THE FLEXRAY NETWORKS IN THE MODERN MOTORCARS

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Abstract

Advancing the evolution of mot orcars, understood as c omplex mechatronic systems are connected with the ever emerging constrains on coordination between the components of the system objects.

Adopted by all environment related to the automotive, the way of communication between the vehicle components via network for data exchange, connected with the necessity to keep up w ith increasing demands on the transmission speed and level of security.

The answers to these requirements concerning the ways to control x-by-wire or complex mechanism to optimize the operation of the engine, seems to hav e been cre ated by the big automobile companies FlexRay prot ocol. The article presents the basic features of this method of communication that allows for a 10 fold increase in data rates compared to the conve ntional CAN network. The re maining features of transmission such as reliabi lity and level of time determinism, which are important for control systems are discussed later in the paper. Included in the summary comments indicate pote ntial further deve lopments and the possi bilities of the application if this method of transmission in automotive applications.

Keywords: *FlexRay, car networks, data exchange, engine operation, motorcars*

1. Introduction

The progressive evolution of automotive understood as complex mechatronic systems are linked to the ever emerging constraints on the coordination of work making up the system objects. The necessity of integration and cooperation of the vehicle is the result of elements utmost to achieve greater and greater efficiency, reliability and comfort of use. Parallel to the work carried out in the field of technology, development in materials and researches on modern ways to obtain energy for mechanical power train systems, the automotive industry has become a significant participant in the development of such branches of science as electronics and computer science. Conscious and intentional interference with a highly complex process and dependence, taking place in contemporary vehicles for support is based on large amounts of information. Many years of experience have shown that the most effective way to replace them is to use computer networks. Natural phenomenon, with large-scale economic motoring as part of the world economy [4], is a continuous evolution of technical solutions including communication standards and protocols. The newest tendencies and challenges set by automotive companies are x-by-wire technologies. The idea of connecting control systems and mechanical actuators using electrical fastens has been applied only in so called throttle-by-wire. A significant obstacle in the replacement of the classic hydraulic and mechanical elements in the steering and braking systems is the necessity to ensure the highest degree of reliability and safety. Although at present, the standard of network is used to support the work of these components (not counting the prototypes such as in Nissan Murano or Citroen C5.) none of the manufacturers have so far decided to completely replace traditional mechanical and hydraulic elements with purely electrical elements. One response to the described difficulties could be developed in year 2000 FlexRay data exchange network. The FlexRay creates a new quality among previously used means of on-board communication. Detailed description of

FlexRay is in [3]. In contrary to Can, designed by Bosch, or ByteFlight coming from BMW, FlexRay was born as the result of cooperation between several competing concerns. A new technology such as FlexRay does not make the entire predecessor obsolete at once. Rather, it replaces the traditional systems and gradually builds on proven solutions. Therefore existing components and applications have to be migrated into new systems in order to make this migration path as smooth and efficient as possible [5]. FlexRay is some kind of synthesis of experiences gained during designing such networks as Can, ByteFlight as well as networks coming from the aviation industry for example TTP. The connection of features of many networks makes it possible to spread the fields of applications. An example of a new approach to automotive usage is the very high flexibility of the physical topology of FlexRay connecting linear topology as well as the topology of active and passive star (Fig. 1).

