FEASIBILITY ASSESSMENT OF THE SMART STANDARTIZED SENSORS DESIGN FOR VEHICLE TESTS AND DIAGNOSTICS

Georgi Dotsov Geshev, Emil Nikolov Dimitrov

Department of Electronic Engineering and Technologies, Technical University of Sofia, Bulgaria

The paper examines the basic principles set by the IEEE 1451 standards. A review of the current status of the standards has been made. Some recommendations are given how to design electronic monitor systems with a variety of requirements taken into account. The paper is focused on a vehicle real-time diagnostic systems design. The developed idea is based on the IEEE 1451.4 standard and provides a mixed analog and digital data transmission. The possible transducer electronic data sheet (TEDS) implementations are examined: basic, extended and virtual.

Keywords: smart sensors, real-time diagnostic, measurement, standards

1. INTRODUCTION

The real time diagnostic (while running) is important part of the vehicles diagnostics. The advantages of such diagnostics are maintenance and repairs by condition instead of the so-called planned repairs existing in many enterprises so far. The efficiency and the condition of different vehicle systems could be established on the basis of the nature of the forced vibrations. The vibration analysis could be used as a criterion to assess the passenger comfort as well. The real-time vehicle condition determination increases the reliability and safety of movement and alarms in case of emergency.

The developed sensor could be used not only for the vehicle diagnostics, but also for determining the track condition using a vehicle model (a vehicle with known technical features).

To develop such a system, a few approaches can be used: a fully integrated/ closed system, an open system built with standardized modules or a combination of both approaches.

2. IEEE 1451 STANDARD

The fast growth of electronic industry, the increase of the integral circuits integration, the vast complication of firmware, the increase of the number of manufacturers, the usage of distributed embedded have imposed the necessity to open the systems and to standardize the individual functions. In the 1980, the ISO started to develop the Open System for Interconnection (OSI): a 7-layer model, which became a standard for designing systems with network communication between the different nodes.

The IEEE organization aims at the standardization of interconnected sensors and actuators systems. In 1993 the IEEE 1451 project was initiated. It is a standards family for smart sensors system design with a full name: Standards for Smart Transducer Interface for Sensors and Actuators. In general, the purpose of the IEEE 1451 is to design plug-and-play devices in distributed automated systems with a network capability.

Besides that, the IEEE 1451 protocol defines several standardized layers:

- Network Capable Application Processor (NCAP) – a link between the transducer module and the industrial network. The IEEE 1451.1 standardizes the network independent information model or a meta-language describing how NCAP can be adapted to the different network specifications of field and higher levels.
- Transducer Electronic Data Sheet (TEDS) – The particular device data are stored in a dedicated file in its memory. The electronic specification is described in 1451.0. There are two levels of its implementation: basic and complementary.

Fig. 1 shows the typical structure of the IEEE model layer stack. The specification mentioned above exists independent of the physical layer implementation.

