IEEE 1451 SMART TRANSDUCER STANDARDS: STATUS, GOING WIRELESS, AND PULLING IT ALL TOGETHER

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ABSTRACT

There are seven parts of the Institute of Electrical and Electronics Engineers (IEEE) 1451 Smart Transducer family of standards either approved, in work, or in review. These documents are providing a nonproprietary set of standards for the implementation of smart transducers (i.e., sensors and actuators). This paper overviews these standards and their status. In particular, the IEEE P1451.5, which addresses wireless transducers, and the IEEE P1451.0, which will provide a common high level architecture for the entire family, will be discussed. A reference model, which is being used as a focus for the IEEE P1451.0, will be introduced to help show the relation between all the members of the family.

KEYWORDS

IEEE 1451, Smart Transducers, TEDS, Wireless Transducers

INTRODUCTION

The IEEE 1451 family of standards addresses smart transducers. This paper overviews the seven current members of this family and provides status on each. The word ?smart' in this context means different things to different people. There are, in some sense, two aspects of adding intelligence to a sensor. The first of these is simply the ability to communicate with the sensor over a network or through another form of direct communication. The second of these, local processing, places some electronic intelligence at the sensor site itself, allowing some level of data fusion, process control, or self tests to be implemented. The IEEE 1451 standards address the communications aspect that must be in place in order to take full advantage of any local processing ability. Indeed, if there is a standard method of communication, then individual manufacturers can innovate in regards to local processing.

Within the working groups, it is normal to refer to the different standards as 'the dots'. Thus, 'dot 1' refers to IEEE 1451.1 and 'dot 2' refers to IEEE 1451.2, etc. Formally, a 'p' is added to the title in order to indicate that the standard is still in a 'proposed' state and is not formally approved yet. Thus, the IEEE P1451.5 has not been approved, whereas the IEEE 1451.1 has.

The dot 2 was the first to be approved, although the dot 1 was well on its way at the time. Since then, the number of dots has grown. The dot 1 was intended to be an overriding architecture for the other family members. Unfortunately, the working groups for the other dots did not have a member that knew the details of the dot 1 well enough to provide the link back into the dot 1. Thus, some of the working groups implemented their standards without a strong tie to the dot 1 and the family is less cohesive than desired. The dot 0 was established to try and bring the family members back into a cohesive group. Consider figure 1, which presents the dot 0 reference model and depicts the relation between the different members.

