THE INGV (Catania Section) NETWORK SYSTEM: USE OF BROADBAND NETWORKS FOR REAL TIME VOLCANIC MONITORING TECHNIQUES

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Abstract

The Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania (INGV, Catania Section) has a Monitoring Centre in Catania, based on semi-automatic systems, able to transmit all the most significant seismological and volcanic information in near real time. New monitoring techniques, with on line data processing and continuous data updating, are highly useful to understand volcanic activity and for correct hazard evaluation in volcanic areas, such as Eastern Sicily and the Aeolian Islands. However, the huge usage of hardware and software for real time systems requires a very large number of broadband connections. Hardware and software architectures in this field have been developed to acquire, analyze and visualize on line data, providing higher accuracy, band optimization and system robustness.

1. Introduction

Sicily is not only a beautiful island but also a well known high risk region. Volcanic eruptions and seismic activities produce a wide range of risks to inhabited areas: strong earthquakes and explosive volcanic activities have a deep impact on the local population and can also generate considerable economic damage. The presence of Mt. Etna, the islands of Vulcano and Stromboli in the Aeolian Islands, represent natural systems suited to be studied with all the present technologies.. In order to provide a stable control and surveillance of these areas, new monitoring techniques, based on real time processing, are used to understand volcanic activity and correctly evaluate hazard.

Starting from 2002, The "*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania*" (INGV – Catania Section) has developed a new research and development division called the *Unità Funzionale Sala Operativa (UFSO).* The group is involved in monitoring and surveillance operations during regular activities and also in presence of

volcanic and seismic phenomena. UFSO staff supervise the Control Room which is active 24 hours a day. This monitoring centre is based on semiautomatic systems: all signals coming from remote stations are acquired, analyzed and visualized in real time, providing higher accuracy and robustness. They represent the latest development in data processing techniques (in particular for seismic signals, digital image processing, etc). All the obtained outputs are immediately available and are continuously compared with assigned thresholds to produce alert signals. The most significant parameters are furnished as continuous data on the Intranet and Internet INGV – CT web sites.

In this paper, the importance of new technologies concerning broadband network connections for geodynamics evaluation and analysis will be considered. Field results and acquired expertise will be used for LAN, WAN and Wireless connections to support the optimization of very large amounts of data transmitted in continuous mode, with strong robustness requirements.

This paper is organized as follows: after a brief description of the main characteristics of the *INGV CT – Sala Operativa* given in Section 2, Section 3 outlines the most important transmission data flow and how the INGV uses connection lines for geophysical data. Section 4 concludes this paper.

2. The UFSO Control Room

Monitoring active volcanoes has been increasingly augmented by the "on line" multidisciplinary analysis of some physical and geodynamical parameters. Recent techniques in digital treatment of different data-streams, prompted the UFSO staff to concentrate all the different variables in a single Monitoring Centre, active 24 hours a day, able to analyze each small variation inside active volcanoes in real time. To guarantee good performance of the system, expert personnel is often present in the field and on duty personnel is also available if necessary to rapidly evaluate critical changes in monitored patterns.

2.1 New developments

Inside the UFSO, software development is one of the fundamental areas in devising new surveillance methods for volcanic areas. New hardware and software architectures have been planned to acquire, analyse and visualize on line data, providing higher accuracy and robustness.

Fig. 1 shows the aspect of the actual Control Room; it is possible to recognize analogue drum recorders, seismic data stream in new digital video format and some images from visible and thermal cameras. The Control Room is in constant contact with the National Seismic Centre (INGV- Rome), Civil Defence Department, in Rome and also the local municipalities. In case of seismic events, or when there are explosive or effusive volcanic activities, expert personnel immediately declare an alert status, sending the most significant parameters by email and fax, also using the Net. An automatic alert software, instead, transmits SMS messages to INGV personnel to activate on duty experts.

Fig 1. The Control Room inside INGV in Catania

3. Transmission data flow

The seismic network around Sicily is composed of a large number of analogue and digital stations which allow continuous recording of data using broadband and short period sensors. All data are received in the Centralized Data Acquisition Centre (CUAD) with satellite, wireless and radio transmission system.