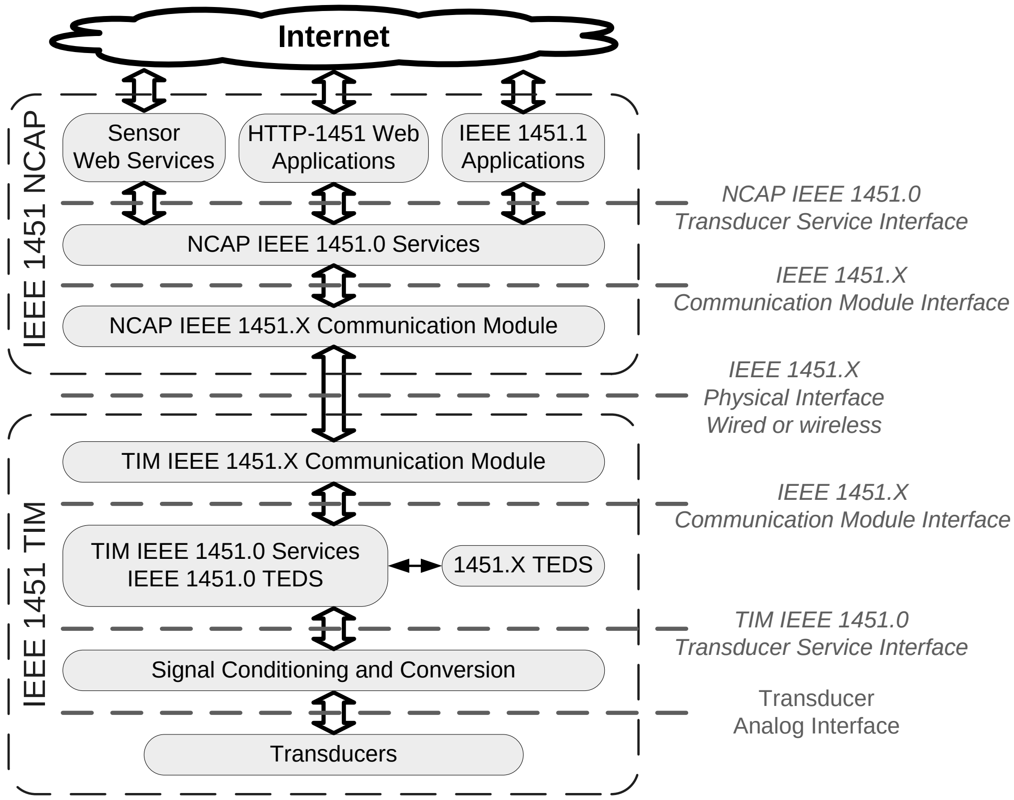

Fig. 1 IEEE 1451 Stack

The different specifications within the IEEE 1451 define standardized technical and programming methods for interconnection keeping the existing network solutions. The specifications do not contain special requirements for the network type, the used hardware components (microcontrollers, ADC etc.).

There are six standards or standard drafts defining the different physical layers of the communication – 1451.2, P1451.3, P1451.4, P1451.5, P1451.6, 1451.7. A system containing all standard specifications is shown in fig.2 [1].

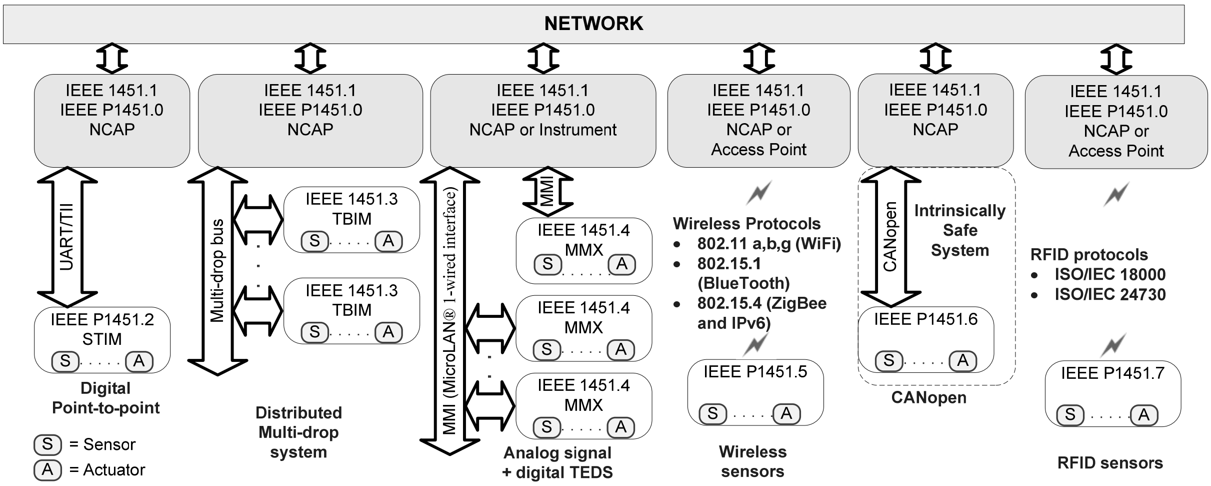

Fig. 2 IEEE 1451 Suite of standards

Each sub standard could be applied independently.

