OBSEA's seismic station joins the IGC network

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Abstract- A cabled system for collecting real-time seismic data has been developed and was deployed in spring of 2011. Nowadays (2013) this seismic station is being part of the Catalan Seismic Network managed by the IGC (Institut Geològic de Catalunya). The seismic system is part of Western Mediterranean Cabled Observatory, OBSEA (www.obsea.es). A key component in this cabled system is the use of IEEE 1588 standard that serves as a clock synchronization mechanism for the seismometer with Universal Time Coordinates (UTC) clock. This paper presents the seismic measurements results of the broadband seismometer. The seismic data are time stamped using a UTC clock which is traceable to within the desired level of precision of sub milliseconds through IEEE 1588 protocol.

Keywords-IEEE 1588, seismometer, time synchronization, cable observatory

I. INTRODUCTION

Locating an earthquake is performed by reading the time that P- and S-waves (primary and secondary waves also known as compressional and shear waves produced by an earthquake) arrive in group at seismograph stations.

An important requirement to have an accurate location of the earthquake is to provide one-microsecond timing to all seismographs with GPS reference. In underwater seismic stations known as Ocean Bottom Seismometers [1], the instrument has no access to a GPS signal for time synchronization. Cabled ocean observatories as OBSEA (Expandable Seafloor Observatory) [2] are widely used to monitor many ocean parameters as seismic activity. Furthermore, Tsunami warning systems that are based on seismic stations need a precise time base in order to generate a precise and reliable alarm.

Commercial products that support IEEE 1588 Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems [3], [4] are now becoming available. However there is no broadband seismometer available in the market with IEEE 1588 capabilities. IEEE 1588 allows sub-microsecond timing accuracy in a pulse per second signal at the ocean observatory junction box [5].

Precision time protocol (PTP) equipment will be installed on the shore station working as a Grand Master synchronized GPS. Extraction of the timing is the responsibility of the seismic instruments, whether the signal is pulse per second or simply the time stamps of data. The PTP can also be available to other instruments that need sub-microsecond timing accuracy. This can reduce the performance of synchronization, because the traffic generated for real-time observation may load the non IEEE 1588 switches installed in the observatory. For this reason VLANs will be used to create a virtual connection for seismometers with IEEE 1588 Grand Master.

II. SEISMOMETERS USED

Two types of ocean bottom seismometers (OBS) have been used for the OBSEA network. One is the Trillium 120P/PA Broadband seismometer together with Taurus data logger [6]. This is a commercial seismometer used for land seismography which is adapted to be synchronized through IEEE 1588. An external LM3S9B96 module which implements the IEEE 1588 protocol with the master clock on land is in charge of providing the precise timing and PPS (Pulse per Second) synchronization trigger to the seismometer through serial communication using Trimble Standard Interface Protocol (TSIP).

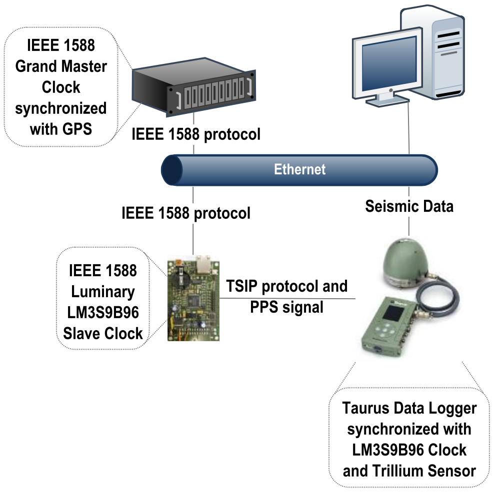

Figure 1 Taurus Broadband Seismometer synchronized with GPS through IEEE 1588 protocol

The IEEE 1588 Grand Master Clock (GMC) is synchronized with GPS on the land station. The real time clock of the LM3S9B96 board is synchronization through Ethernet network of the OBSEA with GMC using IEEE 1588 protocol. The real time clock of the LM3S9B96 is used as the time reference for the TSIP protocol that synchronizes the Taurus Data logger. Also the LM3S9B96 board provides a PPS signal to the logger to adjust the internal clock deviation.

III. OBSEA NETWORK DESIGN

OBSEA is a cabled seafloor observatory 4 km offshore Vilanova i la Geltru (Barcelona, Spain) coast located in a fishing protected area, and interconnected to the coast by an energy and communications mixed cable. The proposed solution is the implementation of an optical Ethernet network that transmits continuously data from marine sensors connected to the observatory.

