SAS 2009 – IEEE Sensors Applications Symposium
New Orleans, LA, USA - February 17-19, 2009

Integration of IEEE 1451 Smart Transducers and OGC-SWE Using STWS

Eugene Y. Song,
National Institute of Standards and Technology
100 Bureau Drive, MS# 8220
Gaithersburg, Maryland USA 20899-8220
E-Mail: ysong@nist.gov

Kang Lee
National Institute of Standards and Technology
100 Bureau Drive, MS# 8220
Gaithersburg, Maryland USA 20899-8220
E-Mail: kang.lee@nist.gov

***Abstract**: This paper describes the integration of IEEE 1451 smart transducers and Open Geospatial Consortium - Sensor Web Enablement (OGC-SWE) using the Smart Transducer Web Service (STWS). An integration architecture and a prototype system are presented. The integration is illustrated via case studies of the prototype system.*

***Keywords**: IEEE 1451, IEEE 1451.0, integration, NCAP, OGC-SWE, smart transducers, SOS, TIM, STWS.*

I. INTRODUCTION

Sensors are used in a variety of distributed measurement and control applications that touch our lives every day, ranging from industrial automation to intelligent transportation systems to health care to smart appliances to homeland defense [1]. A Sensor Web shown in Figure 1 refers to Web-accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and Application Program Interfaces (APIs) [2]. Some sensors are already on the Web and able to return their location information as well as observations and measurements. The missing element for Sensor Web is a universal framework for describing and tasking sensors in eXtensible Markup Language (XML). The Open Geospatial Consortium - Sensor Web Enablement (OGC-SWE) group is building a framework of open standards for exploiting Web-connected sensors and sensor systems, such as flood gauges, air pollution monitors, stress gauges on bridges, mobile heart monitors, webcams, satellite-borne earth imaging devices, and other sensors and sensor systems. The OGC-SWE initiative is focused on developing a set of standards to enable the discovery, exchange, and processing of sensor observations, as well as the tasking of sensor systems [3].

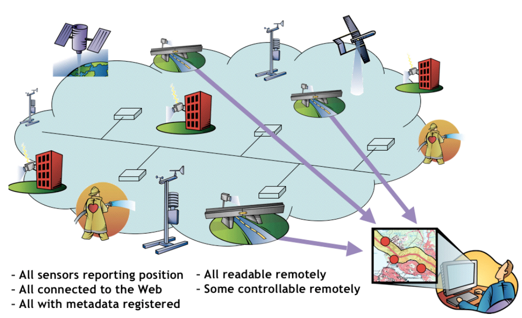

Fig. 1. Sensor Web (courtesy of OGC).

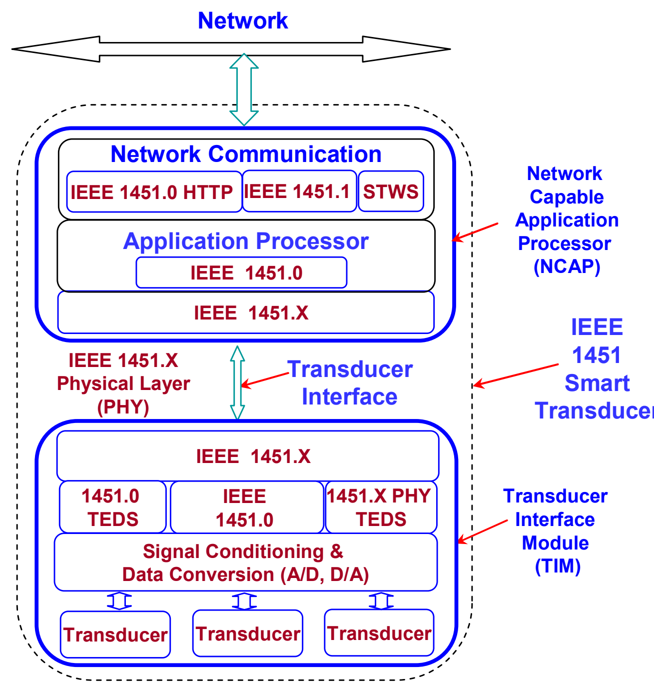

Fig. 2. IEEE 1451 smart transducer.