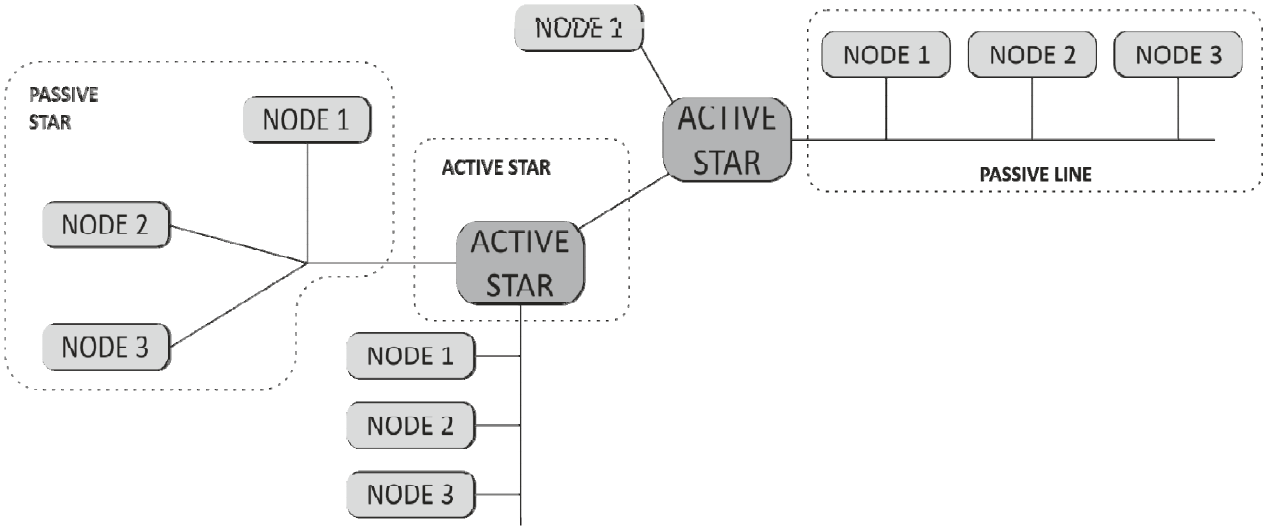

Fig. 1. Example of physical topology in FlexRay

2. Time determinism in FlexRay

The most important feature of FlexRay, which gives it it's predispositions to applications in highly demanding usages for control, is the possibility to achieve full time determinism. This feature was obtained thanks to the synchronous work of the bus and thanks to a fully predictable arising of some concrete information on the bus at a precise point of time. However to make the bus more flexible as well as increasing its capacity, the possibility of transmission in a non deterministic mode was predicted. For the sake of the synchronous work of bus every participant of the transmission must be based on a common for all nodes time scale. This function is fulfilled by a system of so called macroticks – elementary markers of time periods. Macroticks are the base for determining the length of all the rest of time allocation units. The functioning of bus as a whole, and every independent node, happens on the macroticks time axis. Contrary to this, taking into account the difference in frequency and phase between inner clocks of particular nodes, the primary source of ticks is so called microticks proper to every node separately (Fig. 2).

In every node the length of the macroticks is established as a multiplicity of the number of microticks. The time synchronization is done using synchronization frames. The correction of synchronization is carried out in every node by comparing an expected and real moment in time in which a synchronization frame comes. The synchronization frames are sent by 2 to 15 dedicated synchronization nodes. Thanks to the full synchronization of nodes on the bus, there is the possibility to have collision-free media access. The moment any message on the bus appears has already been planned beforehand at the designing stage of the network. Such a kind of transmission eliminates the necessity of arbitration. The data designated to be send is prepared in the proper

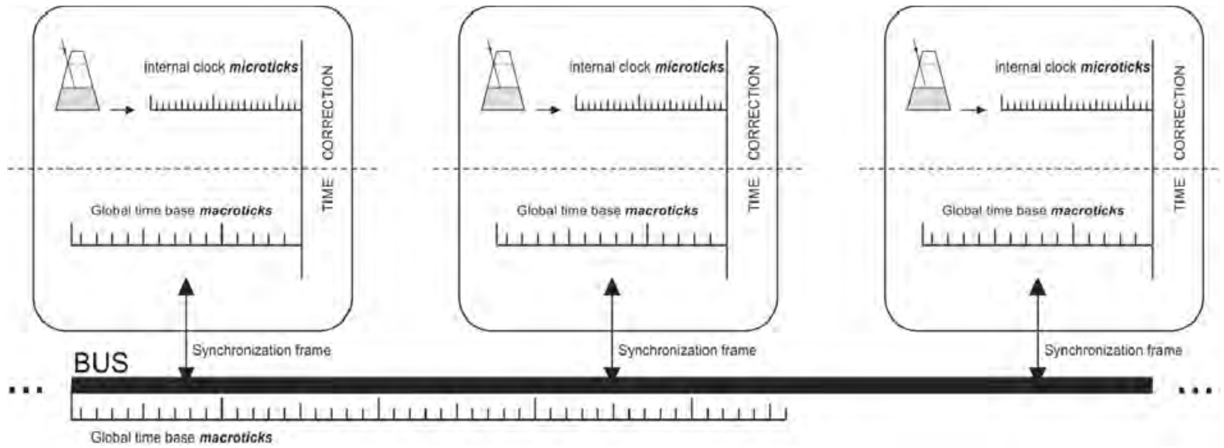

Fig. 2. FlexRay bus timing

controller buffer together with information about their location in the communication cycle. An outline of the optimal organization is described in [6]. The period of time destined for the transmission of one frame is called a slot. Several consecutive slots make up one cycle. Every cycle is the same time length, it means that the cycle is equal to a constant number of macroticks. The longest in a time hierarchy unit of transmission is a sequence consisting of 64 cycles. The scheme of time hierarchy in FlexRay is shown in Fig. 3.

