Smart Sensor interface for sea bottom observatories

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Abstract- *In order to be able to use all the marine sensors currently available in the market, a new module has to be built to implement the smart sensor standard IEEE-1451[1] as well as other services used in marine measurements. The smart module is aimed to be used in ALL observatory configurations: autonomous, cabled and buoy-based observatories. This module can also be used for low power data acquisition and control applications in new instrument design such as Ocean Bottom Seismometers (OBS) [3] or any other instrument where data logging, clock synchronization, and plug and play capabilities are important. Therefore, the power consumption of the smart module has to be minimized for batteries based observatories and autonomous instruments.*

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INTRODUCTION

Marine instruments commonly use RS232/RS422/RS485 as a communication interface to be connected with an observatory. The possibility to enhance the instrument capabilities and make it smarter is the objective of this development. Ifremer has been working in a preliminary hardware design of the smart sensor module, which has the capability of converting serial interface data into a low power Ethernet interface by adding several services such as: clock synchronization, time stamping, data logging, embedded instrument driver…. This way, all serial instruments (90% of the marine sensors) will be accessed through Ethernet protocol. At Technical University of Catalonia, the IEEE1451 and IEEE1588 [4] had been evaluated in order to be applied to marine instrumentation. Both works will contribute to the design of this module, which will provide IEEE-1451 output data for standardization and interoperability.

In order to use marine instruments in observatory, we have developed software layer that allows observers to communicate with instruments. In this context, we have proposed a language [2] to describe smart sensors in deep-sea observatory. It plays a major role since it provides necessary abstraction to use and interact with sensors.

SMART SENSOR BOARD CARACTERISTICS

The smart sensor design is based on a Stellaris LM3S8962/LM3S9B96 microcontroller from Luminary/Texas instrument[5]. This low power consumption microcontroller, with its internal peripherals, is the main core of the smart sensor board. The system is designed to have these features:

Power supply input (network side)

a. Power Over Ethernet (POE) from the network
b. Battery power supply (VBAT 10V - 60VDC)
c. Direct power supply from the network (10V - 60VDC)

Power supply output (instrument side)

d. Protected output with a resettable fuse
e. Mosfet power switch for reducing the power consumption between data acquisition

Data management and plug and play protocols

f. IEEE-1451 Standard for a Smart Transducer Interface for Sensors and Actuators

Network interface:

g. Ethernet 100BaseT port compatible with POE (Power Over Ethernet)

Instrument interface:

h. Serial port (RS232, RS422, RS485) selectable by software, for the scientific instrument
i. Bus CAN, I2C, SPI, GPIO, USB 2.0 On The Go (OTG),… if the smart board is used as a main controller in a new instrument design
j. PPS (Pulse Per Second) output and NMEA (National Marine Electronic Association) Serial interface output for the time code

Clock synchronization and time stamping services

k. IEEE-1588 Precision clock synchronization protocol for networked measurement and control systems (PTP V2)
l. Underwater GPS clock emulation (PPS+NMEA)
m. Embedded time stamping services compatible with all existing instrument
n. High accuracy clock from 3.10-6 to 3.10-8. TXCO (Temperature Compensated Crystal Oscillator) and MCXO (Microcomputer

Compensated Crystal Oscillator including external clock: ex. Seascan MCXO)

Memory Storage

o. Up to 2*64GByte SDHC flash memory cards with software RAID-0, RAID-1 and JBOD capabilities
p. Embedded generic file system or specific file system (Single File System, Fast File System,…)

Additional features and services:

q. Embedded Tiny Linux core system
r. Power save modes and wake-up capabilities
s. Peer to Peer communication between two Smart Sensor modules
t. Synchronization of Biofouling protection system [6]
u. UDP Server for transparent bi-directional data flow
v. Web services
w. FTP server
x. Temperature sensor
y. Vacuum sensor for measuring the vacuum inside the pressure housing before the deployment
z. Expansion Bus for piggy back application

Embedded Software modeling

We have proposed a language to describe smart sensors. One of the goals of this language is to model the network and to generate the software code that will be embedded in the network nodes to allow communicating with sensors.

