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Anno 2010_Numero 142

rapporti tecnici INGV

# Geophysical Data Acquisition and Transmission for the SN-1 observatory to be deployed off shore Catania

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# GEOPHYSICAL DATA ACQUISITION AND TRANSMISSION FOR THE SN-1 OBSERVATORY TO BE DEPLOYED OFF SHORE CATANIA

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## Introduction

Starting from 1995 the European Commission funded the GEOSTAR (Geophysical and Oceanographic Station for Abyssal Research) and GEOSTAR-2 projects, in order to develop a prototype autonomous deep-sea observatory hosting a wide range of oceanographic, seismic and geophysical sensors in a single frame [Beranzoli et. al. 1998, 2000a, 2000b, Favali et al. 2002]. GEOSTAR is a single-frame autonomous seafloor observatory composed by the Bottom Station, which hosts the monitoring devices, the dedicated deployment/recovery vehicle MODUS and the Communication System. The system satisfied the definition of sea floor observatory [Thiel et al., 1994] with multidisciplinary, long term monitoring capability providing time referenced data series and the capability to transmit data in (near) real time through a surface communication buoy [Favali and Beranzoli 2006].

The SN-1 (Submarine Network 1) observatory is a reduced version of GEOSTAR: its dimension are 2.9 m x 2.9 m x 2.9 m (GEOSTAR dimensions are: 3.5 m x 3.5 m x 3.3 m) and its weight is 14 kN (in air, 8.5 kN in water), while GEOSTAR weighs 25.4 kN (in air, 14.2 kN in water); the operative depth is rated 4000m for both the observatories [Favali et al. 2006a]. They also share the same procedure for deployment and recovery based on MODUS operations, the special device for the seismometer release and a similar data acquisition system. The SN-1 observatory completed a first long term experiment off-shore Catania at 2105 m w.d. in autonomous mode from October 2002 to May 2003 [Favali et al. 2003]. After that the Communication System of SN-1 was upgraded with a fibre optic telemetry interface so as to be compatible with the electro-optical cable deployed by INFN off-shore Catania. In 2005 SN-1 was deployed in the same site and connected to the submarine cable receiving power from the shore and communicating in real time with the shore station located in the LNS-INFN laboratory inside Catania harbour [Favali et al., 2006b].

SN-1 was recovered in 2008 in order to be upgraded to the new configuration to be used in the ESONET – LIDO (Listening to the Deep Ocean environment) Demonstration Mission. In fact in the framework of the ESONET – LIDO DM, it is foreseen the installation of the SN-1 abyssal observatory offshore the Catania coast for the real time acquisition of seismic, geophysical and oceanographic data during a long term experiment. The LIDO DM proposes to establish a first nucleus of a regional network of multidisciplinary seafloor observatories contributing to the coordination of high quality research in the ESONET Network of Excellence by allowing the long-term monitoring of Geohazards and Marine Ambient Noise in the Mediterranean Sea and the adjacent Atlantic waters. Specific activities are addressed by the long-term monitoring of earthquakes and tsunamis and the characterisation of ambient noise induced by marine mammals (Bioacoustics) and anthropogenic noise.

This document describes the new planned architecture for the data acquisition, storage and transmission of the geophysical and seismic data supplied by the SN-1 observatory which will be deployed in the TSN (Test Site North) termination of the deep Sea Test Site installed and operated by the Laboratori Nazionali del Sud (LNS) of the Istituto Nazionale di Fisica Nucleare (INFN), located at 2100 m of depth, Lat. 37° 33’ Long: 15° 23’ about 25 km offshore the Port of Catania (Sicily, Italy). The TSN is connected to shore trough an electro optical cable (2 conductors, 2 fibres) that lands in the port of Catania. The onshore termination of the cable is housed in the Catania Test Site Laboratory (CTSL) of the LNS, where the main power supply, the onshore data acquisition and data storage units are hosted. A radio link between CTSL-LNS and LNS is also available to allow the access to the internet through the network infrastructure of the INFN-LNS.

In the following Table I the complete list of scientific instruments that will be installed on board of the observatory is shown. All the devices listed in the table, apart the four high frequency “bio-acoustic” hydrophones, are managed by the acquisition scheme here presented. The “bio-acoustic” hydrophones will be managed directly by INFN dedicated acquisition board and procedures.