A smart transducer is the integration of an analog or digital sensor or actuator element, a processing unit, and a communication interface [4]. An Institute of Electrical and Electronics Engineers (IEEE) 1451 smart transducer provides functions beyond those necessary for generating a correct representation of a sensed or controlled quantity. Its functionality simplifies the integration of the transducer into applications in a networked environment [5]. Figure 2 shows the essential elements of an IEEE 1451 smart transducer: a Network Capable Application Processor (NCAP), a Transducer Interface Module (TIM), and a transducer interface between the NCAP and TIM. The NCAP, a network node or gateway, is an application processor capable of network communications. The TIM, a sensor node, consists of transducer signal conditioning and data conversion elements, and a number of sensors and actuators. The TIM also includes a set of Transducer Electronic Data Sheets (TEDS), which describe the metadata of transducers. The IEEE 1451 family of standards defines a set of common communication interfaces for connecting transducers to microprocessor-based systems, instruments, and networks in a network-independent environment [6]. As shown in Figure 2,

9781-4244-2787-1/09/$25.00 ©2009 IEEE

Figure 11 shows two screenshots of the transducer discovery service of the demonstration system. The screenshot on the left shows the request of transducer discovery, while the right shows the response. The result shows that TIM with a timId(1) has two transducer channels. The first transducer channel is a VOC sensor with a channelId(1). The second transducer channel is a FLM sensor with a channelId(2).

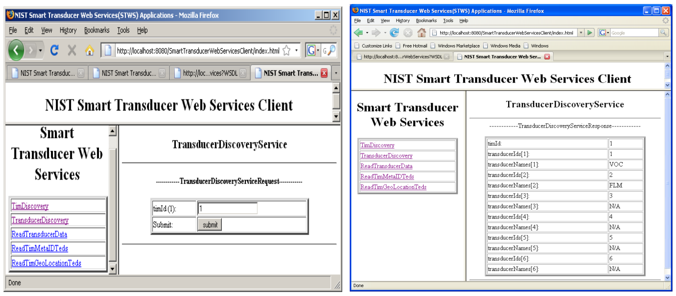

Fig. 11 Transducer Discovery screenshots.

C. Read TIM MetaID TEDS

Figure 12 shows two screenshots of performing the ReadTimMetaIDTeds service. The screenshot on the top shows the request of the service, whereas the screenshot on the bottom shows the response. The result shows the MetaID TEDS data of TIM with timId(1). Table 1 shows the detailed information of MetaID TEDS of the TIM.

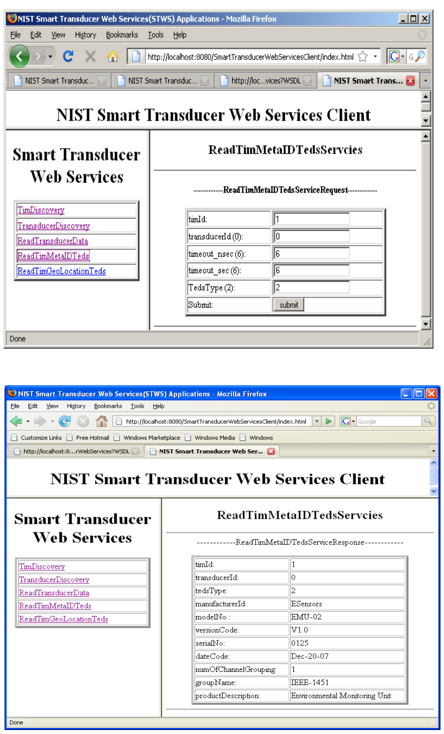

Fig. 12. Read TIM MetaID TEDS screenshots.

