INTEROP

PLUGFEST 2020

INTEROPERABILITY PLUGFEST

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INTEROP 2020

IES STANDARDS
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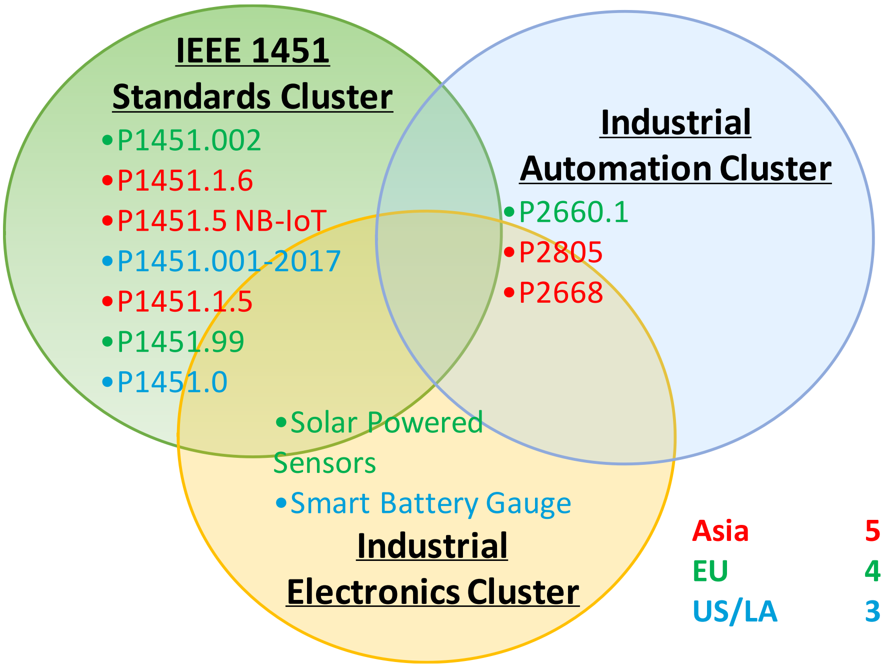
INTEROPERABILITY PLUGFEST



Industrial Electronics Society – IES Standards TC
Standards Technical Committee

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About INTEROP

The INTEROP Plugfest was introduced by the Industrial Electronics Society's (IES) Standards Technical Committee in 2018 as an initiative for the Society's community to participate in a practical and demonstrative fashion in interoperability and potential standards compliance applications.

This event is in conjunction with IES' yearly flagship conference, the Industrial Electronics Conference (IECON)

This is especially targeted to the society's academic and industry collaboration partners to come together in a physical neutral environment conducive to open technical discussions. The goal is to provide periodic gatherings of like-minded members to discuss progressive results and new ideas.

First INTEROP at IECON2018 – Washington DC - USA

This year, 2020, will be the third edition in the INTEROP Plugfest yearly series. The first two were successfully held in Washington, DC, USA at the IECON 2018 (October 21 – 23, 2018), and in Lisbon, Portugal at IECON 2019 (October 14 – 17, 2019). The inaugural event in 2018 had eight participants, followed by eleven participants in 2019.

This year's INTEROP Plugfest is held at IECON 2020 in Singapore on October 18 – 21, 2020. Due to the worldwide Covid-19 pandemic, the IECON 2020 conference is held as a virtual conference, where the INTEROP Plugfest is held as a virtual event as well.

The Objectives of the INTEROP Plugfest are three-fold.

First, to provide the IES Standards community with onsite verification and validation platforms for the standards so the community can test their development of their applications to these benchmarks, ensuring compliance and interoperability to their systems in IES fields of interest. The goal of these platforms is to support users with "turn-key approaches" to their applications, by providing relatively effortless initial start-up processes, allowing easy installation and configuration

Second, provide a forum for demonstrations and prototypes for interoperability and standards. In addition, a forum for onsite IES standards working groups sessions for active standards discussions and development

Third, to encourage industry partners to participate in IEEE Standards by providing verification and validation platforms for standards compliance and interoperability in the industry context.

Lastly, and most importantly, the long term goal is to provide stable or permanent validation and compliance Centers of Expertise (COE) for industry and academia use, distributed globally under IES Standards support.

Second INTEROP at IECON2019 – Lisbon – Portugal

This edition of 2020 INTEROP Plugfest features eleven participants at IECON 2020. They are listed here.

We welcome our participants and their Plugfest demonstrations, briefly elaborated in this brochure.

We thank you and your support to the IES Standards initiative and to the IES Standards Technical Committee and to the Industrial Electronics Society.

INTEROP Plugfest 2020 Organizers:

Victor Huang, Allen Chen, Dietmar Bruckner, Jing Bing Zhang

INTEROP 2020 PRESENTATION DAY 1

Group ID	Group	Organizer	Presentation time on 19 Oct 2020	Cluster/IOP
Session Chair (Victor Huang), 10:30 -12:00				
1	*P1451 Family*	*E. Song/K. Lee, NIST, USA*	*10:30am*	*A*
2	*Smart Battery Gauge*	*B. Balagopal/M. Y. Chow, NCSU, USA*	*11:00am*	*C*
3	*P1451.5 NB-IoT*	*Tsang (ASIA)*	*11:30am*	*A*
BREAK, 12:00 – 14:30				
Session Chair (Dietmar Bruckner), 14:30 -16:30				
4	*P2805 Edge Computing*	*W. Dai, Shanghai Jiaotung Univ., China*	*2:30pm*	*B*
5	*P1451.1.5 SNMP*	*J. Wu (IMS), Shanghai Jiaotung Univ, China*	*3:00pm*	*A*
6	*P1451.99 Harmonization*	*P. Waher/G. Kuppa, Trust Anchor Group/IEEE India, Sweden/India*	*3:30pm*	*C/A*
7	*P2660.1 Industrial Agents*	*P. Leitao, Polytechnic Institute of Braganca, Portugal*	*4:00pm*	*C*

INTEROP 2020 PRESENTATION DAY 2

Group ID	Group	Organizer	Presentation time on 20 Oct 2020	Cluster/IOP
Session Chair (Allen Chen), 10:30 - 12:00				
1	*1451.001-2017 Signal Treatment*	*G. Monte, U. Tecnological Nacional, Argentina*	*10:30am*	*C*
2	*IEEE 1451 & IEC 61499 interoperability*	*R. Abrishambaf, U. Miami, Ohio, USA*	*11:00am*	*C*
3	*P1451.1.6*	*H. Nishi, Keio University, Japan*	*11:30am*	*C*
BREAK, 12:00 – 14:30				
Session Chair (Victor Huang), 14:30 - 16:30				
4	*P2668 IDEX*	*K. F. Tsang, City University of Hong Kong*	*3:00pm*	*A*
5	*P1451.002*	*A. Espirito-Santo, U. da Beira Interior, Portugal*	*3:30pm*	*C*
6	*Distributed Smart Transducers for Industrial Automation*	*H-P. Bernhard, J. Kepler U. Linz, Austria*	*4:00pm*	*C*

Short Papers Collection

Distributed Smart Transducers for Industrial Automation

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***Abstract*— Over the last years, smart transducers (sensors or actuators) were dramatically improving in performance and cost efficiency. However, transducers are still not readily incorporated into factories for automation, given reservations regarding the interoperability of different vendor devices. The IEEE P1451 standard was developed to unify the description and manipulation of transducers to solve this problem. Here, we show the advantage of interoperability among multi-vendor transducers. It is achieved by implementing IEEE P1451 transducers services interface hosted on network capable application processers (NCAP). Furthermore, it presents the implementation of Plug-and-Play functionalities in NCAP for wireless transducers interfaces (WTIM).**

Introduction

Improved performance and cost efficiency of sensors has led to widespread sensor applications ranging from industrial automation to remote environmental monitoring [1]. Fast and easy access to sensing data and information across heterogenous sensor networks is important for the correct functioning and interoperability of many sensing applications. Interoperability can be defined as the ability of nodes to communicate and exchange sensor data effectively among multiple heterogenous networks [2]. This interoperability is difficult to achieve given the large number of sensor vendors and each network using different data formats and interfaces. To use defined data formats derived from standardized description and simple flexible interfaces are the key elements of solutions to this challenge.

The family of ISO/IEC/IEEE 21450/21451 or IEEE P1451 standard provides a solution for enabling interoperability. It defines a set of common interfaces and standardized message formats added on to smart transducer nodes. Hence, these heterogenous smart transducers can communicate in wired or wireless networks which creates a vendor neutral communication environment [3-5]. IEEE P1451 wireless sensor network consists of network capable application processor (NCAP) and several wireless transducer interface modules (WTIMs). Here a transducer can be a sensor, or an actuator. A transducer module is considered "smart" (STIM), if it is described by a machine-readable transducer electronic data sheets (TEDS), has digital control and outputs and provides triggering, status, and control for proper functioning of the transducer. A WTIM provides the command and data interfaces to a single transducer or multiple transducers.

To demonstrate this remote interoperability, we employ the IEEE P1451-1.6 MQTT services for communication between an IEC 61499 control application running on the NCAP at Silicon Austria Labs in Austria and sensors at University of Beira Interior in Portugal. The demonstrator uses the IEEE P1451 common network services at the NCAP to read data and TEDS from the sensors. The demonstrator is used to evaluate the interoperability of different sensors with the NCAP irrespective of specific locations and vendors by using the IEEE P1451 family of standards.

Standard Overview

If IEEE P1451 is applied to wireless sensor networks (WSNs) several WTIMs communicate with one NCAP. The NCAP is operating as a gateway for the attached nodes to the user network. All WTIMs in the WSN are devices containing transducers, signal conditioning, ADC conversion and a non-volatile memory to store the node information in a TEDS. The TEDS contains meta information, information to calibrate the sensing channels and configuration information of a radio interface along with information to identify individual WTIMs.

An NCAP has a network interface to connect to the external user network (IEEE P1451-1.x) and offers the transducer services which allow common control commands between the NCAP and WTIM (IEEE P1451-0). The communication module implements the physical communication capabilities for smart transducers e.g. in wired IEEE P1451-2 or wireless networks IEEE P1451-5. Common network services including discovery, transducer data access, TEDS access, event notification and transducer management in order to address, control map all available WTIM devices. Additionally, the common network services allow "plug-and-play" capabilities to add new transducers into the operated network.

Material and Equipment

In this section, the components used in the demo are described, which are listed below.

- UBI setup
    - RaspBerry Pi 3b+ (NCAP)
    - MSP-EXP430f5529 (TIM)
- SAL setup
    - Raspberry Pi 4 (NCAP)
    - NORDIC nRF52840-Dongle (WTIM)
    - Laptop (Dashboard Application)

- IEEE P1451 Parts
  - IEEE P1451-0
  - IEEE P1451-1

Raspberry Pi's were used to host standalone NCAPs. A STIM was implemented on MSP-EXP430f5529 board from Texas Instruments. It provides data from temperature sensors, and LED states. A WTIM network using nRF52840-Dongles from NORDIC Semiconductor is implemented within SAL. Additionally, a dashboard application developed in Node-Red is hosted on a laptop. The TI communication API and transducer services were implemented according to the definition provided in IEEE P1451-0 and IEEE P1451-1.

Demo Structure

In this section, we describe the setup, components, and implementation of the interoperability demo for IEEE P1451 systems, see Figure 1. The demo contains two NCAPs independently developed and deployed. One NCAP is deployed at University of Beira Interior (UBI), Portugal, which will be referred to as UBI NCAP. It integrates a voltage sensor, temperatures sensors, and 6 LEDs to interact with. The NCAP is hosted on a Raspberry Pi 3b+ Model. The TIMs and NCAP are serially connected via standard UART port.

Another NCAP is located at Silicon-Austria Labs (SAL) in Linz, Austria, which will be referred to as SAL NCAP. It integrates a temperature sensor and a LED through a WTIM. The NCAP is hosted on a Raspberry Pi 4. The NCAP was developed using a component-based design approach of IEC 61499 programming language. A dedicated function block (FB) library was developed to implement IEEE P1451 transducer services and common network services. The FBs allow iterative development and testing of the transducer services in an IEC 61499 application.

An IEC 61499 control application was developed to connect with IEEE P1451 transducer FBs to standard NCAP devices. Here we interconnect UBI NCAP and SAL NCAP devices. These FBs at the NCAP utilize IEEE P1451-1 common network services to read data and TEDS from the remote transducers. The demo is a simple control application to monitor the temperature values from UBI NCAP and SAL NCAP and to set the status of LEDs if the temperature values overshoot certain threshold. A dashboard application for visualization of temperature values, LED status, and TEDS was developed for the demo.

