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THE PROBLEMS IN FIBRE OPTIC COMMUNICATION IN THE COMMUNICATION SYSTEMS OF VEHICLES

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Summary. The diversification of technical solutions occurred as a result of almost thirty years of evolution of the communication systems between the mechatronic systems in motor vehicles. The vehicles are equipped with the conventional cable connections between the switches and actuators as well as with advanced data exchange networks. These networks show more and more similarities to computer networks. They are the new solutions; even their classification has been created a few years ago (class D). Therefore the personnel engaged in the scope of functional programming and vehicles servicing encounter the problems associated with networks operation. The purpose of the article is to present the principles of functioning of the basic networks with the medium in the form of an optical fibre. Particular emphasis has been placed on the detection of failures consisting in the damage of communication node and optical fibre.

Key words: Media Oriented Systems Transport, Domestic Digital Bus.

INTRODUCTION

The systematics associated with networks classification presented in the year 1994 contained 3 types of networks. Such systematics was also presented in 2007 in literature in 2007 [12]. This approach has been established as a result of the standardization introduced by SAE J1850 [5, 10]. Three classes of communication systems have been specified in SAE J1850. The applications group associated with bus throughput is used as the criterion of subdivision. The increase of the vehicles users' requirements enforced the increase of the networks throughput and the launching of two new additional classes of networks indicated as C+ and D or Infotainment [7]. The summary of essential parameters for individual classes is presented in Table 1 [2, 19].

The networks and communication busses with lower throughput are built on the basis of standard copper conductors. Their topology can be diversified. There are simple systems in the form of linear bus as well as the systems in star configuration. The ring topology is rarely applied. The combination consisting of point-to-point connections, linear buses and star buses is more popular than ring topology. The optical fibre performs the role of medium in the networks with higher throughput. Its use is almost obligatory in D class (MOST, D2B buses) or optional in C+ class (FlexRay, Byteflight buses). The introduction of fibre optic communication into the vehicles networks and the introduction of fibre optic solutions into the telecommunication was based upon the same factors.

The possibility to achieve high throughput of data exchange (> 1 Gb/s) is the principal factor justifying the introduction of fibre optic solutions. The price of the vehicle subassemblies would be significantly increased in case of such throughput level achieved in traditional vehicles communication networks operating in difficult working conditions (wide range of temperature and humidity changes, vibration). The transmission security is automatically improved as a result of fibre optic technology. On the one hand an optical fibre is resistant to electromagnetic interference and on the other hand it does not generate any interference potentially affecting the operation of other devices. The achievement of similar throughputs of fibre optic and "copper" buses is possible at smaller diameters of the wires. The diameters of fibre optic cables, smaller than the diameters of copper cables result in reduced weight of vehicle and, consequently in reduced fuel consumption in course of the vehicle operation. Unfortunately, there are some additional problems introduced by the fibre optic connections of high-speed communication buses; said problems are described in further parts of this article.

Table 1. The classification of bus communication systems [2, 19]

Diagnostic	
Typical application	Testers, analysers
Throughput	< 10 Kb/s
Example of bus (network)	ISO 9141 K-Line
Class A	
Typical application	Electronic elements included in the motor vehicle body, connections of circuits and actuators
Throughput	< 25 Kb/s
Example of bus (network)	LIN, SAE J1587
Class B	
Typical application	Electronic systems included in the motor vehicle body, connections of controllers in the systems of additional equipment of motor vehicle
Throughput	25÷125 Kb/s
Example of bus (network)	CAN low-speed
Class C	
Typical application	Power transmission system and running gear; connections of controllers in the power transmission and chassis system, real time systems
Throughput	125Kb/s÷1 Mb/s
Example of bus (network)	CAN high-speed
Class C+	
Typical application	Real time systems; power transmission and safety system; „X-by-wire" control
Throughput	1÷10 Mb/s
Example of bus (network)	FlexRay, Byteflight
Class D / Infotainment	
Typical application	Multimedia, connections of controllers in telematics systems
Throughput	>10 Mb/s
Example of bus (network)	MOST, D2B