Table 1 MetaID TEDS

MetaIDTEDS of TIM	
`ManufacturerId`	`ESensors`
`ModelNo.`	`EMU-2`
`VersionCode`	`V1.0`
`SerialNo.`	`0125`
`DateCode`	`Dec-20-07`
`NumberOfChannels`	`2`
`GroupName`	`IEEE-1451.2`
`ProductionDescription`	`Environmental monitoring Unit`

D. Read TIM Geolocation TEDS

Figure 13 shows the results of reading a Geolocation TEDS of a TIM. The top and bottom screenshots show the request and response of executing the `ReadTimGeoLocationTeds` service, respectively. The location of the TIM in terms of latitude (43.0019 degrees), longitude (-78.8377 degrees), and altitude (131.1 degrees) was presented in the response.

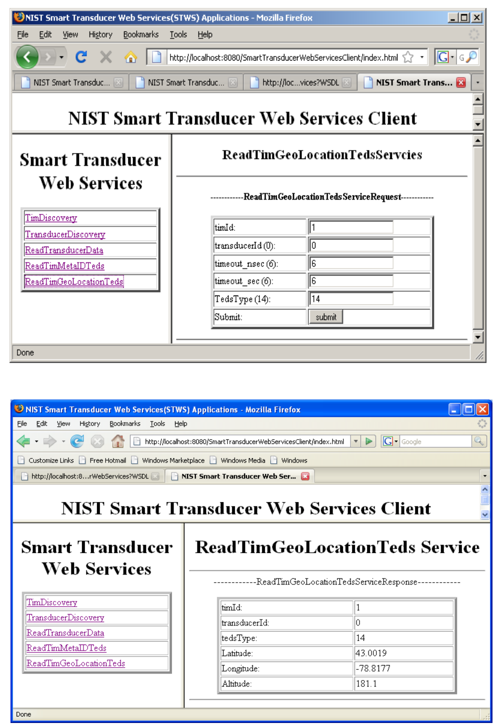

Fig. 13. Read TIM Geolocation TEDS screenshots.

E. Read Transducer Data

The SOS client can determine the location of a sensor based on the information of the sensor Geolocation TEDS. It can remotely read sensor data by sending a sensor reading request to the SOS. In turn, the STWS client of the SOS passes the request to the STWS. Finally, the STWS communicates the request to the IEEE 1451 smart transducer, in this case the EMU, using the IEEE 1451.0 HTTP protocol. After the EMU reads the sensor data from the specified transducer channel, it

The STWS consists of a set of Web services for IEEE 1451 smart transducers, such as TIM discovery, transducer discovery, read transducer data, read transducer MetaID TEDS, and read Geolocation TEDS. Figure 8 shows a successfully deployed Web Service Definition Language (WSDL) file, which is used to generate a STWS client for the prototype system. In the OWS-5 case, the STWS, an independent module, is a bridge between the IEEE 1451 smart transducers and the OGC-SWE SOS.