The dashboard and the control application are the consumers of IEEE P1451 transducer service interfaces provided by UBI NCAP and SAL NCAP. Service interfaces are exposed to the communication network by MQTT protocol. A general scheme for MQTT Pub/Sub topics and message structures to map IEEE P1451 transducer services was proposed in the demo. For example, a MQTT Pub/Sub topic for "readTeds" service interface may look like:

"IEEEP1451/TransducerServices/TedsManager/ReadTEDS/*NCAPId*/*TIMId*/*ChannelId*/MetaTEDS"

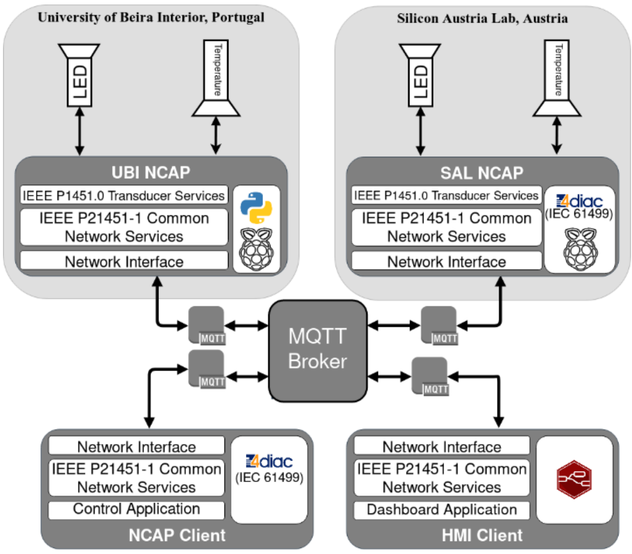

Figure 1 Interoperability demo setup

In the topic "NCAPId", "TIMId", and "ChannelId" are used as placeholders of unique identification for NCAPs, Transducers and channels connected to the NCAPs. NCAP publish their TEDS on specific topics (e.g. MetaTEDS, TransducerChannelTEDS, UserDefinedTEDS etc) with retain flag set to true. It enables a broker to store the last published message and push it to later subscribing clients. This feature is extremely valuable for all the static data of the TEDS.

Outlook

As this is ongoing work we aim towards integrating smart agriculture applications of smart sensors to collect real farm data together with Keio University. At SAL, we are also developing a solution to support "Plug-and-Play" functionality between WTIMs and NCAPs.

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Industrial Edge Computing InterOP Demo

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***Abstract*—With digital transformation in the industrial automation domain, runtime intelligence could be introduced in industrial applications. Compared to cloud computing for big data processing and analysis, industrial edge computing suits better for low-latency and high-reliability scenarios. The IEEE P2805 standard series provide a reference for self-management, data processing, and cloud-edge collaboration for edge computing nodes. In this demo, an early demo of the sorting and warehousing system is presented with these protocols applied.**

Introduction

With the development of Industry 4.0 [1] and the Industrial Internet [2], factories have a higher demand for flexible and intelligent production systems for various industrial applications. Industrial Internet consists of a combination of cloud computing and edge computing that edge part takes extra care from the real-time and the security perspective [3].

Industrial edge computing changes traditional communication, computing, and storage methods by introducing more flexible network topology, real-time data optimization, and intelligent decision-making to traditional industrial automation and monitoring systems [3]. Industrial applications not only rely on the powerful computing capabilities of industrial clouds but also integrate the real-time computing capabilities of edge devices [4]. The IEEE P2805 edge computing standards can realize self-management, data processing, and cloud-edge collaboration for machine learning for edge computing nodes. Also, the deployment of hybrid cloud-edge applications provides great convenience for the operation and maintenance of industrial applications. This demo provides a smart factory production scenario based on edge computing, which can realize automatic deployment of industrial applications, edge data acquisition and analysis, and cloud-edge collaboration.

Standard Overview

The IEEE P2805 standards make use of edge devices (known as edge computing nodes, ECNs), that build connections between the physical world and digital world by acting as smart gateways for assets, services, and systems. It is divided into three parts.

The IEEE P2805.1 specifies the self-management protocols for ECNs. As the number of ECNs grows, the management of computing node networks and distributed applications will become a huge challenge. This part of the management protocol is aimed at the deployment of distributed applications between ECNs and edge gateways to reduce the complexity of user deployment. ECNs can make decisions based on current information and knowledge to deal with the real-time problems caused by communication delay from the industrial cloud.

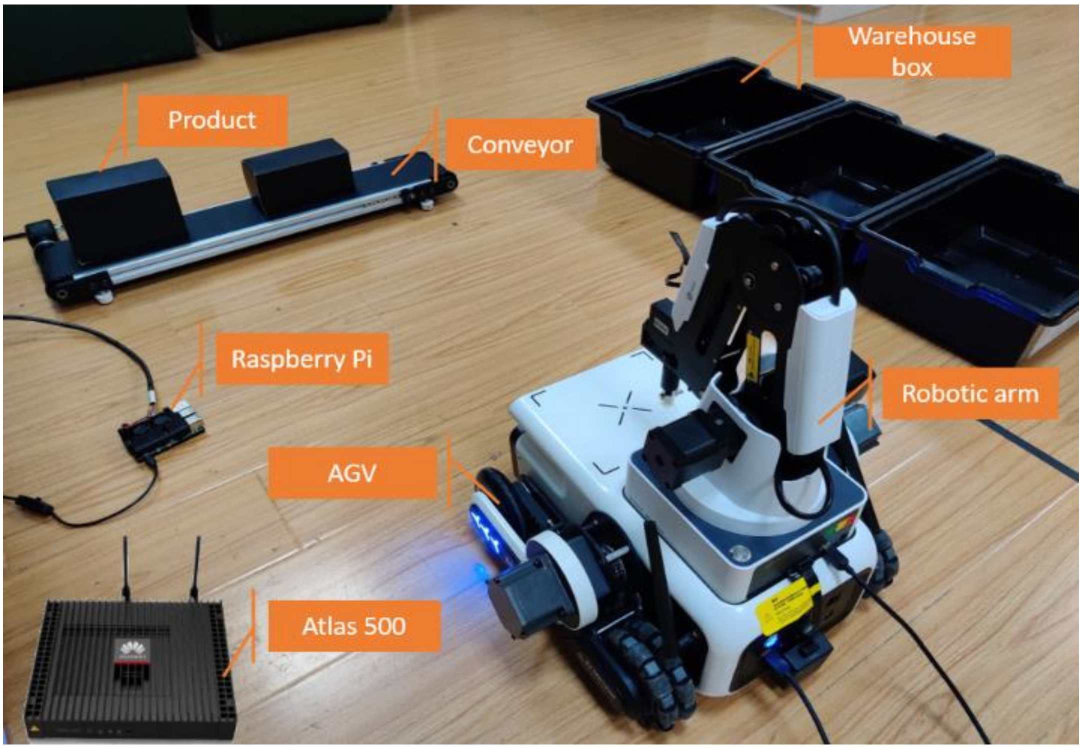
The ECNs as data-acquisition entry points usually generate massive amounts of real-time process data. Therefore, the IEEE P2805.2 is proposed for data acquisition, filtering, and buffering protocols to perform data preprocessing. Through the data preprocessing operation, the data can be cleaned and compressed before it is forwarded to the industrial cloud so that the historical data can be analyzed efficiently and the production process can be optimized.

The IEEE P2805.3 focuses on cloud-edge collaboration protocols. This part provides an implementation reference of collaboration for machine-learning between industrial cloud and lower power, cheaper, embedded devices. It uses the container, such as Docker to pack up code and all its dependencies on edge gateways and ECNs. Besides, deployment of distributed machine learning models and online optimization are covered by this standard.

Material and Equipment

Three types of actuated devices including a robotic arm, AGV, and conveyor are used in the demo that uses an AGV and two raspberry Pi boards to manage the robotic arm and the conveyor. In addition to the above three edge nodes, a gateway is added to improve interaction efficiency between cloud and edge nodes. The brief introduction of the used equipment is described as follows:

- *Robotic Arm*: The DOBOT Magician is a multifunctional desktop robotic arm with different end-effectors. It supports not only multiple motion modes in both the joint coordinate system and Cartesian coordinate system but also secondary development by various extensible I/O interfaces.
- *AGV*: EAIBOT LEO is a ROS-based automatic guided vehicle designed for practical training education with various sensors like gyroscope and laser radar. It can be integrated with the robotic arm to realize



complex functions. Besides, it also supports secondary development in its Ubuntu system.

- *Conveyor*: The conveyor kit for DOBOT Magician with adjustable speed and the photoelectric sensor is a perfect tool to create a highly effective simulated production line.
- *Raspberry Pi*: Raspberry Pi is integrated with the robotic arm and conveyor, making them capable of communication and storage.
- *Gateway*: Huawei Atlas 500 acts as an edge gateway in this demo. Having great efficiency in interaction with cloud and other edge devices, it is a perfect middleware in cloud-edge interaction.

Demo Structure

The intelligent industrial system completes the sorting and warehousing process through the collaboration of intelligent gateway, AGV, robotic arm, and conveyor. The specific process structure of the system is described as follows:

- According to the ECNs situation and requirements from the user, the industrial cloud conducts task decomposition based on P2805.3 protocols. It creates the industrial edge computing application and sends it to device 4 through Docker, and then distributes it to the other ECNs to decompress the Docker container and install the application.
- When receiving tasks from the cloud, the system starts to execute. Firstly, the conveyor begins to transport products with different specifications. The AGV carrying the robotic arm moves to the receiving position of the conveyor belt. Then the robotic arm recognizes the product specifications and catches it through a suction cup. Next, the AGV moves to the corresponding location and stores the product in the warehouse. Finally, the gateway checks its task queue to decide whether to schedule ECNs to the next round of storage.
- The ECNs perform data acquisition, data storage, and node self-management according to P2805.1/2 protocols. The real-time data are transmitted to the gateway and cloud for analysis and monitoring. Feedback information can be ECNs for dynamic adjustment and preventive maintenance.

Useful Links and Aditional Information

The equipment used in this demo can be reference at:

https://cn.dobot.cc/

https://edu.eaibot.cn/products/view/16.html

https://e.huawei.com/cn/products/cloud-computing-dc/atlas/atlas-500

Acknowledgment

Thanks the edge computing group from Huawei technology to provide the Atlas 500 edge node.

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Power Quality Analysis Using the Standard IEEE 21451-001-2017

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***Abstract*—This paper shows the application of IEEE 21451-001-2017 to the power quality analysis. The algorithms described highlight the benefits of this standard signal representation. Power quality monitoring is a hot topic since the worldwide increase of distributed generation systems. The novel algorithms presented are computed in time domain allowing an exact determination of events. A demo hardware was built to test algorithms developed in C language.**

Introduction

The monitoring of power quality on a grid has taken on extreme importance due to the increase in distributed generation experienced throughout the world. The main concept of a quality system is the measurement of the variables that affect the service. Electric grids are migrating to smart grids, which generate very dynamic operating patterns that require constant monitoring of supply quality.

With different levels of development, all countries are involved in this migration. In this transition to smart grids, the existing infrastructure of conventional grids designed for a unidirectional energy flow is used. Therefore, the measurement of power quality becomes essential given the multiple generation associated with the grid of diverse nature and power. Variations and disturbances on the electrical network can cause from inadequate operation, loss of efficiency due to production plant shutdowns, to the breakdown of connected devices and machinery.

This short paper presents how to apply the signal representation described in the IEEE 21451-001 [1] for detecting power quality events with high precision and simplicity.

Standard Overview

MCT sampling, described in the IEEE 21451-001, is a simple but effective algorithm that expose the information structure of a sensor signal. Instead of samples, the signal is considered as a union of simplified segments. By tracking rising and falling segments, it is straightforward to get maximum and minimum events. From signal segments, it is possible to resample it to conform a low pass version of the original waveform. Since there is no time shift, MCT allows algebraic operation combining processed signals. If MCT is applied, and if the reconstructed signal is subtracted from the original, the output will be the high frequency component of the signal with exact timing localization. The reconstructed signal spectrum is controlled by the iteration number and interpolation error applied to get signal trajectories.

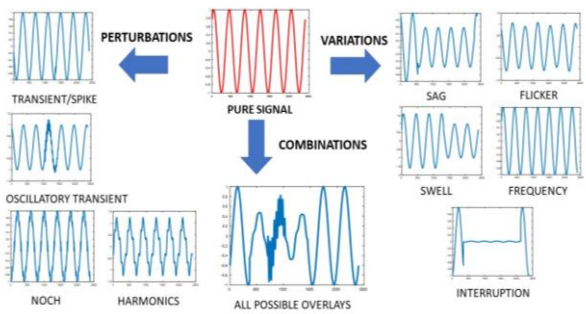


Fig. 1 Variations and perturbations that affect Power Quality.