COMMUNICATION USING „MOST" BUS

The connections in ring topology prevail in multimedia networks. Such topology is also applied in Domestic Digital Bus (D2B) and in Media Oriented Systems Transport (MOST) buses. Domestic Digital Bus has been created in 1992 and was promoted by the group of companies i.e. Matsushita, Philips and Optical Chip Consortium [8]. At the moment this bus is not developed. This solution was applied at the turn of the 20^{th} and the 21^{st} century in the vehicles: Mercedes S class and Jaguar X-type. MOST bus is the successor of Domestic Digital Bus (D2B). The works associated with this bus have been commenced in the year 1998 by the following companies: Audi, BMW, Daimler -Chrysler, Becker Automotive and Oasis Silicon [2, 4, 20, 21]. The problems encountered by the designers and users of D2B bus at that time are the problems associated with MOST bus at the moment. MOST Cooperation Association informs that MOST bus has been used by 16 manufacturers of motor vehicles in more than 90 models in the year 2010 [13]. The fibre optic cable is the basic communication medium of MOST bus ensuring required throughput of this bus. It is possible to integrate 64 multimedia slaves in ring topology (Fig. 1) [4, 21]. The possible slaves are: control panel, radio and TV tuners, CD and DVD players; amplifiers systems; navigation system, phones, telephone assistance systems (e.g. Tele-Aid, Automatic Collision Notification, Stolen Vehicle Recovery), voice control systems, game consoles, displays for the passenger on the front and rear seat.

The role of the master node is performed by one of elements of the ring. The task of the master consists in the events management on the bus (timing master function) i.e. in generation of communication frames [6, 21]. The frames are handed over by other nodes (slaves) in unchanged form or in a form supplemented with individual data. The communication is possible with the speed of 25 or 50 Mb/s in accordance with specification [21]. The members of the MOST consortium assure that it is possible to changeover to third generation of bus in a smooth manner and to ensure the communication speed of 150 Mb/s [13, 16]. Another function of the ring management consists in the addressing of bus slaves and is assigned to „network master" node. Four groups of addresses (logical, physical, group and broadcast addresses) determined by the addresses master are used in further communication between the nodes. The third management function consists in the informing, reservation and release of resources required for synchronous communication. This function is called „connection master". The configuration with all three managing functions performed by single physical device is possible in practice; most often in the form of the vehicle console control module [2].

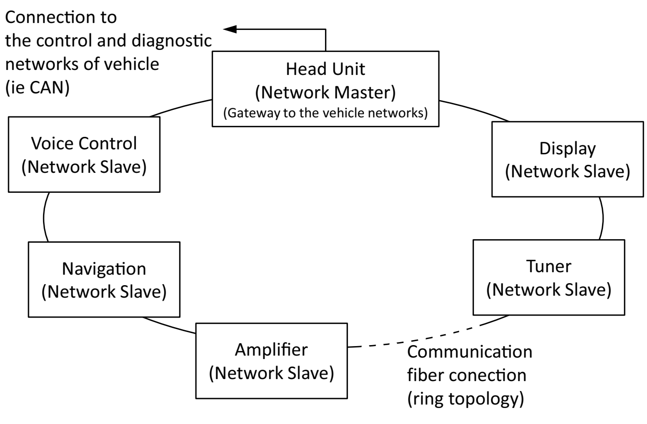

Fig. 1. Typical topology of MOST bus [2, 6, 20, 21]

After startup of the bus devices, the addressing of slaves is performed by „network master". The next step consists in the reservation of synchronous channels by the slaves requiring synchronous communication (audio and video data) as considered by the „connection master" in its table. Since then „timing master" is responsible for the distribution of communication frames (Fig. 2).

