IEEE 1451 Smart Transducer Standard for Sensor Interoperability

Workshop on

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The standard for the unit of mass the kilogram, is a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures near Paris. A duplicate in the custody of Manufacturing Engineering Laboratory, NIST serves as the mass standard for the United States.
Smart and Wireless Sensor (SAWS) Laboratory

• The SAWS Lab is established for the:
  – development, implementation, and evaluation and validation of smart and wireless sensor interface standard specifications.
  – development of test methods for sensor standards.

• Research and application areas:
  – IEEE 1451 sensor interfaces for instruments, computers, and networks,
  – remote and wireless sensing for machinery condition monitoring,
  – RFID for inventory control of instruments and equipment
  – Sensor and RFID integration
  – Time stamping and synchronization of instruments and networked systems
Industry is fast moving toward using networked, digital, and wireless communications technology for sensors, e.g.,

- U.S. Navy planning to use thousands of networked and wireless sensors in ships to reduce manning, enhance automation, and condition-based maintenance.
- Airplane manufacturers moving to use networked, wireless systems for sensor connectivity to lower life-cycle costs.
- Homeland security applications moving to use networked, wireless sensor systems for remote monitoring and situation awareness.

All these example applications are seeking open standards solutions.

Off-shore monitoring of environmental condition, pollution, and oil spills could benefit from using these standards.
IEEE 1451 Smart Transducer Interface System Approach

1451.X Transducer Interface Module (TIM)

- XDCR
- ADC
- DAC
- D I/O
- Address Logic

Transducer Interface (wired or wireless)

Network Capable Application Processor (NCAP)

- 1451.0 Common Commands
- p1451.1 Network Interface (STWS, HTTP, Client-server, Pub-sub)

Network Interface

Any Network

Physical parameters to be measured

A mix of up to 255 sensors & actuators in a TIM

XDCR = sensor or actuator
IEEE 1451 Suite of Standards
(support different physical interfaces and configurations)

Network

Network nodes

IEEE 1451.1 1451.0 NCAP

IEEE 1451.1 1451.0 NCAP

IEEE 1451.1 1451.0 NCAP or Instrument

IEEE 1451.1 1451.0 NCAP or Access Point

IEEE 1451.1 1451.0 NCAP

Wireless Communications Protocols:
- 802.11 (WiFi)
- 802.15.1 (BlueTooth)
- 802.15.4 (ZigBee)

IEEE P1451.7

Tag

Sensor-integrated RFID

Point-to-Point

Distributed Multi-drop Bus

Analog Signal + Digital TEDS

Wireless

S = Sensor or Actuator
T = TEDS

IEEE 1451.2 1451.3 1451.4 1451.5

MicroLAN 1-wired Interface

IEEE 1451.1 1451.0 NCAP

TII / UART
How do IEEE 1451 Standards change the paradigm of using transducers?

TEDS - standardize Transducers Electronic Data Sheets for sensors and actuators
- Enable self-identification of transducer
- Know physical units to use (e.g., pressure in Pascal, temperature in K, etc)
- Provide calibration information
- Allow command for triggering transducers
- Integrate the concept of measurements with transducers
- Enable group of measurements and readings
- Help how to make measurements
- Help how to interpret measurements
IEEE 1451 Stack

- Encoding
- Compression
- Authentication
- Routing

- IEEE 145.0 HTTP Protocol
- IEEE 1451.1-1999
- STWS (Smart Transducer Web Services)

- Measurement Abstraction
- TEDS Mgmt & Correction
- TIM Behavioral Model
- TIM Discovery
- TIM Communication Abstraction

- Message Fragmentation and Reassembly
- Encoding
- Security
- Routing

- Physical transducer interface
- Signal Conditioning
- Triggering
- Data Conversion (A/D and D/A)
**Transducer Electronic Data Sheets (TEDS)**

TEDS, a memory device attached to the transducer in a TIM, stores transducer identification, measurement range, calibration, correction data, user and manufacture-related information.