**Figure 1.** The INFN Catania Test Site Laboratory where the data acquisition system will be hosted.

| Sensor | rate | Model |
|---|---|---|
| 3-C broad-band seismometer | 100 Hz | Guralp CMG-1T (0.0027-50 Hz) |
| Differential Pressure Gauge (DPG) | 100 Hz | Prototype Univ. of California-St. Diego |
| Hydrophone (Geophysics) | 200 Hz | OAS E-2PD |
| Hydrophone (Geophysics) | 2000 Hz | SMID Technology (0.05-1000 Hz) |
| 4 Hydrophone (Bio-acoustics) | 96 kHz | Reson (10-48000 Hz) |
| Absolute Pressure Gauge (APG) | 1sample/15 s | Paroscientific 8CB4000-I |
| 3-C Accelerometer + 3-C Gyro (IMU) | 200 Hz | Gladiator Technologies Landmark 100 |
| Gravity meter | 1 Hz | Prototype IFSI-INAF |
| CTD + Turbidity meter | 1 s/h | SeaBird SBE-37SM-24835 + Wet Lab |
| ADCP | 1 profile/h | RDI Workhorse Monitor (600 kHz) |
| Vectorial magnetometer | 1 Hz | Prototype INGV |
| Scalar magnetometer | 1 Hz | Marine Magnetics Sentinel (3000 m) |
| 3-C single point current meter | 2 Hz | Nobska MAVS-3 |

**Table I.** SN1 scientific payload.

**Figure 2.** Example of sensors which are going to be installed on the SN1 observatory; from the left: gravimeter, ADCP, absolute pressure sensor, CTD.

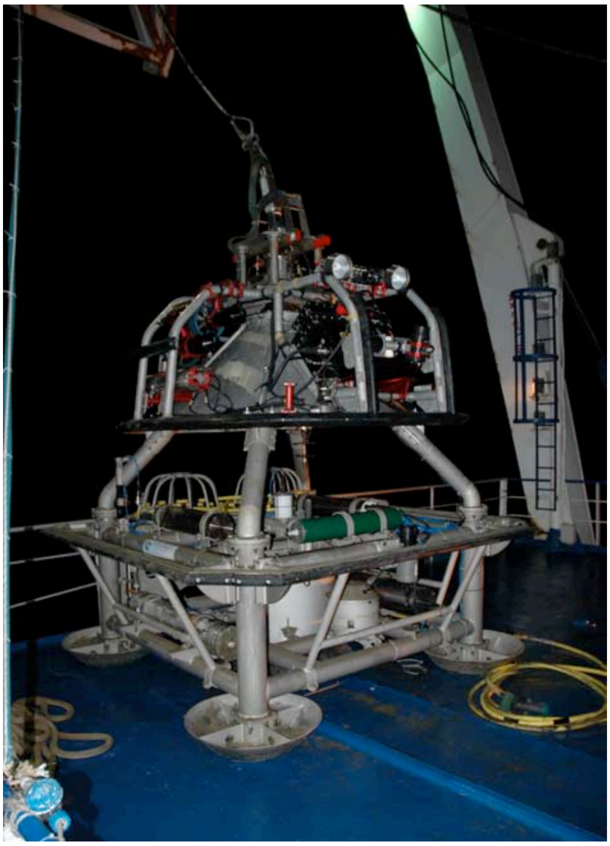

**Figure 3.** The SN-1 Abyssal Observatory during a previous recovery mission.

## 1. The on shore SN -1 Data Acquisition architecture

Data from SN-1 will be continuously transmitted from deep sea to CTSL through optical fibres. The expected data rate from the deep-sea SN-1 observatory that will be installed on TSN is about 13Kbits/s of geophysical data payload. Raw data from the underwater observatory must be acquired and stored locally at CTSL.

Geophysical data from deep sea will be collected by a machine called SN-1 Telemetry (SN1TELEM) that will receive raw data and will make them available on the CTSL Local Area Network. Two clients are foreseen for the SN1 geophysical data flux:

- a TECNOMARE dedicated workstation (SN1 Control Unit - SN1CU);
- an INGV dedicated workstation (SN1 Data Unit - SN1DU).

SN1CU will be dedicated to the control of the SN1 observatory; SN1DU will be dedicated to the acquisition and control of all geophysical devices of SN1. Data flow between SN1TELEM and the clients

SNC1U and SN1DU will be implemented via dedicated serial links. Each serial line (bidirectional) will be devoted to one device data flow.

SN1DU will store all data received on a local storage system and it will run applications for real time analysis.