- IEEE Std 1451.2-1997, Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats – the standard has been completed and published. It specifies a digital point-to-point communication interface.
- IEEE Std 1451.3-2003, Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems – the standard has been completed and published. It is designed for high speed continuous data stream. The specification makes possible to design sensors with a bandwidth of several hundreds kHz and synchronization of the sensors to several ns.
- IEEE Std 1451.4-2004, Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats – the standard has been completed and published. It offers a possibility to transmit an analog signal combined with digital communication to the sensor. The standard is suitable to design systems where multiple analog signals are sent from the transmitters to the NCAP with a relevant bandwidth and time synchronized, "smart" options included – electronic data-sheet, self-test and self-calibration. The appropriate physical implementation gives a possibility to design cheap systems with a possibility to use standard sensors produced by different manufacturers.
- IEEE P1451.5, Wireless Sensor Communication and Transducer Electronic Data Sheet (TEDS) Formats – the standard has been completed and published. It includes some of the existing standards of wireless communication – IEEE 802.11 (WiFi), 802.15.1 (Bluetooth), 802.15.4

(ZigBee and IPv6). The standard uses not only the physical layer, but also the security methods and key exchange algorithms already specified.

- IEEE P1451.6, A High-speed CANopen-based Transducer Network Interface – under development. It is a transducer and closed-loop controller standard for operation in an intrinsically-safe cascaded network environment with multiple controllers on each level.
- IEEE P1451.7, Standard for a Smart Transducer Interface for Sensors and Actuators - Transducers to Radio Frequency Identification (RFID) - under development. The draft standard provides to use already specified physical layers ISO/IEC 18000 and ISO/IEC 24730 [2].

The IEEE 1451 series have been designed to work together but they could be used separately as well. For example, the 1451.1 could be used alone, without any of the IEEE1451.x hardware interface. The opposite is also valid: the 1451.x physical interfaces could be used without the IEEE 1451.1. Nevertheless, such software provision ensuring applied software and network support, is required to integrate the 1451.x device into the IEEE standardized distributed system.

3. IMPLEMENTATION

Paper [3] has examined the requirements to the vehicle diagnostic electronic equipment. To the criteria already mentioned, it is necessary also to add some specific requirements imposed by standardization, economic parameters and other criteria:

- Synchronized data transmission along several channels – the IEEE 1451 set of standards offers analog (IEEE 1451.4), network (IEEE 1451.3, IEEE 1451.5, IEEE 1451.6, IEEE 1451.7) and digital point-to-point (IEEE 1451.2) data transmission.
- Compatibility with already existing sensors – it is possible in combination with virtual electronic data-sheet.
- Economic parameters of the designed system – the term and funding for development, the price of the modules developed, the price of sensor modules produced by other manufacturers, etc.
- Noise immunity and lack of signal detection with signal transmission at a distance of dozens of meters in a very noisy environment.
- Digital data transmission – it is not noise-immune if not included in a protocol. The data encapsulating in such a sophisticated protocols (handshaking, data re-transmission) is an obstacle for the development of real-time systems – synchronous data transfer, data transmission delay is not allowed etc.
- Analog data transmission – it could be voltage single ended, voltage differential and current. The 4-20mA current interface is wide spread in industry. It meets the requirements of noise immunity and lack of signal detection.

- Self-test ability – with the initial start of the system or in a certain period of time, it is necessary for the system to enter the mode of self-test and to report in case of errors, faults or inaccuracies.
- Compatibility and inter-replacement of the used sensors – with using Plug&Play sensors the downtime of the system can be reduced significantly

After analyzing the requirements and the specific task, the following components of the system have been chosen:

- Usage of an analog data interface for data transmission from the different channels of the system. That has imposed to use the IEEE 1451.4 standard specification.
- Paper [3] has examined the details of the sensor, signal path and interface design. On the basis of that analysis, a current interface 4-20mA has been chosen. The IEEE 1451.4 [4] specifies the usage of a 4-wire connection mode between the transducer and the NCAP for such an analog signal.

Fig. 3 shows the implementation of the sensor system according to the IEEE 1451 conception.