Different TEDS are defined:
- Meta-TEDS
- Transducer Channel TEDS
- Physical TEDS
- Calibration TEDS
- Frequency Response TEDS
- Manufacturer-defined TEDS
- End User Application Specific TEDS
- Geo-location TEDS
- and more….
Benefits of Having a TEDS with a Transducer

Having TEDS will

- enable self-identification and self-description of sensors and actuators.
- help self-configuration of sensor system.
- simplify field installation, upgrade, and maintenance of sensors by simple “plug and play” of devices to instruments and networks.
- provide self-documentation.
- enhanced support for Conditioned-Based Maintenance (CBM) systems.
IEEE 1451 Provides

Standard ways to connect sensors and actuators to networks and instruments that facilitate

*Interoperability*

Network Level Interoperability
Through STWS

Sensor Level Interoperability
*(IEEE 1451.0 and 1451.x)*
What Is STWS?

STWS (Smart Transducer Web Services) is a set of web services for IEEE 1451 smart transducers. The STWS includes:
- NCAP Discovery
- TimDiscovery,
- TransducerDiscovery,
- ReadTransducerData,
- ReadGeolocationTEDS, and
- ReadTimMetalDTeds services.

The STWS is based on the IEEE 1451.0 transducer services.
The STWS is described in WSDL (Web Services Description Language)
The STWS provides standard-based sensor interoperability (XML, SOAP, WSDL,…)
Web and Network Access of IEEE 1451 Sensors and Actuators

IEEE 1451 NCAP

IEEE 1451 TIM

IEEE 1451.0 HTTP Protocol

IEEE 1451.1 TEDS

IEEE 1451.0 Services

IEEE 1451.0 Transducer Services

IEEE 1451.X PHY TEDS

IEEE 1451.X PHY layer

Smart Transducer Web Services

NCAP IEEE 1451.0 Transducer Services

NCAP IEEE 1451.X Communication Module

TIM IEEE 1451.X Communication Module

TIM IEEE 1451.0 Services

Signal Conditioning and Data Conversion

Transducer

1451.0 TEDS

1451.X PHY TEDS
Integration of IEEE 1451 with OGC-SWE and Ocean Instruments (Demo architecture)
Ocean Sensor Demo Layout:
1 - Sensor App
1 - OGC-SOS
1 - STWS Client
1 - STWS
4 - NCAPs
10 - TIMs
41 - sensors

STWS Client
SOS
OGC-SOS
STWS
STWS Application (SOS Client)
IEEE 1451.0 HTTP
MBARI NCAP
Kiel NCAP
Bremen NCAP
Barcelona NCAP
Seabird CCD
(Water temperature, Conductivity, Pressure, Salinity)
Ocean Weather Station
(speed, direction, Water temperature, Humidity, Precipitation, Air Pressure, Air temperature, Sea level, Surface downwelling)
Ocean Weather Station
(speed, Water temperature, Humidity, Surface downwelling)
Seabird CCD
(Temperature, Conductivity, Pressure, Salinity)
WetLabs Triplet
(Chlorophyll, Turbidity, Turbidity)
XR-420 CTD
(Temperature, Conductivity, Pressure)
Dummy Instrument
(Dummy1, Dummy2, Dummy3)
SeaBird
(Temperature, Conductivity, Pressure, Salinity)
Sensor Standards Harmonization Working Group

Meet quarterly with participation and coordination:

- IEEE
- OGC
- ISA
- Industry
- US Government
  - NIST
  - national labs
  - DHS
  - DoD
  - DoJ
  - …

[Diagram showing sensors and interfaces]
For More Information About
TC-9 Sponsored IEEE Standards

- Contact: Kang Lee at kang.lee@nist.gov

- IEEE 1451 websites:
  - 1451 smart transducers: http://ieee1451.nist.gov
  - 1451.0 common commands: http://grouper.ieee.org/groups/1451/0
  - 1451.4 mixed-mode transducers http://grouper.ieee.org/groups/1451/4
  - 1451.5 wireless sensors http://grouper.ieee.org/groups/1451/5
  - 1451.7 sensor RFID integration: contact Kang Lee

- STWS paper – contact Kang Lee or http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4553885


- Published IEEE standards can be purchased at http://standards.ieee.org/reading/ieee/std/numerical.html