A Standard-based Global Ocean Monitoring System

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Abstract *- This paper describes a standard-based global ocean monitoring system developed at the National Institute of Standards and Technology (NIST) with collaborating partners. This system adapts the Institute of Electrical and Electronics Engineers (IEEE) 1451 smart transducer interface standard, Programmable Underwater Connector with Knowledge (PUCK) protocol, and Smart Transducer Web Service (STWS) interface to monitor the ocean environment globally via the Internet. A prototype system is presented with a case study to illustrate the ocean monitoring scenario.*

Keywords - *Environmental Monitoring, IEEE 1451.0, NCAP, Ocean Monitoring, Ocean Instrument, PUCK Protocol, Sensor, Smart Transducer, STWS, TIM*

Ⅰ. INTRODUCTION

Global warming and climate change are the greatest environmental challenges facing the world today. The effects of global warming are beginning to be felt in the ocean environment [1]. Red tides are Harmful Algal Blooms (HABs), which is a small subset of algal species that produce toxins and/or bloom to excess, thus creating harm to humans and ecosystems. HABs occur, often discoloring the water red, brown, green, or yellow. Figure 1 shows the HABs [2-3]. Red tide phenomenon naturally occurs world-wide and its seasonal occurrence depends on environmental conditions and meteorological factors [4]. It is reported that all U.S. coastal states have experienced HABs over the last decade, and new species have emerged in some locations that were not previously known to cause problems. Monitoring water quality activities might reveal conditions conducive to or indicative of HABs. Improvements in infrastructure including availability of standards and probes, shared-use facilities, platforms for continuous, real-time monitoring including integrated observing systems could support state-of-the-art HAB monitoring and detection and lead to be more accurate short- and long-term HAB predictions [5].

Fig. 1. Harmful algal blooms

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Interest is increasing in open-ocean environmental monitoring [6]. To monitor ocean waves, tides, temperature, and salinity is routinely completed using sensors and ocean instruments. Today's oceanographic instruments are characterized by very diverse non-standard software protocols and data formats. This diversity of protocols poses serious challenges to integration of large-scale sensor networks. Data interoperability of ocean instruments has becoming globally important, as users from many organizations and disciplines may wish to access and process data from multiple observatories [7]. Standard instrument protocols are now being developed to address these challenges. Open sensor standards will make easy sensors discoverable and accessible in ocean monitoring systems.

The Monterey Bay Aquarium Research Institute (MBARI)'s Programmable Underwater Connector with Knowledge (PUCK) is a somewhat minimal native protocol for RS-232 and RS-485 devices and enables "selfidentifying" instruments that can be automatically integrated into an observing system [8].

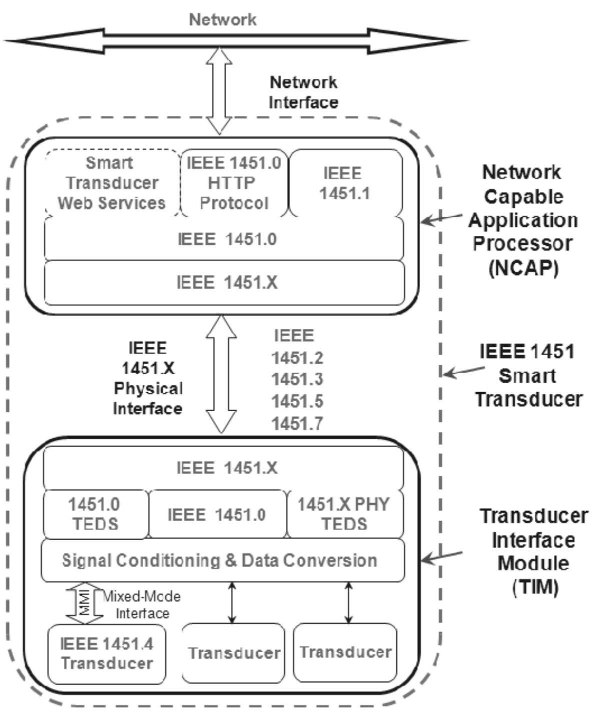

Fig. 2. IEEE 1451 Smart Transducer.