Fig. 1 shows all the events that affect voltage waveform. Variations like, sags, swell, flicker and frequency are computed using the MCT iterated N_1 times, where N_1 is the iteration that achieves the expected number of maximums for the fundamental frequency.

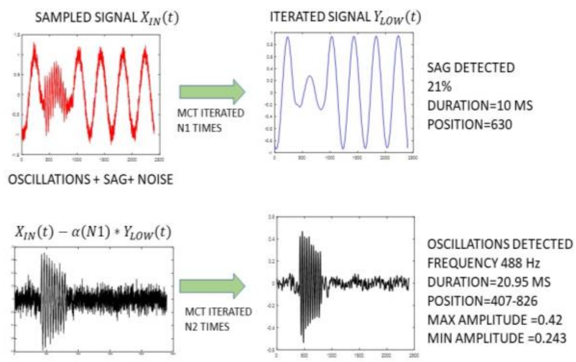
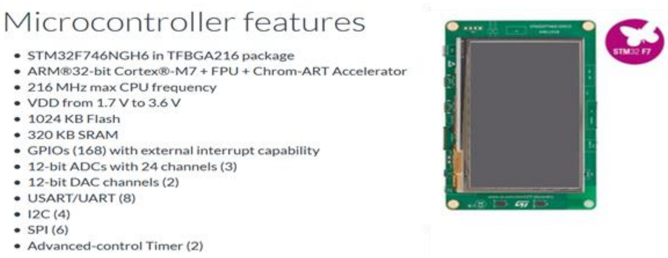
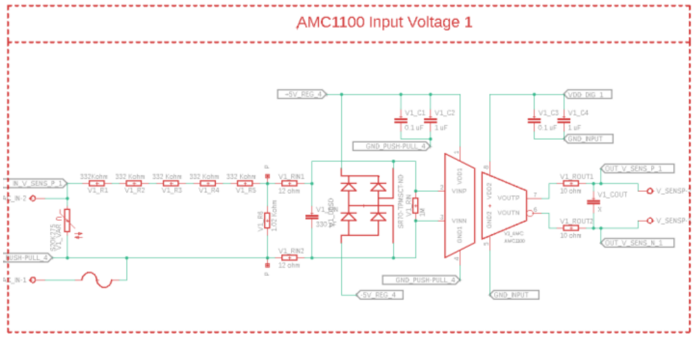


Fig. 2 Processing of a noisy signal with sag and oscillations.

Fig. 2 shows an example of application. The input signal has noise, sag, and oscillations. First, MCT is iterated over the input N1 times. From this output, all the possible variations are computed by triggering the corresponding algorithm. In this case, a sag is detected and processed.

For perturbation processing, the following operation is computed:





Voltage acquisition circuit

Demo Structure

$$Y_{HIGH}(t) = X_{IN}(t) - \alpha(N1) * Y_{LOW}(t) \qquad (1)$$

Where $X_{IN}(t)$ is the sampled signal, $Y_{LOW}(t)$ is the MCT iterated signal, and $\alpha(N1)$ is the inverse of the attenuation for N1 iterations at fundamental frequency. Then, $Y_{HIGH}(t)$ is processed by N2 iterations to reduce noise. Therefore, this signal is a band-pass filtered version of the sampled signal. On this new signal, the algorithms for spike, oscillations and notch events are executed. In Fig. 2, oscillatory pattern is detected by observing the time between maximums. When a regular pattern is found for three consecutive times and the maximums exceed a threshold, oscillations are detected and computed.

Material and Equipment

These algorithms were first simulated in MatLab using a model for Power Quality events [2] and databases of real events [3] [4]. After this stage, they were implemented into an embedded system based on a microcontroller ARM Cortex M7 [5]. The voltage acquisition is shown in the demo structure. It is based on an AMC1100 isolated amplifier [6] with a 0.075% of nonlinearity and 60 kHz bandwidth. The software was developed using the MBED [7] compiler.

Useful Links and Aditional Information

Additional information about the IEEE 21451-001-2017 can be found in [8], [9]. The fundamental frequency is calculated from the low pass filter signal $Y_{LOW}(t)$ by averaging the periods obtained with the maximums position. The ten seconds average fundamental frequency is reported according to the standard IEC 61000-4-30 [10].

Inside the structure of IEEE 1451 standard family, these algorithms run into the TIM (transducer Interface Module).

Acknowledgment

We want to thank Universidad Tecnologica Nacional, Facultad Regional del Neuquen for their support in this work.

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IEEE 1451 and IEC 61499 Interoperability

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***Abstract*—This demo focuses on the interoperability of smart devices (sensor and actuators) in the context of Industrial Internet of Things. IEC 61499 and IEEE 1451 standards are employed to address how two standards can interoperate and communicate efficiently by complementing each other. Both standards share common properties which are the essential elements of any IoT system. The Message Queue Telemetry Protocols (MQTT) is utilized to provide an interoperable network interface between the IEEE 1451 family of standards and the IEC 61499 standard. An interoperability test platform is given to show how both standards communicate efficiently for a simple read/ write automation process. (*Abstract*)**

Introduction

Interoperability is an essential property to support the integration between devices and systems inside the IoT, Industrial IoT (IIoT), Industry 4.0 (I4.0), and Cyber Physical Production System (CPPS). Smart sensors are contributing to extend the IoT concept supporting with more innovative solutions and higher potential of integration. This contribution can easily be found in various applications as the ones described next. The IIoT is supporting a new industrial revolution, denominated by I4.0, with great diversity and dispersion of information. Energy, water, and transport services are application examples where smart sensors collect information, that supports the entire decision-making chain, and optimize the quality and performance of services. Smart sensors in health care services can continuously detect problems or monitor the clinical state of an individual. Some tasks can be performed by smart sensors with reduced computational and memory resources. Sensor Network (SN) is a network of several smart sensors where each can gather data from its environment and process the collected data locally. This gives an ability to the nodes to perform local decision making independent from the constraints of the overall system. Therefore, each sensor node in a network can be an autonomous and intelligent unit, making decisions with an on-board microcontroller.

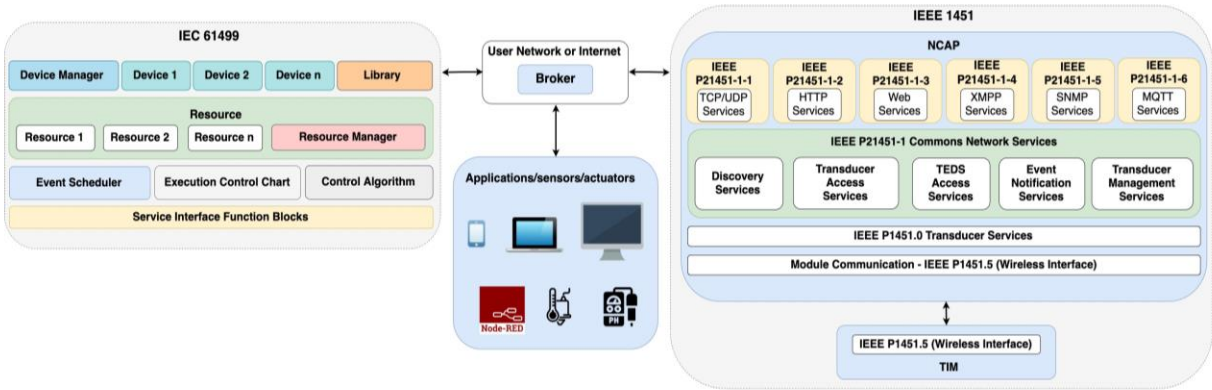
Due to the distributed nature of the sensor network, it has become one of the enabling technologies for distributed industrial measurement and control applications. Their use and effectiveness have been validated in process monitoring, fault detection, real-time data collection and location tracking applications. Recent technological developments have also proven the potential of merging actuators into the industrial SNs. That is, not only the sensors but also actuators can be integrated into sensor nodes in order to produce actions for controlling processes in industrial environments. The addition of the actuators can make nodes capable to monitor and control mechatronic devices. The nodes can act as gateways to the mechatronic devices to collaborate and enhance manufacturing operations. Design and implementation of SNs in manufacturing systems can enable adaptive and flexible automation and enable better process adaptability and quality control.

The main goal of this demo is to address the interoperability in distributed control and smart measurement systems, under the IoT umbrella, connected with the Cyber Physical System (CPS), and identify how these concepts can be addressed in an Industry 4.0 framework. The discussion leads to the proposal of a case study, concerning interoperability among the IEC 61499 and IEEE 1451, and show how they can complement each other, at any level of abstraction.

Standard Overview

IEC 61499 Function block has been recently adopted in Distributed Control Systems (DCS). It is developed by International Electrotechnical Commission in 2005 for Industrial-Process Measurement and Control Systems (IPMCS) [1]. Function Block (FB) was first utilized in IEC 61131 for Programmable Logic Controller (PLC) programming. However due to the lack of flexibility and reusability, it was modified and became as the basic building block and functional software unit in IEC 61499. It tends to be utilized for hardware-independent applications, in order to increase the interoperability and configurability between different device vendors.

The IEEE 1451 is a family of standards provides a roadmap to design and implement smart transducers. Its main goal is to combine data acquisition control systems with networking [2]. There is a collection of standards defined in the IEEE 1451 family which covers all the aspects of the smart transducers from physical to application layer. The IEEE 1451 smart transducers architecture is very similar to the ones already proposed in the industry. However, there are some differences which are added to the IEEE 1451 smart transducer. One is adding Transducer Electronic Data Sheets (TEDS), which facilitates the



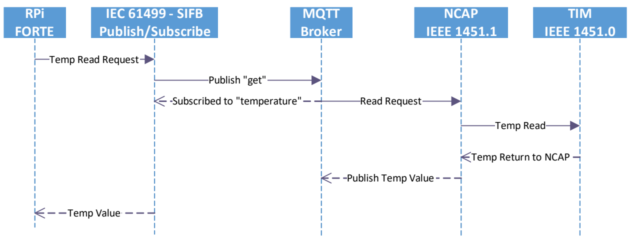
integration of the datasheets of smart transducers digitally. Second is the division of the whole smart transducer concept into two main sections: Network Capable Application Processor (NCAP) and Transducer Interface Module (TIM). The Transducer Independent Interface (TII) facilitates the connection between the NCAP and TIM.

Material and Equipment

To enable the interoperability between the IEC 61499 and the IEEE 1451 a semantic interoperable method by the determination of specific topics using the publish/subscribe paradigm was developed. The method enables that two or more different standards exchange information between them without changing the internal structure using a broker as an interoperable middleware.

- 4diac [3] and FORTE installed on Raspberry Pi
- Low power MSP430F5529 MCU as TIM
- Raspberry Pi 3 B+ as NCAP

Demo Structure



Acknowledgment

Helbert da Rocha and António Espírito-Santo works was supported by Project " INDTECH 4.0 –Novas Tecnologias para Fabricação Inteligente", project grant No. POCI-01-0247-FEDER-026653.

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A Platform for the Development and Validation of IEEE P1451 Standards

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***Abstract* — The fourth industrial revolution is supported by concepts such as the Internet of Things and Cyber-Physical Systems. Introducing these concepts, a digital representation of the factory and the production process is possible. The work of developing a new standard does not end with its approval and publishing. It should be known to industrial agents, who through educational examples, will identify the standard's potential application and advantages. A platform to support educational, development, and validation activities, and contribute to disseminating the IEEE 1451 family of standards is presented. The platform was developed using commercially accessible platforms and open-source tools, making it suitable for academic and research use. The platform was developed to allow devices not based on the IEEE 1451 family of standards to connect with devices that follow these standards**

Introduction

The development of a standard does not end with its approval and publishing. To be accepted by the industry, it must be clearly understood and the benefits achieved through its adoption are known. it is possible to observe that the IEEE 1451 family of standards was designed to allow the access of smart transducers to the users' network, meeting the requirements of Industrial 4.0 (I4.0). In addition, it will be desirable to have a platform that can be used to promote for it's the acceptance of these standards by the industry. The platform include hardware, firmware, software, and demonstration system that can to be used to construct smart transducers, provide communications with a user network, facilitates proper documentation and supports. The main aim is to contribute in the wide acceptance of the IEEE 1451 family of standards by the industry, taking the advantage of its features in I4.0.