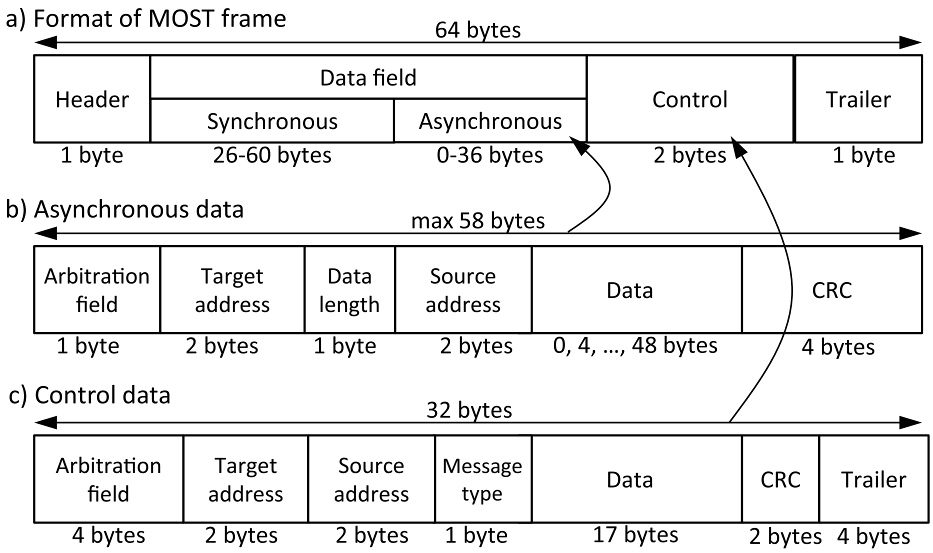

Fig. 2. Data format [4, 20, 18, 21]

The communication unit of MOST bus is defined as the block consisting of 16 frames (Fig. 2a). The following data are transferred in the framework of a single frame:

- synchronous data – audio and video data being transferred in reserved channels of the frame data field (Fig. 2a). The size of the synchronous data field is configured in the frame header and has the impact on the size of asynchronous field;
- asynchronous data – packages of non-multimedia data i.e. the information about the compositions being played; GPS data, computer network packages. They are packaged in the frames in accordance with structure illustrated in Fig. 2b and transferred in an asynchronous data field. The asynchronous packages are subdivided into smaller parts and transferred in several frames. In case of attempted access to the bus by several devices simultaneously, the arbitration is performed by means of initial fields of package. The package with the highest priority is directed to the frame which is practically associated with the lowest binary number in the arbitration field;
- control data – data required for network functioning control and for the devices functions control. Their required arbitration and subdivision are similar to those required for asynchronous data (Fig. 2c).

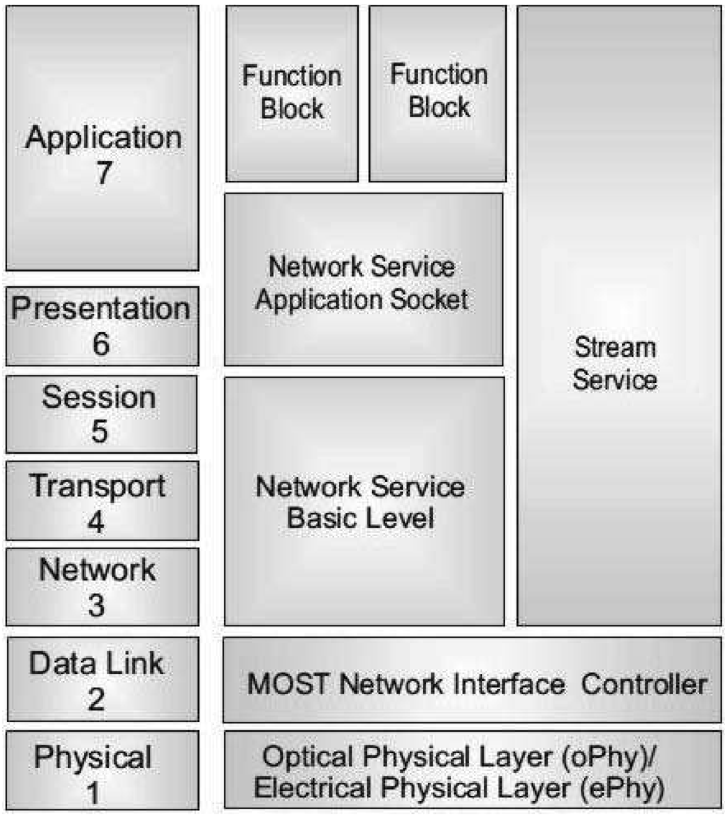

Fig. 3. MOST layers in the ISO-OSI model [4]

One of the features inherited by MOST bus from D2B bus consists in the method of its description, manner of the bus specification preparation. One layer or only a few of selected layers of protocol are often defined for CAN or LIN buses [1, 9, 15, 14]. In case of MOST bus, the specification encompasses the elements from the lowest physical layer up to the commands from application layer (Fig. 3). It is possible to support the complex devices originating from various manufacturers thanks to precise description of the addressing, services, functions and commands (Function Blocks).