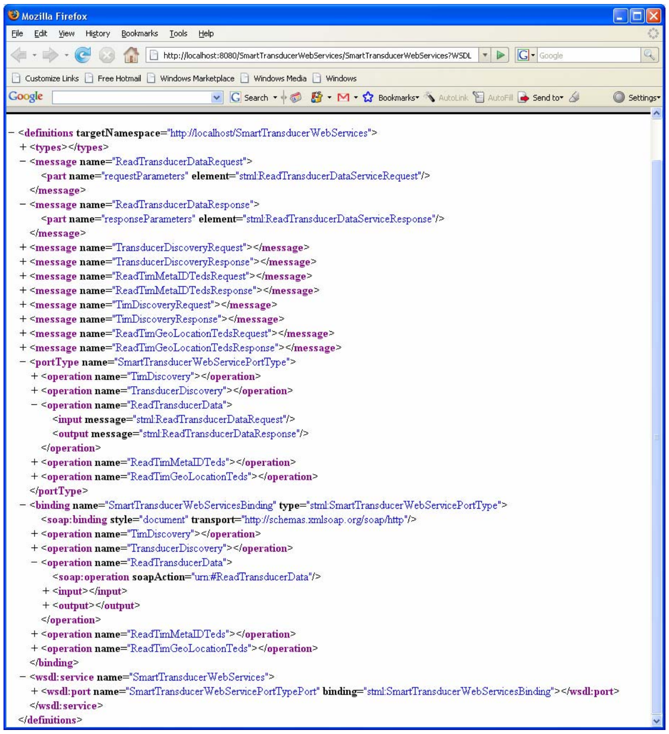

Fig.8. Deployed WSDL of STWS.

C. OGC-SWE SOS

The OGC-SOS standard, one of the OGC-SWE standards, provides an API for managing sensors and retrieving sensor data (metadata and observation). Whether from stationary sensors (e.g., water monitoring) or mobile sensors (e.g., satellite imaging), measurements from sensor systems using the SOS provide much of the geospatial data by volume used in geospatial systems today [14]. The SOS in the prototype system is implemented in Microsoft .Net at TASC.

D. Sensor Application

A sensor application could be for sensor alert or environmental monitoring. The sensor application in the prototype system, including SOS client, is implemented in Microsoft .Net at TASC.

V. CASE STUDIES

The Team-1451 demonstrated the implementation and integration of IEEE 1451 smart transducers and OGC-SWE SOS using STWS as shown in Figure 9**.** The demonstration showed two ways of communicating with sensors, via two different clients. The first one demonstrated the access of IEEE 1451 smart transducers using SOS and STWS via a SOS client. The second one demonstrated the access of the smart transducers by means of STWS using a STWS client. Functionalities were illustrated: TIM discovery, transducer discovery, reading of the TIM MetaID TEDS, reading of the Geolocation TEDS, and the reading of transducer data.

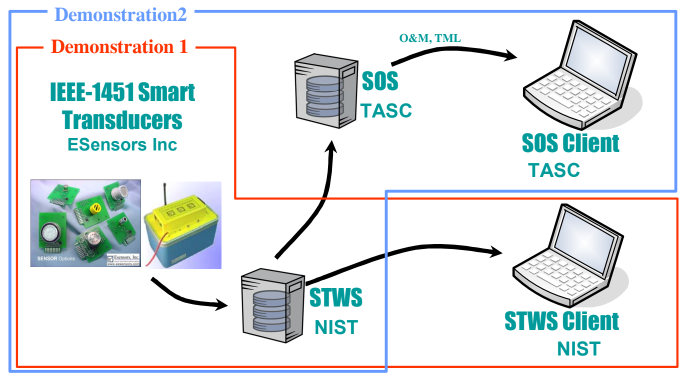

Fig. 9. IEEE-1451/ OGC-SWE demonstrations.

A. TIM Discovery

When a NCAP performs a TIM discovery, it can find out all the TIMs announced to the NCAP, and obtain the TIM identity number (timIds) of all the TIMs. Figure 10 shows two screenshots of the demonstration system. The screenshot on the left shows the request of TIM discovery by the NCAP with ncapId(1). The screenshot on the right shows the response of TIM discovery resulted in one TIM with timId(1).

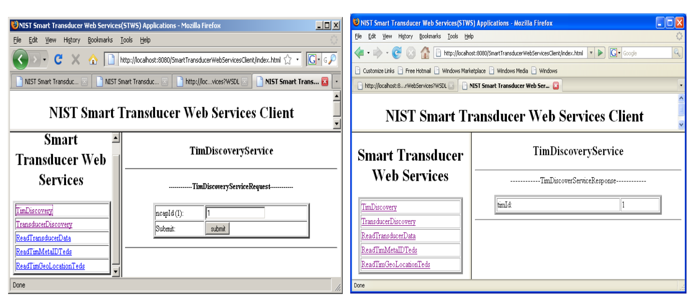

Fig. 10 TIM discovery screenshots.

