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APPLICATION OF INDUSTRIAL CAN BUS TECHNOLOGY FOR LEO-SATELLITES

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ABSTRACT

The applicability of the CAN bus technology for cost reduction potentials in the area of onboard automation of LEO-satellites is investigated. Due to its source from automotive applications the CAN bus technology is a very promising candidate in terms of functionality, performance, environmental robustness and cost. It furthermore supports efficiently functional redundancy due to its multi-master capabilities. The paper analyses the specific features of the CAN bus compared with other industrial field busses and discusses the functional performances for a combined telecommunication and earth observation reference mission. A simulation tool is presented which allows to analyse and optimise the bus arbitration design.

1. INTRODUCTION

Low Earth Orbit (LEO) satellites play an increasing commercial role in the area of mobile communication and earth observation including traffic and environmental monitoring. These LEO-satellites are built under stringent commercial constraints. Considerable *cost reduction potentials* in the area of onboard automation are found through the implementation of functional redundancy to decrease the overall number of equipment and through the use of well proven industrial (COTS - commercial off the shelf) technologies for the onboard implementation. Functional redundancy for the onboard automation requires appropriate bus-technologies for an efficient real-time communication between the different equipment with maximum freedom for reconfiguration. Due to its source from automotive applications the CAN bus technology is a very promising candidate in terms of functionality, performance, environmental robustness, real-time features and cost.

The paper investigates the applicability of the CAN bus technology for a *combined telecommunication and earth observation* reference mission which deals with road traffic monitoring (TUD-Satellite [1]). The underlying onboard data handling and control system has in this case to deal with standard platform and complex payload data originating from a radio data collecting payload and an earth observation camera.

2. INDUSTRIAL FIELDBUS SYSTEMS

For the above described mission three international field-busses were compared: *Profibus DP*, ***L**ocal **O**perating **N**etwork (LON)* and ***C**ontroller **A**rea **N**etwork (CAN)*. Table 1 shows some results. In principle all three field-busses meet the requirements for LEO satellite applications, but differ in details. The master slave bus access method of *Profibus DP* demands a redundant bus master. *LON* is used mainly for building services automation and supports therefore a lot of - in our case not necessary - network and routing functionality for distributed networks up to some 100 m bus length. The special advantage of *CAN* is the design for robust environmental and reliable application in the automotive industry.

Table 1: Comparison of several industrial field-busses

Criterion	Requirement	Profibus DP	LON	CAN
No. of nodes	max. 20	max. 32	max. 64	max. 64
Bit Rate	> 1Mbit/s	12 Mbit/s	1,25 Mbit/s	1Mbit/s
Hardware	Environ.robustness	partly	partly	typical for auto-motive industry
Length @ max bit rate	max. 40 m	40 m	500 m	40 m
Telegram	flexible word size	partly (0 .. 32 byte)	partly (0 .. 228 byte)	partly (0 .. 8 byte)
	high data security	high (HD=4, parity)	high (16bitCRC,HD=4)	high (16 bitCRC,HD=6)
Protocol	access procedure with	Master-Slave	multi-master	multi-master
	guaranteed response	yes	no	for high prior mess.
Economical Condition	international standardisation	DIN EN 50170	no/ at the market	ISO/DIS 11519 ISO/DIS 11898
Cost	less than space qualif.	yes	yes	yes

3. SATELLITE APPLICABILITY ANALYSIS FOR CAN-TECHNOLOGY

3.1 Standardisation and availability

Due to the use in automotive industry a lot of cost effective CAN controllers exist with different characteristics. CAN controllers, operating directly in the engine compartment of a car, correspond already nearly to the requirements of LEO satellites with regard to temperature range and mechanical robustness. So they are already well suited for space applications. With CMOS-technology also the radiation robustness of the low orbit can be met to a large extent. New developments offer e.g. integrated sensors with included CAN-controllers applicable directly as navigation sensors [2],[3].

A considerable advantage of industrial field-bus technology is its widely spread international standardisation. According to the OSI reference model (see Fig.1) the CAN architecture incorporates two layers: *data link layer* and *physical layer*. CAN layers 1 and 2 are international standards. So we use the defined interface to layer 2 for our application.

