timeline frame. Blue line represents response time and red line shows dead line which is maximum stipulated time frame in which data can transfer.

Moreover, it is very important to note that violation of deadline would lead to the instability. In order to make sustainable system there is necessarily measure for every transmission that it complete with in time frame. α is maximum number of error bits one particular message can make before the transection of message being completed. Tα is a transmission time for α.



Graph 1: Response Time calculation with full frame

Response Time calculation with Arbitration bits and Data bits: In CAN protocol use 64 bits for data and uses standard arbitration bit values which is 11 bits or extended bit values which comprise of additional 18 bit values. Response time calculated with the assumption of no error occur during the data transmission.

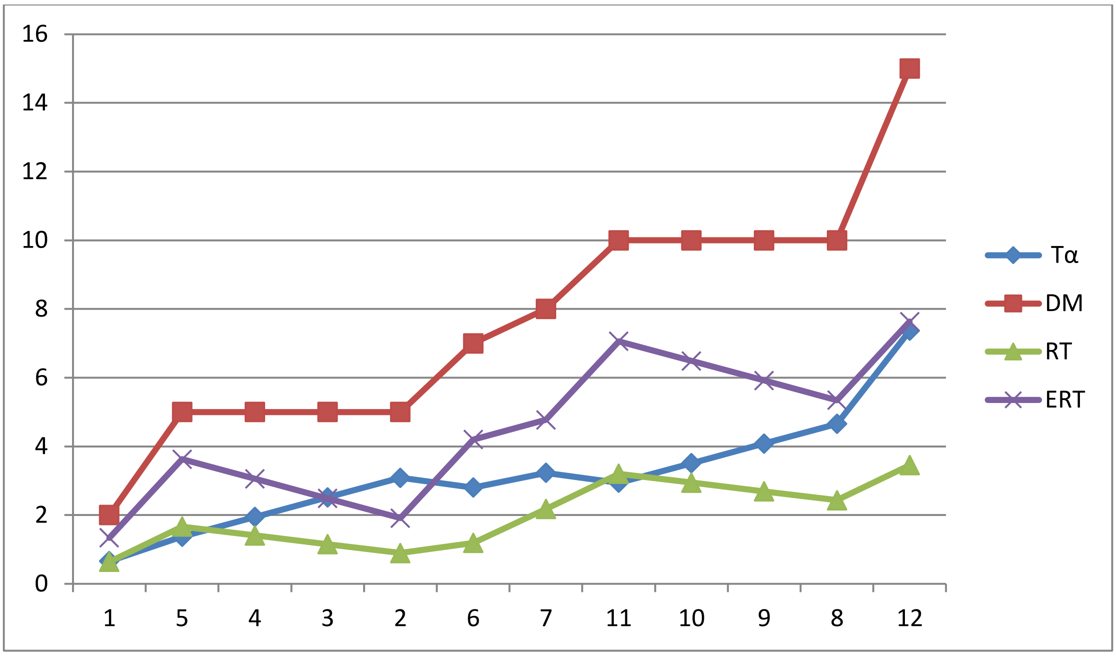
OM	Message	α	Tα	RTB	RT	DM	DMB
1	M1	680	1.36	320	0.64	2	1000
5	M2	1808	3.616	692	1.384	5	2500
4	M3	1901	3.802	599	1.198	5	2500
3	M4	1994	3.988	506	1.012	5	2500
2	M5	2087	4.174	413	0.826	5	2500
6	M6	2715	5.43	785	1.57	7	3500
7	M7	3122	6.244	878	1.756	8	4000
11	M8	3750	7.5	1250	2.5	10	5000
10	M9	3843	7.686	1157	2.314	10	5000
9	M10	3932	7.864	1068	2.128	10	5000
8	M11	4029	8.058	971	1.942	10	5000
12	M12	6157	12.314	1343	2.686	15	7500

Table 2: Response Time calculation with Arbitration and data bit

Response time calculation with one bit error with maximum stuff bits: Response time calculation with one bit error and the error occur when a bus just about to finish the transmission. Moreover, we assume error occurs at 127th bit value and which makes network to retransmit the whole data along with additional 31 bits due to fact that error which makes additional (17 to 31) stuff bits added on bus.

OM	Message	α	Tα	RTB	RT	ERT	ERTB	DM	DMB
1	M1	330	0.66	320	0.64	1.34	670	2	1000
5	M2	686	1.372	832	1.664	3.628	1814	5	2500
4	M3	972	1.944	704	1.408	3.056	1528	5	2500
3	M4	1258	2.516	576	1.152	2.484	1242	5	2500
2	M5	1544	3.088	448	0.896	1.912	956	5	2500
6	M6	1400	2.8	960	1.192	4.2	2100	7	3500
7	M7	1614	3.228	1088	2.176	4.772	2386	8	4000
11	M8	1470	2.94	1600	3.2	7.06	3530	10	5000
10	M9	1756	3.512	1472	2.944	6.488	3244	10	5000
9	M10	2042	4.084	1344	2.688	5.916	2958	10	5000
8	M11	2328	4.656	1216	2.432	5.344	2672	10	5000
12	M12	3684	7.368	1728	3.456	7.632	3816	15	7500

