AN EXPLORE TO SMART SENSOR STANDARDS

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Abstract— **Due to evolvement of technology immense efforts are put to build smart sensor. Curiosity for smart sensor continues to grow as they begin to find real time application in multiple fields. Several standard are being developed to extend greater interoperability between sensors. The IEEE 1451 is a growing family of standards responsible for the development of Smart Sensors. IEEE 1451 involves developing technology for a seamless connection between smart sensors and networks. The paper will review on concept & objectives of existing approved standards of IEEE P1451.**

Index Terms—**IEEE 1451 & Smart Sensor.**

I. INTRODUCTION

Sensors are being used widely in most of the industries, due to increased usage of process controls and sensing elements in different sectors. Changing end-user requirements in these industries are being met through advancements in term of small, cheap and smart sensor technologies. Sensor producers are increasingly emphasizing on using smart sensors.

The rapid development and emergence of smart sensor and field network technologies have made the networking of smart transducers (sensors and actuators) a very economical and attractive solution for a broad range of measurement and control applications. However, with the multitude of incompatible network specifications that have been created, a certain degree of confusion and uncertainty has arisen about which network(s) to support. It is clear that a variety of networks will exist to solve specific problems. However, it seems that industry is in a crossroad and this predicament has imposed unnecessary economic burden to both transducer end users and vendors to support the variety of networks. This condition has also impeded the widespread adoption of these technologies despite a great desire to build and use them.

When these standardized interfaces are in place, transducer producers can design their devices to a single set of specification for transducers and networks connectivity. This will hopefully alleviate the uncertainty and allow for the rapid development of smart sensors and actuators for use with the networks [1]. In the long run, it will most likely lead to a lower development cost for the smart sensor producers and a proliferation of smart devices in the market. Thus, the emergence of smart devices and control networks will make available a wide variety of products for users to choose from based on their merits. If this trend continue, it will eventually lower the total system cost and broaden the application domain for distributed control applications for the users [2].

The companies are seeking ways to build low-cost, networked smart transducers. Many control network or field bus implementations are currently available, each with its own strengths and weaknesses for a specific application class. Interfacing transducers to all these control networks and supporting the wide variety of protocols represents a significant and costly effort to transducer manufacturers. A universally accepted transducer interface standard would not only allow for the development of smart sensors and actuators, but would also lead to lower development costs. Therefore, the objective of these standards is not to propose another control network, but to develop a standard that will isolate the choice of transducers from the choice of networks. This relieves the burden from the manufacturer of supporting a cross product of sensors versus networks, and helps to preserve the user's investment if it becomes necessary to migrate to a different control network

As discussed earlier, a smart sensor interface standard is needed in industry. In view of this situation, the Technical Committee on Sensor Technology of the Institute of Electrical and Electronics Engineer (IEEE)'s Instrumentation and Measurement Society sponsored a series of projects for establishing a family of IEEE 1451 Standards [3]. These standards specify a set of common interfaces for connecting transducers to instruments, microprocessors, or field networks. They cover digital, mixed-mode, distributed multi-drop, and wireless interfaces to address the needs of different sectors of industry. A key concept in the IEEE 1451 standards is the Transducer Electronic Data Sheets (TEDS), which contain manufacture-related information about the sensor such as manufacturer name, sensor types, serial number, and calibration data and standardized data format for the TEDS. The TEDS has many benefits:

- Enable self-identification of sensors or actuators - A sensor or actuator equipped with the IEEE 1451 TEDS can identify and describe itself to the host or network via the sending of the TEDS.
- Provide long-term self-documentation - the TEDS in the sensor can be updated and stored with information such as location of the sensor, recalibration date, repair record, and many maintenance-related data.
- Reduce human error - automatic transfer of TEDS data to the network or system eliminates the entering of sensor parameters by hands which could induce errors due to various conditions.

The objectives of the IEEE 1451 standards are to:

- Develop the common functionality among IEEE 1451 standard
- Develop network-independent and vendor-independenttransducer interfaces,
- Define TEDS and standardized data formats,
- Support general transducer data, control, timing, configuration, and calibration models,
- Allow transducers to be installed, upgraded, replaced and moved with minimum effort by simple "plug and play",
- Eliminate error prone, manual entering of data and system configuration steps,
- Ease the connection of sensors and actuators by wireline or wireless means.