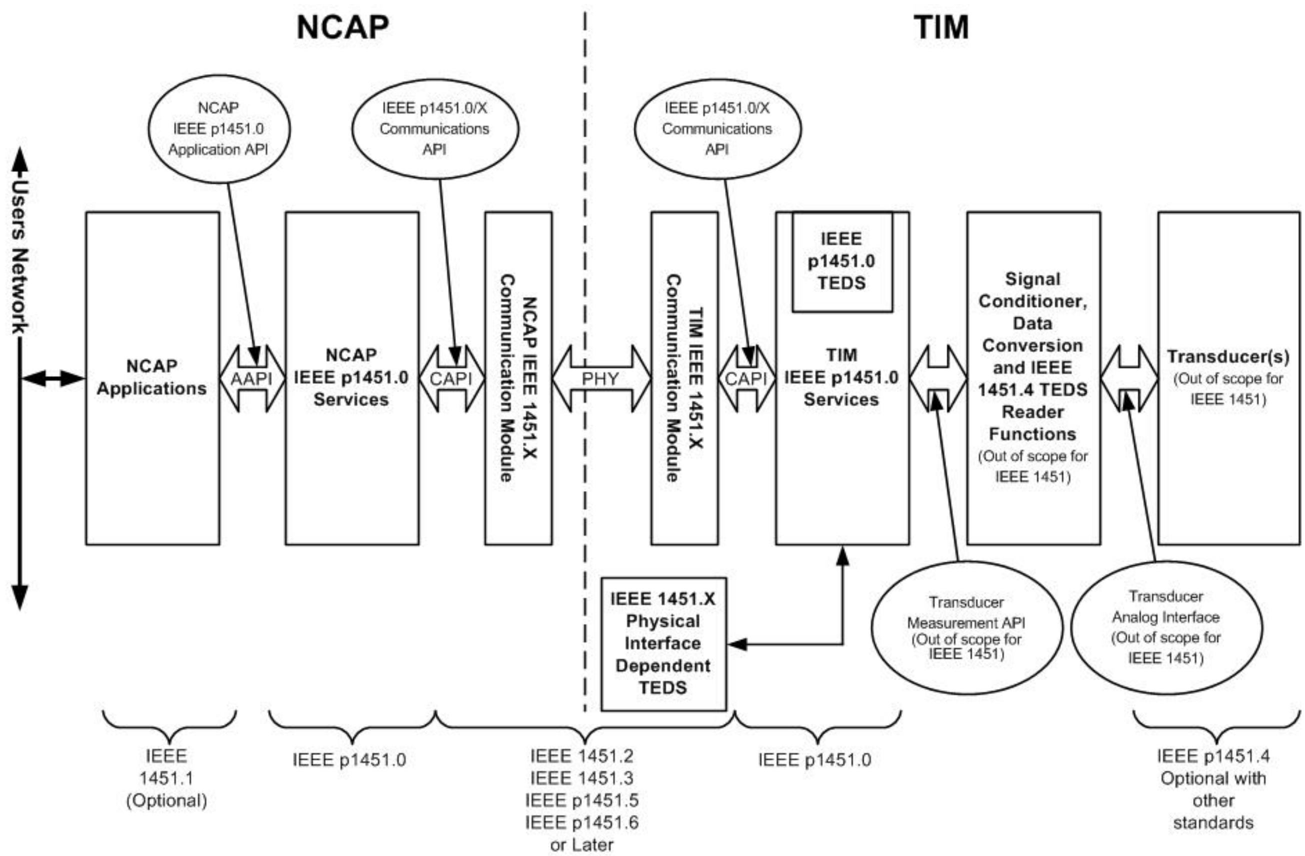

Figure 1 – IEEE P1451.0 Reference Model

For the purposes of this paper, it is not necessary to understand every detail of this figure so let us focus on the high points. On the left is the network, which can be thought of as the main access for users or applications. This access is accomplished via the network capable application processor (NCAP). This communicates with the transducer (on the right) via the transducer interface module (TIM). The original concept of the NCAP was to have a standard hardware module for each different network (e.g., Ethernet, fiber channel, etc.) that would communicate in a standard way with the TIMs. That way, a transducer manufacturer could build a TIM that could plug into any network by simply providing the appropriate NCAP.

Focus now on the middle of figure 1. The dots 2, 3, 5, and 6 are different physical layers (e.g., multidrop bus, wireless, etc.). The dot 0 intends to provide the common functionality that is physical layer independent and is represented as the logical interaction on either side of the physical layers. The dot 1 is a higher level application view of transducers. The dot 4 is kind of the orphan child that serves a purpose but fits into this scheme differently than the other family members. Note that the dot 1 and dot 4 are labeled 'optional' and that the rest of the reference model can stand alone without them.

IEEE 1451.1

Full Title: Standard for a Smart Transducer Interface for Sensors and Actuators - Network Capable Application Processor (NCAP) Information Model

Status: Approved 1999, about to enter 5-year review.

Description: This provides a high level, object oriented, application model for transducers. It was intended to be used as a basis for the other family members. Due to lack of input from knowledgeable players, the other family members have not incorporated this as much as they could have. Its most notable contribution is the NCAP. However, with the advent of the dot 0 and the participation of a dot 1 knowledgeable working group member, this high level model is being reinvigorated. It appears that the dot 0 will provide a reasonable link between the dot 1 and the other family members.

IEEE 1451.2

Full Title: Standard for a Smart Transducer Interface for Sensors and Actuators - Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats

Status: Approved 1997, in 5-year review.

Description: Although technically, this standard allows for multiple transducers per Standard Transducer Interface Module (STIM), it is mostly built around the concept of a single transducer interfacing to a network. It defines a ten-wire interface to the transducer and requires an NCAP for every STIM. Five years after its approval, it is clear that this standard has not been as successful as desired. The author's opinion is that this is for two reasons. First, the ten-wire interface is just not commercially viable (many sensors only need two wires to function). Second, the required TEDS defined are much too large – providing another commercial difficulty. As part of the required five year review, the working group is addressing both of these issues. They are currently considering adding other physical interfaces (most notably RS232) that will necessitate distinct changes to the TEDS as well. Further, the dot 0 working group is working closely with the dot 0 to try to define common functionality among the family. The biggest contribution this standard has made is the introduction of the TEDS; some form of TEDS has been incorporated into every other family member.

IEEE 1451.3

Full Title: Standard for a Smart Transducer Interface for Sensors and Actuators - Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems

Status: Approved 2003, published 2004.

Description: The 'multidrop' in the title can be translated as 'sensor bus.' It is possible to have 256 transducers per bus and 254 buses per NCAP. One of the considerations was to try and limit wiring and this was partially implemented by transmitting power and data over the same wire. Specifically, the standard endorses the use of HomePNA™. This is a readily available chip set that manufacturers can use to develop the smart transducer interfaces. There are several manufacturers actively implementing this standard now that it is approved and there is quite a bit of hope that this standard will become a success.