BUS FAILURES AND METHODS OF THEIR DETECTION

As a result of the use of fibre optic cables in MOST bus and thanks to the protections applied in the protocol frames (Fig. 2), the average rate of errors for MOST bus is equal to 10^{-10} [21]. In case of secure CAN protocol, the average rate of errors is equal to 10^{-11} in case of situations with superimposing artificial errors resulting in the reduction of undetected rate of errors of 10^{-7} [21, 17].

There are 3 principal reasons of potentially occurring problems in the bus functioning:

– incorrect bus functioning as a result of incorrect software (incompatible version of the slave software, erroneous function call);

– corruptions or lack of communication resulting from the failure of master or slave node of the bus (power supply voltage out of permissible range; physical damage of the node;
– corruptions or lack of communication resulting from the failures of fibre optic cables.

The first one of three specified groups of errors can be extremely difficult to detect in case of rarely occurring errors without significant importance. Lack of repeatability of the problems and their incidental occurrence prevents their elimination by means of simple methods applied in workshop practice. In case of persistently occurring error, the errors can be detected by means of the network traffic recorder. For example the Data Logger manufactured by Telemotive AG – model „the blue PiraT 150M6-C2LE" can be used for the recording and further analysis of the traffic on MOST bus. The Data Logger is provided with an interface enabling the connection of tester to optical network MOST150 and the recording of control messages, bus status information, bus data packages. The additional interfaces are provided to enable the recording of the activity of other devices in the vehicle, because the recorder is provided with 4 inputs of CAN protocol, 2 inputs for LIN protocol, 4 serial interfaces and four Ethernet ports.

The second one of three specified groups of errors results from the partial or total failure of one of nodes. In case of damaged „time master" or „network master" any correct startup of the network and its functioning is impossible. In case of additionally failed gateway to diagnostic network, any network diagnostics is completely impossible. In such case the replacement of the node performing the role of "master" and the replacement of gateway is the only possible solution. In other cases it is necessary to detect the slave nodes deforming or locking the optical signal. In this case the procedure is similar to that applied in case of the elimination of fibre optic cables failures .

The third group of errors results from the failures of fibre optic cables. Their result consists in the reduction of luminous flux or its decay. The failures consist in:
– broken conductor or conductor plug;
– excessive bending angle of fibre optic conductor;
– scratching or cracks on the fibre optic cable sheath;
– contamination of contact surfaces in the connector.

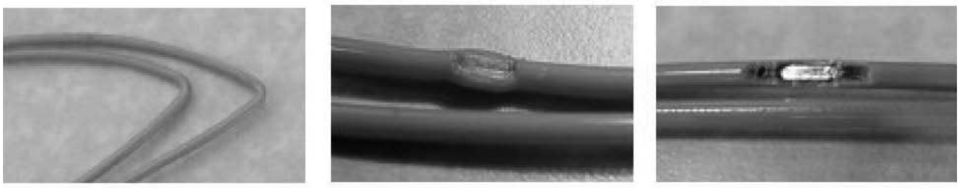

Fig. 4. Typical failures of fibre optic cables: bending, damage of sheath, damage of fibre [11]

The sole efficient method preventing the operation interruptions of the fibre optic bus built in ring topology consists in the application of nodes with many transmitters and receivers supporting several rings simultaneously or in an additional cable connection between the nodes (Fig. 5) [3, 21].