Standard Overview

In industry, standards are essential manufacturers and users to follow, therefore, they must be accepted as a way to ensure devices and systems interoperability. The IEEE 1451 family of standards offers a set of specifications by which the requirements are established by I4.0. The main goal of this family of standards is to ensure the access of the transducers to the communication network, and, through it, support the exchange of information between the network elements. Production process elements connect to the user network by the Network Capable Application Processor (NCAP). The services provided by the NCAP allow the discovery of new Transducer Interface Modules (TIMs), which consist of transducers (sensors or actuators); the access to the information sent to, or received from, a transducer; the access to the information contained in the Transducer Electronic Data Sheet (TEDS); the notification of events detected by sensors, e .g., an alert function; and the management of transducers. The structure of the IEEE 1451 family of standards is described by the IEEE P1451.0 standard. Communications with TIMs can be achieved wirelessly, complying with the IEEE 1451.5 standard, using one of the following protocols: WiFi, 6LoWPAN, Zigbee, and Bluetooth]. Wired connections can use serial interfaces suggested in the IEEE P1451.0 standard The connection of the NCAP to the user network can use a variety of protocols: TCP/UDP, HTTP, XMPP, SNMP, and MQTT.

Characteristics and behaviors of TIMs are fully described by a set of TEDS attached in the TIM, some of which are mandatory, while other TEDSs are optional. Transducer channels associated with the TIM include sensor channels which acquire sensory information and actuator channels manipulate actuator for process control. Embedded transducer channels, which only exist inside the TIM, are used to control internal aspects of the TIM. The information associated with the transducer channel is located in the TEDS and can be read/write by a production process element through the NCAP

Material and Equipment

Hardware component

The IEEE P1451.0 defines a network interfaces that enable the passing of sensors and actuators information and data to the user network. The publish/subscribe and the client-server paradigms to communicate to the network is supported by the NCAP. Topics available in the broker need to be subscribed by the NCAP first, using the MQTT protocol, that implements the publish/subscribe paradigm, before it can be accessed. The NCAP receives the message and processes it. This produces a command that is sent to the TIM that owns the temperature sensor, through a wired or wireless communication link, as shown in Fig. 1. Moreover, the NCAP can receive the commands from the application to directly access the TIMs. Whenever this command is sent to a TIM, the TEDS stored in that TIM are returned. Two communication media between the NCAP and the TIM are supported. The first one is a wired communication based on the UART, which establishes a physical connection between the Raspberry Pi 3 B+ and the MSP430F5529 board, the last one from Texas Instruments. The second possibility is a wireless connection implemented using the eZ430-RF2500, also from Texas Instruments. The eZ430-RF2500 radios are used to transmit the packets from a radio connected to the Raspberry Pi to the radio connected to the MSP430F5529 board, without a

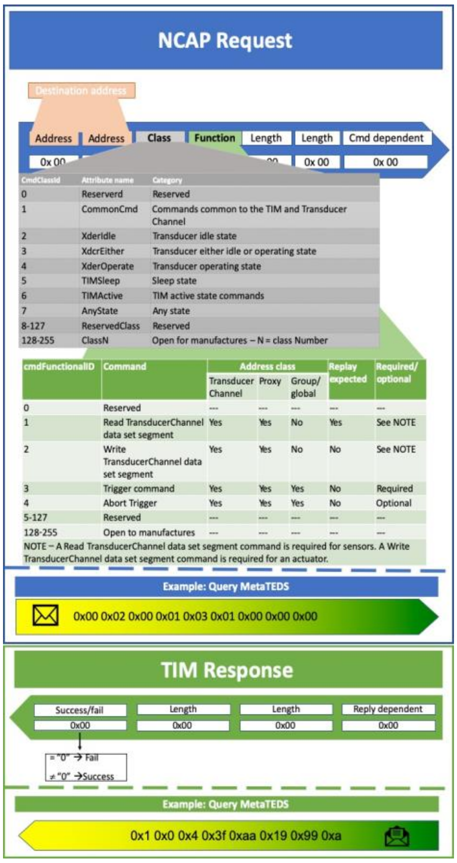

Fig. 1. Command sent from the NCAP to a TIM.

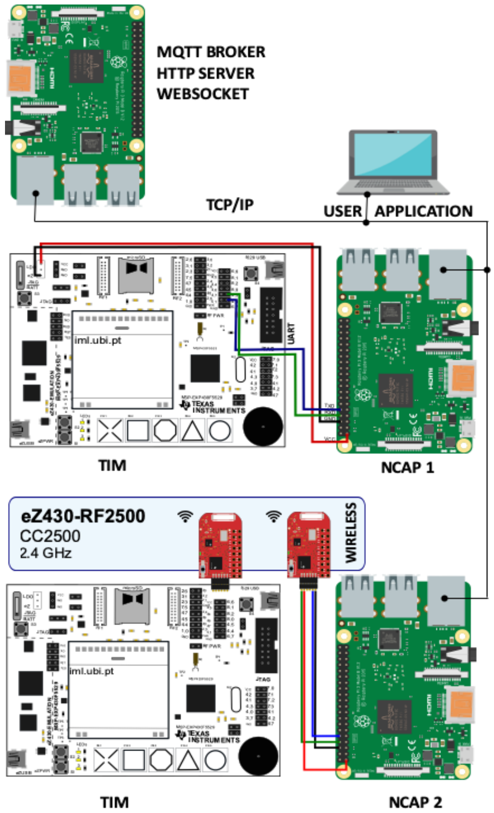

Fig. 2. Platform environment

communication protocol between them as shown in Fig. 1.

Software application and firmware

The user's application was developed by employing the following programming languages: Hypertext Processor (PHP), JavaScript, HiperText Markup Language (HTML), and Cascading Style Sheet (CSS). All data are stored in a MySQL database installed on a Raspberry Pi, which operates as a server. The user's application was developed using a WebSocket that connects to a Mosquitto broker, installed on a Raspberry Pi, that handles all the messages exchanged.

DEMO STRUCTURE

The data that can be accessed as an MQTT subscriber are the temperature, voltage, and LEDs states of the MSP-EXP430f5529, from Texas Instruments. The board is designated as a TIM and the Raspberry Pi 3b+ as the NCAP. We use serial communication through the UART port. There are two implementations of the NCAP. In the first one, the commands are published as bytes to topics, and the NCAP responses bytes to the corresponding topics. The second, the commands are published as text and the NCAP interprets the commands, and responses are converted

Implementation 1

To get and set the data: The first line represents the topics to publish and the second line is the command. The last topic represents the method '/Get' to request data, '/Set' to set data. Both implementations allow one command at the time, to request data publishes to the topics using the last topic '/Get' and subscribes to the same topic structure removing the '/Get' off the end.

Example: Read TEDS

Publisher: INTEROP/IEEE1451/NCAP2/ReadTEDS/MetaTEDS/Get
Subscriber: INTEROP/IEEE1451/NCAP2/ReadTEDS/MetaTEDS

Implementation 2

To get and set the data: The first line represents the topics to publish, and the second line the command. The last topic represents the method '/Get' to request the data, '/Set' to set the data.

Example: Get Voltage

Publisher: INTEROP/IEEE1451/NCAP2/Voltage/Get
Subscriber: INTEROP/IEEE1451/NCAP2/Voltage

USEFUL LINKS AND ADDITIONAL INFORMATION

Additional information about this demo can be found at http://iml.ubi.pt.

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INTEROP 1451 Plugfest

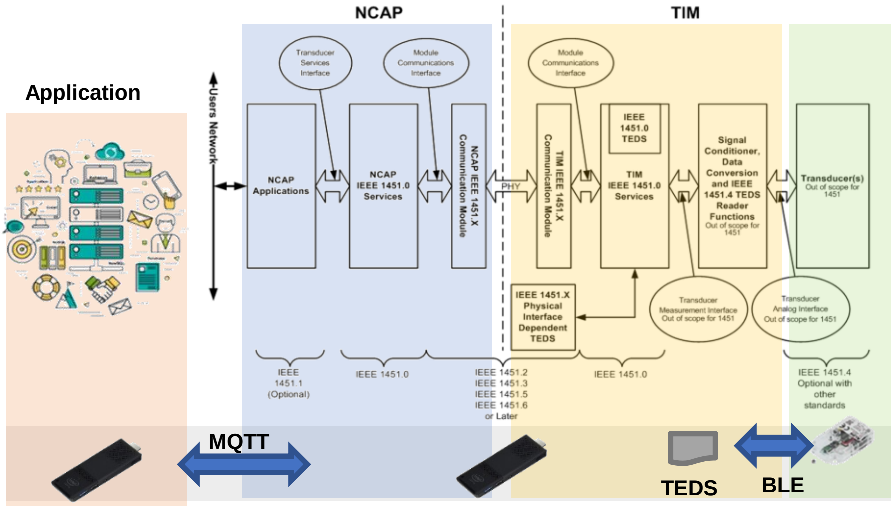
IECON 2020

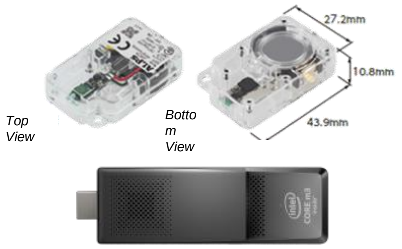
Keio University / Waseda University / NARO

West Lab Computing and Networking

IEEE1451-1-6 pilot implementation and interoperable demos

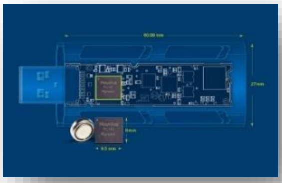
- Sensor
  - Multiple sensor modules with BLE of ALPS Electric Inc are used. The module has temp., humid., pressure., illuminance, UV, and 6-axis acceleration / geomagnetic sensors.
- TIM: Transducer Interface Module
  - The demo system is designed with Python on CentOS8.2 and Intel Computing Stick. TIM manages sensor modules and exchanges sensory data and Transducer Electronic Data Sheet (TEDS), including sensor specifications with external application servers via NCAP.
- NCAP: Network Capable Application Processor
  - Application Processor for connecting with other networks, especially with the Internet, is used. IEEE21451-1-6 uses MQTT for distributing sampled data and TEDS. In this demo, TIM and NCAP are implemented in one stick style PC.





- Request-Response style communication
  - In addition to the conventional MQTT publish-subscribe style messaging, request-response style messaging like HTTP, which sends messages in response to the received messages, is supported. MQTTv5 allows this style of communication by supporting key-value message format. In this style, the requested client indicates the destination topic of the response message.
- Time Synchronization
  - For achieving time synchronization, timestamps must be sent when requested. MQTTv5 fulfills the requirement by allowing to send key-value style timestamps on the request-response communication.

- MQTTv5 Broker
  - MQTT is a simple and popular protocol for IoT devices. While general communication protocol uses peer-to-peer and server-and-client based communication, MQTT supports publish-and-subscribe style communication through MQTT broker. MQTT uses a topic to index communication like a socket.
  - mosquitto >1.6 supports MQTT v5, and it enables request-response style MQTT message, and 1451-1-6 supports this feature for sensor data distribution, TEDS distribution, and new time-synchronization function. MQTTv5 advanced in security, authorization, and usability. MQTT v5 Request-Response feature was used for TEDS distribution.
- Protocol Conversation system on Edge for IoT protocols
  - IoT systems use various application protocols, such as MQTT, XMPP, and CoAP. The contention of communication protocols raises interoperability problems. For maximizing the use of IoT systems, protocol conversion is indispensable. Application protocol conversion methods for supporting various IoT protocols was proposed and demonstrated. It supports various protocols simply but has enough conversion function was prepared. It supports high-throughput processing and high flexibility in its conversion rule description. The special intermediate description eliminates the conversion design cost.
- Edge AI
  - Intel Neural Computing Stick 2 is an application-specific hardware accelerator as a neural computing engine. It has 16 powerful processing SHAVE Core and high-throughput memory fabric. Intel OpenVINO fully supports this hardware accelerator. The result is also handled as sensor data, and some super parameters can be given and controlled by TEDS and NCAP operators, respectively.