The Institute of Electrical and Electronics Engineers (IEEE) 1451 smart transducer interface standard for sensors and actuators define a set of network-independent communication interfaces to connect smart transducers to microprocessors, instrumentation systems, and control/field networks [9]. An IEEE 1451 smart transducer provides functions beyond those necessary for generating a correct representation of a sensed or controlled quantity. This additional functionality typically simplifies the integration of the transducers into applications in a networked environment [10]. Figure 2 shows an IEEE 1451 smart transducer [11], which consists of a Transducer Interface Module (TIM), a Network Capable Application Processor (NCAP), and an interface between the TIM and NCAP. The NCAP provides a network connection or gateway function between the TIMs and a user network. The TIM is basically a sensor module, which consists of elements, such as transducers (sensors or actuators), signal conditioner, analog-to-digital converter and/or digital-to-analog converter, a physical interface, and a set of Transducer Electronic Data Sheets (TEDS). The NCAP communicates with the TIM through the physical interface, which could be wired or wireless. There are three possible network interfaces that can be used to access sensors of the TIM from a user network. These interfaces are defined in 1.) the IEEE 1451.0-2007 Hyper Text Transfer Protocol (HTTP) [10], 2.) the IEEE 1451.1-1999 standard [12], and 3.) the proposed Smart Transducer Web Services (STWS) [13-14]. The interface between the NCAP and TIM is defined the IEEE 1451.X physical interface specification.

This paper focuses on standard-based global ocean monitoring systems. Section II describes related work. An architecture of a standard-based global ocean monitoring system is proposed in section III. Section IV describes a prototype system with a case study to demonstrate ocean monitoring globally.

Ⅱ. RELATED WORK

The Ocean Observatories Initiative (OOI) constructs a networked infrastructure of science-driven sensor systems to measure the physical, chemical, geological, and biological variables in the ocean and sea floor. Greater knowledge of these variables is vital for improved detection and forecasting of environmental changes and their effects on bio diversity, coastal ecosystems and climate [15]. The Integrated Ocean Observing System (IOOS) is a multidisciplinary system designed to enhance our ability to collect, deliver, and use ocean information. The goal is to provide continuous data on our open oceans, coastal waters, and the Great Lakes in the formats, rates, and scales required by scientists, managers, businesses, governments, and the public to support research and inform decision-making [16]. The OOI will focus on discoveries enabled by new technologies; IOOS will concentrate on direct applications to everyday societal needs. IOOS data will feed into the Global Ocean Observing System (GOOS), an international program with similar goals. The GOOS is a global system for observations, modeling and analysis of marine and ocean variables to support operational ocean services worldwide. The GOOS provide accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible, and the basis for forecasts of climate change [17]. The Global Earth Observation System of Systems (GEOSS) is being built by the Group on Earth Observations (GEO) based on a 10-Year Implementation Plan running from 2005 to 2015[18]. GEOSS seeks to connect the producers of environmental data and decision-support tools with the end users of these products, with the aim of enhancing the relevance of Earth observations to global issues. A DRAGONESS Project funded by the European Union's (EU) Framework Program for 3 years supports harmonizing European and Chinese marine monitoring for Environment and Security System [19].

The Ocean Innovation 2008 World Summit – Ocean Observing Systems Workshop was held in Newfoundland, Canada [20]. A sensor and instrument interoperability demonstration was performed in this workshop. The demonstration focused on a harmful-algal-bloom-alert scenario, in which active sensors were discovered, accessed, controlled, and read in real-time using browser-based applications that communicate via open standards. The IEEE 1451 standard and PUCK protocol, which are implemented on sensor hardware and software, were demonstrated working with OGC Sensor Web Enablement (SWE) standards at the Web application level. These standards are proven to work together to support interoperability among these systems as well as making it easy to provide public access to sensor information [21]. The Plug and Work Sensors demonstration was also held in the OOI Instrumentation Workshop, March 12-13, 2009 -Portland, Oregon [22]. The work described in this paper played key roles in the two demonstrations.

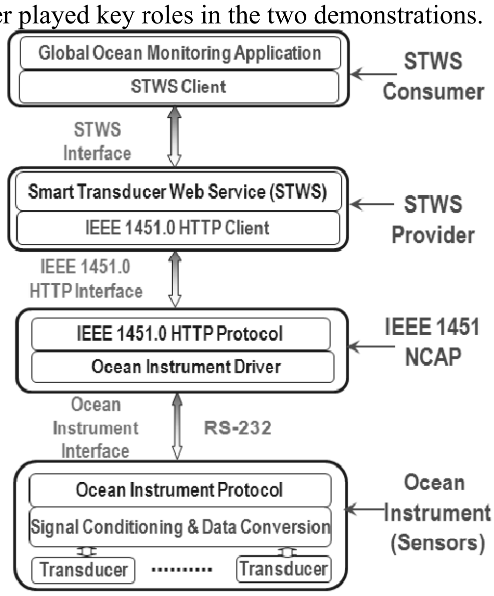

Fig. 3. Architecture of a global ocean monitoring system.