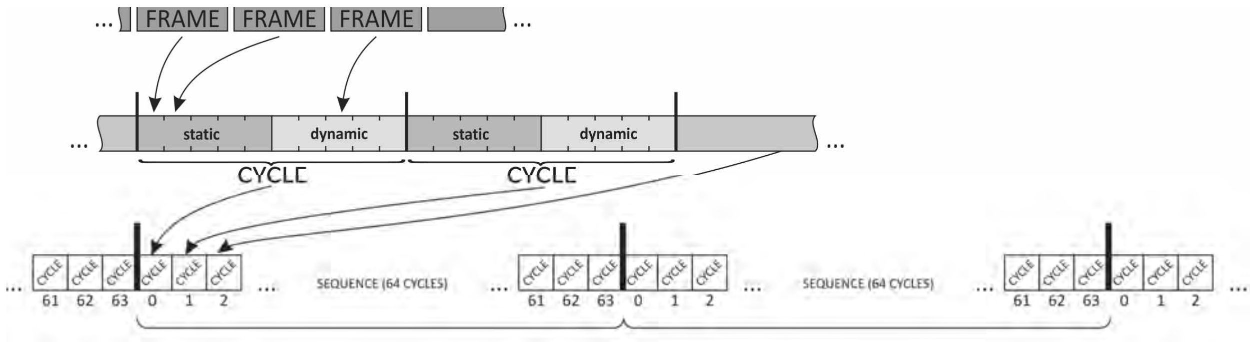

Fig.3. Timing hierarchy in FlexRay

In spite of the fact that the high degree of time determinism is a very desirable feature in control systems, it is burdened with some disadvantages. In systems in which not all data must be delivered in the same time period, time triggered systems turn out less effective than systems triggered by events. An example of the efficiency of this second system, due to its flexibility is illustrated in Fig.4.

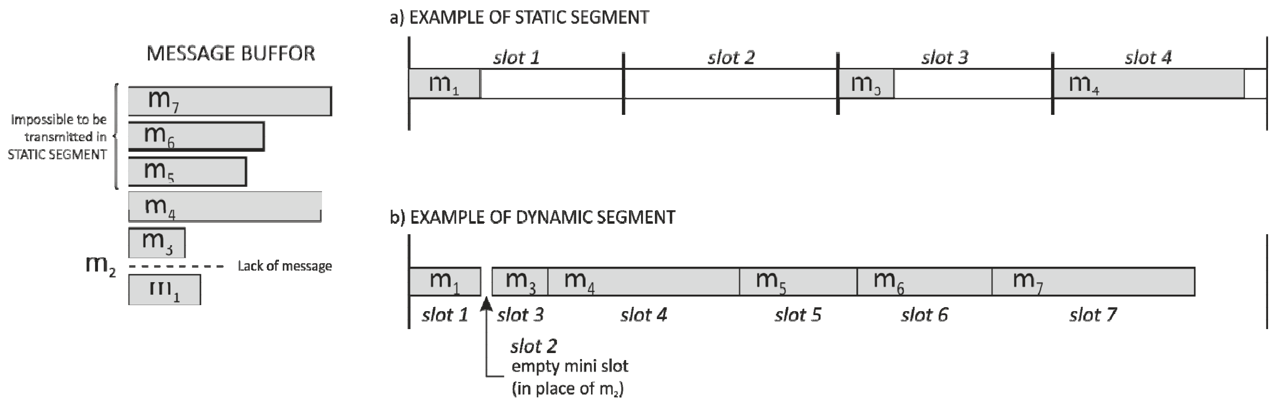

Fig. 4. Illustration of Bandwidth using for static and dynamic segments of FlexRay

Owing to this, FlexRay is designed as a hybrid system which connects both ways of triggering. It's achieved by sharing a communication cycle in two intervals. The first part of every cycle, called a Static segment, is fully deterministic. It consist of a constant number of slots the same length and access to media is ruled by TDMA (time division multiple access). The second part ruled by FTDMA (flexible time division multiple access) is called a dynamic segment, and incorporates slots fitted to length of a frame. To keep track of the location on the time axis and to keep the numeration order, the dynamic segment is divided into so called minislots, so every slot in the dynamic segment consist of a finite number of minislots. Slots which don't carry any frames (because of their lack in buffer) have the size of one minislot.

The Final consistency of an on-board network and the proportion between using static and dynamic segments depends on the demands of specific cases. The description of the attempts of optimization of bus access, scheduling traffic, performance analysis and modelling can be found in e.g. [8-10].

3. Safety and reliability of FlexRay

Expected development systems based on x-by-wire safety critical solutions, additionally to the highest demands of the time determinism of used networks, focuses on increasing their capacity reliability and safety. Ways offered by FlexRay to meet these conditions are:

- bit rate 10 Mbit/s,
- transmission through two channels,
- supervising transmission by bus guardian.