Our language describes a sensor by three levels:

1- Static properties: like the location, the type and the battery power of the sensor.
2- Interface: It allows observers to communicate with the sensor. It provides a set of services dedicated to physical measures that a sensor can do based on event detection. Each service is associated with events and can be obtained by invoking a set of operations or commands. The interface specification provides description of sensor events, provided services including operations (sensor commands) and parameters.
3- Behavior: It indicates what the sensor can do. We have described the sensor interface behavior through an automaton, which is composed of a set of states and transitions, to indicate how and in which orders the provided services can be executed. This specification emphasizes the correlation between event reception and the invoked services. A deep-sea observatory operates on a long time period and smart sensor behavior must be sensitive to dedicated event to stop or start their observations synchronized with other smart sensors of the network. With this approach, the service interfaces are behavioral centric based on reception of real time events. We have extended this description to address the internal behavior of the sensor. It indicates how the sensor behaves during service processing. In this context, we must describe the behavior of each service included in the sensor interface. The service behavior indicates how and in which order the service operations must be invoked. We have used a finite state machine to describe the service behavior.

This is the preliminary list of services drawn and it would be completed in the next meetings between the participating institutions. One smart module will be used for each marine sensor adding IEEE-1588 and IEEE-1451 capabilities to each sensor. PPS and NMEA data provide GPS emulation for autonomous observatories. In the case of unknown sensor data format, a UDP server for transparent time stamped data flow is used (non-smart link). The module in equipped with MOSFET switching components in order to power on/off other sensors and instruments between two data acquisition (power save mode) or if it requested by another instrument to avoid any conflict (lights, acoustic, electrolysis system such electronic biofouling device…). Flash memory cards (up to 2*64 GB) are used to store data if the link between seafloor observatory and shore station is a temporary connection (satellite link) or accidentally damaged. Moreover, autonomous observatories and autonomous sensors will store data on the flash memory cards. The smart module can be powered through the marine cable (POE or a separate power supply provided by the cable) or through a battery pack (VBAT). Figures 1,2,3 show the architecture, the services and a block diagram of the smart module under design. Pictures 4,5 show the top view and the bottom view of the smart sensor board.