Ⅲ. ARCHITECURE OF A STANDARD-BASED GLOBAL OCEAN MONITORING SYSTEM

Figure 3 shows the architecture of standard-based and service-oriented global ocean monitoring system, which consists of ocean instruments (sensors), IEEE 1451 NCAP, STWS (a part of the proposed IEEE 1451.1 standard), global ocean environment monitoring. The communications among four parts that adapt standard protocols include STWS, IEEE 1451.0 HTTP protocol, RS-232, and PUCK protocol.

3.1 Ocean Instruments

The ocean instruments involved mainly focus on the measurement of conductivity, temperature, and depth (CTD), which is the primary parameter for determining essential physical properties of sea water. The ocean instruments include Triplet[1], Seabird CTD, ocean weather station, and other instruments. Most ocean instruments use RS232 interface and different proprietary protocol. The PUCK protocol enables "plug-and-work" instruments, meaning that when the instrument is physically plugged into an observatory port, the observatory automatically determines the instrument identity and reconfigures itself to accommodate the new instrument and its data stream. This automation eliminates time-consuming and error-prone manual configuration steps [7].

3.2 IEEE 1451 NCAP

The IEEE 1451 NCAP, a gateway, consists of the IEEE 1451.0 HTTP Web server and ocean instrument driver. The IEEE 1451.0 HTTP protocol focuses mainly on accessing transducer data and TEDS through the HTTP 1.1 protocol. Sensor applications can send a HTTP request to a HTTP server on a NCAP. The server response can be either in Extended Markup Language (XML), Hyper Text Markup Language (HTML), or Text format. In this manner, the IEEE 1451.0 HTTP Protocol retrieves sensor data records and returns the data in standardized format, thereby achieving sensor data interoperability. The ocean instrument drivers enable IEEE 1451 NCAP to interact with ocean instruments through the ocean instrument protocols. The ocean instrument drivers provide a mapping function between the IEEE 1451.0 HTTP protocol and ocean instrument protocols.

3.3 STWS

The STWS described in WSDL consists of a set of Web services for IEEE 1451-based sensors or instruments, such as TIM Discovery, Transducer Discovery, Read Transducer Data, Read Geolocation TEDS, and Read TIM Meta Identification TEDS services [10-11]. The STWS communicates with the IEEE 1451 NCAP through the IEEE 1451.0 HTTP protocol to access these services.

3.4 Global Ocean Monitoring

As shown in Figure 3, a global ocean monitoring application communicates with the STWS through a STWS client. The application has an integrated STWS client with a Google Earth application programming interface (API), which let Web developers embed Google Earth, a 3D digital globe, into the Web pages [23].

Ⅳ. PROTOTYPE OF A GLOBAL OCEAN MONITORING SYSTEM

Figure 4 shows a prototype of the global ocean monitoring system, which consists of a monitoring application, a STWS unit, four IEEE 1451 NCAPs, and associated sensors and ocean instruments. The NCAPs are located in various locations across the ocean, such as in California of United States, Breman of Germany, Barcelona of Spain, and Kiel of Germany, respectively. Each NCAP is connected to one or more ocean instruments through RS-232 interfaces.

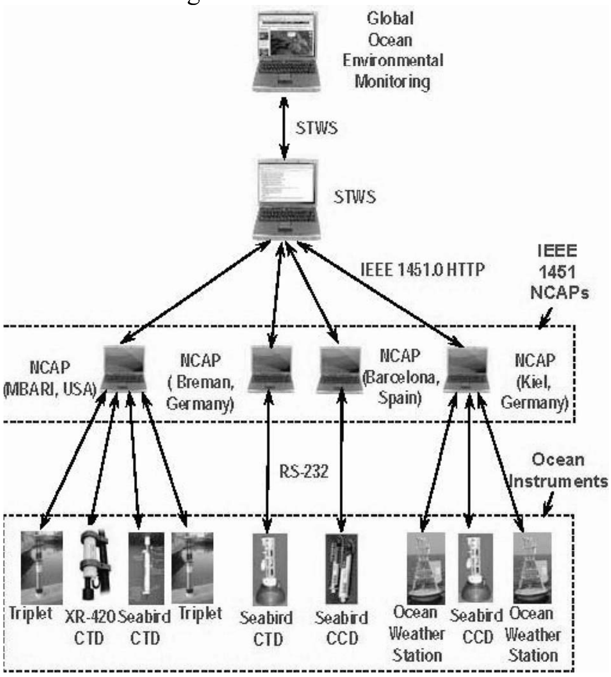

Fig. 4. A prototype of a global ocean monitoring system.

