IEEE 1451 and IEEE 1588 Standards

Contact: Kang Lee (kang.lee@nist.gov or kang.lee@ieee.org),
Chair of IEEE I&MS TC-9, Technical Committee on Sensor Technology

1. Brief description:

The family of smart transducer interface standards, under the designation of IEEE 1451, was created by the IEEE Instrumentation and Measurement Society's TC-9 Technical Committee on Sensor Technology. The main goal of the IEEE 1451 standard was to define a set of common communication interfaces to standardize the connectivity of **transducers (sensors and actuators)** to instruments, instrumentation systems, or control/field networks, which allow the access of transducers via local area networks or the Internet. The family of IEEE 1451 standards can be used to build sensor networks with devices, such as sensors and actuators, and can **facilitate device and data interoperability** in the realm of the Internet of Things (IoT), Industrial Internet of Things (IIoT), and Cyber Physical Systems for applications ranging from smart grid to smart building to smart manufacturing to smart healthcare to intelligent transportation systems to any systems that involves sensors and actuators and sensor networks and their applications.

IEEE 1451 standardizes two interfaces – a transducer device interface and a transducer network interface. The transducer device interface is the interface between a transducer device and a network device, whereas, the transducer network interface is the interface between a network device and user applications.

Clarification: In IEEE 1451 terminology, a transducer device is known as IEEE 1451 TIM (Transducer Interface Module), or recognized by many as a sensor node in industry. A network device is known as IEEE 1451 NCAP (Network Capable Application Processor), or recognized by many as a network node or a gateway device.

IEEE 1451 also defines a set of metadata, called **Transducer Electronic Data Sheets (TEDS).** TEDS contain manufacture-related information about the transducers, such as manufacturer ID, serial number, measurement ranges, calibration data, location information, and more. TEDS allow the self-identification and self-description of transducers to the system or network.

The IEEE 1451 suite of standards provides a set of common interfaces that enable transducer manufacturers or users to support different networks, allow users to pick transducer devices and networks for their applications based on merits, and help users to solve the transducer devices to networks interchangeability and interoperability problems.

IEEE 1451 enables users
1) to access any transducer devices in wired or wireless networks or Internet using a common set of commands and replies in standardized messaging formats, and the data returned in standardized data and physical units in XML format.

2) to "plug and play" of transducer devices to a network and to achieve sensor data interoperability at the application.

See Figure 1 below for the relationship among the family of IEEE 1451 standards and their interfaces.

