PROSPECTS FOR THE DEVELOPMENT OF AUTOMOTIVE NETWORKS BASED ON ETHERNET

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Abstract

The increasing complexity of automotive electronic systems is linked to the continuous development of new or adaptation of those already proven has been efficient in other fields of information management. Contemporary vehicles are characterized by great diversity of data exchange used in them ways. Communication protocols proposed and used by car manufacturers, such as the K-line, Can, Lin, and FlexRay have been changing their position as a part of formally adopted group of standards. The article is an attempt to outline the evolution and prospects of implementation of automotive networks, taking into account current technological capabilities as well as the requirements and expectations of potential users.

The advantages of Ethernet are proved by the fact, that many of the leading automation companies which developed and popularized the standards of their own network such as Profibus (Siemens), Cc-link (Mitsubishi), Modbus (Modicon/Shneider) for years, move to Ethernet protocols, which is solutions based on the OSI layer 2 - respectively Profinet, CC-Link IE, Modbus TCP. It is a significant difference between industrial and automotive network applications is the difference in desired behaviour of controlled object. In most of the cases in the industrial systems, a proper reaction in critical situations should be to stop the activity of particular elements of controlled plant.

Keywords: *Ethernet ABV, TTEthernet , automotive networks,*

1. Introduction

Operations of modern motor vehicles are inherently connected with the use of data network. Despite differences in the technical solutions used by the various manufacturers of vehicles there is a group of network solutions presently considered as a classic, mainly because of their popular presence and the regulations, which oblige manufacturers to use them. Regulations or recommendations developed by the relevant institutions are the result of the compromise between the current technological capabilities and expected effects associated with the widely considered state of safety, environmental impact and economic factors.

Alike the powertrain or suspension system, systems of control and communication are subject of ongoing evolution and intensive search of cheaper and more reliable solutions. As in every discipline of technology some solutions remain unchanged, other appear for a time and then disappear, other developed and are still present on the automotive market, other exist because many vehicle produced several years earlier are still on our roads. The first commonly used automotive networks were K-line (harnessing a character-based transmission) and SAE J1850 (USA). Currently, these networks are obsolete and their functions are taken over by the CAN or LIN. The root cause of their absence in modern automotive systems is their low bandwidth and lack of development opportunities for multi-user configurations. Due to its simplicity, UART protocol used in those networks, however it is still used in LIN, which doesn't require high speeds transmission and is used in so-called comfort class. Nowadays the most common network technology present in modern car is CAN [18] described in numerous publications [1-4]. Due to the high flexibility and high bandwidth [1Mbit/s] CAN is basic protocol in many systems such as comfort, powertrain, safety, diagnostics and as a backbone integrating the other subnets. Because of increasing amount of information necessary to control more and more modern car, the attempts to work out and design new network solutions or adopting solutions proven to have been efficient in another branches of technology have been made. The best known of them are TTCAN, TTP or Byteflight, however their applications in automotive were not numerous. Experience gained as a result of work with mentioned protocols contributed to the development of FlexRay protocol, which offers higher security level and 10 times higher bandwidth than CAN but is more complex [1-3, 5]. In the field of the infotainment networks the MOST protocol gained the biggest popularity. Versions MOST25, MOST50, MOST150, offers the bandwidths 25Mbit/s, 50Mbit/s, 150Mbit/s. Forecasts of further growth of the volume of transmitted information exchanged between ECUs tends to introduce the network protocols able to meet the requirements in transmission speeds over 100 Mb/s. The solutions based on the classic Ethernet are evaluated as those most promising.

2. Ethernet

Ethernet was presented to the public in 1976. Since then it has dominated most of the office and home networking. The vast universality of this protocol formalized in the IEEE 802.3 moved into many fields of technology, taking significant positions mainly in the industry, but also in aviation and space technology.