4.1 Distributed Ocean Instruments

The following ocean instruments were deployed at the Monterey Bay Aquarium Research Institute (MBARI):

- PUCK-enabled Seabird CTDs
- PUCK-enabled WETLabs fluorometer and optical backscatter
- PUCK-enabled RBR CTD
- ASIMET wind sensor

The following ocean instruments were deployed at The European Seafloor Observatory Network (ESONET):

- Seabird CTD at the Polytechnic University of Catalunya

[1]ommercial 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.

- Sea and Sun CTD at the Bremen University
- Seabird CTD and meteorological instruments at the Bremen University and Christian Albrechts University in Kiel

Each ocean instrument consists of a few sensors, for example, Seabird CTD has three sensors: temperature sensor,
conductivity sensor, and pressure sensor.

4.2 IEEE 1451 NCAP

The IEEE 1451 NCAP consists of an IEEE 1451.0 HTTP Web server and an ocean instrument driver, which is used to communicate with the ocean instrument. Various sensors and instruments are connected to the NCAPs located in the United States and Europe as shown in Figure 4.

Software Infrastructure and Applications for Monterey Ocean Observing System (SIAM), an instrument driver developed by MBRAI, maps between IEEE 1451.0 requests and instrument services of the SIAM interface. When the IEEE 1451.0 server receives a client HTTP request, it calls to the SIAM instrument service(s), transforms the values returned by the instrument service to IEEE 1451.0 format, and returns the values to the IEEE 1451.0 client. The SIAM recognizes the PUCK protocol and retrieves the payload of a PUCK-enabled instrument when an instrument is plugged in [7].

4.3 STWS

The STWS developed and deployed at NIST in Gaithersburg, Maryland is a bridge between global ocean monitoring applications and IEEE 1451 NCAPs. The STWS provides a service-oriented solution to achieve sensor data interoperability.

4.4 Ocean Monitoring

An ocean monitoring application integrates the STWS client with the Google Earth application programming interface (API). Users can use Google Earth to globally monitor the ocean environment.

Ⅴ. CASE STUDY

Figure 5 shows a screenshot of a standard-based ocean monitoring system. This system can be applied globally for monitoring the ocean environment and conditions using standard interfaces and protocols. Ocean parameters can be monitored via the Internet using common Web browsers.

We take the monitoring system tested in MBARI as a case study. Referring to Figure 5, the NCAP with an Id of 1 has three ocean instruments (IEEE 1451 TIMs) - each consists of a group of sensors. For example, instrument2 with a TIM Id of 130 is a Seabird CTD, which has four sensors that measure sea water temperature, conductivity, pressure, and salinity. The location of the instrument can be shown on the Web browser. For example, instrument2 is located at latitude (36.962), longitude (-121.928) and altitude (-10.0). The Meta ID TEDS of the instrument can be viewed via the "instrument description" tab on the browser. The TEDS includes instrument identification information. For example, the manufacturer identification is Seabird Electronics, the model number is SBE37-SM, the serial number is 2765, and the date code is October 2, 2008. Likewise, various sensor readings can be obtained via other tabs, such as sea water temperature monitoring, conductivity monitoring, pressure monitoring, and salinity monitoring. For example, the temperature sensor reading on channel 1 is 291.6768 degrees in Kelvin.

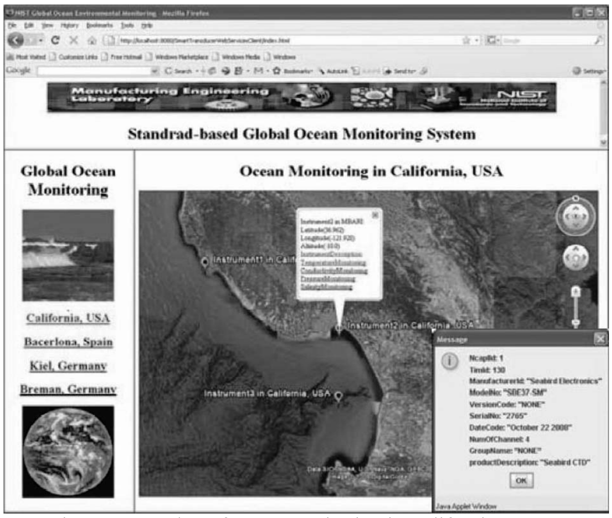

Fig. 5. Screenshot of ocean monitoring in California, USA.

Ⅵ. CONCLUSION

This paper presents an ocean monitoring system, which is based on the IEEE 1451 smart transducer interface standard, MBARI's PUCK protocol, service-oriented architecture, and NIST's STWS interface. The case study has demonstrated that a standards-based system can be built to access sensors and ocean instruments distributed globally using common Web browsers for monitoring the environment and conditions of oceans.

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