Apart from traditional mechanisms of controlling transmission such as CRC or error handling, using two channels to transmit data and supervising the network by bus guardian are optional resolutions which can be used by designers in specially demanding applications. As shown in Fig. 5, every node can be connected to one or two channels simultaneously. Regarding specific situations, the use of A and B channels can be different. In the simplest case both channels can transmit independent data. This way, the global capacity of the network will be equal, even 2x10 Mbit/s. More typical for the sake of safety and reliability is the redundant transmission of the same data on channel A an B. The comparison of data received by nodes from both streams, maybe an additional source of information about errors and faults on the media. In the case of damage to one of the lines, the other can still transmit data necessary to work controlled objects.

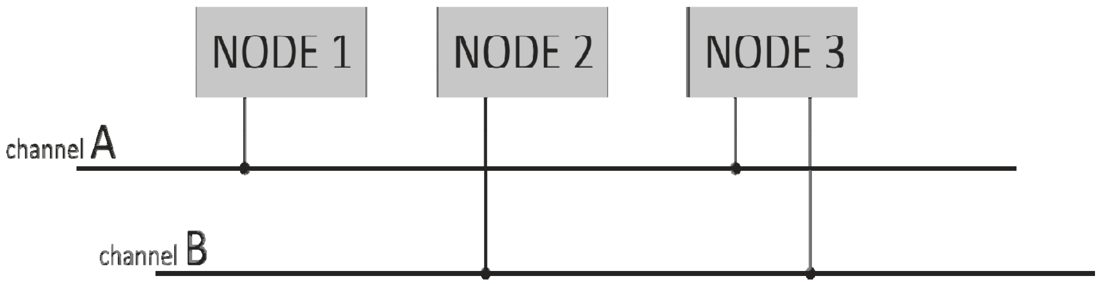

Fig. 5. Example of two channel flexRay communication

The Bus Guardian (BG) is an independent element working parallel with a node controller. Its task is to control the access of the communication controller to media. Every BG has its own clock and a set of information about a slot's description, exactly the same as every other node in the bus. There can be various physical configurations of BG, however, the main goal is to ensure that the fault in the communication controller shouldn't disturb the work of the supervisor. BG keeps track of all signals on the bus including synchronization frames and if it notices incorrect behaviour of the supervised communication controller, BG locks its activity in traffic. In Fig. 6 two kinds of bus guardians are shown – the node local BG which supervises the work of a single node and the central BG which supervises the activity of cluster in active star topology.

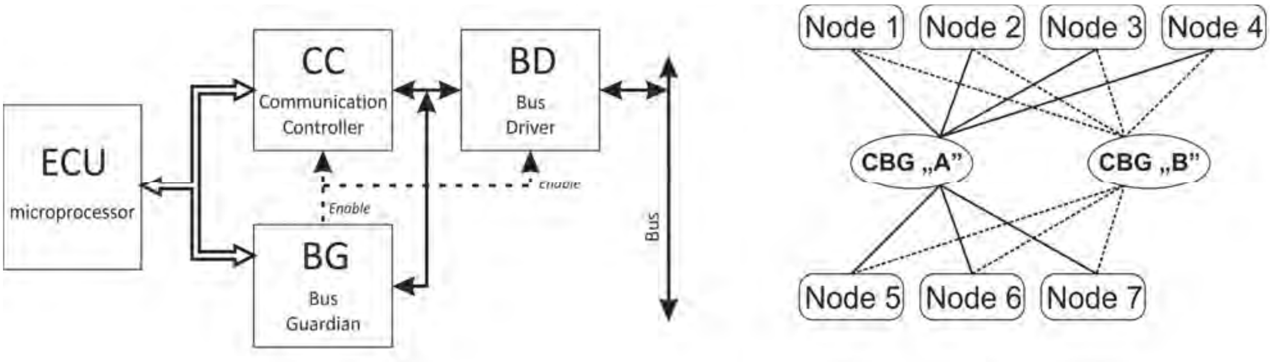

Fig. 6. Example of node and global Bus Guardian [1]

4. Conclusion

The most important features of FlexRay described in this paper, makes this standard efficient enough and effective enough for new, very demanding applications in modern cars. The first car, in which the FlexRay architecture is the communication base for electronic damper control, is BMW X5 (start of production September 2006). results were achieved in resolving the conflict between high ride comfort and high driving safety as well as the minimization of wheel load variation and chassis/ body oscillation [8]. Audi is the next producer which has decided to apply FlexRay in its luxury car Audi A8 (2010). These facts prove the assumed direction in the development of new communication standards. As stated by engineers working for BMW, it's very likely that, in the close future FlexRay will integrate other networks present on-board, as their backbone.

A very significant fact is, that producers in many automotive branches are trying to combine their efforts to prepare common standards. FlexRay is very explicit example of such tendencies. A problem attached to using such complex and complicated protocols as FlexRay is the need to create software devices to handle it. One of the very interesting activities in this field is the works of AUTOSAR organization which is trying to standardize all software aspects around the modern car including the application of communication protocols.

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