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Numerous researches and implementations of the Ethernet systems include a wide spectrum of transportation means: from trains [7] to spaceships. An example of a presence of Ethernet (IEEE 802.3) in avionic is the development and implementation of the AFDX (Avionic Full-Duplex Switched Ethernet) standard (aka. ARINC 664 Part.7). This network standard has been implemented for example in Boeing 787 Dreamliner or the Airbus A380. ARINC 664 has been design as a successor of ARINC 429. In space technology, Ethernet (TTEthernet) was used as a backbone system in the NASA Orion Spacecraft [8].

As it is pointed in [9] the significant difference between industrial and automotive network applications is the difference in desired behaviour of controlled object. In most of the cases in the industrial systems, a proper reaction in critical situations should be to stop the activity of particular elements of controlled plant. Unlike to previously mentioned, in mobile applications like automotive or aircraft such scenario may prompt serious consequences. Thus direct transfer of the industrial network protocols is impossible. There are other issues standing in the way, such as different criteria concerning mass of installation or typical distance between particular elements. It doesn't change the fact that adaptation of some ready-made and proven solutions in other fields, can significantly shorten the phase of preparing and implementing effective network system for a given object. Most fields of application of Ethernet currently under consideration in the automotive applications, is primarily infotainment and DoIP. Regardless of it, such technologies like e.g. TTEthernet gives perspectives on the use of Ethernet also in Real-time usages

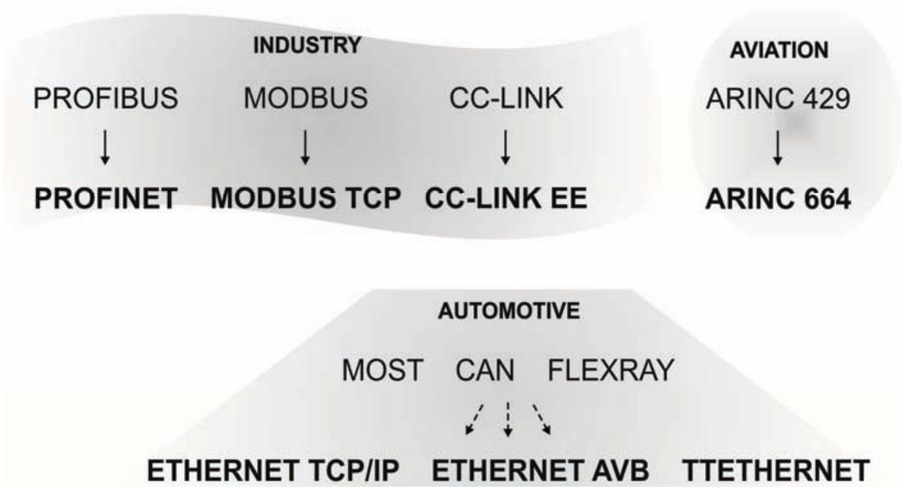

Fig. 1. Expansion Ethernet IEEE 802.3

3. Ethernet AVB

The bandwidth requirements for modern Infotainment are continuously growing. Despite of the time regimes in this field are not as important as in the case of the network coordinating the work of powertrain and safety systems, the synchronization of data streams is necessary for the proper operation of audio-video installation. One should note, that in the case of very intensively developed drive assistant systems the delay in the image delivery can cause collision. In such cases it is particularly important to ensure appropriately low latencies in data transmission. Similarly, the use of Infotainment network for monitoring and visualization of the state of a vehicle imposes that networks needs to meet certain parameters. The classic solution currently used in these systems is the MOST(Media oriented system transport). The proposed alternative to the MOST is Ethernet AVB (audio video bridging) based on IEEE 802.1. Basic mechanisms of ABV are depicted in:

- IEEE 802.1AS (approved 2011, known as PTP precise time protocol),
- IEEE 802.1 Qat (approved 2006, known as SRP stream reservation protocol),
- IEEE 802.1 Qav (approved 2009, known as Queuing and forwarding).