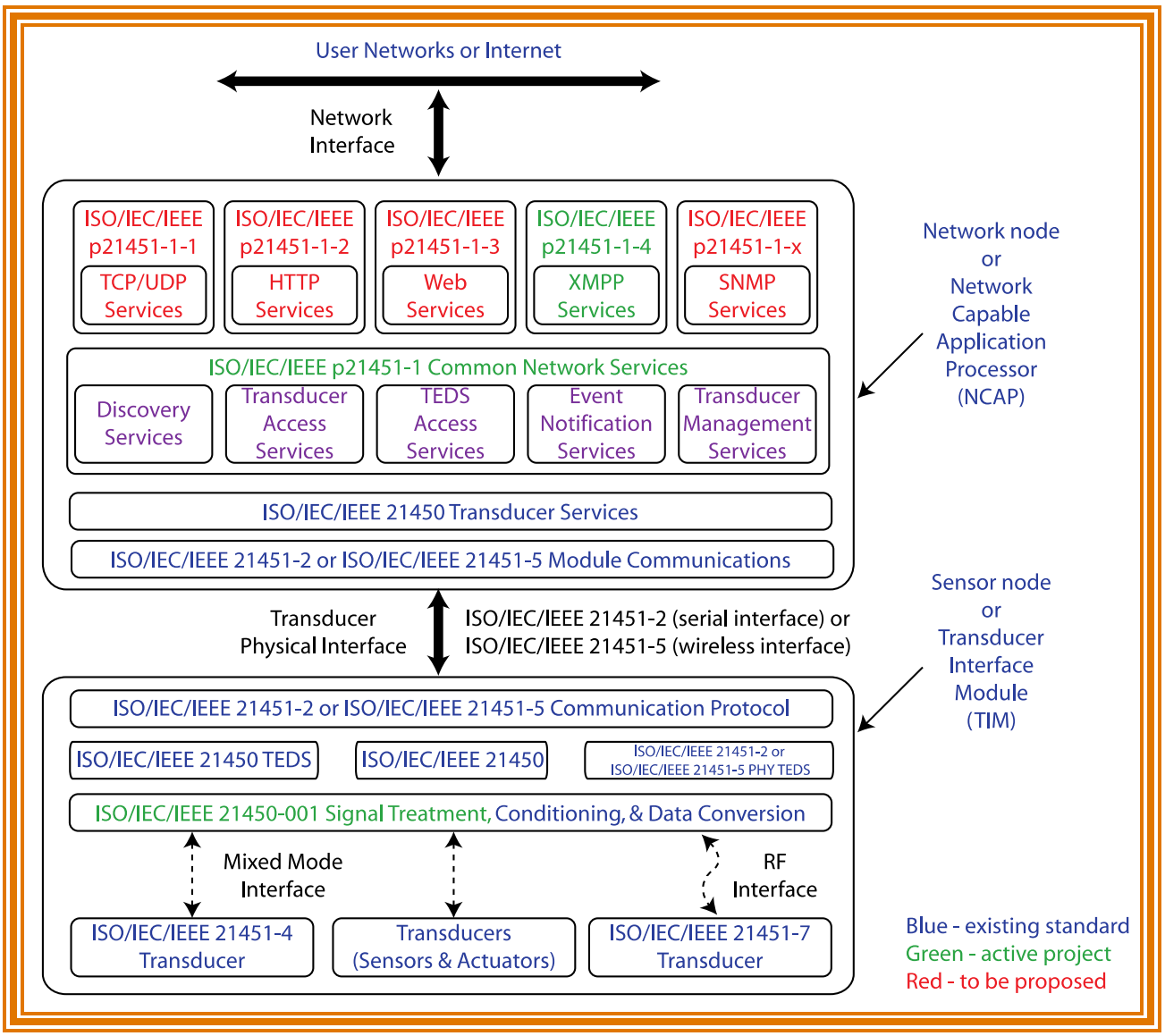

Figure 1. IEEE 1451 Family of Standards and Interfaces

2. The IEEE 1451 family of standards:

1. The IEEE 1451.0 standard defines a set of common functionality, commands, and Transducer Electronic Data Sheets (TEDS), for the family of IEEE 1451 smart transducer standards. This functionality will be independent of the physical communications media. It includes the basic functions required to control and manage smart transducers, communications protocols, and media-independent Transducer Electronic Data Sheet formats.
   Website: http://grouper.ieee.org/groups/1451/0/

Status: the standard is in publication since 2008. It was also designated as ISO/IEC/IEEE 21450 standard.

2. The IEEE 1451.1 defines a set of common network services for smart transducers. These common network services, defined for IEEE 1451 smart transducers, communicate transducer and relevant information through a network via various network communication protocol services providing transducer discovery, transducer and TEDS data access, event notification, and transducer management services to support the interoperability of networked smart transducers.

   Status: Standard in publication since 1999 and a revision is in progress, aiming to be revised and balloted by 2016. It was also designated as the ISO/IEC/IEEE 21451-1 standard.

3. IEEE 1451.2 defines a digital sensor interface for connecting a transducer module, containing sensors and actuators, to a network. The previous version of the standard is being revised to include serial interfaces, such as SPI, I2C, and RS-232/UART. This interface standard works with the IEEE 1451.0 standard for sensor and actuator access.

   Status: Standard in publication since 1997 and a revision is in progress aiming to go into balloting in 2016. It was also designated as the ISO/IEC/IEEE 21451-2 standard.

4. IEEE 1451.4 defined a mixed-mode interface (MMI) that allows the transfer of analog sensor signal and digital TEDS on the same wires. The standard specifies a "one-wire" protocol for MMI. It also defined a multiple wires protocol to support bridge-type transducers. In operation, initially the transducer sends the TEDS information in the digital mode, and then it sends analog signal on the same wires (Class 1) to the instrumentation systems or networks. In Class 2 operation, the TEDS and transducer data are sent simultaneously in parallel wires.

   Status: Standard was approved in 2004. It was also designated as the ISO/IEC/IEEE 21451-4 standard. A revision is in progress, aiming to be balloted in 2016.

   > The IEEE-SA Registration Authority has set up a website for online registration and purchase of Unique Registration Numbers, manufacturer IDs, and templates for sensors based on the IEEE 1451.4 standard. See more detail at http://standards.ieee.org/regauth/1451/index.html

5. IEEE 1451.5 is a wireless communication interface standard for transducers. This project aims to establish a standard for wireless communication methods and data format for transducers. The standard adopts existing popular wireless communication protocols, such as IEEE 802.11x (WiFi), IEEE 802.15.1 (Bluetooth), IEEE 802.15.4 (ZigBee), and 6LowPAN. The 6LowPAN is an IP-driven protocol (IPv6 compatible) that allows direct access of transducers from the Internet.

Status: The standard in publication since 2008. ISO/IEC/IEEE 21451-5 standard is aimed to be revised and balloted in 2016-17.

6. IEEE 1451.7 specifies communication methods, command set, data formats and Transducer Electronic Data Sheet (TEDS) for sensors working in cooperation with Radio Frequency Identification (RFID) systems. This document does not outline, recommend, or prescribe any specific air-interface protocol. It is intended to be air-interface agnostic.