B. Transducer Discovery

After the discovery of TIMs, a transducer discovery service can be invoked to obtain all the transducer channel identities and transducer channel names of the specified TIM.

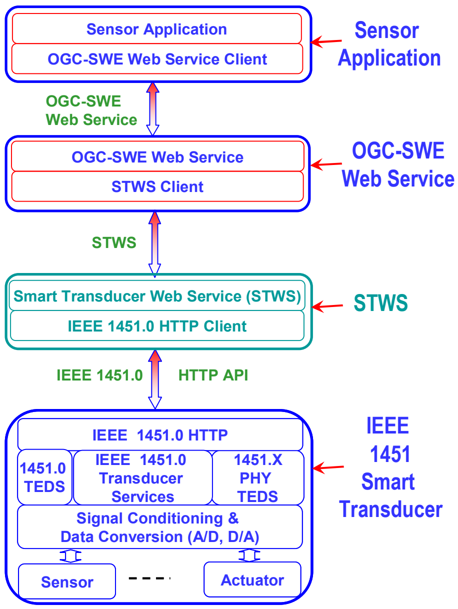

Fig.5. Integration architecture for IEEE 1451 smart transducers and OGC-SWE.

Figure 5 shows the integration architecture of IEEE 1451 smart transducers and OGC-SWE Web Services using STWS. This architecture includes a sensor application, OGC-SWE Web Service, STWS, and IEEE 1451 smart transducer. The OGC-SWE Web Service consists of the SOS, SPS, SAS, WNS, and STWS Client. The sensor application communicates with the OGC-SWE Web Service using the OGC-SWE Web Service Client. Then the OGC-SWE Web Service conveys the information to the IEEE 1451 smart transducers through the STWS. The OGC-SWE Web Service communicates with the STWS via the STWS client. Finally, the STWS converses with IEEE 1451 smart transducers via the IEEE 1451.0 HTTP client using the 1451.0 HTTP application programming interface (API). The IEEE 1451.0 HTTP API is a Web interface for easy access to IEEE 1451 smart transducers.

IV. PROTOTYPE SYSTEM FOR INTEGRATING IEEE 1451 SMART TRANSDUCERS AND OGC-SWE SOS

Figure 6 shows a prototype system integrating IEEE 1451 smart transducers with the OGC-SWE SOS. The prototype system was constructed by three collaborators – Esensors**, NIST, and The Analytical Sciences Corporation (TASC) of the Northrop Grumman. In this system, there are two ways to demonstrate the access of smart transducers: 1) sensor applications access the transducers through the SOS and STWS via the SOS client, and 2) STWS clients access the transducers via the STWS module. In the lower level, the STWS converses with the IEEE 1451 smart transducers using the IEEE 1451.0 HTTP protocol.

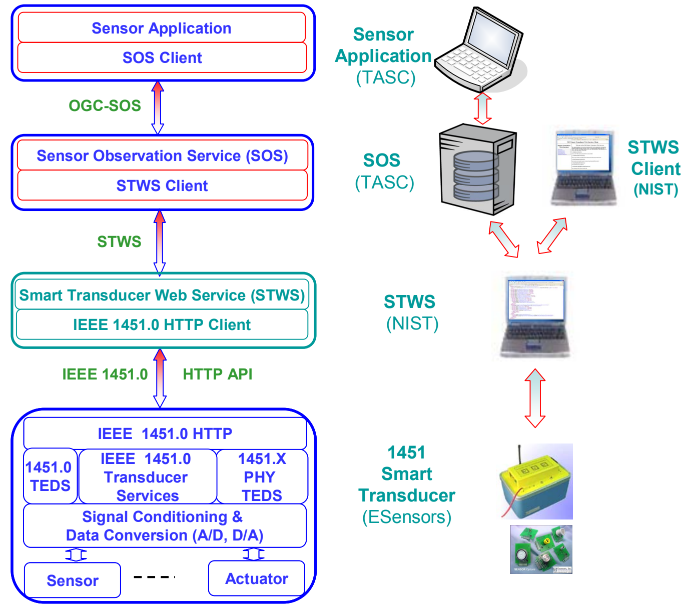

Fig. 6. Prototype system for integration testing.