PTP periodically synchronizes the internal time of all nodes thereby eliminates the need for determining the latency at each transmission. The initial reference time can be obtained e.g. from the GPS system. Synchronization takes place in two stages. At first the offset is determined, than base of the time of each slave is readjusted. In the second stage the delay is calculated as 1/2 of time between sending the delay request message and the delay response message – Fig. 2.

SRP reserves bandwidth and buffer resources for specific traffic schemes. Participant of traffic called listener send registration message to another participant called Talker, and informs every device on its way to take into account its share in traffic. In the next step devices send back reservation messages.

Queuing & Forwarding organizes the traffic in AVB net, ordering messages into queues with certain priority. There are two kinds of data packets – isochronous (time critical) and asynchronous (none time critical). Messages with isochronous status are sent on the beginning of every cycle.

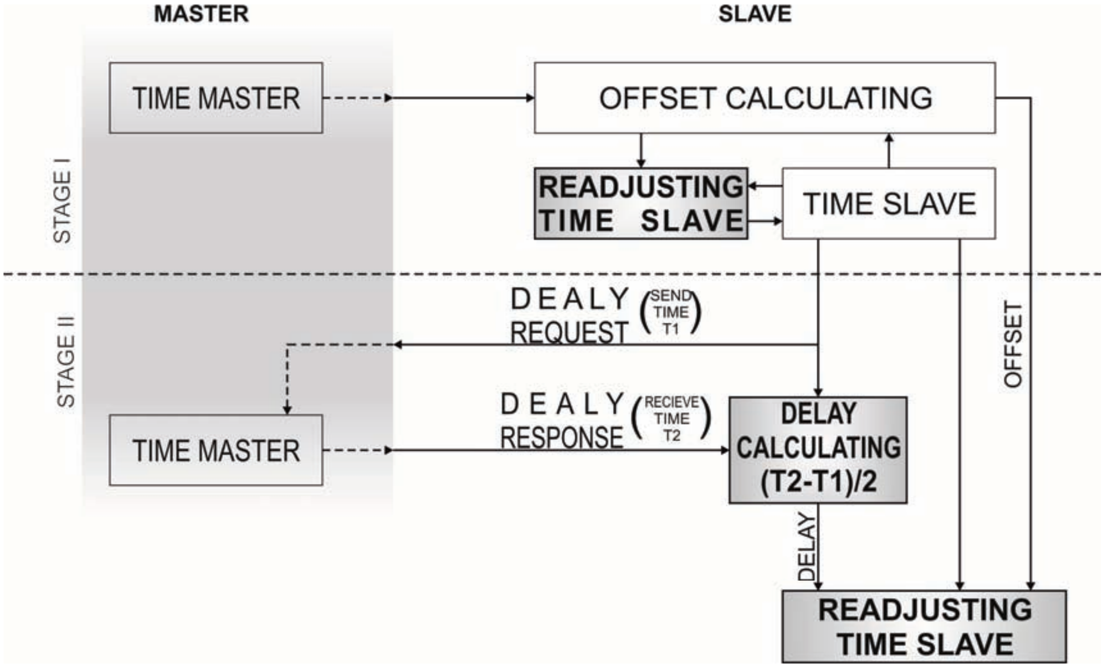

Fig. 2. Example of PTP synchronization

In the Infotainment class in addition to MOST and Ethernet, FireWire (IEEE 1394) is also considered, due to its high bit rate (100-3200 Mbit/s), time triggered synchronous communication, and wide possibilities configure various topologies as opposed to e.g. MOST with its only ring topology.