The INGV – CT has different sites located in Eastern Sicily and also some in the Aeolian Islands. Sometimes it is difficult, at others impossible, to connect two different sites by wired connection. To ensure the system works also when wired connections are lost (due to degraded line service, loss of connectivity etc) all centres are equipped with local acquisition systems. Re-transmission is made when the connection is up again. Inside each centre there is a local data buffer and client/server custom applications regulate file transfer with bandwidth optimization.

In addition, in order to increase system performance, a new satellite transmission network has been developed. Seismic data are collected locally and part of a satellite channel is used to transmit in continuous mode. Due to the presence of a delay time, we refer to it as a *near real time* network; nevertheless, the system can be considered very robust especially in the case of strong earthquakes. The collection centre (the *CUAD* data acquisition centre in Catania) is equipped with a 3.80 m dish.

At present, there are also a number of centres throughout Italy, for example in Rome (INGV- Central Site) for the centralized national seismic network (*Centro Nazionale Terremoti*) [1]. In case of emergency, master/slave configurations guarantee that each centre can manage the whole network and provide details and information to Civil Defence, while receiving data from all remote stations located inside epicentre areas.

3.1 Seismic Data

To have a picture of the complete *state of health* of a volcanic area, and to be able to record in real time minimum pattern variations of volcanic activity, it is necessary to set up different networks around a volcano. Most seismic stations of INGV Catania use the Earthworm system [2] to perform acquisition and near-real time analysis of the Sicilian regional seismic network signals [3]. Each Earthworm node is made up of one or more seismic stations. It transmits data from remote sites to the data acquisition centre over the Net and/or dedicated links. Earthworm is an open source software able to realize a complete monitoring system for seismic waveforms [2].

The obtained outputs, generated by custom software, are useful for real time analysis and alert communications; moreover, using *Earthworm* based acquired systems, all software are consistent with most worldwide seismic networks and participate in the *Earthworm community*: Local ring buffers are available to be shared by Earthworm users in order to realize a worldwide surveillance network.

In order to improve system performance, UFSO has developed a dedicated software to generate virtual drum recorders, able to perform near-real time (with only 10 sec delay) plots of acquired data from remote Earthworm nodes. For the seismic network there are four different sites as shown in **Fig. 2.** Depending on the interested area earthworm node concentrates many stations. Wired Garr connections are used to connect the single nodes to the whole network.

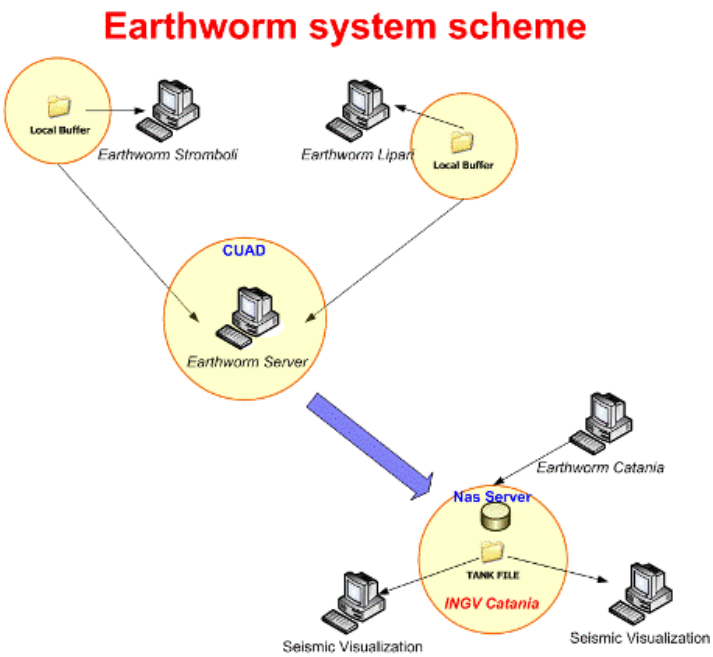

Fig. 2 Earthworm scheme for analogue and digital stations

Table 1 shows the average amount of bandwidth required for different links. Most digital stations have three different channels for spatial evaluation of seismic waveform.