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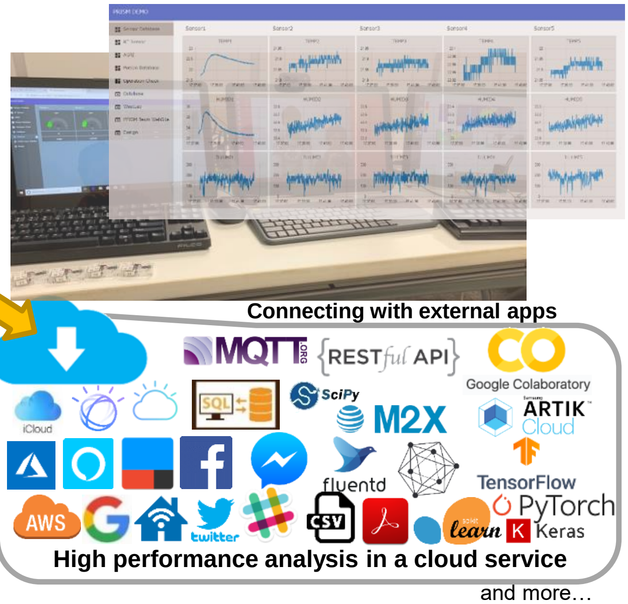
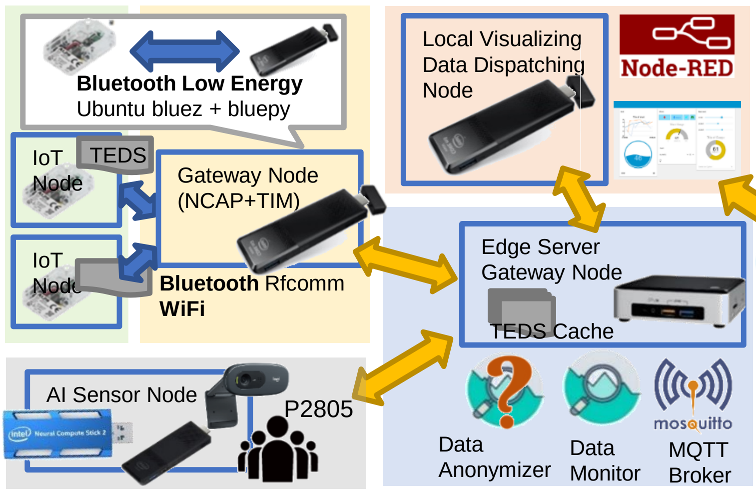
1451 + MQTTv5 + IoT + Edge + AI
for
Cyber-Physical System Platform + Smart Agriculture

Keio University / Waseda University / NARO

West Lab Computing and Networking

IEEE1451-1-6 pilot implementation and interoperable demos





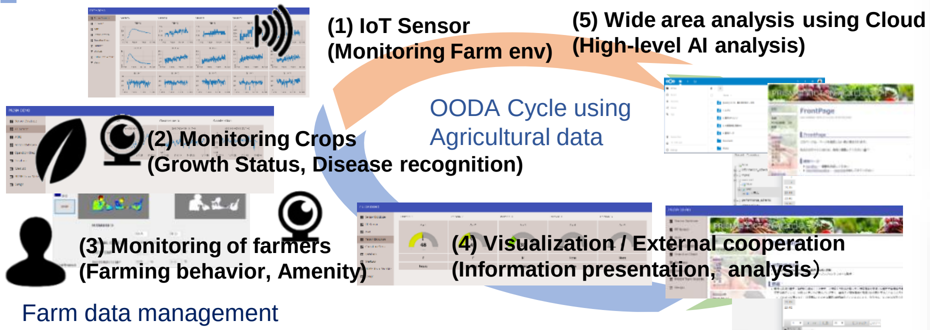
Cross-ministerial Strategic Innovation Promotion Program, Japan

Intelligent Processing Infrastructure of Cyber and Physical Systems

SIP

- For establishing Physical Space Digital Data Processing Platform
  - A highly sophisticated cyber-physical system, which is the key to establish Society 5.0, is required to collect, process, and use the data from physical space. This platform gives a solution to technical problems for establishing a cyber-physical system. It also gives a common platform to provide solutions for those who are not familiar with IT technologies. The penetration and use of this platform give a solution to social problems, achieve economic development, and bridge technological gaps. We provide the technologies, such as collection and process of required data from anywhere, battery-less IoT devices using energy harvesting, digital data sampling and processing from physical spaces, wireless communication, even in the extreme environments, providing scalability in the increase of data transaction and the number of nodes, QoS guaranteeing of communication, real-time control, physical AI processing, and low-power IC processes. These technologies enable highly integrated and sophisticated service provisioning, especially for real-time systems in a physical space.
  - The establishing technology for building a physical space digital data processing infrastructure will bridge these gaps and realize Society 5.0. One of the key technologies for filling the gaps is to use and collaborate with the newest sensor, actuator (IEE 1451 family), and edge computing (IEEE P2805 family) standards.

Use Case for Smart Farm



Farm data management

- Cost down / Harvesting yield, quality / Growth control / EMS
- Abstraction: Anonymization, Labeling using AI
- Crystallization: Ultimate improvement of farming

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IEEE P21451-1-5: Accessing and Managing Internet of Things Based on Customized SNMP

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***Abstract*—IEEE P21451-1-5 standard specifies a universal and standardized way of accessing and managing Internet of Things (IoT) based on customized Simple Network Management Protocol (SNMP). In this paper, we explain the basic concepts in IEEE P1451, provide an overview of IEEE P21451-1-5 and introduce the demonstration system to be presented in INTEROP 2020, including its building blocks, over-all architecture and the workflow of IEEE P21451-1-5 in this demonstration system.**

Introduction

IEEE P21451-1-5 standard specifies a universal and standardized way of accessing and managing Internet of Things (IoT) using Simple Network Management Protocol (SNMP), which conforms to IEEE P1451.0 standard and thus features high interoperability with other application layer protocols, such as HTTP, XMPP and MQTT.

IEEE P21451-1-5 standard, like IEEE P1451.0, is a member of IEEE P1451 standard family [1], whose goal is to define common interfaces and services for IoT, enable "plug and play" of smart transducers (i.e. sensors and actuators) and promote interoperability among transducers made by different vendors or using different protocols.

In the context of IEEE P1451, an IoT instance is carefully divided into two types of entities, named Transducer Interface Module (TIM) and Network-Capable Application Processor (NCAP), respectively. TIM is a smart transducer in which Transducer Electronic Data Sheet (TEDS) is located. TEDS is another key concept in IEEE P1451 standard, which stores comprehensive information about this transducer in a standardized format and makes the transducer self-describable, self-identifiable and therefore, "smart". NCAP is the gateway of the transducer network, who provides network services to IoT users (clients) over various application layer protocols. Such a "TIM-NCAP" division naturally results in two types of interfaces. The one between TIM and NCAP is called Transducer Independent Interface (TII) while the one between clients and NCAP is called Network Interface (NI), both of which are defined in IEEE P1451 standard.

Specifically, IEEE P21451-1-5 standard focuses on NI of IEEE P1451-compatible IoT, exploits the management functionality of SNMP and extends its usage from traditional networks to IoT, providing a universal and standardized way of accessing and managing IoT using SNMP.

Standard Overview

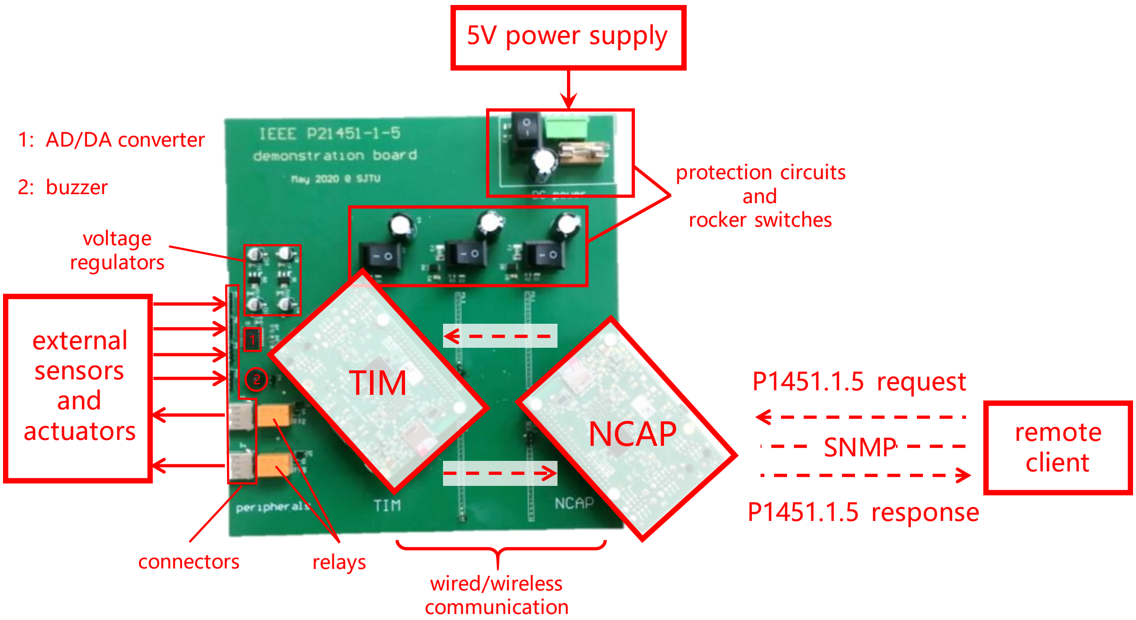
The draft of IEEE P21451-1-5 standard is under active development. This standard is aimed at addressing common issues during the process of accessing and managing IEEE P1451-compatible IoT using SNMP, and tentatively, the draft is going to include these featured contents:

- Management Information Base (MIB) tailored for IEEE P1451-compatible IoT, as well as its coordination with TEDS.
- Event notification service based on Trap PDUs of SNMP.
- Security mechanisms based on View Access Control Model (VACM) or User-based Security Model (USM).
- Time synchronization mechanism over SNMP messages.

Material and Equipment

The main components of the demonstration system are listed below:

- Raspberry Pi 3's are used as the controller of NCAP as well as the controller of TIM. On each Pi there is a Broadcom BCM2837 SoC with 4 cores and 1.2 GHz clock rate, 1 GB memory, on-board 802.11n and BLE 4.1 adaptor. Interfaces include 4 USB 2.0 ports, one HDMI port, a 100 Mbit/s Ethernet port and a 40-pin GPIO port. A 16 GB TF card is used to boot the system and also serves as the external storage. For more information about Raspberry Pi's hardware specification, please refer to the section *Useful Links and Additional Information*.
- The operating system running on NCAP is CentOS 7 for `armv7hl` architecture, while the one running on TIM is Raspberry Pi OS (32-bit), which is previously known as Raspbian and is the official operating system for Raspberry Pi.
- Various external sensors and actuators, for example, temperature sensor, photosensitive sensor, humidifier, fan, lamp and so forth.
- A specially designed motherboard connects different parts of the system. It is a printed circuit board and should be powered by an external DC power supply with 5V output. It features protection circuits against



overvoltage or short circuit, voltage regulators that generate 3.3V power supply, and rocker switches that enables the operator to control the on/off status of different subsystems. It has sockets and mechanical connectors whereby Raspberry Pi's can be reliably installed. It provides pin headers to which external sensors and actuators can be connected. On the board itself there is an AD/DA converter chip that can perform signal conversion, an alarm buzzer and several relays, which are controllable and can be considered as on-board actuators.

- A switching power supply with 5V/20A output is used to drive the whole system. Note that the power consumption of the system is much less than the supply and "5V/20A" is only chosen for redundancy and for scalability in the future.
- Keyboard, mouse and display can be connected to the system for programming, debugging and testing.

Demo Structure

Combining together all the components introduced in the last section, we obtain the demonstration system's over-all architecture, as shown in the figure.

The process of accessing or managing IoT using SNMP goes as follows: Firstly, a client on the network initiates a request that is packed in P1451.1.5 format (that is, "1451.1 over SNMP") and is sent to NCAP. Secondly, NCAP receives the request message, resolves it, translates it into standardized 1451 commands that can be recognized by TIMs (that is, "calls transducer services") and then issues the commands to certain TIMs. The transmission in this step can either requires a physical cable between NCAP and TIM (using protocols like UART) or goes over the air (using Wi-Fi, BLE, etc.). Next, TIM responds to the commands by reading a sensor or regulating an actuator's output, and replies with a response message. At last, the response message goes in reverse as the request message and is sent back to the client.

Useful Links and Aditional Information

1. Project main page of IEEE P21451-1-5 standard:

   https://standards.ieee.org/project/21451-1-5.html

2. Hardware specification of Raspberry Pi 3B:

   https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

3. Popular open-source SNMP implementations:

   `net-snmp`: http://www.net-snmp.org/

   `pysnmp`: https://github.com/etingof/pysnmp

4. Some of the published research papers related to this topic are [2], [3] and [4].

Acknowledgment

The IEEE P21451-1-5 working group would like to express their very great appreciation to Kang Lee, Eugene Song and Victor Huang, for their generous help and insightful suggestions during the whole process of standard development.