Data stored in SN1DU will be duplicated first in a storage server located at CTLS, the Raw Acoustic Data Server (RADS), then in a second server located at LNS, the Main Acoustic Data Storage (MADS) server. Both MADS and RADS are foreseen also for the storage of all bio-acoustic data obtained by four hydrophones installed on the SN1 station and managed by INFN. Data retrieving is handled via RSYNC protocol. Only authorised users can have access to MADS to retrieve data. Another Acoustic Data Storage unit will be installed at LNS for general public access (Figure 4).

All the node at the CTSL will be connected by an intranet network. The access to the CTSL intranet will be allowed only to authorised people to remotely maintenance purpose. The Figure 4 shows the data flow that is managed by the acquisition and transmission system.

A detailed description of each node of the data acquisition network is presented in the following sections.

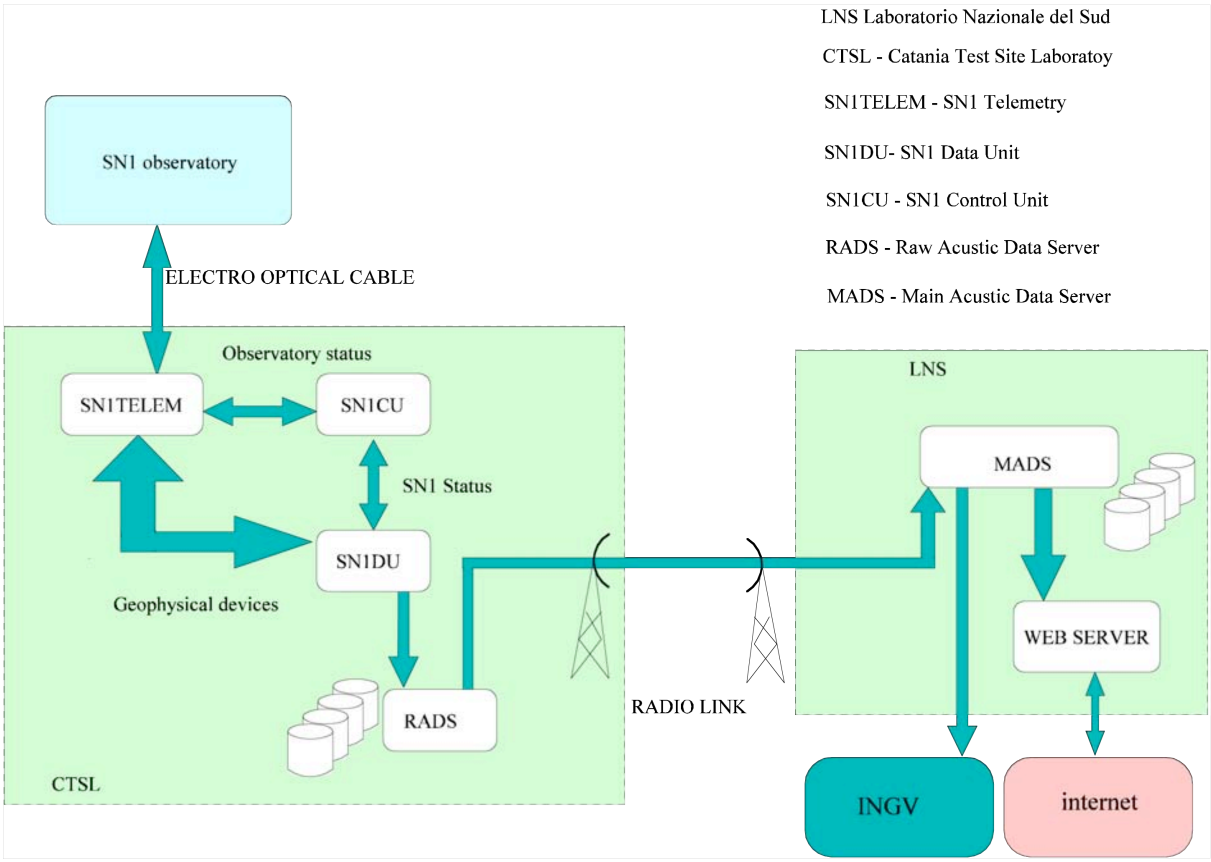


**Figure 4.** SN1-LIDO geophysical data flow.

### 1.1. SN-1 Telemetry (SN1TELEM)

The SN-1 Telemetry (SN1TELEM) will receive raw data from the observatory by means of the Ethernet protocol on the optical cable and it will distribute them to clients (SN1CU and SN1DU) using both the local LAN network and dedicated serial lines.