The 1451 Family:

1451.0-2007 IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats

1451.1-1999 IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Network Capable Application Processor Information Model

1451.2-1997 IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Transducer to Microprocessor Communication Protocols & TEDS Formats

1451.3-2003 IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Digital Communication & TEDS Formats for Distributed Multidrop Systems

1451.4-2004 IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Mixed-Mode Communication Protocols & TEDS Formats

1451.5-2007 IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Wireless Communication Protocols & Transducer Electronic Data Sheet (TEDS) Formats.

1451.6-IEEE Standard for a Smart Transducers Interface for Sensors & Actuators- CAN Open-Based Network for Multi-Channel Transducer Module

1451.7-2007 IEEE Standard for a Smart Transducers Interface for Sensors & Actuators- Transducers to Radio Frequency Identification (RFID) Systems Communication Protocols and TEDS Formats A Figure.1 below illustrates the IEEE1451 family Standards

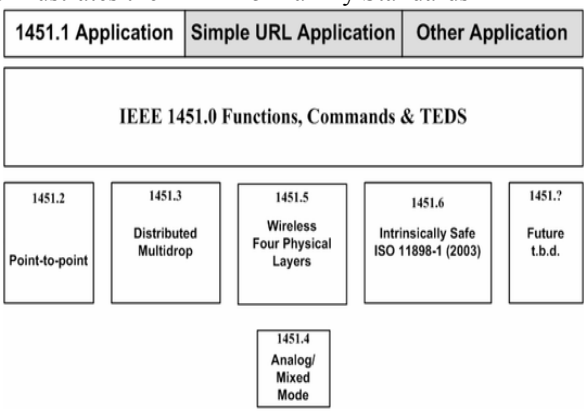

Figure 1.The IEEE P1451 Family

II.IEEE P1451.0: COMMON FUNCTIONALITY

There are certain characteristics shares by several standards in IEEE 1451 family, however does not have common set of function, communication protocols and transducer electronic data sheet format that provide interoperability among these standard. The standards describes a set of common functionality which is independent of the physical communications media and includes the basic functions required to control and manage smart transducers, common communications protocols, and media-independent Transducer Electronic Data Sheet formats. The block diagram for IEEE P1451.0 is shown in Figure 2. P1451.0 defines functional characteristics, but it does not define any physical interface.

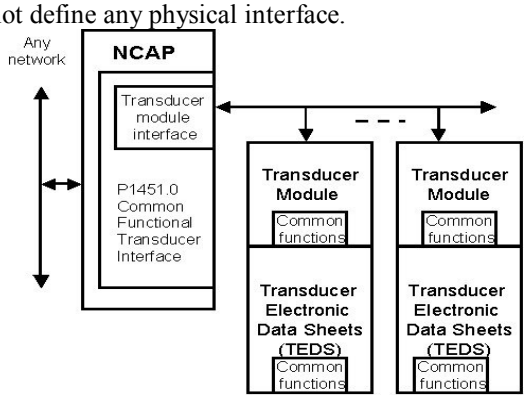

Figure.2 Block diagram of IEEE P1451.0

III. IEEE P1451.1: INFORMATION MODEL OF NETWORK CAPABLE APPLICATION PROCESSOR

The IEEE 1451.1 standard objective is to provide a network neutral application model that will reduce the effort in interfacing smart sensor & actuator to network. It also provides a network capable processor to control network through the development of a common control network information object model for smart sensor. This group of standard consist of Transducer blocks, Functional block, Network Capable Application Processor. These standard provides several benefits such as uniform design model for system implementation, for managing & representing event data, parameter data, bulk data, time, memory management and provides defined network independent models for communication & interoperability of all communication.

The IEEE 1451 logical interfaces are illustrated in Figure 3. The transducer logical interface specification defines how the transducers communicate with the NCAP block object via the transducer block. The network protocol logical interface specification defines how the NCAP block object communicates with any network protocol via the ports.