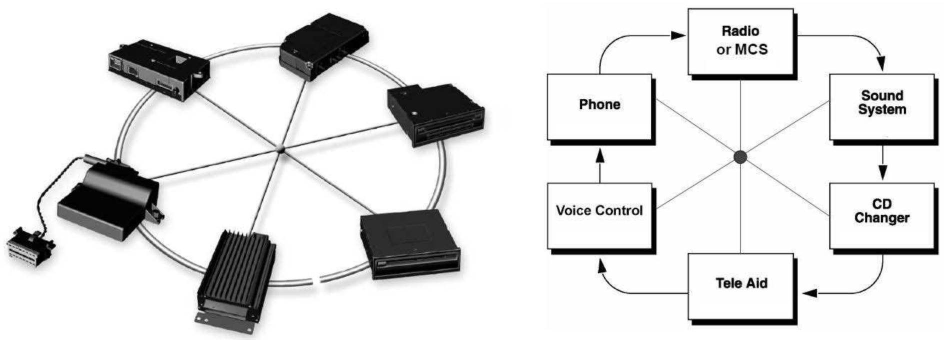

Fig. 5. Optical ring bus aided by means of copper star configuration. MOST bus in AUDI car (on the left) [4]. D2B bus in Mercedes car (on the right) [11]

There are two methods of use of an additional cable connection. The first method consists in the use of cable connection for the application of an independent diagnostic protocol (e.g. CAN). This protocol makes it possible to perform the complete diagnostics of the nodes irrespective of optical protocol. Another method originates from D2B bus and is based upon the information supplied from master node and concerning the configuration (sequence) of devices in the ring. In this method, after decoupling of optical bus, a diagnostic wake-up signal is sent by the master node and the slave nodes respond in the form of electric signals in the sequence conforming with the order of the devices occurring in the list. The lack of an "electric" response of the node indicates its failure (Fig. 6).

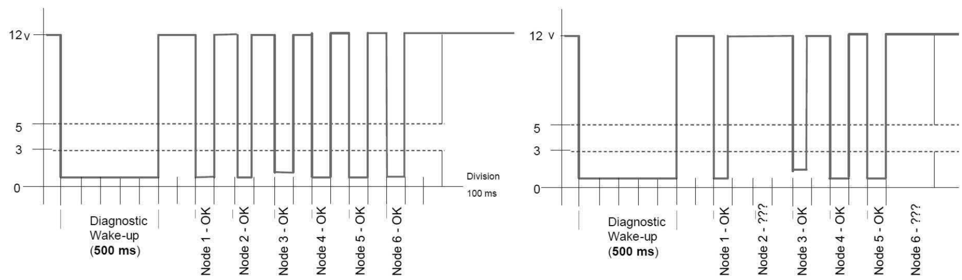

Fig. 6. Response to diagnostic wake – up in D2B bus. Efficient nodes (on the left), the second and sixth nodes failed (on the right) [11]

The evaluation of the fibre optic connections status is impossible by means of the method consisting in the use of an additional electric connection for diagnostic purposes. The partial and complete failures of the fibre optic ring can lead to the ring de-synchronization, problems with the execution of "ring lock" operation and unsuccessful network startup, lack of communication resulting from the fibre optic conductor discontinuity. The evaluation of the network node, fibre optic cable failure is possible by means of one or two fibre optic testers (Fig. 7).

