IEEE 1451 -- A UNIVERSAL TRANSDUCER PROTOCOL STANDARD

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Abstract - The expansion of smart sensors usage is being slowed by the lack of a universal standard, especially in the wireless area. Recognizing that no single sensor bus or network is likely to dominate in the foreseeable future, the IEEE 1451 set of standards was developed to unify the diverse standards and protocols by providing a base protocol. One feature of the IEEE 1451.0 open standard is that the data and TEDS of all transducers are communicated on the network (Internet) with the same format for all sensors and actuators for both wired and wireless networks. The development of the main parts of the IEEE 1451 standards, including those relating to wireless, have recently been approved. This smart transducer standard is illustrated with several wired and wireless network examples.

INTRODUCTION

Smart sensors (and actuators) with digital outputs are improving in performance and decreasing in cost as the components of smart sensors, including signal conditioners, microcontrollers and communication electronics have improved. However the widespread use of smart sensors is currently inhibited by the lack of a widely accepted standard, especially in the wireless area. Recognizing that no single sensor bus or network is likely to dominate in the foreseeable future, the IEEE 1451 set of standards was developed to unify the diverse standards and protocols by providing a base protocol which allows interoperability between sensor/actuator networks and busses. A key feature of the IEEE 1451.0 (Dot 0) standard is that the data (and meta-data or TEDS) of all transducers are communicated on the Internet with the same format, independent of the sensor physical layer (wired or wireless). The development of the main parts of the IEEE 1451 standards, in particular those relating to wireless, have recently been approved. They extend, improve and partially supersede the older version of the standard, including the original IEEE 1451.2 (1997). The purpose of this presentation is to describe the standard briefly, illustrated with specific implementations.

IEEE 1451 CONCEPT

The NIST-supported IEEE 1451 standard based system contains a pair of components (Fig. 1). The TIM also holds a Transducer Electronic Data Sheet (TEDS) that contains the calibration and operating data necessary to create a calibrated result in standard SI units. The TEDS contains additional information necessary to uniquely identify the TIM as well as providing supplemental information to the application. Information is passed between the NCAP and TIM via a common hardware and software interface. The software interface is standardized for the 1451 system, thus simplifying the task of adding new transport interfaces. The hardware interfaces defined in the various 1451 documents to include open standard interfaces as RS-232/ USB, CAN, IEEE802.11, Bluetooth and ZigBee (802.15.4).

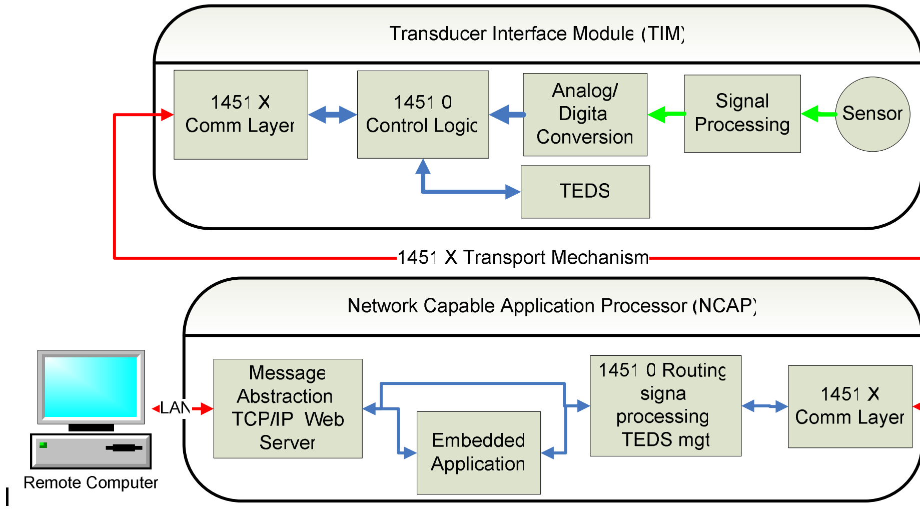


Fig. 1 – IEEE 1451 Block Diagram (from Smart Sensor Systems)

The system is built around the NCAP, which manages the TIMs and processes data to be used by the application. When an NCAP is initialized, it searches its interfaces for TIMs and claims the ones it finds. It then transfers a copy of each TIM's TEDS database to a cache area within the NCAP. When a TIM is asked for a reading, it will acquire the data and generally return it in fundamental A/D counts. The NCAP will then apply the correction data found in the TEDS and convert it to calibrated SI data. The data is then transferred over the external network using HTTP protocol and XML.