The advantage of IEEE1588 PTP synchronization in OBSEA is the use of the existing Ethernet network with sub-microsecond accuracy. The disadvantage is the influence of the traffic in the Ethernet network. Many scientific instruments are connected to OBSEA and the real-time communication may affect the precision of the synchronization of the seismometers. For this we are using VLANs configuration to separate the IEEE 1588 devices from other instruments that are not using PTP synchronization.

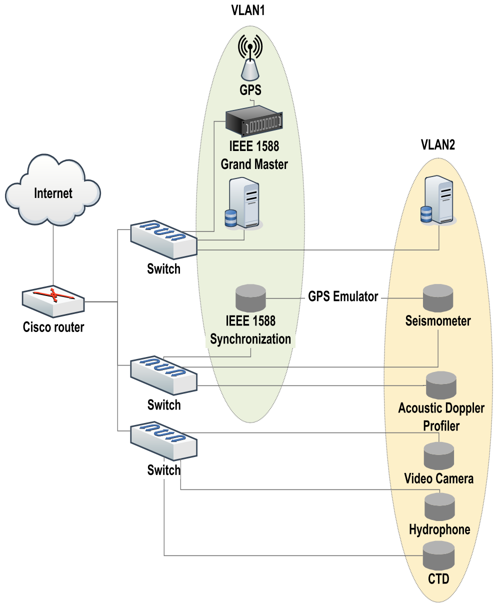

Figure 2 OBSEA network with IEEE 1588 and VLAN setup

IV. SYNCHRONIZATION RESULTS

To test the IEEE 1588 time synchronization in the OBSEA network a demonstration test was performed. The test was done using the same communication hardware, which is installed in the OBSEA network. The test setup included the shore station, node Ethernet switches and ocean bottom seismometer running PTPd stack as illustrated in Figure 3 An oscilloscope was used to measure the offset between pulse per second (PPS) from the master clock and slave clock.

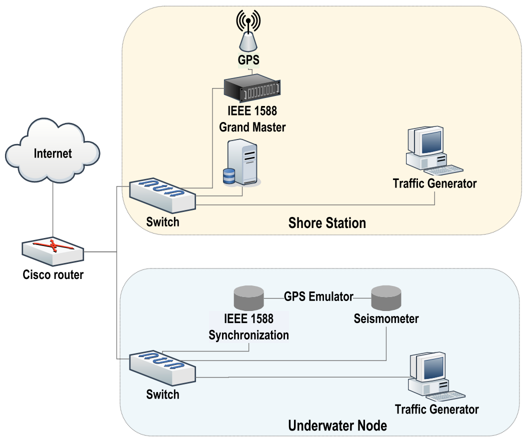

Figure 3 IEEE 1588 Underwater Demonstration Test Setup

The evolution of the PPS offset between the Master clock and the Seismometer is presented in the Figure 4.

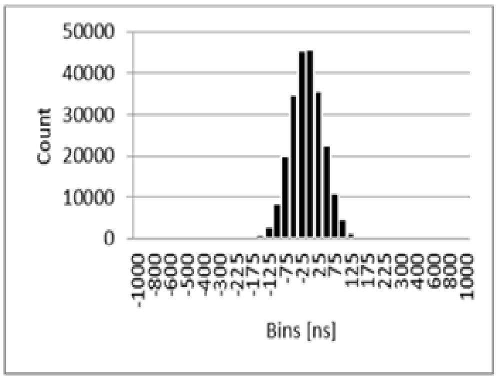

Figure 4 PTP Time synchronization drift on laboratory

First synchronization tests realized on laboratory, shows that synchronization accuracy, defined by the PPS delay offset between the master clock node and slave clock node, connected through one switch, is lower than 200 ns as can be seen on figure 4.

The synchronization accuracy after installation of the OBS to the submarine observatory, with network traffic, five routers on the path between master and slave clock and four km optical fiber cable between observatory and shore, is lower than 2.5 µs as shown on figure 5.

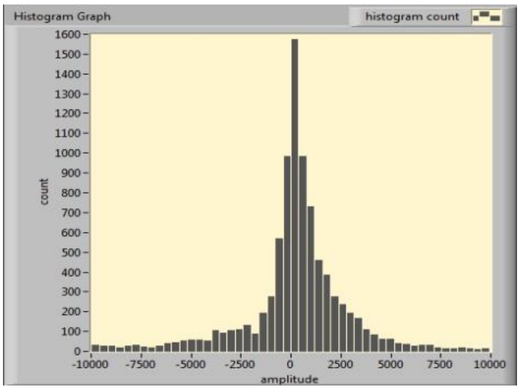

Figure 5 PTP time synchronization drift post deployment (X axis in nanoseconds).