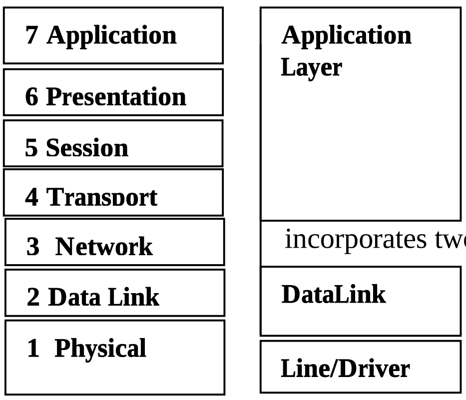

Figure 1: CAN versus ISO/OSI Reference Model

On this basis almost every commercial software development environment (compilers) have available well tested CAN-software components, which offers enormous potential for cost reduction of onboard software development.

3.2 Data handling

One CAN-message transmits up to 64 Bit non structured user data (see Fig.2). This allows the transmission of device or process system data with one or only a few messages. Data blocks have to be structured into 64 bit units. There are no services for structured data or block transfer. CAN supports a max. bit rate of 1 Mbit/s at a max. 40 m bus length. Assuming 70 % bus capacity utilisation, will allow a maximum user data rate of 400 Kbit/s, which meets most small satellite platform data requirements.

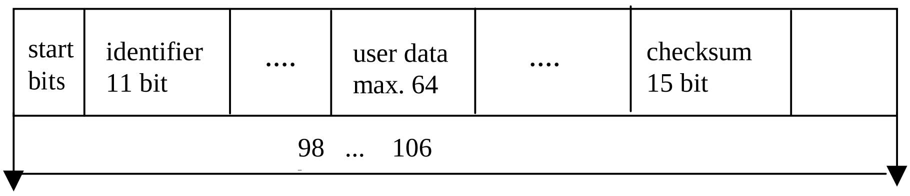

Figure 2: CAN data frame

3.3 Multi master bus access

A rigid Master-Slave protocol access procedure is not suitable for an autonomous satellite application because of the necessary redundancy of the bus master. CAN uses a multi-master, priority-based bus access with a modified CSMA/CD access method. All nodes are operating as masters. When the bus is idle, any node may start to transmit a frame. If two or more nodes start to transmit frames at the same time, the bus access conflict is resolved by contention-based arbitration using an 11-bit identifier. The mechanism of arbitration guarantees that no information and no time is lost. The transmitter with the frame of highest priority receives bus

access. So the protocol already realises inherently flexible communication structures and broadcasting capabilities. Frames, that have lost arbitration because of lower priority will be retransmitted automatically when the bus is idle again. The resulting time delay depends on the other higher prior frames. So a predictable time delay is only possible for highest prior frames. Nodes may be added to the CAN network without requiring any changes in the software or hardware.

3.4 Error detection, isolation and recovery

The advantages of the CAN results of his automotive application area and the demanding requirements for error detection, isolation and recovery. Corrupted frames will be detected by any transmitting nodes and any nominally operating receiving node. Such frames will be aborted and retransmitted according to the implemented recovery procedure. CAN nodes can distinguish short disturbances from permanent failure. A node can have several error states with different access rights. Unfortunately if completely defect, no more transmitting nodes are not automatically detected at layer 2. Therefore user defined services are necessary.

4. REAL TIME BEHAVIOUR ANALYSIS OF A REFERENCE ONBOARD STRUCTURE

Paragraph 3 shows some critical aspects especially concerning the real time behaviour of the CAN. Therefore some algorithms were tested for analysing the real time characteristics. Basis for the tests is a reference onboard configuration (nodes, incl. the awaited frames with their cyclic time, user data length, permissible deadline) as shown in Figure 3. For cyclic frames the expected bus load can be determined (frame length/cyclic time for all frames). Under the assumption of a bus load lower than 100%, it is possible to define with special algorithms the identifier for every frame and calculate the real worst case deadline [4],[5]. If all real deadlines are lower than the permissible ones, the onboard configuration meets the real time requirements else better suited identifiers have to be found.