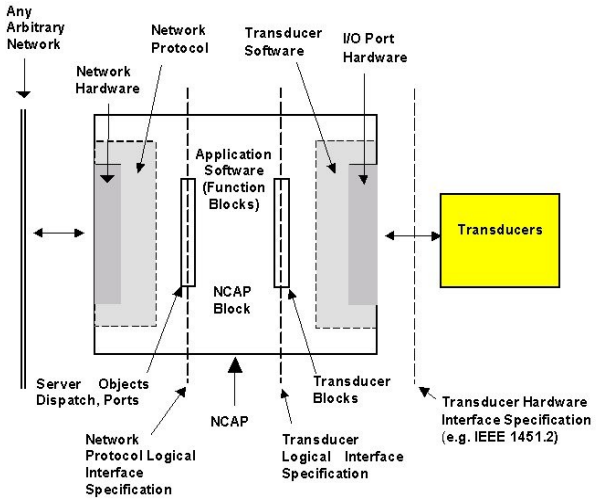

Figure 3.The 1451.1 Logical Interface

IV. IEEE P1451.2: TRANSDUCER TO MICROPROCESSOR COMMUNICATION PROTOCOL & TEDS FORMAT.

The purpose of this standard is to provide a minimum implementation subset that allows self-identification & configuration of sensors & actuator. This standard consists of Transducer Electronics Data Sheet (TEDS), Transducer Independent Interface (TII), and Smart Transducer Independent Module (STIM). The standard is compatible with IEEE1451.1 standard which describes about the STIM that is controlled by NCAP module by means of digital network interface which provide the local intelligence.The TEDS which is soul of this standard, fully describes the type, operational, characteristics, calibration, attributes & data format aspects of transducer which is generally stored in non-volatile memory attached with the transducer. The objective is to enable plug & play at the transducer level by providing common communication interface for transducer, simplify the creation of networked smart transducer & to facilitate the support of multiple network.

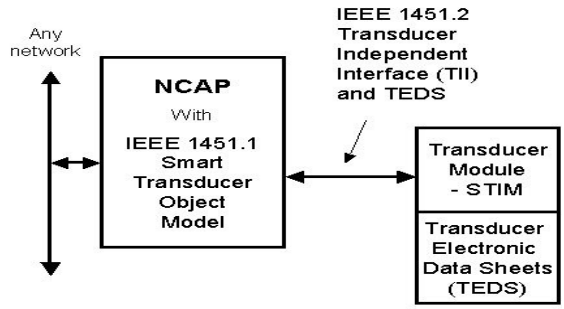

Figure 4 – System block of 1451.1 and 1451.2 interface to an integrated STIM.

V. IEEE P1451.3: DIGITAL COMMUNICATION & TEDS FORMATS FOR DISTRIBUTED MULTIDROP SYSTEMS

This standard describes the concept of Transducer Bus Interface Module (TBIM), Transducer Bus Interface (TBC). The TBIM module consists of bus interface, signal conditioning, analog to digital conversion, digital to analog conversion and many case transducers. A TBIM range in complexities from single sensor to multiple transducer. A TBC is software & hardware in the NCAP that provides the interface to the transducer bus. The tbc provides the communication path between an NCAP or one or more TBIM. Figure .5 illustrates the IEEE P1451.3 Basically the standard is developed to provide the digital interface for connecting multiple physically separated transducer to a single processor over a single pair of wire. It supports both asynchronous & isochronous data transfer. The main objective of this standard is to provide minimum implementation that allows multidrop, hot swapping, self-identification & configuration of transducer.