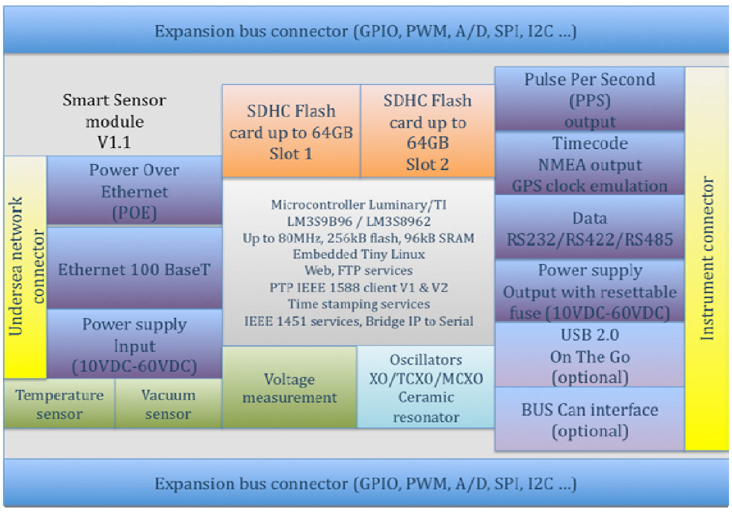


Figure 3: Block diagram of the smart module

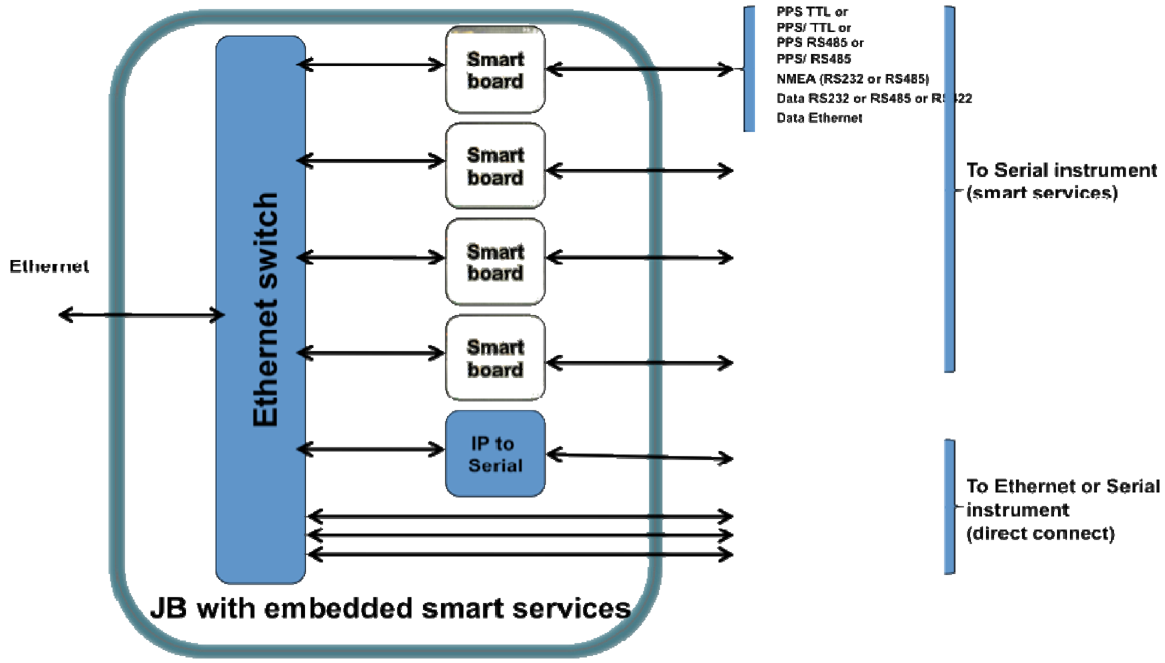


Figure 1: Junction box architecture with Smart Boards

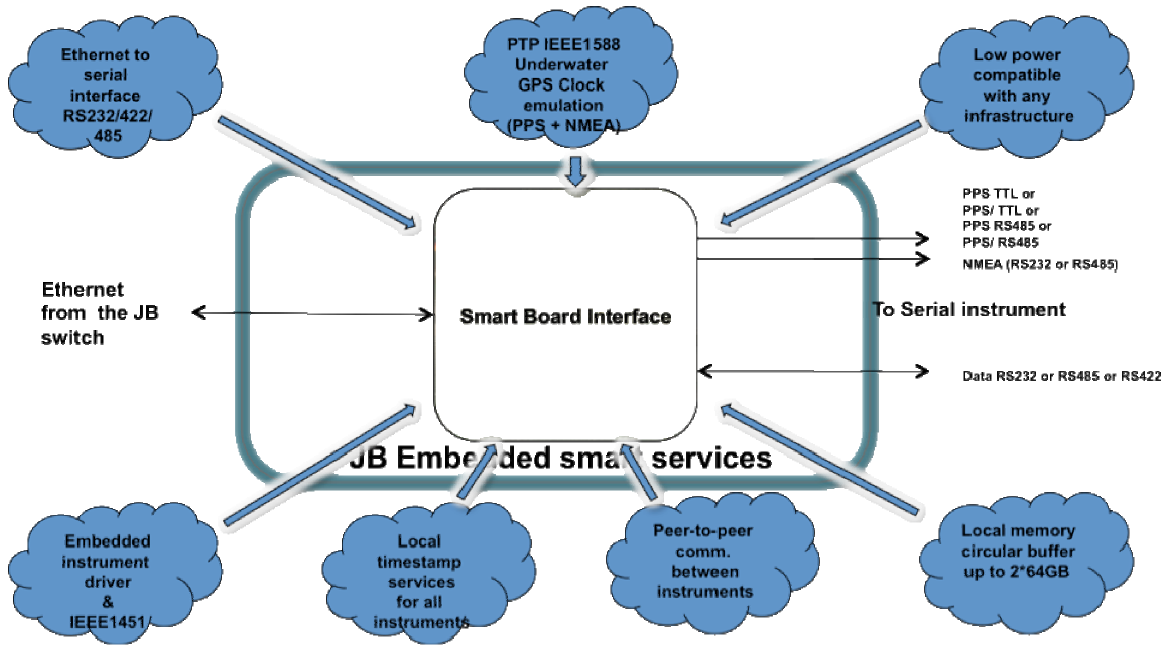


Figure 2: Smart sensor module services

This smart sensor module is based on the Stellaris® Luminary (Texas Instruments) LM3S8962/LM3S9B96 [5] microcontrollers which integrates hardware-assisted support for synchronized industrial networks utilizing the IEEE 1588 Precision Time Protocol (PTP) V1 and V2. The Stellaris® LM3S9B96 microcontroller is based on the ARM® Cortex™-M3 controller core operating at up to 80 MHz, with 256 kB flash, 96 kB SRAM and ROM. Addition of external memory will increase the power consumption, therefore we have decided not to use external memories unless is absolutely necessary. The manufacturer provides many code examples and also applications. PTP IEEE1588v2 clock synchronization is based on the Zurich University of Applied Sciences (ZHAW- development [7]. Tiny Embedded Linux implementation will be based on Unison Operating System from RoweBots [8]. However this application needs to be ported to the target LM3S8962 microcontroller [5].

STANDARDS DESCRIPTION

The complete IEEE-1451 implementation can be very memory consuming, therefore we have decided to implement a simplified IEEE-1451 version onboard and use a standard Linux board (PC104, Coldfire, etc.) installed in the junction box for IEEE-1451 complete implementation. This is useful for autonomous observatories and in the case of a cable cut in the case of cabled observatories. For cabled observatories, a PC in the shore station also has to implement the complete IEEE-1451 standard. As the smart module has the size of a credit card, it can easily be integrated in the existing observatories in 3 different ways:

- Installed inside the sensor: In this case, the sensor connector on the junction box has to be Ethernet compatible.
- Installed inside the seafloor cable: In this case, the sensor connector on the junction box has to be Ethernet compatible.
- Installed inside the junction box: In this case, the junction box has to include the smart module before the deployment.

The following metadata are decided to be included in the smart board:

TEDS (Transducer Electronic Data Sheet):

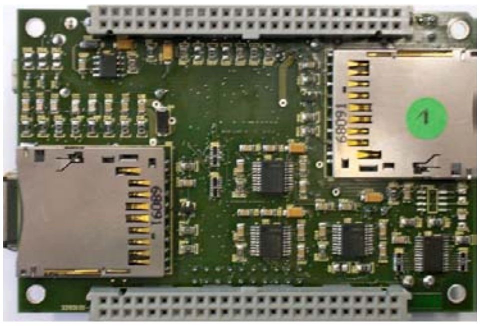
- Manufacturer name
- Model number
- Serial number
- Code version
- Sensor type
- Sensitivity
- Bandwidth
- Owner
- Last calibration date
- Geo-location (water depth, longitude, latitude)

Configuration parameters:

- Number of channels
- Channel measurement type
- Measurement unit
- Parser parameters: Channel, frame length
- Pull command
- Push command
- Event: minimum and maximum values for every channel

For IEEE-1451 standard implementation, it is necessary to define the different commands that are needed for sensor data acquisition. Today, commands as Start sensor, Stop sensor, Change Sampling rate and Standby mode are needed in order to prevent interference between many sensors operating at the same time. For example, LEDs of an underwater camera have to be turned off for optical sensors to operate correctly. These commands have to be implemented for each sensor according to IEEE-1451 Standard. It is planned to include a parser script in the configuration data that implements the sensor commands providing transparency to the scientists. Currently UPC is collaborating with the NIST (National Institute of Standards and Technology) in the implementation of the IEEE-1451 standard. The commands that have not been defined by the standard will be developed in near future.

Picture 1: Smart Sensor Board V1.1 – Top view



Picture 2: Smart Sensor Board V1.1 – Bottom view

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