V. SEISMIC ACQUISITION RESULTS

In order to include this system to Catalan seismic network (www.igc.cat) as shown in figure 6 (in green), time reference of our seismometer was modified from International Atomic Time (TAI) [7] which is PTP reference to Coordinated Universal Time (UTC). Once this change was realized, this seismometer entered on this seismological network. In Figure 7 is shown a seismic event detected by the offshore OBS designated VILA. Provided data it is referenced to counts, where the system sensitivity is 1.201e+9 Counts/(m/s), so it can be scaled to meters per second from the output data shown in this article.

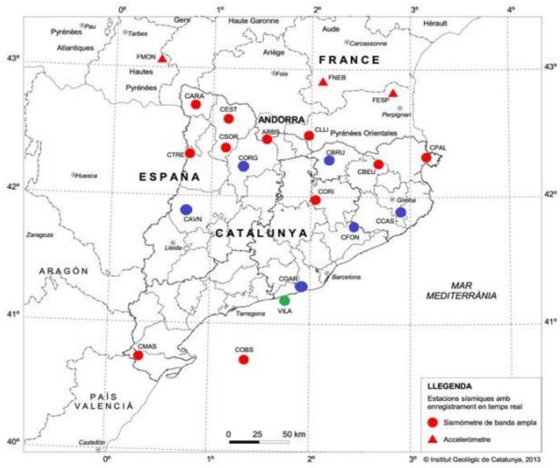

Figure 6 Map of seismic stations network. Green point depicted position of Seismic station VILA deployed at Obsea underwater observatory

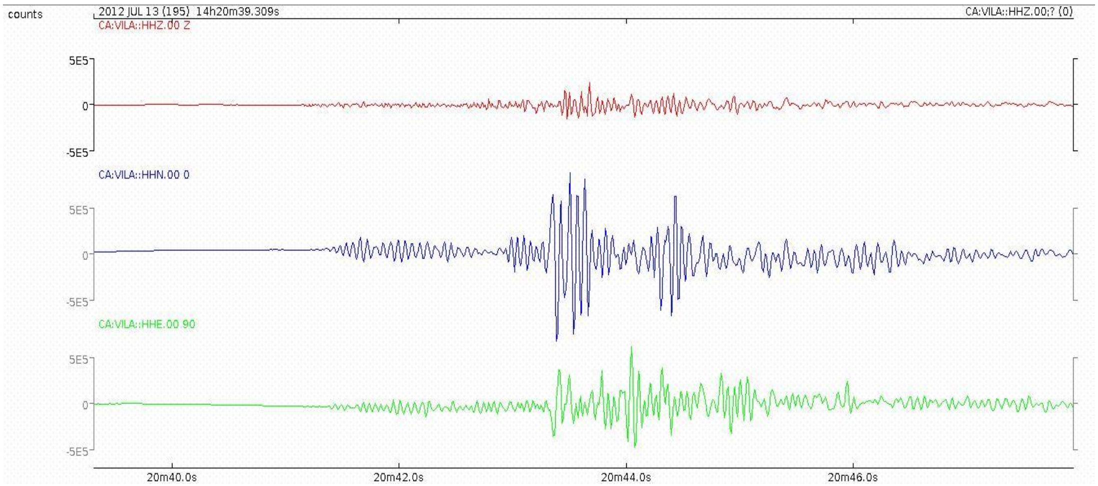

Figure 7 Seismic recordings from VILA station for the local event, magnitude 2.2, on July 13, 2012, in Sant Pere de Ribes (Spain).