### 1.2. SN1 Control Unit (SN1CU)

The SN1 Control Unit (SN1CU) will be managed by TECNOMARE to control the status of the seafloor observatory using the data connection supply of the SN1TELEM via the dedicated Ethernet link. All the PCs will be synchronized by SN1CU that will distribute a reference clock to all clients in the CTSL intranet, via the Network Time Protocol (NTP) to accurately timestamp all datasets. Time synchronization will be guaranteed thanks to a GPS antenna connected to SN1CU. The SN1CU workstation will also supply status information of the observatory to SN1DU using a dedicated serial link.

### 1.3. SN1 Data Unit (SN1DU)

The SN-1 Data Unit recovers raw data from the observatory via the SN1TELEM, parsing and saving them on hourly or daily files. Each instrument on the SN1 seafloor observatory is reachable by the SN1DU via a dedicated two way serial line supplied by the SN1TELEM. Two dedicated real time procedures will run on SN1DU to analyze seismic and pressure data. A dedicated tsunami detection algorithm will analyze pressure data in order to detect an anomalous wave (tsunami). The acquisition software for the signals of the seismometer will be able to detect seismic event using a STA/LTA threshold procedure. All data from the SN1DU will be transferred to the RADS server hosted at CTSL by an application based on the RSYNC protocol. Data will be recovered hourly, as soon as the corresponding files will be available on the SN1DU. The requested disk size of SN1DU is of the order of 1 TB, to allow data storage redundancy and possibility of local backup in case of radio link failures for long time periods. SN1DU will be accessible via SSH protocol by operators only for maintenance purpose. The SSH server running on the SN1DU will manage user authentication and supply dedicated TCP/IP port forwarding to manage seismic data acquisition and allow the control software client to remotely manage the data acquisition system.

## 2. Data Acquisition Architecture at LNS

The data acquisition architecture at LNS relies on the network infrastructure available at the Computer Centre of LNS. Network and hardware monitoring will be in charge of LNS Computer Centre. For the LIDO experiment two storage units will be installed:

- a Raw Acoustic Data Storage (RADS) unit, hosted at CTSL
- A Main Acoustic Data Storage (MADS) unit, hosted at LNS

The Raw Data Storage unit will store all the acoustic data from the bioacoustics hydrophones, and it will maintain a synchronized copy of geophysical data from SN1DU via the RSYNC protocol. RADS is located in the CTSL site in the Catania port.

The Main Acoustic Data Storage will have a dedicated link to CTSL and it will continuously download the compressed data files and store them on disks. MADS will be the main data repository of the experiment (i.e. for all the SN-1 data). Access to the MADS will be restricted to dedicated machines of the LIDO partners. MADS is hosted in LNS, contains a synchronized copy of data acquired by SN1DU and can be accessed by INGV network to retrieve data. The total disk size is expected to be approx 20 TB (for a year) for acoustic raw data files (compressed) plus a 20 TB backup unit (tape based). The LNS Computer Centre will also take care of MADS software/hardware maintenance.

The LNS network infrastructure provides SSH access to the SN1DU from internet via a dedicated VPN access to the INFN intranet in LNS. All connection to the SN1DU are allowed only after the SSH authentication.

## 3. SN1 Data Unit (SN1DU) Software Architecture

This section describes the software architecture of the SN1DU for acquisition and control of scientific payload in SN1-LIDO project. A Linux Ubuntu 8.04 OS is installed on the workstation. The remote control of the whole system is allowed to users who can connect to the station only via SSH protocol.

### 3.1. Software applications installed on the system

Three main applications are installed on the SN1 Data Unit in order to manage data acquisition, allow the system monitoring by a remote user and automatically check the status of the system:

- SN1Daemon: manages and controls all the devices. Anomalies and malfunctioning in the acquisition system are notified to remote users via email.
- SN1client: supplies a user interface that allows human users to interact with the SN1Daemon to gather data from device, change configurations manually, etc.
- Scream: Guralp software manages the Guralp subsystem (digitizer and control module for the seismometer, DPG and OAS Hydrophone) .

### 3.2. SN1Daemon

A daemon program will continuously run (SN1Daemon) starting immediately after the system booting. It is composed by a server application which manages the mission and interacts with specific modules, the Instrument Interfaces, each one dedicated to the management of one single sensor (Figure 5).