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<< Implementation of IEEE 1451 Standardized LPWA System on CMHK OneNet Platform >>

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***Abstract*—Emerging Low Power Wide Area (LPWA) technologies are the backbones of smart city development and Industrial Internet of Things (IIoT) realization. A large number of smart applications based on LPWA have been developed by connecting various IoT sensors. However, these sensors are usually developed by different manufacturers. Each manufacturer has unique hardware and software designs, which pose the issues of adaptability and compatibility during the integration of an IoT system. Besides, a huge development cost would be incurred when there is no unified sensor standard. Hence, in this project, we proposed a standardized LPWA system based on IEEE 1451. This system designs a standardized Wireless Transducer Interface Module (WTIM) and Network Capable Application Processor (NCAP) in the LPWA network. In the experimental evaluation, the IEEE1451-standardized NB-IoT system on the CMHK OneNet platform was implemented, and the experimental results demonstrate the high feasibility and efficiency of the proposed system.**

Introduction

Nowadays, the Internet of Things (IoT) has experienced explosive growth in academia and the industry. Forecasts pinpoint to 80 billion IoT devices by 2025, which means there will be billions of IoT connections. Low Power Wide Area (LPWA) technologies are emerged to enable these IoT connections to implement large-scale smart applications. Typical LPWA technologies consist of NB-IoT, LoRa, Sigfox, etc. They have similar system architecture, which is composed of four parts, namely sensor-connected end devices, gateways/base stations, network servers, and user application servers. This LPWA architecture facilitates the implementation of smart applications, but it encounters severe challenges when connecting a large number of non-standardized devices. These challenges mainly include:

1) How to decrease the development cost when there are many kinds of end devices?
2) Would various kinds of end devices communicate with a server stably and reliably?
3) Could end devices from different manufacturers integrate into one server platform?
4) How does a server support gateways/base stations produced by different manufacturers?
5) How does a server support end devices produced by different manufacturers?

To address these challenges, a standardized LPWA system based on IEEE 1451 is proposed. In this system, two standardized parts, namely Wireless Transducer Interface Module (WTIM) and Network Capable Application Processor (NCAP) are designed for the LPWA network. In the experiment, an IEEE1451-standardized NB-IoT system on the CMHK OneNet platform is demonstrated to demonstrate the high feasibility and efficiency of the proposed system.

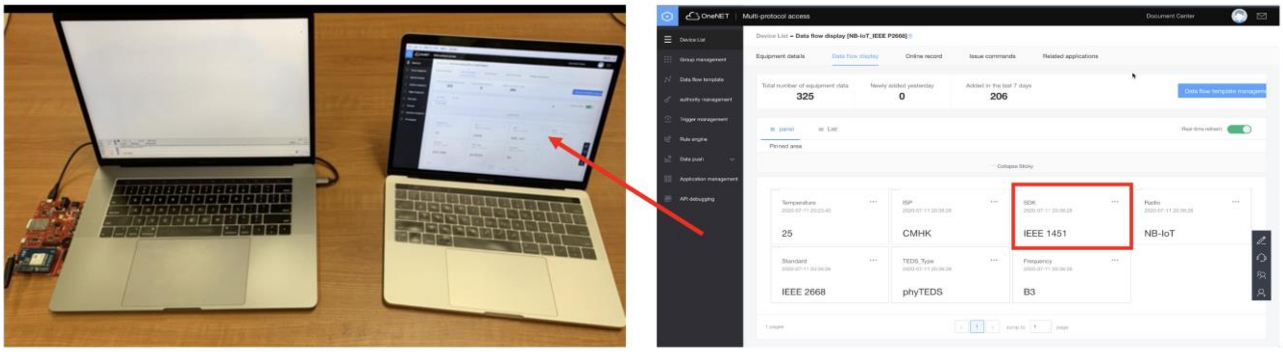
Standard Overview

The IEEE 1451 is a set of smart transducer interface standards to define a set of open, common, network-independent communication interfaces for connecting transducers to microprocessors, instrumentation systems, and control/filed networks [1]. The IEEE 1451 family, proposed by IEEE Instrumentation and Measurement Society's Sensor Technology Technical Committee, consists of many sub-standards to specifies the smart transducer standards pertinent to different wired and wireless technologies. The IEEE 1451 family involves 1451.0, 1451.1, 1451.5 [1-3], etc.

The general IEEE 1451 structure is defined in the IEEE 1451.0. In this sub-standard IEEE 1451.0, two important components are specified that are NCAP and Transducer Interface Module (TIM). In the IEEE 1451 system, NCAPs perform gateway-like functions, and TIMs perform sensing and data transmission functions. The IEEE 1451.1 defines the standardized network services for the IEEE 1451 system. The IEEE 1451.5 defines the interface for wireless protocols. The TIM in wireless networks is named WTIM.

In the IEEE 1451, a set of Application Programming Interface (API) is designed to standardize the TIM and NCAP units. The smart transducersm with the designed Transducer Electronic Data Sheet (TEDS), could perform smart functions, such as self-identification, self-calibration, etc.

A series of standardized functions are defined in the WTIM. TransducerChannel is defined to configure the



specific channel for each sensor or actuator. The TEDS in WTIM defines the type/accuracy/period of a sensor, radio information, security information, etc. Meanwhile, the IEEE 1451 API and IEEE1451 working diagram design are also defined in the WTIM. The WTIM works like an end device. In the industrial area, end devices are developed by different manufacturers, so they may have different design specifications. Hence, designing the IoT products based on IEEE 1451 could achieve high interoperability, and the platform complying with the IEEE 1451 design could manage these standardized end devices conveniently.

The NCAP mainly defines the IEEE1451 software commands, including reading and parsing TEDS, transducer services API, and communication API, etc. The function of NCAP works similar to the integration of the gateway/base station and network server. WTIMs are wirelessly connected with the NCAP [4].

The overall IEEE1451 standardized LPWA system is implemented with the WTIM and NCAP designs, enabling the communication and data management of the IEEE 1451 services. Hence, the development cost of IoT manufacturers and developers would be decreased, and highly efficient service management can be achieved.

Material and Equipment

The IEEE1451 Standardized LPWA System is implemented on the CMHK OneNet platform. This experiment involves the NB-IoT based IEEE 1451 system, which is one of the standardized methodologies of the IEEE P2668. The used materials and equipment are as follows:

- Arduino Module
- M5310A NB-IoT Module
- CMHK OneNet Platform
- Two Computers (MAC)
- USB Cables
- CMHK SIM Card

Demo Structure

The IEEE1451-standardized NB-IoT system consists of the NB-IoT end devices group, NB-IoT core network, and CMHK OneNet cloud. The NB-IoT core network is deployed by the CMHK for exchanging data between the NB-IoT end devices and the OneNet IoT management platform. The CMHK OneNet cloud performs data processing and analysis. The core network and OneNet cloud are connected via the internet.

NB-IoT devices send the IEEE 1451-based messages, comprising the TEDS, sensor information, and other sensor parameters. The OneNet platform receives these standardized messages and parses the message structure for delivering corresponding services to the users or NB-IoT end devices. The entire standardization work involves standardizing communication APIs, defining appropriate TED structures, and deploying TransducerChannels, etc.

Useful Links and Aditional Information

- The IEEE 1451 system setup on the CMHK OneNet platform:

  https://drive.google.com/file/d/1j9OnKjI2fpigdakusxWQT2jvX-aP-3VC/view

- The official website of the CMHK OneNet platform:

  http://onenet.hk.chinamobile.com/

- Project main page of IEEE 1451 standard:

  https://standards.ieee.org/project/1451_0.html

Acknowledgment

We thank Dr. Kim Fung TSANG for the support of the IEEE1451 and IEEE P2668 standards. We thank all the authors for great team cooperation. In particular, we thank CMHK for providing the OneNet Platform to test.

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IEEE P2668 Demonstration for INTEROP 2020

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***Abstract*—The IEEEE P2668 Standards Working Group is developing a universal Internet-of-things (IoT) indicator, namely the IoT Maturity Index (IDex), to evaluate, grade, and rank the performance of IoT objects. The standard specifies the evaluation mechanism and criteria pertinent to the applications of the IoT objects to be evaluated. This article will present the fundamental concept and overview of the IEEE P2668 and introduce the demonstration that will be given in the INTEROP 2020. Smart Streets, Smart Lampposts, and Smart Lifts are chosen to be the demonstration scenario for the IDex evaluation.**

Introduction

The Internet-of-things (IoT) is a crucial building block of Smart Applications, Smart Infrastructure, and Smart Cities. Nevertheless, the ever-growing IoT industry may pose various difficulties in the aspects of cybersecurity, safety, and information privacy. For instance, a high connection density of IoT sensors may lead to severe signal interference, thereby deteriorating the performance of IoT networks. Despite the use of secure IoT protocols, insecure operations may still become a vulnerability in IoT security and privacy. With these concerns in mind, an IoT standard is needed to evaluate IoT solutions systematically and comprehensively.

The IEEE P2668 standard defines a universal internet-of-things (IoT) index, namely the IoT Maturity Index (IDex), for measuring the maturity of IoT objects in a standardized and systematic manner [1]. The IoT objects refer to either devices, networks, algorithms, systems, solutions, or infrastructures. The standard specifies the evaluation mechanism and criteria to classify the maturity of an IoT object into multiple levels in terms of the IDex levels.

In addition, the IDex provides feedbacks and advice to facilitate the performance improvement of IoT objects [2, 3]. For example, if an IoT network suffers low quality-of-service (QoS) and high latency frequently, the IDex will analyze the network design and identify the causes of the problem. After that, the IDex will provide a list of suggestions to the network operator, such as dividing the network into multiple sub-networks, for improving the IDex level of the network.

In this article, Smart Streets, Smart Lampposts, and Smart Lifts are selected to be the demonstration scenario of the IDex evaluation.

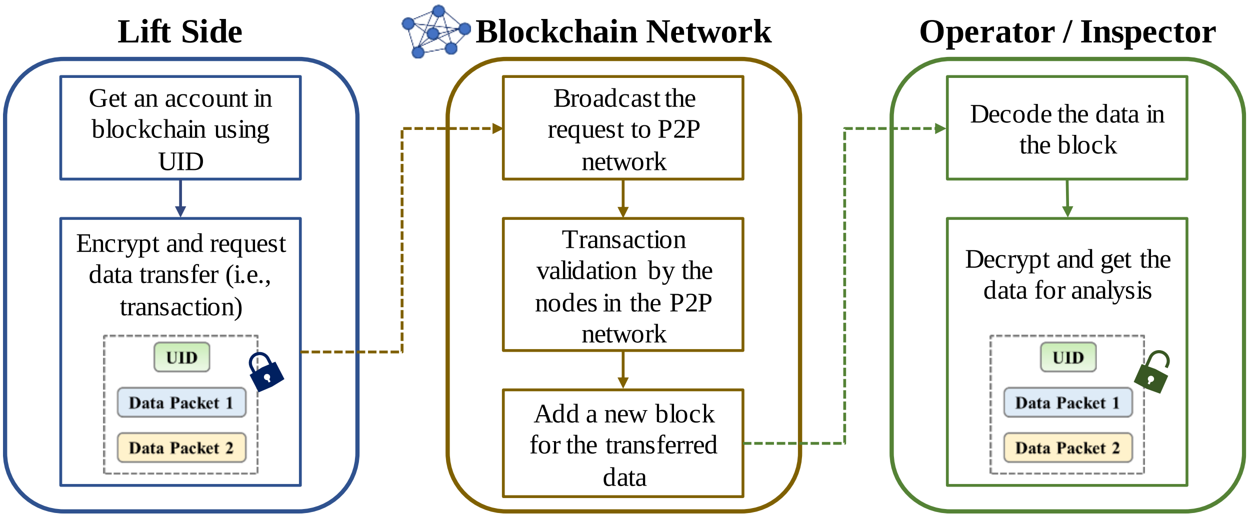
Standard Overview

The draft of the IEEE P2668 standard is under active development. This standard aims to deliver a universal and systematic evaluation for all IoT objects with the use of the IDex indicator. Tentatively, the standard is going to develop the following featured contents:

1. A quantified maturity indicator, namely the IDex, to evaluate, grade, and rank the maturity of IoT objects.
2. Advice for improving the IDex levels of IoT objects based on the IDex evaluation results.

An example of the IDex evaluation on Smart Lamppost in Smart Street is given as follows. Smart Street is one of the vital Smart infrastructures in a Smart City. It comprises multiple Smart Lampposts to deliver various intelligent operations, such as traffic monitoring and control, surveillance for public safety, charging for electric vehicles and drones, data aggregation, communication, navigation for autonomous vehicles and drones, and many others. Such a Smart Lamppost can get a high score in terms of the functionality. However, its overall IDex level may be low (e.g., 3.4 out of 5) due to various factors.