A major benefit is the open nature of this standard that allows different manufacturers to produce products with the assurance that they will self configure and seamlessly operate with products from other manufacturers (Plug and Play feature). All 1451 systems benefit from the use of common codes and formats. This means that TIMs can be configured into systems and be recognized and configured by NCAPs without previous knowledge of that TIM. Sensors and actuators can easily be added to or removed from a system. If a wireless sensor is used, no action needs to be taken other than placing the sensor and ensuring that an appropriate wireless NCAP is within range. This capability allows sensors to be placed during testing phases or when a specific testing need is discovered and then easily removed during normal deployment.

A 1451 based system also returns sensor data in calibrated SI units. This places the correction information in the sensor which reduces the chance for errors to be introduced by unit mismatch or misidentification. In addition, all operating parameters are queryable, thus allowing the application to certify units, calibration and operating data.

The IEEE 1451 standard is intended to include nearly all types and forms of transducers (sensors and actuators), rather than a targeted subset. The advantages are a high degree of interoperability and the possibility of including nearly all smart sensor in a Nationally deployed sensor network. The disadvantage is complexity, especially in the TEDS preparation.

TEDS AND TEDS COMPILER

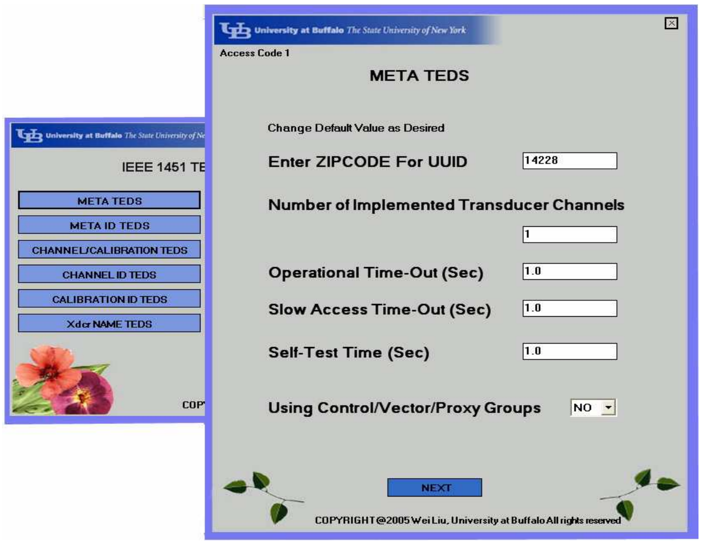
The purpose of the TEDS is to provide both the identification and the detailed specifications of the sensor (or actuator). The required sections of the TEDS (memory block with defined format) are:

- MetaTEDS
- Channel TEDS
- Calibration TEDS
- Xdr-name TEDS
- Phy TEDS

Some optional TEDS are:

- Geographic Location TEDS
- Units Extension TEDS
- Manufacturers Defined TEDS

Normally the TEDS is placed within the TIM with a copy transferred to the NCAP. The required parts of the TEDS are prepared by the transducer manufacturer, normally stored in an EEPROM. Hand assembly of TEDS, especially the machine readable (binary) sections, is tedious and thus a complier is required. A preliminary version of a TEDS complier and Dot 0 format compatibility tester (developed at SUNY/Buffalo) is available. The initial screen for the Meta-TEDS is shown in Fig. 2. To calculate the Universal Unique Identification (UUID), for example, the zip code of the manufacturer is entered and the rest of the required data is automatically calculated. The TEDS data in binary form is downloaded into the TIM EEPROM.



Other data screens are the Channel, Calibration and Phy TEDS, as well as several optional TEDS. In addition to the compiler, an Internet-based TEDS and Dot 0 data format tester is available for serial type TIMs.

SERIAL POINT-TO-POINT EXAMPLE

A simple implementation of a NCAP and TIM using a point-to-point (RS232) connection is illustrated in Fig. 3. The TIM has a temperature sensor and photodiode as well as a relay. Both PC and Internet (HTTP) NCAP protocols were tested.

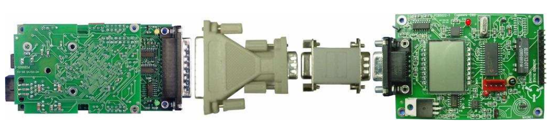


Fig. 3 NCAP (Internet version) and TIM with RS232 interface

Data is requested by an Internet browser using IEEE 1451.0 (Dot 0) format encoded in HTTP (TCP/IP). It is converted to serial (RS232) format and sent to the TIM where the sensor reading is taken and the resulting data in Dot 0 format returned. Other serial buses are RS485 and USB.

WIRELESS EXAMPLES

Several wireless versions were tested. The simplest (Fig .4) is an extension of the serial point-to-point method shown in Fig. 3 with a wireless transceiver replacing the RS232 interface. Data transmitted via the Internet is the same (Dot 0).