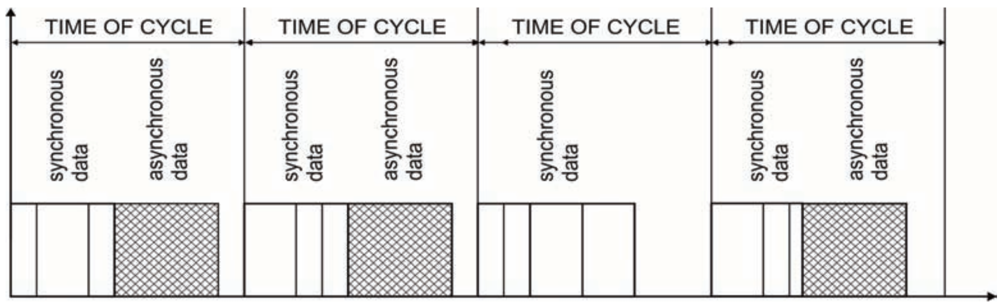

Fig. 3. Example of Forwarding & Queuing

4. Diagnostics over IP

One of the factors which most significantly contributed to the presence of network- systems in vehicles is a development of OBD standard [10]. Formalization of OBD in Europe regarding pollutant emissions issue is contributed in the document [20]. Among others it describes the way to access diagnostic information. Shown in Fig. 4 diagnostic socket (DLC) diagram is an illustration of the evolution in networks used to diagnose of car

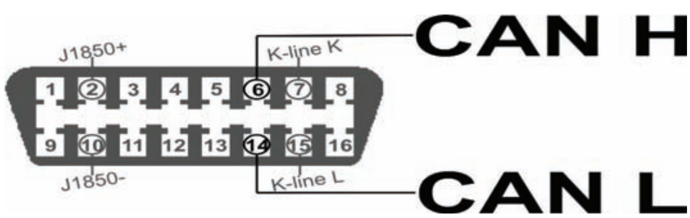

Fig. 4. DLC connector

Presently the most important part of the connector are the lines CAN H and CAN L connected to high seeded CAN bus (ISO 11898-2) as the only permissible for OBD diagnostics since 2008. Comparison of the demanded by ISO 14229-1 bandwidth (250 kbit/s and 500 kb/s) for transmission speeds obtained from the earlier protocols SAE J1850 (41.6 kbit/s PWM to 10.4 kbit/s VPWM) or k-line (10,4 kbit/s) shows the increase of bandwidth for the effective transmission of information about the state of the vehicle. Another proposal of the engineers working for automotive is the further increase of bandwidth by implementing Internet technology known as DoIP (Diagnostic over Internet Protocol) that is made originally by the WWH-OBD (World Wide Harmonized on-board Diagnostics) embodies [19] as well as mentioned above, the Official Journal EU. The results of these activities are being ISO 13400 (current status: under development).

Currently Diagnosis over IP pre-version is implemented in the BMW Series 7 [12]. Significant bandwidth increase, by using Ethernet as a diagnostic network interface may also shorten the time of the ECU flash memory programming. Because the nature of the exchange of such information does not require proper real-time mode, higher layers of the OSI model can be based on the classical TCP/IP solutions the confirmation of the adopted direction can be seen in the AUTOSAR standard [11] concerning DoIP. The expected increase in amount of data exchanged is related to the work of the OBD-3 and the big emphasis on the development of road thematic systems [10].

Common availability of GPRS-based networks in conjunction with GPS-based systems gives them possibility of bidirectional transfer of information about the state of the vehicle its vicinity and the road. In contrast to the classic traffic announcement whose broadcast character constrains bandwidth and precision of information about the situation in the near vicinity of the vehicle, mentioned systems give possibility to filter the information to the different elements of the telematic system.

5. Real time applications

The newest network in the field of automotive systems which demand the most stringent time determinism is FlexRay. Many advantages featuring this protocol such as high bit rate (10Mbit/s), flexibility in creating topology and very high level of transmitted data safety, is caused by the fact that FlexRay was designed to work in exactly Automotive usages. This bus is supplicated still only in several cars (BMW AUDI) but it seems to be very attractive to be used in many others. Arising question is - how long 10 Mbit/s bandwidth will be enough to fulfil the demands of continuously developing car technology. Today classical IEEE 802.3 Ethernet offers 100 Mbit/s transmission speed and 1Gbit/s is becoming more and more common. TTEthernet [16] is network solution completely based on IEEE 802.3. Numbers of features and functionalities of TTEthernet could make this bus capable to supersede. Flex Ray in many automotive applications.