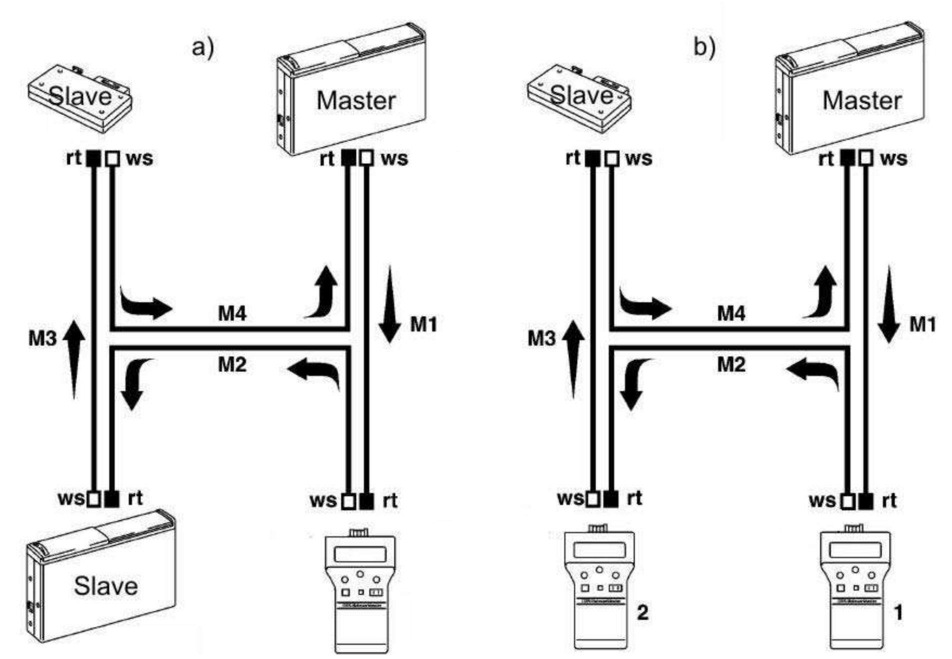

Fig. 7. Testing of bus elements of by dedicated testers [11]

The evaluation of the node failure by means of the fibre optic tester consists in the replacement of "suspected" node by tester. An optical signal is transmitted by the tester operating in "by-pass" mode. If the remaining network components are able to support each other after such replacement, the eliminated element is inefficient.

The use of two testers is required for the evaluation of fibre optic cable. One of them performs the function of a standard source of luminous flux and another is used as the illumination meter. Therefore it is possible to determine if the signal level is optimal for specified type of connection or if the replacement of the fibre optic conductor is required.

CONCLUSIONS

The summary of problems presented above and accompanying to the optical networks functioning in vehicles is based upon Media Oriented Systems Transport and Domestic Digital Bus. The both buses are operated in ring topology. The fibre optic communication makes it possible to achieve higher transmission rates as well as to reduce the impact of electromagnetic interference and its emission. The following operation problems occur in case of application of a fibre optic bus in the vehicle:

1. It is important to maintain the value of the fibre optic cable arc under its limit value which is approximately equal to 25 mm. The luminous flux is reduced and bus operation becomes problematic if this limit value is exceeded.
2. A special device for the terminals connection is required in case of the fibre optic cable failure. Therefore a good practice consists in the replacement of the failed fibre optic cable.

3. In contrast to the typical linear or star cable buses, the knowledge of the route of fibre optic cables forming the ring is necessary in order to localize the failure.
4. In order to localize the failures of the optical ring bus in an easy manner, it is necessary to support this bus by means of an additional communication ring or by means of a standard cable connection in star topology and to plan an emergency procedure.
5. Low-skilled service personnel will be practically unable to eliminate the failure which is not displayed as a legible result obtained from an automatic auto-detection procedure.

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PROBLEMY KOMUNIKACJI ŚWIATŁOWODOWEJ W SYSTEMACH KOMUNIKACYJNYCH POJAZDÓW

Streszczenie. Efektem prawie trzydziestu lat ewolucji systemów komunikacji pomiędzy układami mechatronicznym pojazdów jest zróżnicowanie rozwiązań technicznych. W pojazdach można spotkać zarówno tradycyjne połączenia kablowe pomiędzy przełącznikami i elementami wykonawczymi jak i zaawansowane sieci wymiany danych. Sieci te wykazują coraz więcej podobieństw do sieci komputerowych. Są to rozwiązania nowe, które jeszcze kilka lat temu nie miały nawet swojej klasyfikacji (klasa D). W związku z tym, osoby zajmujące się programowaniem funkcjonowania i serwisem pojazdów napotykają problemy przy pracy z sieciami. W artykule przestawiono zasady funkcjonowania podstawowych sieci z medium w postaci włókna światłowodowego. Nacisk został położony na mechanizm wykrywania uszkodzeń polegających na uszkodzeniu węzła komunikacyjnego oraz włókna światłowodowego.

Słowa kluczowe: Media Oriented Systems Transport, Domestic Digital Bus.