Table 3: Response Time calculation with maximum stuff bit



Graph 2: Response Time calculation with maximum stuff bit

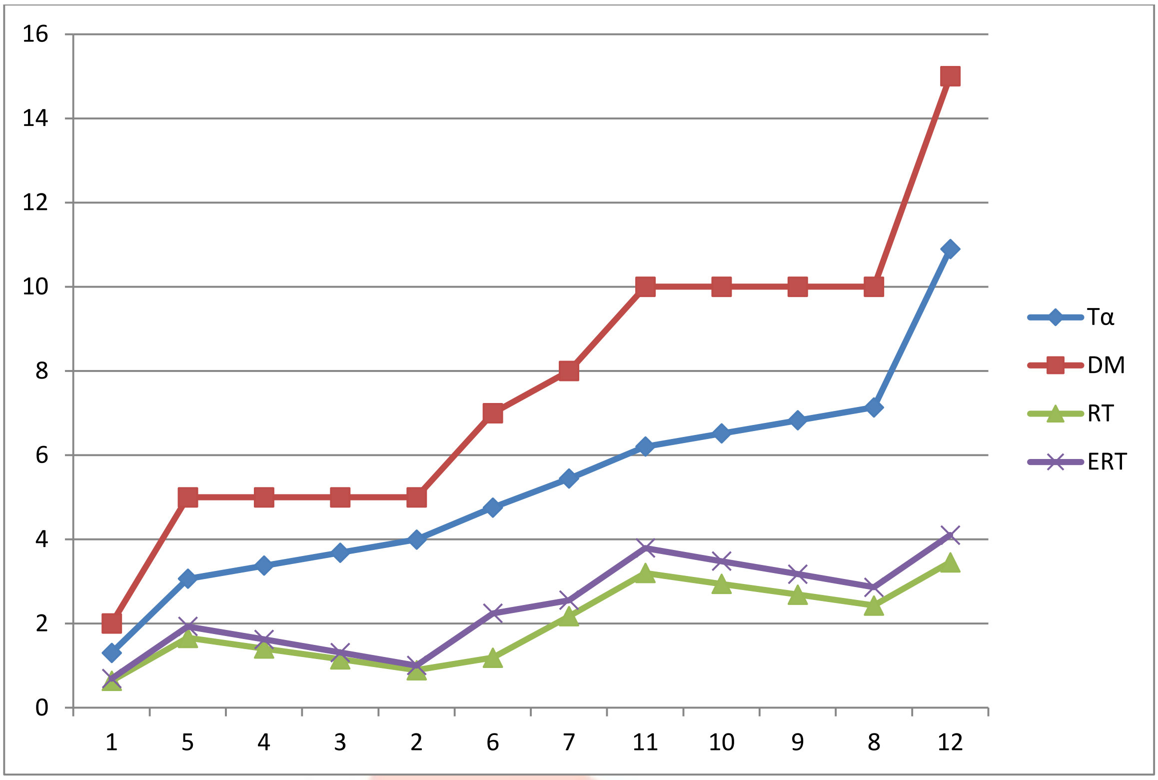
We have illustrated above results in form of lines in Graph-2.Here we have calculated response time of a system in event of error occurs during transmission and that is represented by Error response time (ERT). Line graph clearly shows that system is schedulable accord with above results due to fact that response time of all messages with in the deadline and within stipulated timeline frame. Blue line represents response time and red line shows dead line which is maximum stipulated time frame in which data can transfer.

Moreover, it is very important to note that violation of deadline time would lead to the instability. In order to make sustainable system there is necessarily measure for every transmission that it complete with in time frame. α is maximum number of error bits one particular message can make before the transection of message being completed. Tα is a transmission time for α.

Response time calculation with one bit error with minimum stuff bits: Response time calculation with one bit error and the error occur at very early just after the transmission gets started. Moreover, below result has been calculated by assuming error occurs at 10^{th} bit.

OM	Message	α	Tα	RTB	RT	ERT	ERTB	DM	DMB
1	M1	653	1.306	320	0.64	0.694	347	2	1000
5	M2	1533	3.066	832	1.664	1.934	967	5	2500
4	M3	1688	3.376	704	1.408	1.624	812	5	2500
3	M4	1843	3.686	576	1.152	1.314	657	5	2500
2	M5	1998	3.996	448	0.896	1.004	502	5	2500
6	M6	2378	4.756	960	1.192	2.244	1122	7	3500
7	M7	2723	5.446	1088	2.176	2.554	1277	8	4000
11	M8	3103	6.206	1600	3.2	3.794	1897	10	5000
10	M9	3258	6.516	1472	2.944	3.484	1742	10	5000
9	M10	3413	6.826	1344	2.688	3.174	1587	10	5000
8	M11	3568	7.136	1216	2.432	2.864	1432	10	5000
12	M12	7948	15.896	1728	3.456	4.104	2052	15	7500