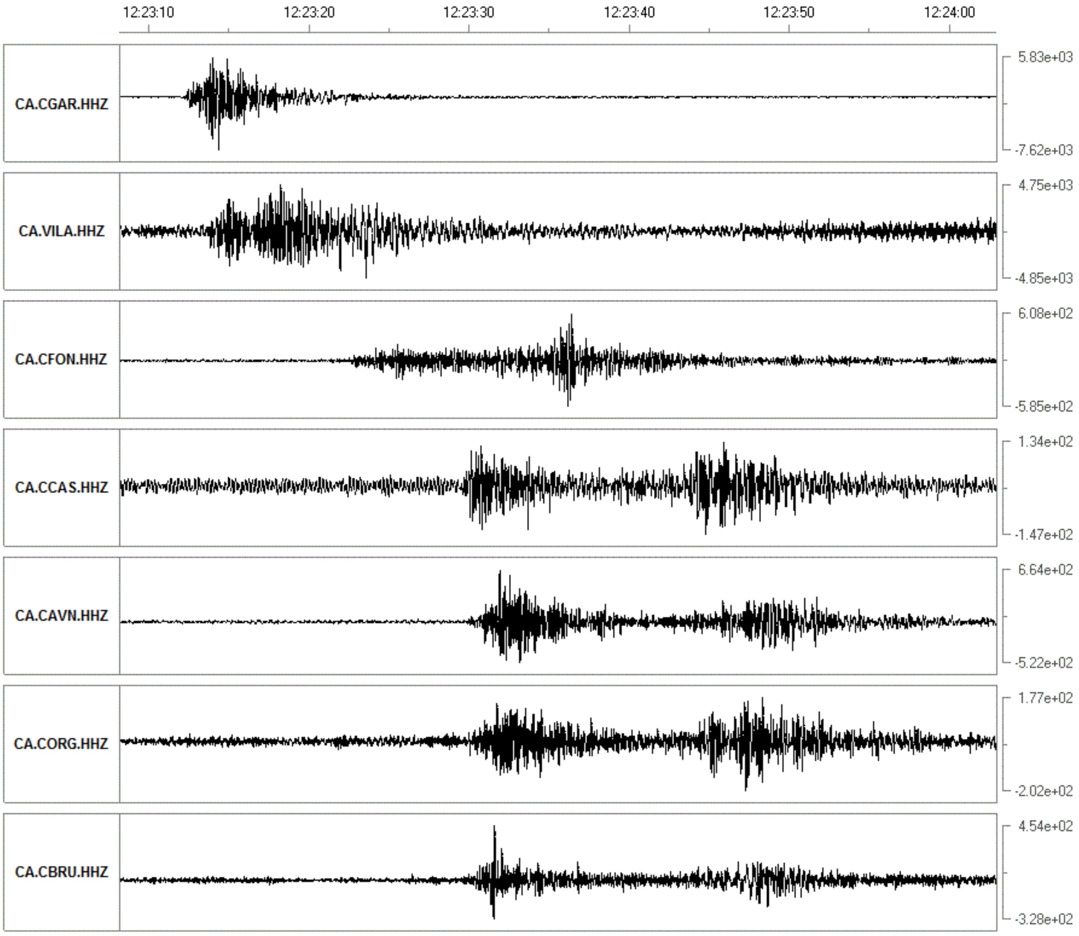

Figure 8 Artificial seismic event recorded by the offshore OBS (VILA) and other seismic stations from Catalan network (CGAR, GFON, CCAS, CAVN, CORG, CBRU), on May 13, 2013 at 12:23 in Garraf (Spain).

In figure 8 is illustrated the seismic event generated artificial in a quarry in Garraf, Spain detected by the offshore OBS (VILA) and other seismic station from the Catalan network. Because the Garraf quarry is situated close to the Garraf seismic station (CGAR) and the offshore OBS (VILA) we can see in this figure how this event is captured with a small delay by both seismic stations accordingly to the distance from the seismic event.

Figure 9. Seafloor deployment

VI. CONCLUSIONS

The SARTI research group has successfully designed and tested an underwater cabled seismometer implementing the PTP protocol over Ethernet to synchronize with UTC time to a high degree precision. The results of different tests carried out show that a precision of sub microseconds is achievable but requires VLAN setup of switches in the OBSEA network.

As shown in Figure 9 the final deployment of the water tight cylinder containing the seismometer was done on the Mediterranian seafloor, in front of Vilanova i la Geltrú shore. Because of bio fouling, currents and other external noise sources, seismically speaking it is planned to bury the watertight cylinder of the seismometer. Therefore this will reduce the impact on the cylinder, which actually are producing seismic noise, and forces us to filter the received signal, in order to acquire useful seismic data.

Furthermore, once buried, it will be necessary to characterize again Peterson's noise coefficients of the seismometer inside the vacuum cylinder and buried [8]. In order to avoid noise due to the sand movements around the cylinder, it will be covered with some heavy and dense material such as concrete.

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