This real time analysis and a follow-on bus simulation to verify and monitor the results were implemented with the simulation tool *STATEMATE* .

The following assumptions have been used for a first test of real time behaviour the following onboard configuration (see Fig 3.):

- redundant CAN bus
- platform attitude and orbit control equipment
- payload: Earth observation camera, RF road traffic data collection equipment

with several nominal and failure modes.

The following results have been found for this configuration:

- bus capacity for platform data : about 15%,
- bus capacity for payload data: about 60%.
- Some single node error can be tolerated (e.g. GPS pre-processing).
- In case of failure of one CAN-bus the payload data rates have to be reduced.

In particular no critical deadline overruns could be detected. So we can assume, that in principle a redundant CAN is suited for this example.

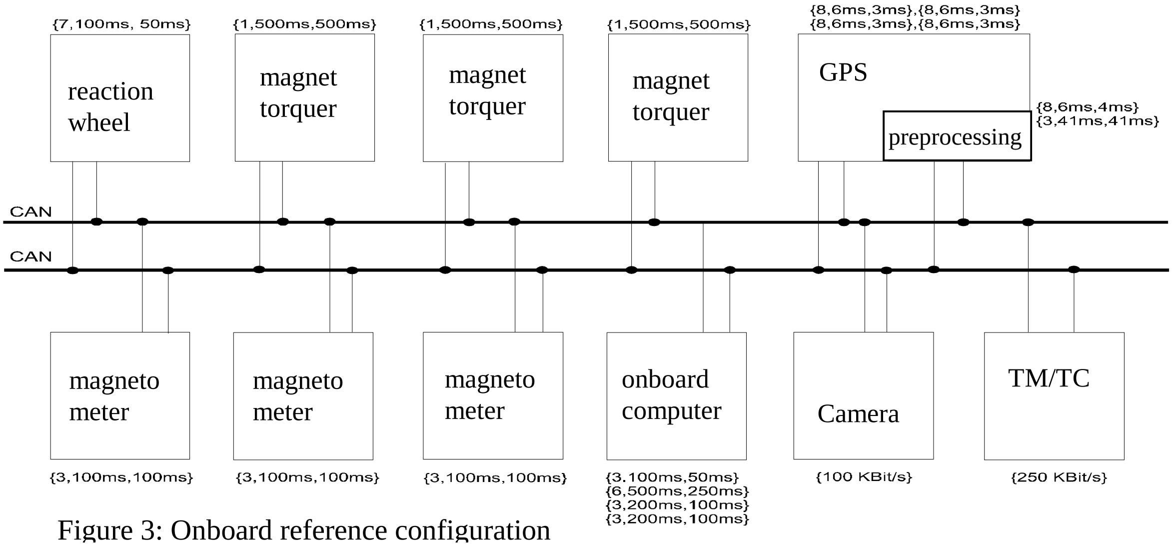

Figure 3: Onboard reference configuration

5. SPACE ROBUST CAN CONTROLLER

The critical issue for the use of onboard CAN systems is the radiation robustness of the controllers. Although in certain LEO environments standard CMOS-technology has shown to operate appropriately, it would be interesting, to have available also components showing *increased radiation robustness*. In this area we are currently performing feasibility investigations in co-operation with the Frauenhofer Gesellschaft (FhG) Institute for Microelectronics, Dresden. The investigations intend to reuse already existing CAN chip design solutions at FhG for automotive applications and to adapt them slightly in terms of functionality and production process characteristics [6].

6. SUMMARY

The investigations show, that CAN bus technology is a very promising candidate for the LEO satellite application due to its basic concepts: multi-master priority bus access, non-destructive contention-based arbitration, multicast frame transfer by acceptance filtering, configuration flexibility, system wide data consistency, error detection and signalling; distinction between temporary errors and permanent failures of nodes and autonomous switching off of defective node.

The standardised industrial controller or modules promote a cost effective design and implementation of failure redundant onboard data handling structures.

7. REFERENCES

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