Table 4: Response Time calculation with minimum stuff bits



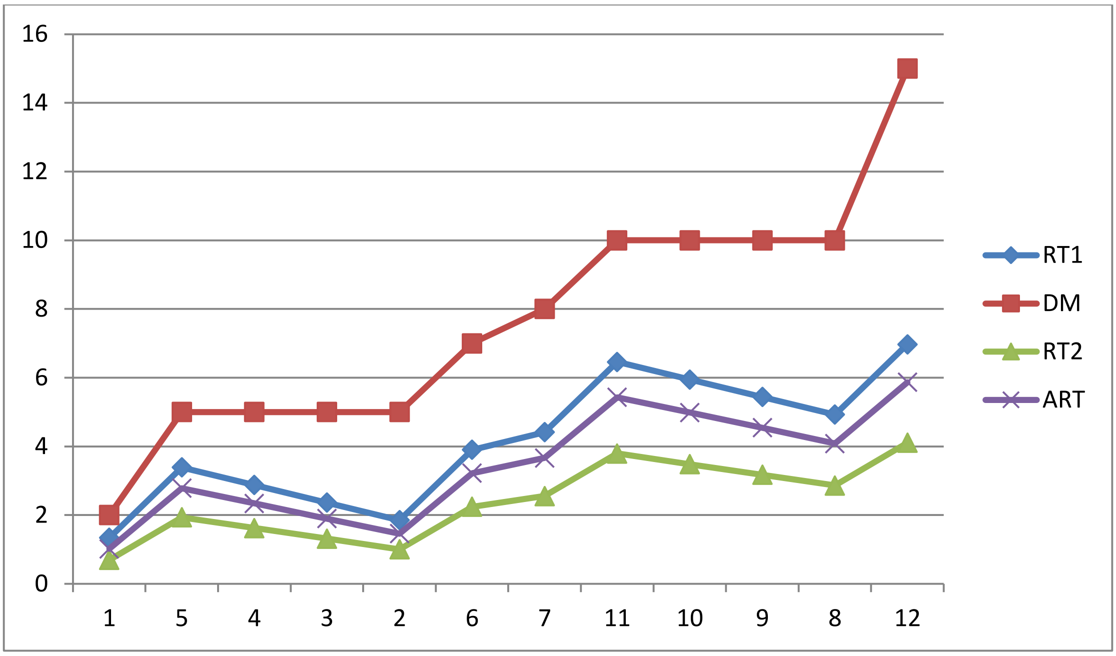
Graph 3: Response Time calculation with minimum stuff bits

Here we have illustrated the results in form of lines. Here we have calculated response time of a system in event of error occurs during transmission and that is represented by Error response time (ERT). Line graph clearly shows that system is schedulable accord with above results due to fact that response time of all messages with in the deadline or with in stipulated timeline frame. Blue line represents response time and red line shows dead line which is maximum stipulated time frame in which data can transfer.

Average response Time: Average response time has been calculated by the Error response time taken from Table 3 and Table 4. On the basis of Error response time we have calculated Average response time. We have also tried to demonstrated Average response time in Line Graph 4 and in which clearly indicated the Average response time is under the time frame. In addition to this graph also shows the ERT calculated in Table 3 and Table 4.

OM	ERTB1	RT1	ERTB2	RT2	RTB	ART
1	670	1.34	347	0.694	508.5	1.017
5	1814	3.388	967	1.934	1390.5	2.781
4	1528	2.876	812	1.624	1170	2.34
3	1242	2.364	657	1.314	949.5	1.899
2	956	1.852	502	1.004	729	1.458
6	2100	3.9	1122	2.244	1611	3.222
7	2386	4.412	1277	2.554	1831.5	3.663
11	3530	6.46	1897	3.794	2713.5	5.427
10	3244	5.948	1742	3.484	2493	4.986
9	2958	5.436	1587	3.174	2272.5	4.545
8	2672	4.924	1432	2.864	2042	4.084
12	3816	6.972	2052	4.104	2934	5.868

Table 5: Average Response Time



Graph 4: Average Response Time

Abbreviation
RT: Response Time
RTB: Response Time Bit
DM: Dead Line
DMB: Dead Line Bit
ERTB: Error response Time
ERT: Error Response Time
TM: Total Time

CONCLUSION AND FUTURE SCOPE

The message id allocation in CAN is done statically which results in biased bus arbitration. So firstly dynamic message id allocation is tested which shows improved and unbiased message id allocation and bus arbitration. Then for emergency messages dynamic message id allocation is tested and it is proved from the simulation results that whenever there is any emergency message then it immediately grants access to that message.

In future the proposed methodology must be tested for a number of other application specific signals. Mainly for those applications which use two or more emergency messages and wants to access the resource or are involved in bus arbitration.

We have calculated response time of transmitting full frame, Data and arbitration bits and error occur during full frame transmission at the rate of 500 Kbit/sec. At the end in table-5 we have calculated average error may occur during transmission and that may effect on response time of a system. Average result has been calculated by considering error happen at particular message with the cost of retransmission.

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