   Status: Standard is in publication. It is also designated as the ISO/IEC/IEEE 21451-7 standard.

7. IEEE 1451.1.4 defines a method for transporting IEEE 1451 messages over a network using eXtensible Messaging and Presence Protocol (XMPP) to establish session initiation, secure communication, and characteristic identification between networked client and server devices using device meta-identification information based on the IEEE 1451 Transducer Electronic Data Sheets (TEDS). The current implementations of sensor and actuator systems do not provide a means of secure session initiation and are limited to transport of native Internet Protocols (IPs) to a local network. The purpose of this standard is to provide session initiation and protocol transport for sensors, actuators, and devices. The standard addresses issues of security, scalability, and interoperability. This standard can provide significant cost savings and reduce complexity, leveraging current instrumentation, and devices used in industry. This project will facilitate technology agnostic and protocol independent transport of data over wired or wireless networks including the Internet.

   Status: Standard development is in progress. It is also designated as the ISO/IEC/IEEE 21451-1-4 standard.

8. IEEE 1451.001 defines recommended practices for signal processing algorithms and data structure for smart transducers in order to share and to infer signal and state information of an instrumentation or control system. These algorithms are based on their own signal and also on the transducers attached to the system. The recommended practice also defines the commands and replies for requesting information and algorithms for shape analysis such as exponential, sinusoidal, impulsive noise, noise, and tendency. Smart transducers are the interfaces to the real world and they are at the source of measurements and signal generation. They generate raw data or transducer signals in an instrumentation or control system. There is no universal treatment for transducer signals that allow signal synthesis and analysis and a dialogue among transducers to validate the measurement processes and to provide a platform for data mining. This framework will allow smart transducers from different manufacturers to interchange signal information in order to infer states of the instrumentation systems, which help to achieve higher reliability and better real world inference. The application field is universal, including industrial, consumer, medical, health, and environment. The purpose of this project is to define a standardized and universal framework that allows smart transducers to extract features of the signal being generated and measured. With the definition of these practices, the raw

data can be converted into information and then into knowledge. In this context, knowledge means understanding of the nature of the transducer signal. This understanding can be shared with the system and other transducers in order to form a platform for sensory knowledge fusion.

Status: Standard development is in progress. This is a joint development with the IEEE Industrial Electronics Society. It is designated as the ISO/IEC/IEEE 21450-001 standard.

3. The IEEE 1588 standard:

1. IEEE 1588 is a standard known as Precision Time Protocol (PTP). It enables precise clock synchronization in networked measurement and control systems. The protocol supports system-wide clock synchronization accuracy in the sub-microsecond range. The standard is applicable in many areas, such as instrumentation and measurement, industrial automation, power generation and utility, avionic, communication and more. It allows high-precision time synchronization of sensor networks.

   Website: http://ieee1588.nist.gov

Status: Standard in publication as IEEE 1588-2008 and IEC 61588:2009(E). *Working group is convened to revise the standard to include higher timing accuracy in 100s of picoseconds and better security consideration and more.*

4. Where to obtain copies of the IEEE standards?

Where to Purchase the IEEE 1451 Standards

The IEEE 1451.X and IEEE 1588 standards can be acquired from IEEE Standard Purchase Online at: http://www.techstreet.com/cgi-bin/results
At the SEARCH box, enter the IEEE 1451.X standard that you want to acquire, e.g., “1451.7” and then push the “enter” key. Click to purchase the standard in the format needed (buy PDF or buy Printed Edition).

5. Summary of IEEE standards sponsored and developed by TC9

IEEE 1451 – Standard for a Smart Transducer Interface for Sensors and Actuators

- IEEE Std 1451.0-2007, Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats – *The Standard is in publication.*

- IEEE Std 1451.1-1999, Network Capable Application Processor (NCAP) Information Model -- *The Standard is in publication.*

- IEEE Std 1451.2-1997, Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats - *The Standard is in publication.*

- IEEE Std 1451.4-2004, Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats – *The Standard is in publication.*

- IEEE Std 1451.5-2007 Wireless Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats – *The Standard is in publication.*

- IEEE Std 1451.7-2010, Transducers to Radio Frequency Identification (RFID) Systems Communication Protocols and Transducer Electronic Data Sheet Formats – *The Standard is in publication.*

- IEEE Std 1451.1.4 Standard for a Smart Transducer Interface for Sensors, Actuators, and Devices - eXtensible Messaging and Presence Protocol (XMPP) for Networked Device Communication –*The standard is being developed.*

- IEEE Std 1451.001, Recommended Practice for Signal Treatment Applied to Smart Transducers –*The standard is being developed*.

IEEE Std 1588-2008, a standard for a precision clock synchronization protocol for networked measurement and control systems. – *The Standard is in publication. Working group is convened to update the standard to include higher accuracy in 100s of picoseconds and security consideration and more.*