TTEthernet provides three types of traffic: TT- Time triggered, RC -Rate constrained and BE-Best effort. Partitioning time between every one of them is shown in Fig. 5.

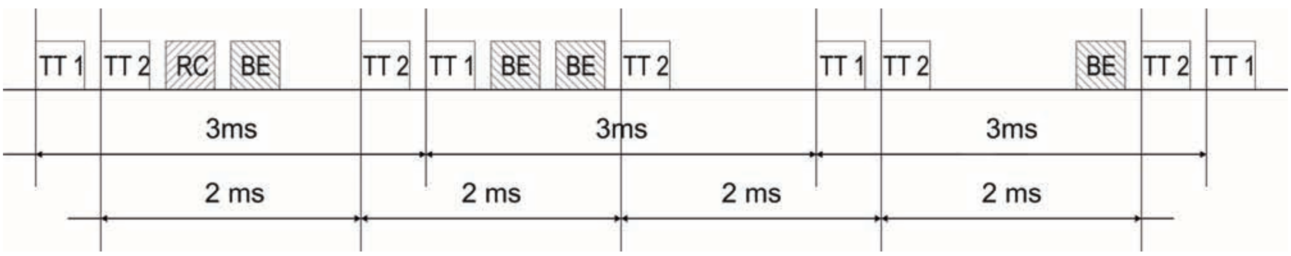

Fig. 5. Partitioning time between TTEthernet messages

TT messages are intended to the stringiest determined data streams. Thanks to sending them in precisely specified time we get the tightest latency and jitter (highest priority level). Any of other traffic type cannot happen when a time slot is reserved by TT. To increase bandwidth for other types of messages TTEthernet is able to recognize inactivity of assigned sender and to allow to other kind of traffic. This type of traffic should be used in systems demanding total predictability in the manner of an addressee receive time. In practice it gives the possibility to use it even in x-by-wire applications

RC is significantly less crucial in time domain than TT. For RC messages the bandwidth is guaranteed which limits the latency to the desired level. Since messages are not sent in strict time domain, the low transmission jitter ca not is ensured. The messages waiting to be sent, are queued in switches which act as buffers.

BE are transmitted just like in classical Ethernet .Messages can be transmitted only in time free of TT and RC .Any jitter and latency are not predictable. Thus it can be applicable only in non time critical usages such like e.g. configuration services or web services.

Presented above types of traffic on the bus illustrate a deterministic Time Triggered transmission and initiated by events Event Triggered transmission in one network .Such connection suggests the use of a so-called TTEthernet as a backbone net coordinating the work of many different subnetworks with the different requirements and features in the time domain. Relation of TTEthernet to other existing communication standards is shown in Fig. 6.