SN1Daemon will provide the following services:

1. listening on a local TCP/IP interface to allow interaction with a remote/local user;
2. managing each Instrument Interface module in order to send commands to a specific sensor and receive answers from it (both data or other device information). Data can be received from the sensors through the Instrument Interface both on request (the daemon asks for information and waits for an answer), and listening to some autonomous notification coming from the Instrument Interface;
3. in the case of notification of events from a single devices (i.e. pressure events, and so on) the daemon will send the notification to an external recipient (i.e. it will send an e-mail);
4. at the beginning of the mission SN1Daemon sends start and configuration command to all Instrument Interface modules;
5. managing station "auto mode", "user mode".

The Figure 5 and Figure 6, graphically show the interaction and scopes of the various modules in the Data Unit.

Two operative modes are managed by the Daemon:

- Auto Mode: each device is acquired and data stored on files. The single device management is supplied by dedicated module (instrument interface).
- User mode: no automatic acquisition is performed. The daemon can receive command from the ClientSN1, forward command to single devices and allow direct access to them (i.e. direct access via the terminal interface to the serial line for low level interrogation). User mode can be set either for all sensors or for any subset of sensors, leaving unaffected the automatic acquisition on the others. This features allows a human user to direct access a sensor for low level interrogation without stopping the other devices acquisition.

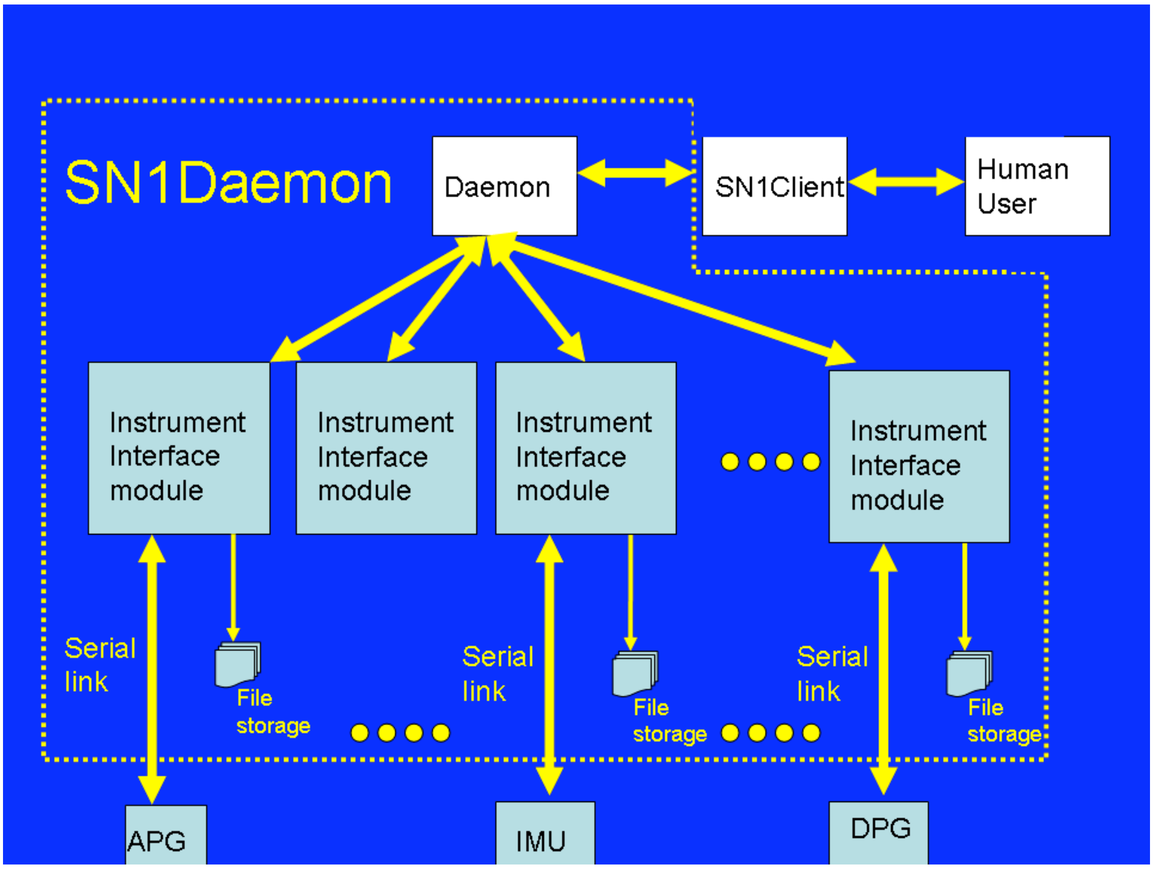


**Figure 5.** The SN1Daemon: interaction with the client and devices management scheme.

**Instrument Interface modules**

For each device (except the Guralp subsystem) a dedicated module will manage the communication with the sensor using the dedicated serial line. The Instrument Interface module is a software driver used by the SN1Daemon application.