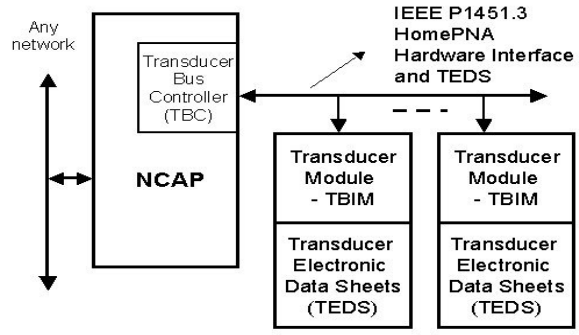

Figure.5.System Block of IEEE P1451.3

VI. IEEE P1451.4: MIXED-MODE COMMUNICATION PROTOCOLS & TEDS FORMATS.

The main objectives of these standard is to provide a bridge between legacy instrumentation system& the smart mixed mode transducer, also enables the implementation of smart transducer with minimum use of memory & to facilitate the support of multiple network with self-describing capability.The development of smart mixed mode transducer that has been simplified by this standard is defined by hardware & software which are independent of specific control network. The standard consist of Mixed Mode Interface(MMI) & Transducers Electronics Data Sheet(TEDS). The MMI, is master slave, multidrop, serial connection. It requires a master device to initiate each transaction with each slave or node according to defined digital communication protocol. MMI is used to access TEDS. A template, which is software object describing the data structure of TEDS. It is implemented in the Template Description Language and resides in the Transducer Block. The Template Description Language, which is a scripted and tagged language providing a standard method to describe the functionality of IEEE 1451.4 Transducer. A Transducer Block, which is software object describing the IEEE 1451.4 Transducer. It resides in the NCAP, which is the master device. The Figure 6.shows the IEEE P1451.5 standard.The standard offers the opportunity to design to a common interface which may be used for control network & data acquisition in variety of application such as portal

instruments & data acquisition plug in card for PC. It lowers the development costs & much easier to implement.

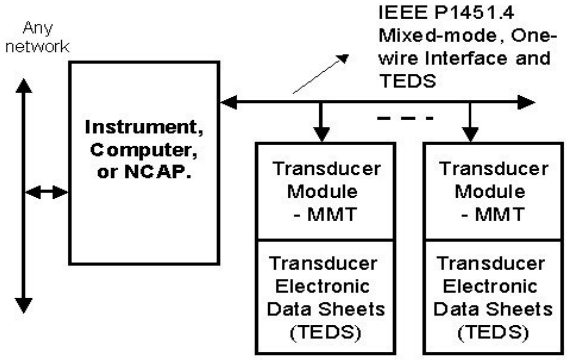

Figure.6. System Block of IEEP1451.4

VII. IEEE 1451.5: WIRELESS COMMUNICATION PROTOCOL & TRANSDUCER ELECTRONIC DATA SHEET

IEEE P1451.5 establishes a standard for wireless communication methods and data format for transducers (sensors and actuators). The protocol to access the TEDS & transducer data sheet and concept are based on the IEEE 1451 standard that are already defined. To facilitate the use of technically differentiated, existing wireless technology solutions it adopts necessary wireless interfaces and protocols

Several companies are on the way of developing wireless communication interface & protocols which will lower the cost, reduce the risk for users, transducer, manufacturers & system integrators and thus enhance the acceptance of wireless technology for transducers connectivity. The figure.7 below shows the IEEE 1451.5 standard

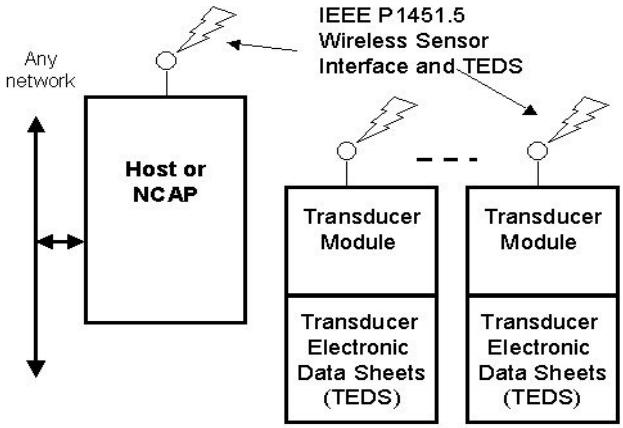

Figure.7. System Block of IEEE 1451.5

VIII. IEEE 1451.6: CONTROLLED AREA NETWORK OPEN-BASED NETWORK FOR MULTICHANNEL TRANSDUCERS MODULE.

IEEE P1451.6 is a transducer and closed-loop controller standard for operation in an intrinsically-safe cascaded network environment with multiple controllers on each level. The network transport layer is a serial CAN(controlled Area Network) bus, which is implemented as an on-board serial interface in a variety of microcontroller families and as stand-alone CAN controller chips manufactured by several companies.