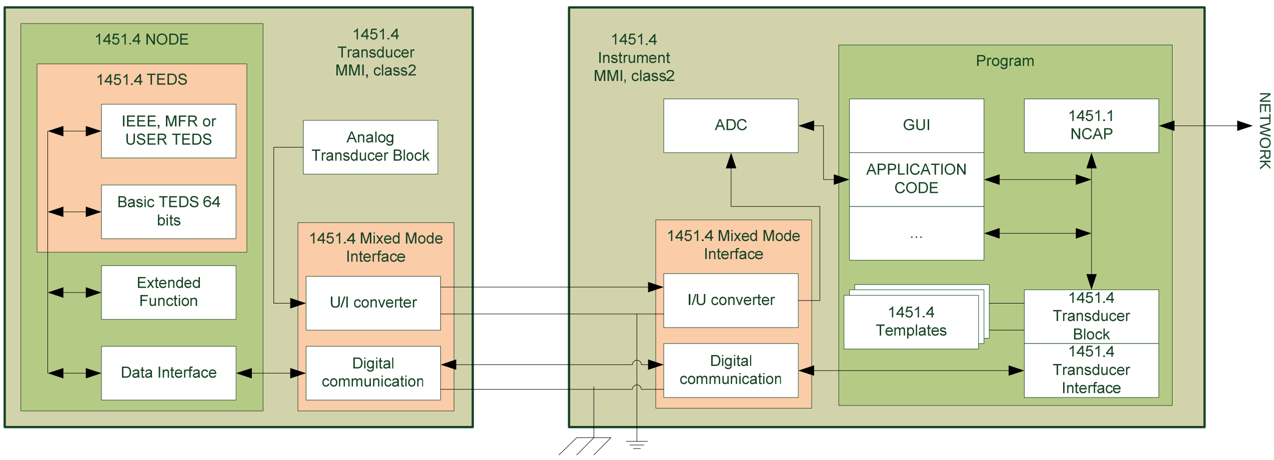

Fig. 3 Block diagram of 1451.4 class2 system

The transducer electronic data-sheet TEDS – two approaches for the implementation are possible: with a discrete 1-wire EEPROM or to be included as part of the microcontroller memory. The standard specifies two levels of implementation: basic and complementary. The basic level is obligatory and it is the same for all types of sensors. It consists of 5 fields distributed in 64 bits: 14bits Manufacturer ID, 15bits Model number, 5bits Version letter, 6bits Version number, 24bits Serial number [4]. The complementary specification is specific for the different types of sensors. The complete information what has to be implemented for an acceleration sensor is described in Annex A of the standard [4]. To entirely implement the complementary specification, for that type of sensors it is necessary to have 187 to 252 bits available depending on the level of the sensor configuration and the used template version.

The analog current interface used is characterized with detecting the lack of a signal, noise-protection in a very noisy environment, transmitting a signal at a great distance and a possibility to synchronically read the signal by a set of sensors. Two wires for interconnection between the sensor and the instrument are provided.

The digital communication specified by the IEEE 1451.4 [4] standard is 1-wire interface. The standard uses a physical layer and a protocol of communication already designed [5]. It is master-slave point-to-point communication. The instrument initiates data transfer. It is provided to read and write under normal and accelerated modes of data transmission. Each data package is protected with a CRC code, which is accomplished by the following polynomial: $X^8+X^5+X^4+1$.

4. CONCLUSIONS

The paper describes the basic principles used to design standardized sensors. There is also a review of the current status of the standards family IEEE 1451.

The system is designed as an idea with considering:

- the requirements to distributed sensor systems vehicle with vehicle diagnostics;
- the recommendation for compatibility of the systems with the 1451 sensors family;
- the possibility to integrate sensors solutions already developed.

5. REFERENCES

[1] Kang Lee, Smart Sensor Interface Standards IEEE 1451.0 and 1451.5, Net-Ready Sensors Workshop, August 2-3, 2006, Oak Ridge, Tennessee

[2] IEEE P1451.7D0.3Draft Standard for a Smart Transducer Interface for Sensors and Actuators – RFID Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats, IEEE, 2007

[3] Emil Dimitrov, Nenov N. and G.Geshev, "Train Spring System Electronic Diagnostic Equipment Using Accelerometer Sensors", 31-st International Spring Seminar on Electronics Technology, pp 564, Budapest, Hungary, 7-11 May 2008

[4] "IEEE Std 1451.4-2004, Standard for a Smart Transducer Interface for Sensors and Actuators- Mixed-Mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats", IEEE Standards Association, Piscataway, NJ, 2004.

[5] "DS2430A 256-bit 1-Wire EEPROM," Maxim/Dallas Semiconductor Corp. Datasheet, http://www.maxim-ic.com/DS2430A.