Each Instrument Interface module:

- reads the configuration file to manage start up procedures of devices (if needed).
- manages the device via a serial module (send and receive data from serial line)
- in auto mode, stores the data on HD files (hourly – daily files, depending on the sensor)
- sets specific command to the device as requested by the daemonSN1 and provides to the daemon the answers coming from the device.

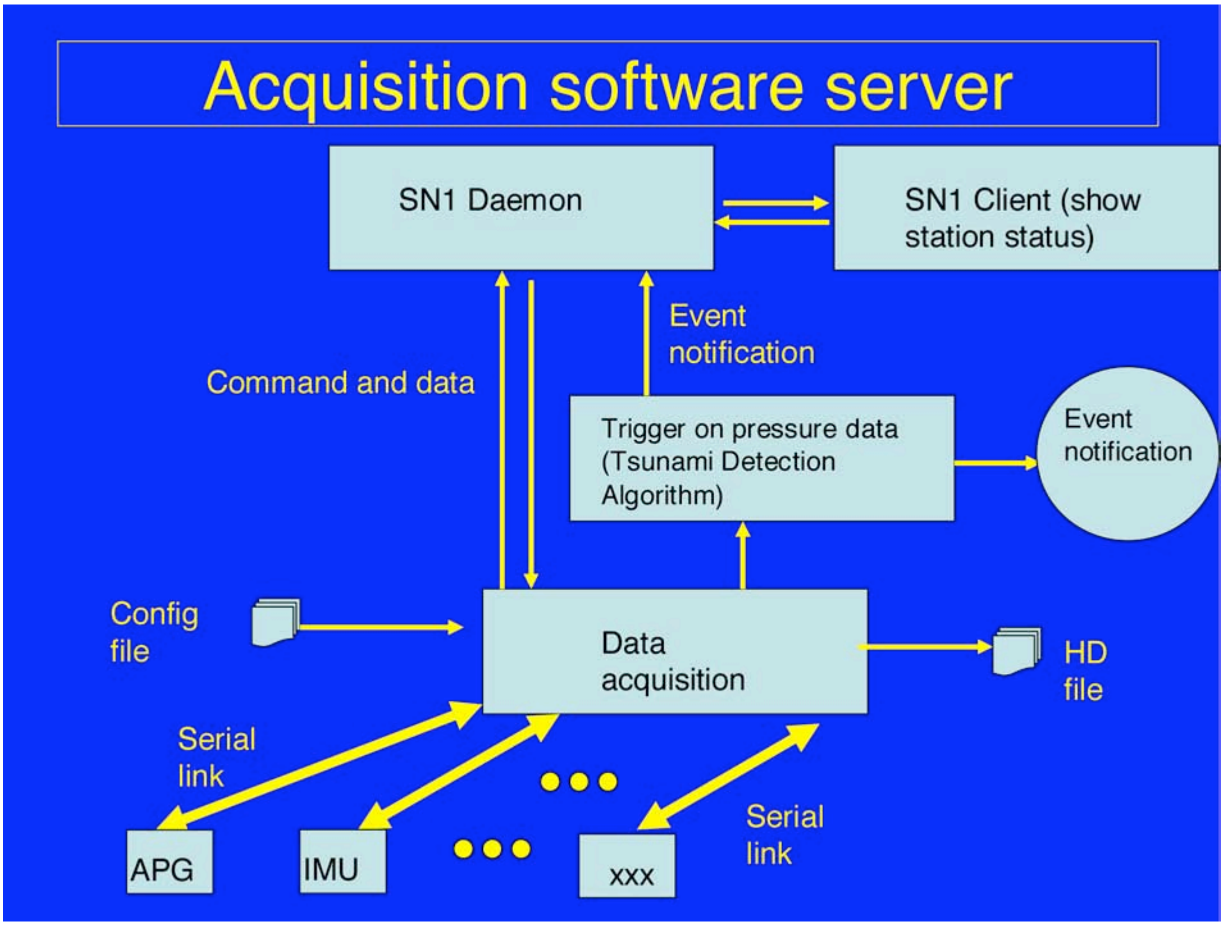


**Figure 6.** Data acquisition daemon, auto mode working: automatic acquisition and storage, control access by the user; the arrow represent data flux, commands or information sharing.