IEEE 1451.4

Full Title: Standard for a Smart Transducer Interface for Sensors and Actuators - Mixed-Mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats

Status: Approved 2004, awaiting publication.

Description: This member kind of sits on the side of the rest of the family. It addresses the issue that there are times when receiving the direct analog signal from a transducer and digital communication are both desirable. This is true, for example, when the transducer is directly hooked to an oscilloscope. (All the other family members assume a complete digital interface; that there is an analog to digital or digital to analog processor directly attached to the sensor.) The basic approach is to be able to switch between analog and digital communications by reversing polarity on the standard two wires most transducers have. (Methods for doing this with transducers having more than two wires are also defined.) This family member stands by itself more than the other members do. However, it would be possible to use this standard to define the low level interface to the transducer as indicated in figure 1. There are several manufacturers actively implementing this standard now that it is approved and there is quite a bit of hope that this standard will become a success.

IEEE P1451.5

Full Title: Standard for a Smart Transducer Interface for Sensors and Actuators - Wireless Communication Protocols and Transducer Electronic Data Sheets (TEDS) Formats

Status: In work, target completion in 2005.

Description: This standard introduces wireless interfaces and is very much awaited by the market. The working group conducted a requirements survey and asked for initial implementation proposals. The working group felt that offering multiple choices was the best way to meet the diverse requirements identified in the survey, therefore the group decided to support multiple wireless protocols. Further, different existing protocols have different applications in terms of distance, number of nodes, security, and quality of service. As of the time of writing there are subgroups working on defining smart transducer interfaces for IEEE 802.11, IEEE 802.15.5, and Bluetooth. Anyone wishing to form a subgroup for another wireless interface is welcome to submit a proposal. Another significant decision was to fully support the concept of the IEEE 1451.0. That is, the dot 5 is working closely with the dot 0 to develop the structures that are felt to be common among the different family members. An indicator that this family member will be a success is that members of the different subgroups are also members of the associated standards committees. That is, this working group includes members of the IEEE 802.11, IEEE 802.15, and Bluetooth working groups. There is a strong feeling that these complementary technologies need to have a clean interface defined.

IEEE P1451.6

Full Title: Standard for a Smart Transducer Interface for Sensors and Actuators - A High-speed CAN open-based Transducer Network Interface for Intrinsically Safe (IS) and Nonintrinsically Safe Applications

Status: Project Authorization Request (PAR) approved Mar 2004, target completion in 2006.

Description: This standard will define an interface for intrinsically safe transducers. That is, for applications where it is not safe to have high voltage or amperage (e.g., sensors in fuel tanks). This working group has also stated a desire to use the common functionality defined by the dot 0. Otherwise, this group has just formed and has not done much work yet.

IEEE P1451.0

Full Title: Standard for a Smart Transducer Interface for Sensors and Actuators – Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats

Status: In work, target completion in 2005.

Description: The dot 0 is intended to bring the different family members back into a coherent set of standards. A guiding principle is that, from the user's perspective, it should not matter what physical layer (or what family member) is used to actually access a given sensor. A user simply wants to be able to configure, control, and receive data from transducers. The reference model in figure 1 is a way of focusing on the relation between the family members, but the real emphasis of the dot 0 is on a common or core set of TEDS and a common command set.

The TEDS is the electronic version of standard data sheets, although they can potentially contain much more information than was ever on a piece of paper. This includes everything from serial number and manufacturer to calibration data and, potentially, full control documentation. At the time of writing there are four required TEDS:

1. Meta-TEDS
2. Transducer Channel TEDS
3. Commissioning TEDS
4. End User Application Specific TEDS

and eight optional TEDS:

- Three calibration-related TEDS
- Five text-based TEDS

Each of the physical layer members of the family would be expected to define their own physical layer TEDS.

The common commands are divided into these categories:

1. Initialization Commands
2. Operational Commands
3. Set Operating Mode Commands
4. Read Operating Mode Commands
5. Run Diagnostic Commands
6. TEDS Access Commands
7. Manufacturer-Defined Commands

The dot 0 is still being developed so none of the TEDS or commands are fully defined. However, the foundation has been laid. There are members from each of the other family members active in the dot 0 working group and there is real commitment to making the dot 0 a full partner in the family of standards. With any luck, the next couple of years will see the IEEE 1451 family mature and become common in the marketplace.

SUMMARY STATUS

IEEE 1451.	Status
0 – Common Functionality	In work, target completion 2005
1 – Object Model	Approved, close to 5-year review
2 – Single Transducer	Approved, in 5-year review
3 – Multidrop (Sensor Bus)	Approved
4 – Mixed Mode	Approved, awaiting publication
5 – Wireless	In work, target completion 2005
6 – Intrinsically Safe	PAR approved Mar 04, target 2006