Point to point transfer	Number of stations	Bandwidth (Mbps)	Occupied Bandwidth (%)	Garr Link (Mbps)
Lipari to CUAD	**33**	**0.058**	**2.9**	**2 Mbps**
Station to CUAD	**36**	**Internal LAN**	**-**	**-**
CUAD to INGV - CT	**67**	**0.12**	**12%**	**1 Mbps**

Table 1: Data amount for seismic signals

3.2 Video network

Fig 1 shows some details of several images coming from different video stations around most active volcanoes. Over the last 15 years, INGV has been the first in the world to plan the use of video cameras for monitoring and surveillance activity.

Initially, the acquisition system was made by a visible camera and a time-lapse recorder able to store all significant images in VHS format. Today, a new architecture using both analogue and digital devices has been devised and realized by UFSO staff.

The new system is now able to guarantee:

- Real time video streaming
- Single frame acquisition
- Time lapse digital video

The current video surveillance network is made up of 9 video stations (Fig.3) located in the following areas:

- 2 - thermal and visible - in Nicolosi (Catania)
- 1 visible in Milo (Mt. Etna)
- 1 visible operating inside the CUAD (Catania)
- 2 - thermal and visible - in Stromboli (Aeolian Islands) on summit area
- 2 - thermal and visible - in Stromboli (Aeolian Islands), 400 m high

Most cameras are equipped with remote control and pan tilt movement and are able to receive different settings by RS232 or TCP/IP data stream.

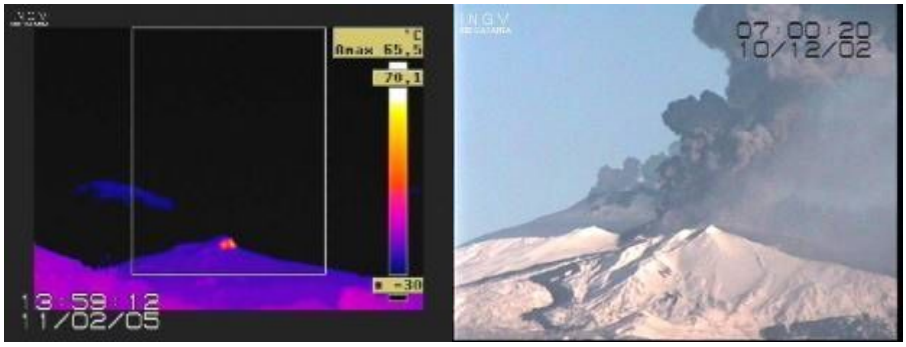

Fig. 3 INGV - Catania camera network – Thermal and visible images from Mt. Etna

Table 2 shows details on each camera setting. Video streaming is buffered with a 10 second delay in order to provide continuous streaming of acquired data without stops between two contiguous images.

Streaming	**Image Dimension**	**Bandwidth (Kbps)**	**Frame per second**	**Image quality**	**Key frames**	**Buffer**
Camera	640x480	50	3 fps	75%	3 seconds	10 seconds delay

Table 2: Video settings and streaming quality details

Customized software, with full automatic parameters, has been developed to realize a video film of 25 frames per second (fps) but with a time-lapse feature: single frames acquired once every two seconds are represented in a single time-lapse film. So it is possible to compress 15 minutes of data acquisition in only 18 seconds. In this way, a great advantage is given to expert personnel in order to evaluate volcanic activity observing 24 H/day image in a very short time [4].

Software is compliant with different CODECs, but the best quality/Kbyte ratio is achieved with MPEG4 “DivX” CODEC. All films are stored in DVD format and it is also possible to see all frames on The Net with an automatic refresh.

3.3 TCP/IP Connections

Because of the different location of active volcanoes and in order to perform good surveillance for the most significant seismic areas, all data sent from stations are collected in different centres. In this way, the Aeolian Centres (Lipari, Stromboli and Vulcano) acquire local stations and a part of northern Sicily. They transmit all data to CUAD via Consortium Garr (Italy) connections.
All Garr connections now have 2 Mbps bandwidth. Stromboli is now connected with a 4Mbps link and also INGV Centre will shortly be upgraded to four, or more, Mbps bandwidth.

In **Fig. 4** INGV- CT network with bandwidth details.