### 3.3. SN1client

A client application (SN1client) is the user interface with the system. Its GUI allows a user to see real-time information on the whole system and on each device. The clientSN1:

- it is the only way trough which a human user can gather information and send commands to the whole system;
- allows a human user to exchange information with the daemonSN1;
- allows the human user to send a command to a specific device and see the answer;
- can open a direct channel to a serial line, performing point-to-point connection with the instrument connected to the line, in order to manually send command to a given device (like having the device directly connected with a serial line) for low level device management (see Figure 7).

SN1client can run either locally or on a remote machine. A local connection has higher priority than any remote one, to prevent deadlocks on the connection.

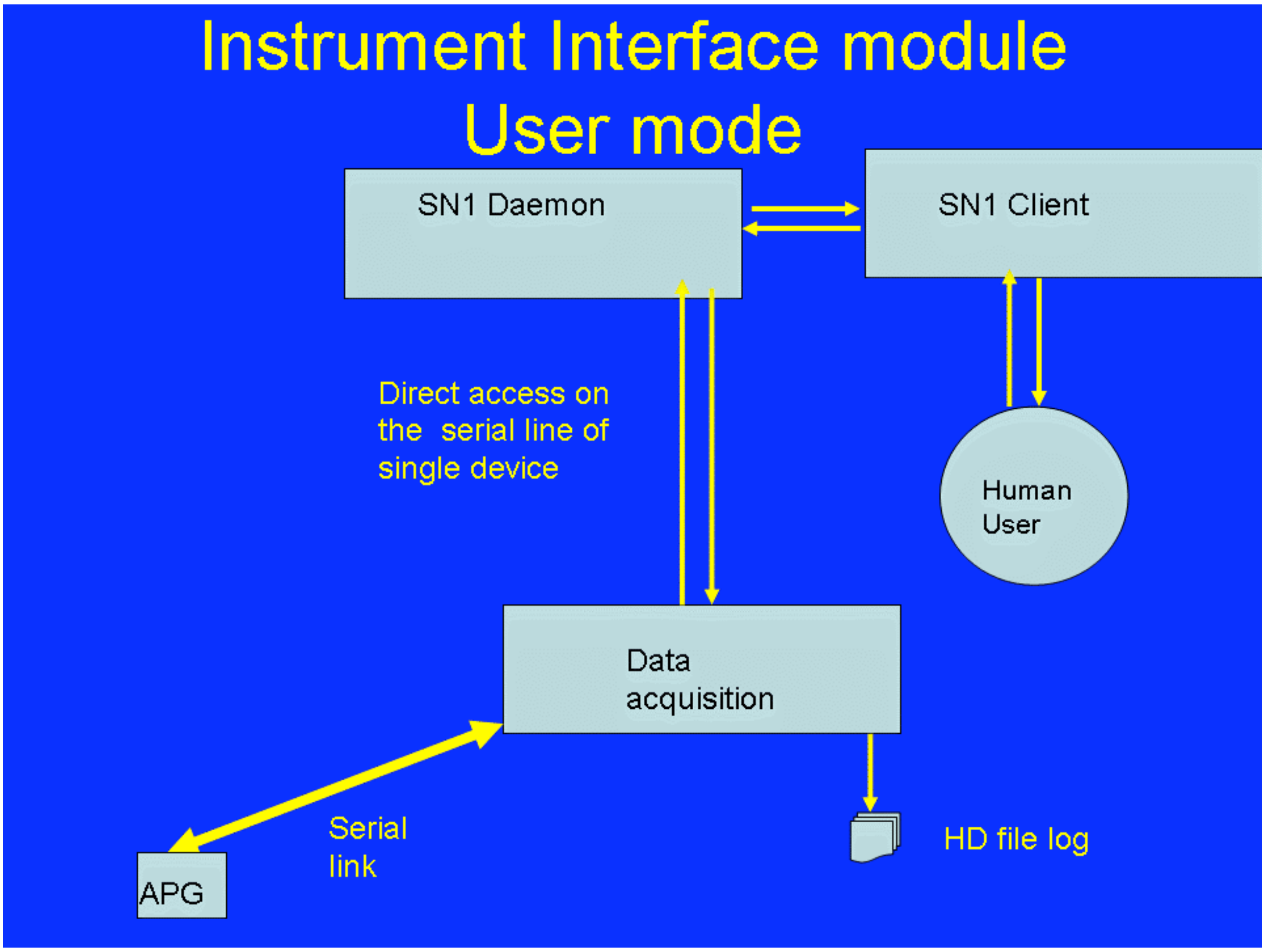


**Figure 7.** Data acquisition working user mode: direct access to a single device supplied by the daemon.

### 3.4. Configuration files

SN1daemon reads its configuration parameters from an xml file stored locally. Changes in such parameters requires an allowed user to simply change values in the configuration file, and tell the application to reload it without any recompilation of the software. Parameters for a single instrument can be reloaded without affecting the ongoing acquisition process on other instruments.