A. IEEE 1451 Smart Transducer - EMU

Figure 7 shows an IEEE 1451-based smart transducer, an Environmental Monitoring Unit (EMU) by Esensors, which consists of multiple sensors and can be used as an early-warning system to detect hazardous gases. [13]. The EMU provides an IEEE 1451.0 HTTP interface, which allows a standard way to access sensors anywhere using a Web browser. This unit can accommodate up to six sensors, such as a volatile organic compound (VOC) sensor, a toxic gas sensor, or a flammable (FLM) compound sensor. The EMU is an integrated IEEE 1451 smart sensor because it combines the IEEE 1451 NCAP and TIM.

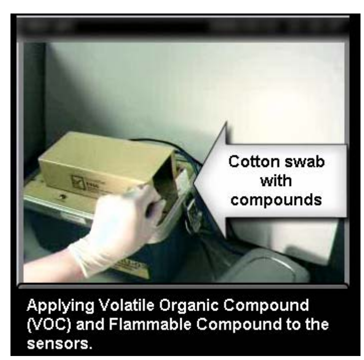

Fig. 7. IEEE 1451 smart transducer – EMU.

B. STWS

three network communication interfaces are available for accessing IEEE 1451 smart transducers. They include the IEEE 1451.1 communication protocols [7], IEEE 1451.0 Hypertext Transfer Protocol (HTTP), and the proposed Smart Transducer Web Services (STWS). The STWS, which is based on the IEEE 1451.0 standard, was developed at the National Institute of Standards and Technology (NIST) [8, 9]. The IEEE 1451.0 standard defines a set of common commands, TEDS formats, and communication protocols for the IEEE 1451 family of standards [5]. The transducer interface between the NCAP and TIM is called the IEEE 1451.X physical interface, which could be in the form of wired (X=2 or 3) or wireless (X=5) configuration.

While the IEEE 1451 suite of standards deals with sensor data and sensor metadata from physical sensors to the network level, the OGC-SWE takes the sensor information, and brings it into high-level sensor applications, in particular via the Web. Applying these two sets of standards together will ultimately achieve the ease of use of sensors and ability to transfer sensor information from physical sensors to high-level sensor applications in a seamless way using consensus-based standards [10].

This paper mainly focuses on the integration of IEEE 1451 smart transducers and OGC-SWE using STWS. Section II describes related work. An integration architecture for IEEE 1451 smart transducers and OGC-SWE is proposed in section III. Section IV describes some case studies to test integration between IEEE 1451 smart transducers and OGC-SWE standards. Conclusions and a summary are presented in Section V.

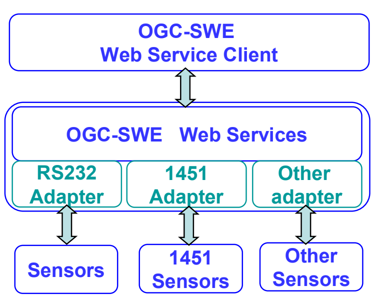

Fig. 3. Sensor connectivity in OGC-SWE.