The IDex evaluation considers various criteria in addition to the functionality. For instance, the IDex will evaluate whether the Smart Lamppost has sufficient security and privacy measures to mitigate cyber risks. Some typical security and privacy considerations include the type and the amount of data to be collected, the management method of collected data, network availability, and data integrity. The IDex evaluation can analyze and identify the weakness of IoT solutions and manifest guidance for improvement. For instance, the IDex may suggest the following measures to enhance security and privacy: (i) adopting blockchain to secure data integrity, (ii) minimizing the amount of collected data to fulfill the regional privacy regulation, and (iii) adding other IoT networks (e.g., LoRa, NB-IoT) to alleviate the data loadings and sustain communications under extreme weather. The IDex can estimate and predict the IDex level after the advised



measures are implemented (e.g., the IDex level will rise from 3.4 to 4.5).

Material and Equipment

In this demonstration, the IDex improvement solution for Smart Lift safety is considered. The main components of the demonstration are listed as follows.

- Raspberry Pi 4 is used as the controller.
- An IoT sensor network for data collection.
- An IoT server operating at the Linux system.

Demo Structure

A Smart Lift comprises various IoT sensors for measuring various safety-related parameters, such as acceleration, vibration, noise, voltage, current, and position. These data should be aggregated to the analytic platform for analysis. However, there are two crucial issues, namely data confidentiality and integrity. These measured data shall not be accessed by the third party. Also, since these data relate to public safety, they shall not be modified, i.e., the data shall be collected and processed accurately. Therefore, the IDex renders advice of adopting blockchain to enhance the Smart Lift safety. The IDex improvement solution for Smart Lift safety goes as follows.

First, a unique identifier (UID) is assigned to the Smart Lift. The collected data, such as acceleration, voltage, and current, are packed into the data packet. The controller at the lift side encrypts the collected data using a public key and requests data transfer. The blockchain network receives and broadcasts the data transfer request in the peer-to-peer (P2P) network. The nodes in the P2P network validate the data transfer request and, after the validation, add a new block to store the encrypted data. At the operator/inspector side, they can access and decode the block from the P2P network. Finally, the operator/inspector can decrypt the data using their private keys.

Useful Links and Aditional Information

Project main page of IEEE P2668 standard:

https://standards.ieee.org/project/2668.html

Acknowledgment

The support from the FONATSCH GmbH is gratefully acknowledged.

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Smart Battery Gauge for Continuous Battery Condition Assessment

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***Abstract*— This is a demo of the Smart Battery Gauge (SBG) that can continuously and accurately assess the State of Charge (SOC), State of Health (SOH) and Remaining Useful Life (RUL) of the battery when in use.**

Introduction

The only measurable signals from a battery are its voltage, current and temperature. To know how long a battery can support an application and to predict the replacement time, it is crucial to assess the State of Charge (SOC) and the State of Health (SOH) of the battery. One of the most important reasons for the development of the smart battery gauge is because the SOH of the battery is not a measurable output from the battery. While commercially available gauges require the battery to be taken offline or are cumbersome in procedure or need a long time to produce results, the smart battery gauge eliminates all of these problems. The key features of the smart battery gauge are:

1. ***Real-time***

Benefit: The battery gauge is able to produce live assessment of the battery's condition and is not time consuming.

2. ***Online Assessment***

Benefit: The smart battery gauge can assess the condition of the battery when it is being used in an application. This prevents any down time that is part of battery maintenance schedule while using other battery gauges.

3. ***Assesses multiple SOH indices***

Benefit: The smart battery gauge can assess the health of the battery both in terms of capacity degradation as well as internal resistance increase. This assessment ability would be key to determine the actual degradation phenomena that led to the aging of the battery.

4. ***Adaptive Circuit structure for accurate battery representation***

Benefit: Current techniques use a fixed circuit model with adaptive parameters. This results in loss of accuracy in the representation of the battery's behavior as it begins to age. To overcome this problem, the smart battery gauge adapts the structure of the battery model based on aging and operating conditions, such as temperature, to accurately represent the battery at its current state.

Currently, the smart battery gauge has been implemented in multiple microcontrollers and implemented at two real-world test facilities - At Mt. Holly Microgrid facility with Duke Energy and at Butler Farm Microgrid Facility with North Carolina Electric Cooperatives (NCEMC). This prevents unnecessary down time and complicated procedures.

Standard Overview

The smart battery gauge is unique because of the following features:

1. ***Adaptive to battery ageing***

Benefit: Unlike most commercially available products, the smart battery gauge can adapt to a battery's performance as it ages. As a result, the assessment of the charge of the battery and rate of degradation of the battery can be easily obtained.

2. ***Improved and comprehensive SOH Assessment***

Benefit: Compared to commercially available battery gauges, the smart battery gauge is able to assess the SOH of the battery using multiple indices and thereby providing a more accurate and comprehensive knowledge of the condition of the battery.

3. ***Provides feedback to maximize remaining useful life***

Benefit: The SBG has the ability to predict the remaining useful life of the battery based on the user's application. It also has the ability to advise the user on appropriate battery utilization schemes to make full use of the battery's capabilities. This is done while ensuring an extended remaining useful life. This is in contrast to most commercial algorithms that are passive and only provide health information and no feedback.

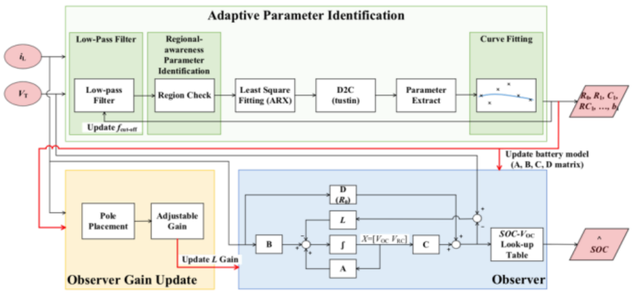

Figure 1. The block diagram of operation for the SBG.

Material and Equipment

The SBG uses the Co-Estimation Algorithm, a combination of an adaptive parameter identification technique and an observer-based estimation method. Using these techniques, the Co-Estimation algorithm is able to acquire the terminal voltage, current and temperature of operation and identify the SOC and SOH in real-time and provide feedback on the RUL of the battery. Figure 1 shows the block diagram of the SBG.

In the future, the SBG will also be using AI and first principle based four-dimensional battery degradation model (4DM) to provide detailed information on battery degradation and State of Function (SOF) of the battery.

Demo Structure

In this demo, the SBG can be seen operating in real-time at a remote location and providing live feedback to the user interface at a remote monitoring station. The SBG can assess the State of Charge (SOC), State of Health (SOH) and the Remaining Useful Life (RUL) of the battery when it is in use and provide accurate information when the battery is in use.

This particular demo highlights the SBG using Modbus over ethernet to communicate to the battery system at Lillington, NC to obtain the voltage and current of the battery. It then assesses the SOC, SOH and RUL and communicates this information to the user interface hosted on the internet using SSL communication.

Useful Links and Aditional Information.

Results:

The SBG is able to adapt to real world operating conditions and battery aging and provide live and accurate assessment of the SOC of the battery within an error margin of 5%. The SBG has been successfully implemented in a Raspberry Pi and deployed at a working microgrid in North Carolina. Figure 2 shows the pilot implementation of the SBG. The innovation of the SBG is discussed in 25 journal and conference papers and 3 patents. The SBG has also generated 4 simulation software products and 3 hardware products.

Impact: The value proposition for stationary energy storage vendors is lowering the total cost of ownership by maximizing the useful life of batteries, increasing battery system uptime, reducing required maintenance and improving the reliability and safety of their products. Potential markets include utility scale storage, microgrids, solar + storage installations and electric vehicles. The SBG has been deployed in a pilot project and has a Technology Readiness Level of 8. NC State has also partnered with multiple battery manufacturers to develop custom battery monitoring solutions. The SBG is in the technology transfer stage and is ready for commercialization.

More Information on the SBG can be found at: go.ncsu.edu/sbg.

Acknowledgment

This work was partially supported by the National Science Foundation Award Number IIP – 1500208.

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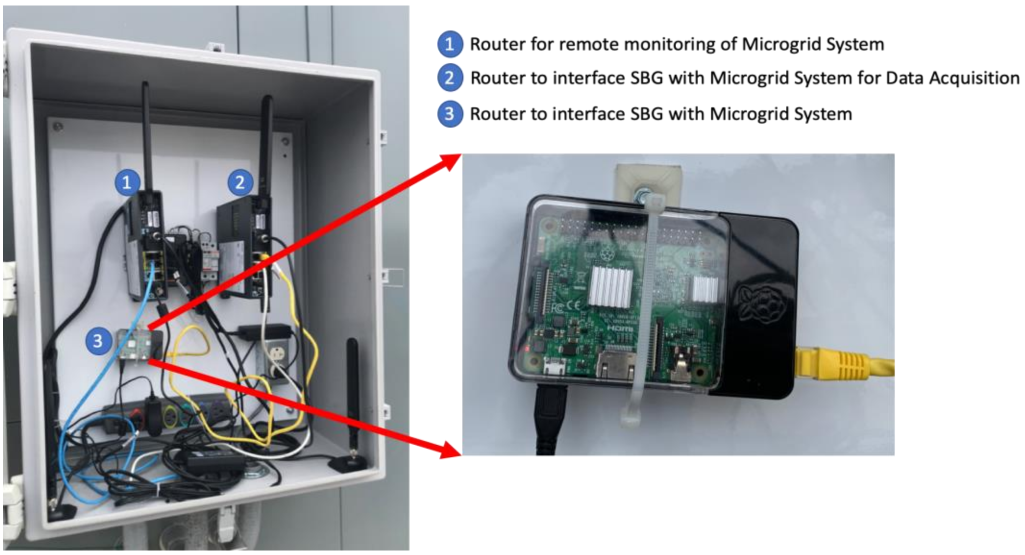

Figure 2. The SBG interfaced with a battery at a Microgrid Facility in Lillington, NC.

A Platform for IEEE 1451.99 Standard's Development and Validation

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Abstract

The fourth industrial revolution is supported by concepts such as the Internet of Things and Cyber-Physical Systems. Introducing these concepts, a digital representation of the factory and the production process is possible. The work of developing a new standard does not end with its approval and publishing. It should be known to industrial agents, who through educational examples, will identify the standard's potential application and advantages. A platform to support educational, development and validation activities, and contribute to disseminating the IEEE 1451 family of standards is presented. The platform was developed using commercially accessible platforms and open-source tools, making it suitable for academic and research use. The platform was developed to allow devices external to the IEEE 1451 family of standards to connect with devices that follow this standard

Introduction

An Asset is the Principal component in the manufacturing Industry. Most often it is a physical *Thing*. There are also virtual assets in the form of process, engineering models which we perceive in our mental space and manipulate their material, energy and information flows to achieve productivity and economic goals The digital twins of these assets, reside in the Cyber physical space as Objects and we perceive by their facets all through their life cycle. Industrial Internet of things (IIOT) is the interplay of these Digital twins through Harmonization of material, energy, and information streams. Industry 4.0 vision has a Reference Architectural Model RAMI 4.0. reflecting this concept. Factories with discrete parts manufacturing and assembling industrial/consumer products would like to upgrade their automation systems to this model to realize the productivity/profitability goals In the process they have to preserve their investments in plant engineering and automation assets and transcend to the level of seamless information integration.

IEEE P1451.99 IOT Harmonization has the software application framework to address this need. Its covers, data acquisition from legacy systems, interpreting it through semantic object models and providing services to federated systems.

The objective of this remote demo is to convey the suitability of this standard to Industrial IOT application.