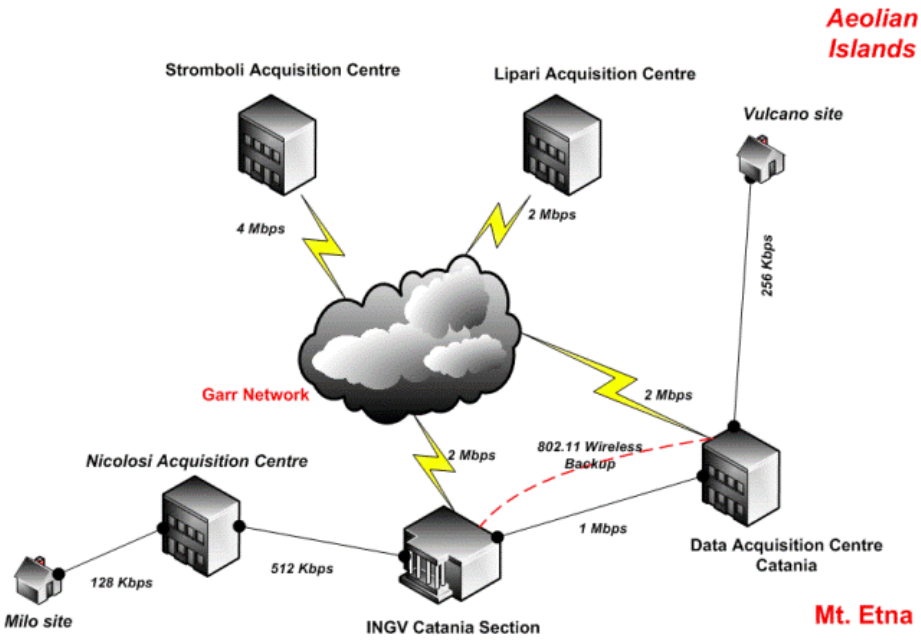

Fig. 4 INGV Catania Section principal network links.

All data are sent to CUAD Centre because of its strategic position. In fact, most remote stations on Mt. Etna are radio linked with CUAD. This continuous data flow, collected, analyzed and, in some cases, elaborated, is sent to INGV Centre to be visualized inside the Control Room. Moreover a wireless 802.11 backup transmission link is used by balanced routing, in a completely automatic way, rebuilding traffic in case of loss of connection between the two sites. An emergency Control Room is also available inside the CUAD in case of serious damage to the principal site.

All sites are equipped with VPN links realized using hardware routing features. Moreover, in order to have secure connections each site is equipped with a customized firewall for packet filtering and flow control. Thus, optimizing the use of correct bandwidth becomes necessary and for this reason, our staff is now investigating new devices to ensure the best service performance.

4. Conclusion

Today, most acquisition systems, used in geophysical research are TCP/IP compliant and the latest transmission devices are robust, relatively inexpensive and represent new frontiers in customized data transfer activity.
Wireless networks, Satellite, 2G and 3G networks are now on the market and new IEEE standards can help ITC operators. For the UFSO staff, it is important to evaluate and apply technological innovations to the monitoring systems and develop new architectures of hardware and software for use within INGV.

5. Reference

[1] INGV site: http://www.ingv.it – INGV Catania Section: http://www.ct.ingv.it

[2] Earthworm overview: http://folkworm.ceri.memphis.edu/ew-doc/OVERVIEW/1_History.htm

[3] INGV Catania Section web site: http://www.ct.ingv.it

[4] "Archiviazione digitale del segnale video delle telecamere di sorveglianza visiva", La Via M., Mangiagli S., Rapporti tecnici INGV n° 20 , 2003

Vitae

Danilo Reitano is an electronic engineer. He graduated from the DIEES State Engineering University in Catania as an electronic engineer with specialization in systems and automatic controls. His expertise is in the design and development of control systems comprising advanced architectures and software tools. Over the last 10 years he has been involved in IT infrastructures and has wide experience in building and supporting IT networks. Since 1997, he has been a technical engineer at the Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania (INGV-CT) and Head of the "Sala Operativa" Division of INGV-CT. He is also involved in the Italian Antarctica Project.