II. RELATED WORK

Sensor Web, a sensor network for environmental monitoring and control [11] developed at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), is a new class of Geographic Information System (GIS). The OGC-SWE members have developed and tested the following candidate specifications: Observations & Measurements (O&M), Sensor Model Language (SensorML), Transducer Markup Language (TML), Sensor Observation Service (SOS), Sensor Planning Service (SPS), Sensor Alert Service (SAS), and Web Notification Services (WNS) [2]. The OGC-SWE standards have been developed and validated by members of the OGC. The goal of SWE is to enable all types of Web sensors, instruments, and imaging devices to be accessible via the Web. Figure 3 shows where sensors fit in the OGC-SWE interoperability framework. The problems of this integration approach are: 1) OGC-SWE Web Services communicate with different sensors using customized adapters, 2) these adapters are not yet developed and it will take a long time and much resource to develop them, and 3) using customized adapters is not a standard way to integrate OGC-SWE with sensors. The STWS is proposed to be used to ease this integration effort, is based on the service-oriented architecture [8], and is a unified Web service for IEEE 1451 smart transducers [9]. Therefore, the STWS is a suitable solution for achieving seamless integration of the IEEE 1451 smart transducers with the OGC-SWE and sensor alert applications.

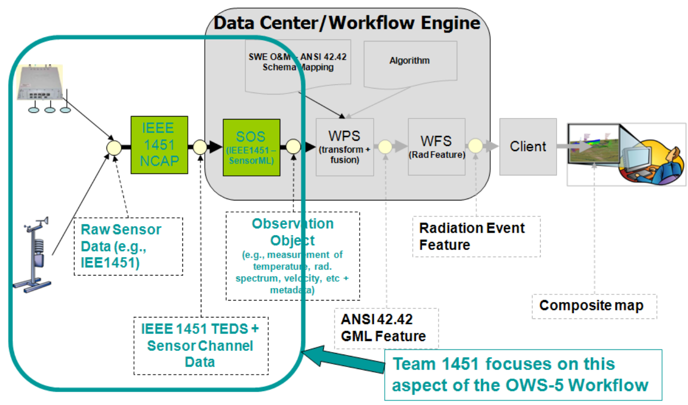

Fig. 4. Team-1451 in OWS-5.

III. INTEGRATION ARCHITECTURE FOR IEEE 1451 SMART TRANSDUCERS AND OGC-SWE

The IEEE 1451 and OGC-SWE standards are sensor interface and sensor application interface standards, respectively. The question is how to seamlessly integrate or apply these two sets of standards together to achieve sensor data interoperability. The OGC Web Services Phase 5 (OWS-5) Testbed was an initiative of the OGC Interoperability Program to collaboratively extend and demonstrate the OGC baseline for geospatial interoperability [12]. The OWS-5 initiative includes four threads: Sensor Web Enablement (SWE), Geo Processing Workflow (GPW), Agile Geography, and Compliance Testing (CITE). The OWS-5 SWE focuses on integrating the SWE interfaces and encodings into workflows to demonstrate the ability of SWE specifications to support operational needs. “Team-1451” in OWS-5 has demonstrated the integration of IEEE 1451-based smart sensors and the SWE Web Services, as shown in Figure 4.

conveys the sensor data to the sensor application via the STWS and SOS. Figure 14 shows screenshots of requesting a FLM sensor reading, and the display of the sensor reading of 282.647.

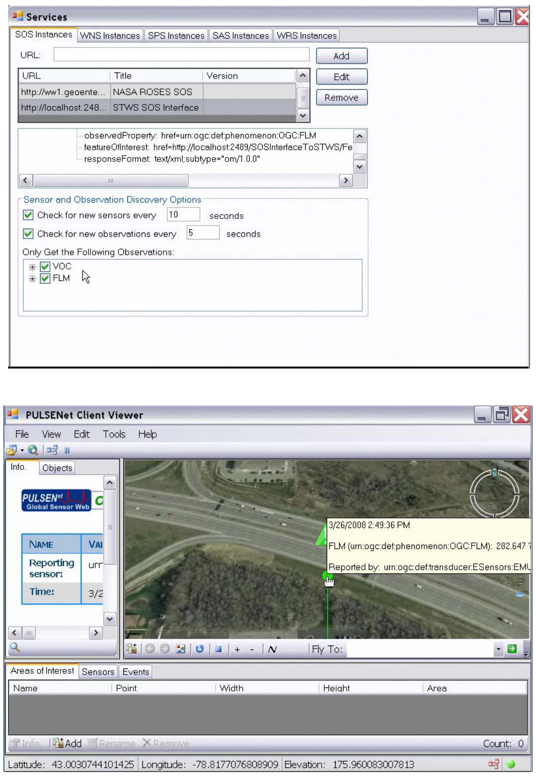

Fig.14. Read Transducer Data screenshots.