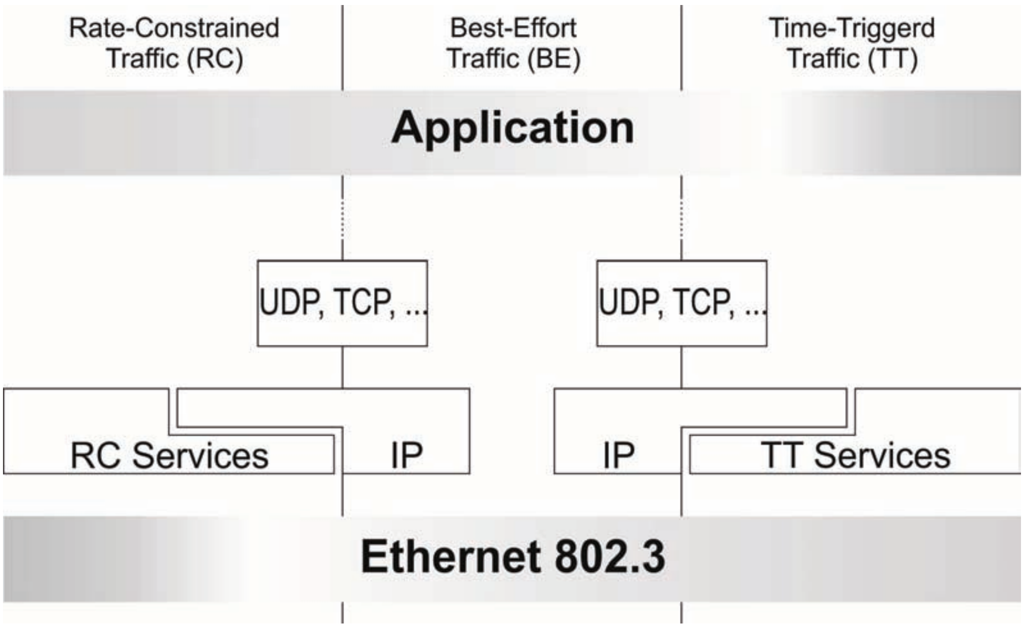

Fig. 6. Relation of TTEthernet to existing communication Standards [16]

6. Summary

The target, however not entirely possible to reach is efforts to unify network solutions due to the ease of their design and operating. Use of the widely common standard such as Ethernet technology decreases the cost of production of the whole system. It is also very essential to improve the network for which the know-how has been developed for over 30 years. Ethernet can decrease the cost in the stage of production and in the workshop by using typical/commonly used interfaces available in every PC. Due to its scalability Ethernet seems to be the perfect proposal for use as a backbone network.

There are many similarities between Ethernet and FlexRay such like partitioning bandwidth to time triggered and event triggered transmission, using of bus guardian (in TTEthernet it is function of switches -IEEE 802.3 is a switch -based network), hardware redundancy considered as doubling net lines from point to point. As far as time dependencies and bandwidth are concerned TTEthernet has significant advantage over FlexRay. It concerns in particularly high payloads when overhead becomes in the case of TTEthernet less significant. As shown in [13] TTEthernet usable bandwidth is not affected by the latency.

Typical for automotive networks ways to keep the correctness of transmitted data are: parity check codes used in transmission based on UART such as k-line or LIN, arithmetic checksum used for LIN and the most common Cyclic Redundancy Codes (CRC) used for CAN ,MOST and FlexRay. In cases mentioned above, there is no error correction, transmitter resend information instead.

To protect physical layer data in Ethernet, CRC-32 error detection technique is used due to its low complexity, simple implementation and good error detection performance. Examples shown in [14] points at high performance of used CRC-32 Polynomial for which we get a hamming distance D higher then 7 to a data word length of 91 bits, D=7 to 171bits D=6 to 268 bits. Comparing to other protocols we get D=6 to 64 bits (CAN CRC-15), D=6 to protect the header and D=4 to protect header and the payload data (FlexRay CRC-24).

The increase in the transmission speed and thus the speed of the rising slope of signal is connected to the power emitted by the lines, therefore important challenge is to ensure proper EMC level. The classic solution of EMC problems is the use of physical layer based on POF (Plastic Optical Fibbers), although copper wire options are being also developed, e.g. developed by BMW and Broadcom UTSP line (unshielded single twisted pair) designed for full duplex transmission on a single twisted pair [15].

The question about the future of the POF and copper wire in automotive networks is very difficult. Simultaneously attempts to replace MOST with Ethernet in infotainment applications, MOST 150 open the possibility to transmit fully preserved Ethernet packet in a separate part of its Bandwidth.

Activity of engineers tends to evaluate automotive network systems towards solutions based on Ethernet. The final argument will probably be the fact that Ethernet is growing highly independent from field of the application in which it is used. Currently, the market starts to gain 1G Ethernet and it is still under way and work on 10G and 100G version.

Acknowledgements

The study financed as part of Research Project No. N N509 573039

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