Standard Overview

IEEE P1451.99 standard provides a unique IOT Gateway device. its functionality goes beyond the traditional gateway devices. It acquires data from PLC, PAS, SCADA, CNC, Robot controller systems. The diversity of their industrial communication protocols is managed by transportation over Ethernet TCP/UDP. Transducer Data services confirming to 1451.0 enables interpretation of data streams with Protocol TEDS and the application TEDS aids transformation to semantic datasets. They are held in a persistent layer in HDF 5 format correlating the sensor, actuator data with the attributes/property of the plant assets. The application objects in this standard portray the digital twin as the virtual assets in cyber physical space. They are organized into IS-95/Automation ML node structures plant-area-asset/control module location: rack-tier-slot etc.,

The Virtual Assets are synonymous to IIOT. The important aspect is how these assets connect to the internet and how they communicate with the outside world and also Vice versa, how the outside world can communicate with these assets. Extensible Messaging Presence Protocol (XMPP) provides stable and exceptional possibilities to both the assets and the applications that communicate with them. The special feature of the server -client communication model acts as message brokers for the federated system. Privacy and Security of data is the strength of this messaging service. The solution architecture is shown with an UML representation below in Figure-1

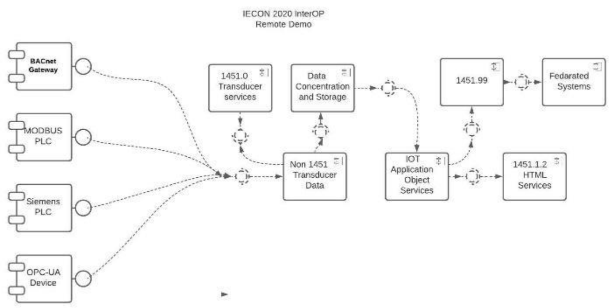

Figure -1: UML representation of the Solution

The key aspects of this solution are:

a) Most of the devices are capable of communicating over Ethernet network layer.
b) Diversity of Data packets over TCP has to be solved by interpreting their payload. This needs Protocol TEDS.
c) Protocol specific application TEDS are needed to interpret the payload of the message
d) Poll the data of the devices with Protocol specific request and response formats
e) Harmonize and concentrate the data in tree and node structure in compliance to industry standard Automation ML.
f) Network communication variants of NCAP active standards continue as they are.
g) Asset Application Objects data as JSON array provide as response to XMPP bridge in Sweden

This is depicted in the diagram figure -2 below.

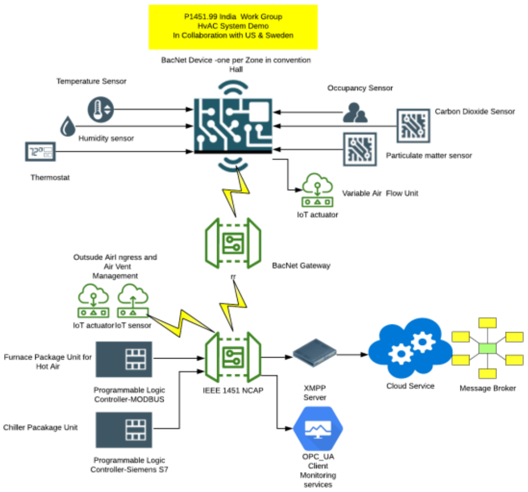

Figure -2: Solution Architecture Diagram

Configuration and components

A minimal configuration is considered to demonstrate data acquisition from devices over legacy industrial protocols as indicated below.

a) BACnet device built using a 3rd party communication board piggy- back mounted on Raspberry PI 4 B
b) BAC net Sedona Configurator used to Build HVAC Objects in air-conditioned zones
c) MODBUS PLC and configurator to build IEC 61131 function blocks for monitoring cooling/heating/venting air dampers
d) Siemens PLC and Configurator to build IEC61131 Ladder logic control scheme for electric motor drives and VFD drives of air handler units
e) OPC-UA server to integrate I/O data from illumination and energy management

The typical set up is shown in the Figure-3 diagram.

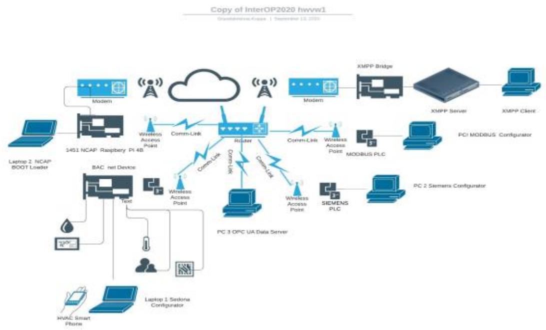

Figure -3: The solution set-up

Features

- Raspberry Pi 4 Model B 2019 Quad Core 64 Bit Wi-Fi Bluetooth (4GB)
- Raspbian OS
- Run-time: Python
- I/O request/response over HTTP/TCP/UDP
- Request/response over HTTP/TCP/UDP
- NCAP can be run as an AWS service on any Linux Virtual Machine

Demo Objectives

a) NCAP Web services

b) XMPP federated system services

Limitations of the current demo:

a) For the present demo there is no provision to read TEDS from legacy devices.
b) In the absence of TEDS generating tool meta TEDS required for the application are coded as JSON arrays
c) Large chunk of I/O are virtual and keyboard inputs are used to demonstrate
d) HVAC virtual plant integration will be available in 1Q 2021.

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DOI: 10.1109/SAS.2017.7894080 Conference: SAS 2017

2. HVAC of a Large convention hall ; Lawrence Berkeley National Laboratory BCVTB, https://simulationresearch.lbl.gov/bcvtb)

3. IEEE Standards:

a) ISO/IEC/IEEE 21450:2010(E)
b) ISO/IEC/IEEE 21451-1:2010(E)

IEEE 1451 Family of Standards

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***Abstract* — The IEEE 1451 standards for smart transducer interfaces for sensors and actuators consists of a family of twelve standards defining specifications for device level interfaces ranging from mixed-mode transducers interface, wireless interface, and RFID-to-sensor interface. At the network level, the family consists of standards for XMPP, SNMP, and MQTT network interfaces, as well as a network interface for the harmonization with other IoT verticals. At the application levels, we have standards dealing signal treatments, low-power operation, and wind and ocean turbine condition monitoring systems. All these interfaces are based on the core of the family of standards, IEEE P1451.0, which define common function and messaging, and TEDS that enable the access of sensors and actuators data and information and pass them to IoT, IIoT, or CPS clients and applications via various network interfaces, both IEEE 1451 and non-IEEE 1451 compatible networks and systems.**

Introduction

The family of twelve smart transducer interface standards, (see Table 1) under the designation of IEEE 1451, was created by the IEEE Instrumentation and Measurement Society's TC-9 Technical Committee on Sensor Technology. TC-9 is cooperating with the IEEE Industrial Electronic Society's Standards Committee working jointly on some of the member standards of common interest [1]. The main goal of the IEEE 1451 standard is to define a set of common communication interfaces to standardize the connectivity of smart transducers (sensors and actuators) to applications in networked systems such as that of the Internet of Things (IoT), Industrial Internet of Things (IIoT), and Cyber Physical Systems (CPS). It allows applications to access sensors and actuators via local area networks or the Internet, via wireline or wireless means. The family of IEEE 1451 standards can be used to build distributed sensor networks with devices, such as sensors and actuators, and can **facilitate device and data interoperability** leading to device plug-and-play for applications ranging from smart grid to smart buildings to smart manufacturing to smart healthcare to intelligent transportation systems to any systems that involves sensors and actuators and sensor networks and their applications.

Table 1. Family of twelve IEEE 1451 Standards.

The IEEE 1451 family of smart transducer interface standards for sensors and actuators consist of:

1. P1451.0 – Common commands, functions, messaging, and transducer electronic data sheet formats -----
2. P1451.4a – Mixed-mode Transducer Interface and TEDS for smart transducers --- Std being revised
3. P1451.5 -- Wireless interface for sensors and actuators---------------------------------- Std being revised
4. P1451.7 – RFID to sensor interface --- Std being revised
5. P1451.1.4 – XMPP network interface for secure sensor data access --------------- Std being developed
6. P21451-1-5 – SNMP network interface for secure sensor data access ------------- Std being developed
7. P21451-1-6 – MQTT network interface for secure sensor data access ------------- Std being developed
8. 21451-001-2017 – Signal treatment applied to smart transducers ------------------- Std published
9. P21451-002 -- Low-power operation for IEEE 1451 smart transducers ------------- Std being developed
10. P1451.99 -- Harmonization of IoT devices and systems ------------------------------- Std being developed
11. P1451.8 -- Wind Turbine Condition Monitoring System ---------------------------------- Std being developed
12. P1451.9 – Ocean Turbine Condition Monitoring System -------------------------------- Std being developed

Standard Overview

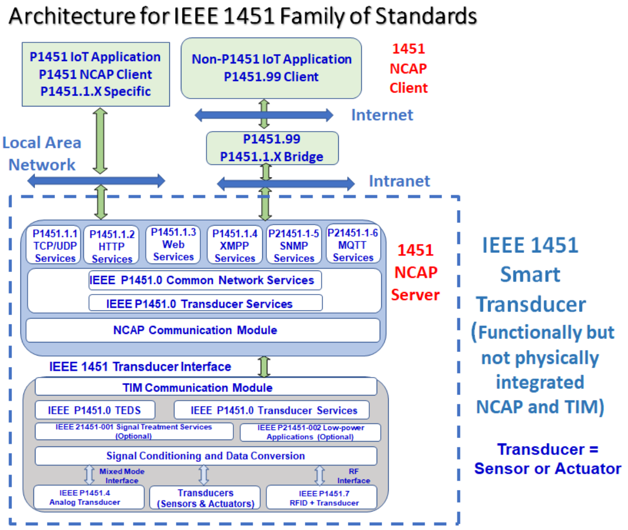
IEEE 1451 standardizes two interfaces – a transducer device interface and a transducer network interface. The transducer device interface is the interface between a transducer device and a network device, whereas, the transducer network interface is the interface between a network device and user applications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

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 in industry as a network node or a gateway device.

IEEE 1451 defines a set of metadata of transducers, 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, timing and synchronization, cyber security, and more. TEDS enable the self-identification and self-description of transducers to the system or network. IEEE 1451 also define signal processing algorithms and data structure for smart transducers in order to share and to infer signal and state information of a network or system to enhance smartness in the system. IEEE 1451 transducers are smart because they can self-identify and self-describe, including signal processing, can communicate in a network or Internet, and provide data with standardized measurement units.

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.

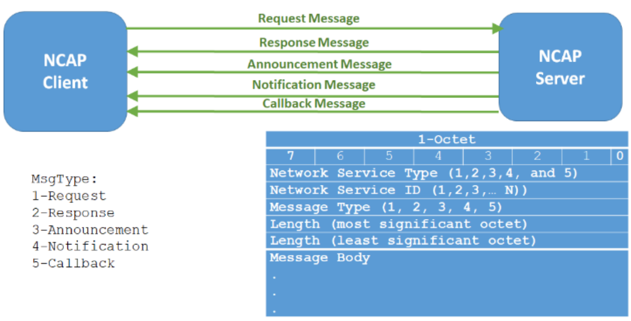
IEEE 1451 enables users, 1) to access any transducer devices in wireline or wireless networks or Internet using a common message set (request and response) in standardized messaging formats, and the data returned in standardized data and physical units in XML format, and 2) to "plug and play" of transducer 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.



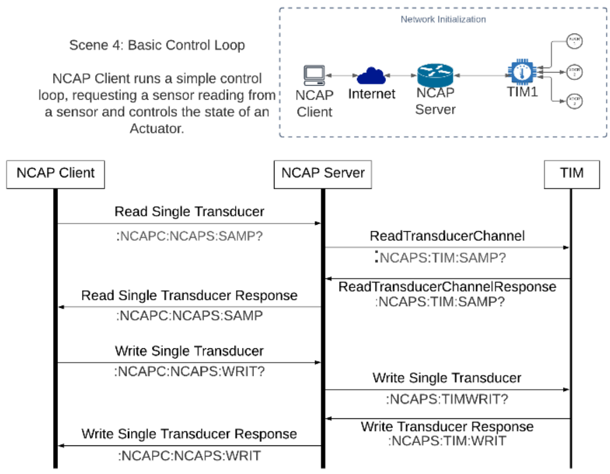
Demo Structure

The IEEE 1451.0 standard defines a set of common functionalities, commands, and (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.

A typical IEEE P1451.0 messaging structure for network services is shown below with request and response, etc.



In this Interop 1451 testing and demo, many scenes of interactions between NCAP clients and NCAP server as well as TIM will be demonstrated that they are interoperable with each other through the exchanges of messages, sensor/actuator data as well TEDS information. An interoperability testing approach is shown in reference [2]. Taking a similar approach, a control loop operation, designated as Scene 4, using the IEEE P1451.0 messaging structure for network services is shown below with requests and responses, etc.



To perform the example simple control loop, our network entities need to perform the following tasks. First, the NCAP Client attempts to obtain the current temperature of the system. This request is passed from the NCAP Client to the NCAP Server which determines what TIM has the sensor information needed. The NCAP Server then requests and receives this information, packages it up, and sends it back to the NCAP Client. The NCAP Client then determines what action it needs to take to maintain the system in control, sending a correction signal to adjust a valve, using almost the same process as requesting the sensor data.

References

[1] IEEE STD 1451.0-2007, Standard for a Smart Transducer Interface for Sensors and Actuators – Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats, IEEE Instrumentation and Measurement Society, TC-9, The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y. 10016, SH99684, October 5, 2007.

[2] E. Song, K. Lee, "An Interoperability Test System for IEEE 1451.5-802.11 Standard," SAS 2010 - IEEE Sensors and Applications Symposium, Limerick, Ireland, 23-25, February 2010.