VI. CONCLUSIONS

This paper describes the integration of IEEE 1451 smart transducers to OGC-SWE using Smart Transducer Web Services. This integration was successfully demonstrated in a prototype system with associated case studies. The work described lays a sound foundation for the standardization of Smart Transducer Web Services.

ACKNOWLEDGEMENTS

Thanks to Dr. Darold Wobschall and Kenny Chow of Esensors Inc., for their contributions in the integration of the IEEE 1451 based smart transducers to STWS.

Thanks to John Davidson of Image Matters, LLC. and Scott Fairgrieve of Northrop Grumman for their contributions in the integration of OGC-SWE SOS to STWS.

** Commercial equipment and software, many of which are either registered or trademarked, are identified in order to adequately specify certain procedures. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

REFERENCES

1. Kang Lee, “Smart and Wireless Sensor Standards for Distributed Measurements”, Instrumentation and Measurement Magazine, April issue, 2008, pp.6
2. Mike Botts, George Percivall, Carl Reed, and John Davidson, OGC White Paper, “OGC® Sensor Web Enablement: Overview and High Level Architecture”. Open Geospatial Consortium Inc., Date: 2007-12-28, Reference number of this document: OGC 07-165, Version: 3
3. Mark Reichardt, “The Sensor Web's Point of Beginning”, [Online]. Available: http://www.geospatial-online.com/geospatialsolutions/article/articleDetail.jsp?id=52681
4. Wilfried Elmenreich, Stefan Pizek, “Smart Transducers–Principles, communications, and configuration”, Proceedings of the 7th IEEE International Conference on Intelligent Engineering Systems (INES), Assuit, Luxor, Egypt, March 2003, pp.510 -515.
5. 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.
6. Lee, K., “IEEE 1451: A Standard in Support of Smart Transducer Networking”, Proceedings of the 17th IEEE Instrumentation and Measurement Technology Conference, Baltimore, Maryland, May 1-4, 2000, Vol. 2, pp. 525-528.
7. IEEE STD 1451.1-1999, Standard for a Smart Transducer Interface for Sensors and Actuators – Network Capable Application Processor (NCAP) Information Model, IEEE Instrumentation and Measurement Society, TC-9, The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y. 10016, SH94767, June 26, 1999.
8. Eugene Song, Kang Lee, “Smart transducer web service based on IEEE 1451.0 standard”, IMTC 2007-Instrumentation and Measurement Technology Conference. WARSAW, POLAND, MAY 1-3, 2007, pp.1-6.
9. Eugene Y. Song, Kang Lee, “STWS: A unified Web service for IEEE 1451 smart transducers”, IEEE Transaction on Instrumentation and measurement, Vol.57, No.8, Aug. 2008, pp.1749-1756
10. Lee, K. B., Reichardt, Mark. E., “Open Standards for Homeland Security Sensor Networks”, IEEE Instrumentation & Measurement Magazine, Dec. 2005, Vol. 8, No. 5, pp.14-21.
11. Sensor Web, [Online]. Available: http://en.wikipedia.org/wiki/Sensor_Web.
12. OWS-5, [Online]. Available: http://www.opengeospatial.org/standards/requests/40
13. ESensors EMU, [Online]. Available: http://www.eesensors.com/environmental.html
14. OGC-SOS, Sensor Observation Service, Open Geospatial Consortium Inc. Date: 2007-10-26, Reference number of this document: OGC 06-009r6, Version: 1.0 Category: OpenGIS® Implementation Standard.