This standard establishes a CANopen-based network for multi-channel transducer modules. The standard defines the mapping of IEEE 1451 TEDS to the CAN open dictionary entries as well as communication messages, process data, configuration parameter, and diagnosis information. It adopts the CANopen device profile for measuring devices and closed-loop controllers. It defines an intrinsically safe (IS) CAN physical layer. The Figure.8 shows IEEE 1451.6 System Block In order to make use of the IEEE 1451 TEDS concept and to achieve data compatibility from a single-sensor to a high-performance closed-loop controller, it is necessary to harmonize the TEDS parameters. The proposed standard allows development of lean gateways and cascaded transducer networks based on a combined specification of IEEE 1451 and CAN open.

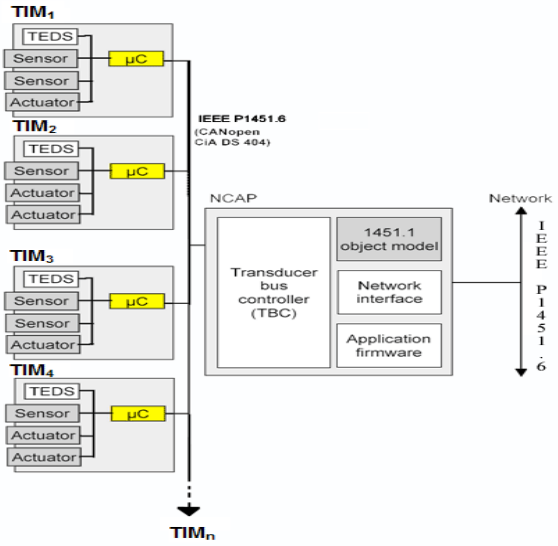

Figure.8. System Block of IEEE 1451.6

IX. IEEE STD 1451.7-TRANSDUCERS TO RADIO FREQUENCY IDENTIFICATION (RFID) SYSTEMS COMMUNICATION PROTOCOLS AND TEDS FORMATS.

The main objective of this standard is to reduce the cost & time required to integrate transducer & RFID system and also acts as means for the device & equipment interoperability. Basically, standard explains communication methods and data formats, and it provides a new transducer electronic data sheet (TEDS) for sensors working in cooperation with radio frequency identification (RFID) systems. To facilitate communications between radio frequency identification (RFID) systems and smart RFID tags with integral transducers (sensors and actuators) which is define by this standard data format It also defines a command structure and specifies the communication methods with which the command structure is designed to be compatible. The IEEE

1451 family of standards is designed to allow the interconnection of a variety of transducers(sensors and actuators) in a network, wired or wireless, with different physical configurations, such as point to point, distributed multidrop, and mixed mode. A transducer is connected to a transducer interface module (TIM), which is connected to a network capable application processor (NCAP) for network access. The Figure.9 below shows TIM and NCAP can be implemented as an integrated unit.

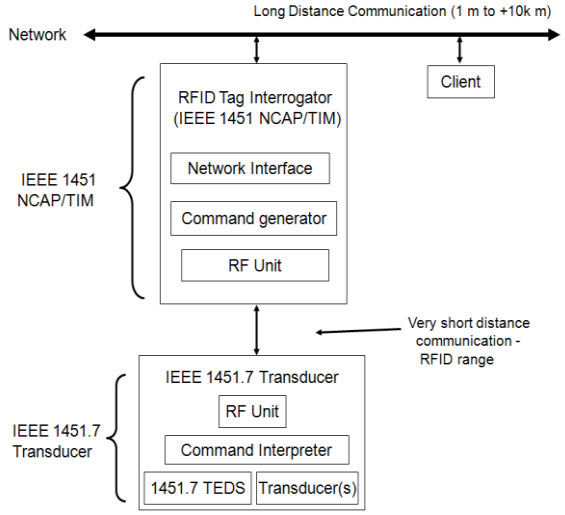

Figure.9 System Block of IEEE 1451.7

X. CONCLUSION

This paper provides a brief overview & also describes about the concept, objectives & technical features of IEEE P1451 standard. These universally accepted transducer interface standards not only allow enhance the peculiarities of smart sensors & actuators but also lower the development costs. Implementation of any standard will narrow the design in specific technical area. Thus, these standards often provide new opportunities for industry.

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