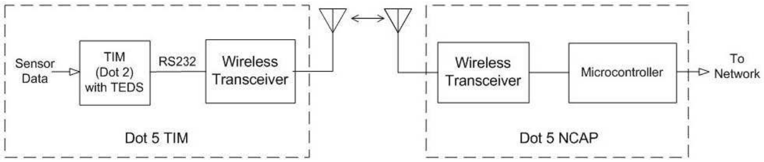


Fig. 4 Point-to-point Wireless

Another popular wireless network, this one a multi-node, mesh network, uses Zigbee (Fig. 5).

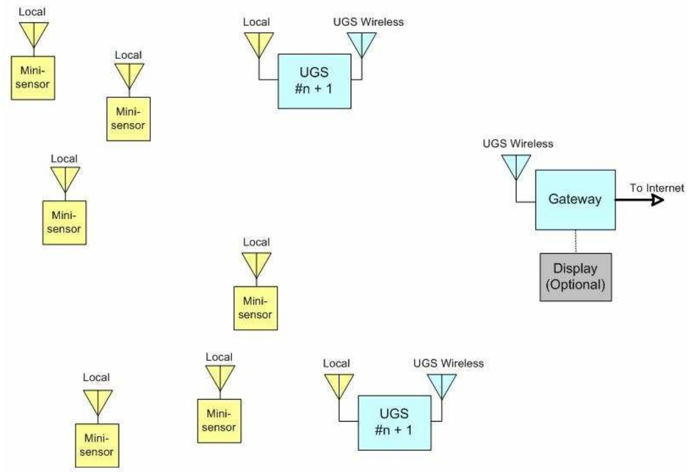


Fig. 5 Zigbee Mesh Network System

This, along with WiFi, Bluetooth, and 6LowPAN are specified under the IEEE 1451.5 standard. The primary network protocol is specified under the wireless network specification and the Dot 5 just adds the reformatting so that all respond to common sensor commands and protocols (Dot 0). A prototype Dot 5 TIM was made by reprogramming a wireless manufacturer's evaluation module with the addition of a temperature sensor.

DOT 4 – TEDS ONLY VERSION

Another IEEE 1451 option is a simplified TEDS-only version (IEEE 1451.4 or Dot 4). The Dot 4

Fig. 6 Wireless Sensor with Dot 4 TEDS

TEDS is usually used with analog sensors (e.g. accelerometers) but also these small size TEDS may be used for networks, such as low-power wireless, which have limited bandwidth. The Dot 4 basic TEDS section is only 8 bytes (plus the built-in UUID of the 1-wire EEPROM in which the TEDS is stored).

To conserve battery power, the short Dot 4 version of the TEDS is used for the local wirelessly transmitted data and the NCAP expands this to the fuller Dot 0 format on the Internet (Fig. 6). A virtual TEDS stored at another location (perhaps accesses via a URL) is another option.

SENSOR STANDARDS HARMONIZATION

The IEEE 1451 standard is the basic sensor format (fusion level 0) standard for various network protocols used on the Internet. A key feature of the IEEE 1451 (Dot 0) standard is that the data (and meta-data or TEDS) of all transducers are communicated on the Internet with the same format, independent of the sensor physical layer (wired or wireless) as shown in Fig. 7.

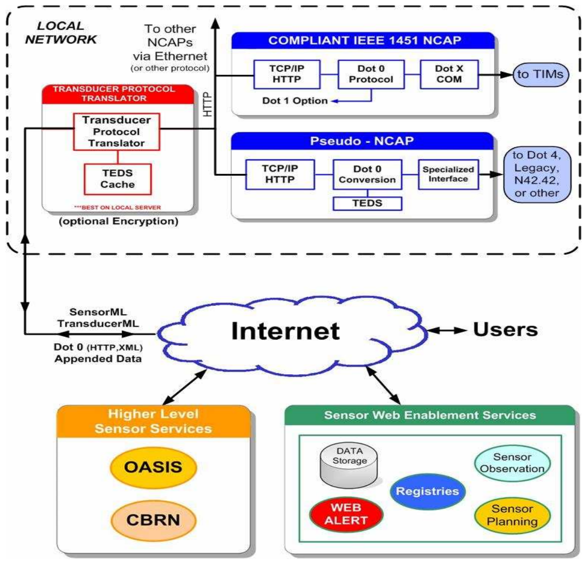


Fig. 7 Internet Sensor Protocols with IEEE 1451 base

A software gateway provides the translation from Dot 0 to other standards, such as Transducer Markup Language (TML).

SUMMARY

The NIST-supported IEEE 1451 smart transducer open standard was described and illustrated with several examples of a TIM and NCAP.

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