Examples of parameters described in the configuration file are: instrument specific settings and initialization sequences, frequency of files closing, system topology.

In a separate xml file, two lists of email recipients are stored: one for maintenance purpose and another one for alerts from the acquisition system (such as tsunami detection).

### 3.5. Time stamping and synchronization

SN1 Data Unit performs NTP synchronization with the SN1CU located in CTSL.

Each sensor data is time-stamped with NTP time when received. This will allow, after the calculation of transmission delay from seafloor observatory to on-shore machine, off-line realignment of measures with the precision of at least one millisecond.

### 3.6. Software for the seismometer acquisition

Guralp software "Scream" manages the Guralp subsystem (digitizer which controls: Seismometer, DPG, OAS Hydrophone) . In case of seismic event, it will send an event notification to a remote user.

## 4. Data storage organization

Data are organized in hourly or daily files, depending on the acquisition rate:

- Hourly data file: DPG, SMID, IMU, Currentmeter, Seismometer, OAS hydrophone.
- Daily file: APG, ADCP, CTD, Magnetometers and gravity meter.

The data format is the native one, as supplied by the devices; date and time information are added in the header of each file or at each sample. File name contains information on date and time of first sample. Each device data files are stored in a separate folder. Guralp subsystem (Scream) stores data in its own proprietary format.

## 5. Acronyms and definitions

GEOSTAR Geophysical and Oceanographic Station for Abyssal Research

SN-1 Submarine Network 1

LIDO LIstening to Deep Sea

INFN Istituto Nazionale di Fisica Nucleare

TSN Test Site North (INFN)

LNS Laboratori Nazionali del Sud (INFN)

CTSL Catania Test Site Laboratory (INFN)

RSYNC open source utility that provides fast incremental file transfer

SSH Secure SHell protocol

NTP Network Time Protocol

## References

Beranzoli L. et al. 1998 GEOSTAR: a Geophysical and Oceanographic Station for Abyssal Research, *Phys. Earth Planet. Int.*, vol. 108, (1998), 175-183

Beranzoli, L. et al. 2000a European seafloor observatory offers new possibilities for deep-sea study, *Eos, Trans. Am. Geophys. Un*., vol. 85, 45-49

Beranzoli, L. et al. 2000b GEOSTAR, an observatory for the deep-sea geophysical and oceanographic researhes: characteristic, first scientific mission and future activity, *Mem. Soc. Geol. It.*, vol. 55, 491-497.

Favali , P and L. Beranzoli 2006 Seafloor observatory science: a review, *Annals of Geophysics*, vol. 49 (2006), 515.

Favali, P. et al. 2002 Towards a permanent deep-sea observatory: the GEOSTAR European experiment, in *Science-Technoligy Synergy for Research in the Marine Environment: Challenges for the XXI Century*, edited by L. Beranzoli, P. Favali and G. Smriglio, *Developments in Marine Technology series* (Elsevier, Amsterdam), vol. 12 111-120

Favali, P, SN-1 Team and NEMO Collaboration (2003), SN-1, the first node in the Italian seafloor observatory network- Background and perspective, in *Proceedings 3rd International Workshop on Scientific use of Submarine Cables and related technologies*, Tokyo, Japan, edited by J. Kasahara and A.D. Chave, IEEE Catalogue No. 03EX660, 19-24

Favali P., et al. 2006a “A fleet of multiparameter observatories for geophysical and environmental monitoring at seafloor”, *Annals of Geophysics*, vol. 49 (2006), 659.

Favali P., et al. 2006b: NEMO-SN-1 the first "real-time" seafloor observatory of ESONET, *Nuclear Instruments and Methods in Physics Research A* , vol. 567 (2006) 462–467, DOI: 10.1016/j.nima.2006.05.255

Thiel, H. et al. 1994. Scientific requirements for an abyssal benthic laboratory. *J. Mar. Syst*. vol. 4, 421-439.

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