USING WIRELESS POINT-TO-POINT CONNECTIONS TO IMPROVE VOLCANO MONITORING: A FEASIBILITY STUDY OF THE WIMAX TECHNOLOGY APPLIED TO THE CAMPI FLEGREI VOLCANIC AREA (SOUTHERN ITALY)

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INTRODUCTION

IEEE 802.16 standards, commonly known as Universal WiMAX (*Worldwide Interoperability for Microwave Access*), is one of the most promising mobile and fix broadband wireless access technology for next generation all-IP networks in the 3.5 GHz band (European spectrum profile). This access technology allows reaching high bit rate (up to 75 Mbps) and covering large areas (up to 50 km) with a single Base Station (BS), giving the possibility to offer connectivity to end users in a cost effective way. A further useful property of the WiMAX technology is the possibility of using the transmission both in Line Of Sight (LOS) and in Non Line Of Sight (NLOS) environments, allowing highly feasible communications. Thanks to these features, IEEE 802.16 opens the way to the use and the introduction of wireless technologies in the environmental monitoring of areas such as seismic and volcanic zones. WiMAX technology can be applied to provide broadband wireless access in seismic and volcano monitoring scenarios, in order to solve all the problems that today limit the possibility to realize a real-time and accurate monitoring of volcanoes activities in emergency situations. In particular, this work focus on a novel solution, designed within the IST EU "WEIRD" (WiMAX Extension to Isolated Research Data networks) Integrated Project, to perform volcano monitoring using the features offered by IEEE 802.16 networks in order to improve transmission *on demand* of data acquired by temporary seismic stations deployed during emergencies.

Image of the Neapolitan volcanic area. (© ESA, distributed by Eurimage S.p.A.)

STATE OF THE ART IN NEAPOLITAN ACTIVE VOLCANOES MONITORING

The Osservatorio Vesuviano, department of Napoli of the Istituto Nazionale di Geofisica e Vulcanologia (Italy) is charged with monitoring the active volcanic areas of Vesuvio, Campi Flegrei and Ischia (Southern Italy). All these volcanoes have erupted in historical times and rise in an area in which about two million of inhabitants live: for these reasons, the volcanic risk is among the highest in the world.

The seismic monitoring of these active volcanoes is based on a Permanent Seismic Network. The signals of the Permanent Seismic Network are telemetered in real-time to the Acquisition Center in Napoli by means of several communication systems. Here the data are gathered and analyzed to study the volcanic activity evolution.

Unlikely, in some circumstances such as seismic crises, the data recorded only at the Permanent Network may be insufficient to correctly analyze the spatial and temporal evolution of earthquakes preceding and accompanying volcanic activity. This is due either to the insufficient number of the deployed seismic stations or to the instrument inadequacy (i.e. too few digital broadband equipments). In that case, the Permanent Seismic Network is improved as soon as possible with Temporary Digital Stations deployed to enhance both the network geometry and the quality of the recorded data.

IMPROVING VOLCANO SURVEILLANCE WITH TEMPORARY SEISMIC STATIONS

The temporary instruments are portable digital seismic stations usually equipped with broadband seismometers and characterized by continuous local recording on removable media. The local recording system agree with the necessity of a quickly improvement of the monitoring system in case of emergency and allows the better deployment of the temporary stations. On the other hand, the local recording needs a periodic maintenance to retrieve the data and therefore the data itself are not available in real-time. For this reason, the fast integration between permanent and temporary seismic networks is not always possible.

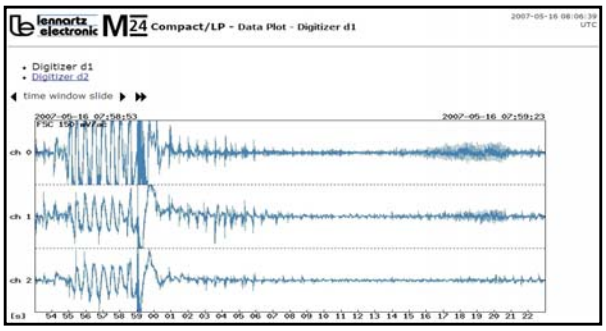
The need to create a communication link between Temporary Seismic Stations and the Acquisition Center to simplify the data retrieval puts new challenging requirements that have to be taken into account. Ideally, data acquired by the Temporary Seismic Stations should be downloaded *on demand* from the Acquisition Center. This feature has several advantages:

- only interesting data are downloaded;
- scientists can analyze in near-real-time more data and activate any action;
- the problem related to the finite storage capacity of the Temporary Seismic Stations can be eliminated;
- scientists do not move to reach all the Temporary Seismic Stations to download collected data spending useful time;
- the data are recorded on the local storage media and therefore they are always available to further access if any problem occurs during the data download.

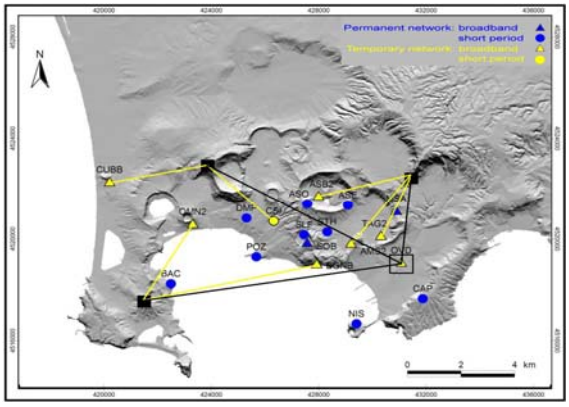
WIMAX TESTBED RESULTS

A WiMAX data transmission test has been realized using a portable digital seismic station Lennartz M24 equipped with a Lennartz LE-3Dlite seismometer. Both the instruments are powered by a 12V battery; the data acquisition is on-site using a 20 GB hard disk. The Lennartz M24 seismic stations are characterized by both standalone recording and remote data retrieval via serial line or TCP/IP protocol on a web-based interface. Dedicated software allows selecting the data format, the compression type, as well as the time-window length of the seismic signal to download.

During the test, the transmission has been obtained by means of a CPE/antenna WiMAX equipment Alvarion linked to the LAN output interface of the seismic station. We have selected a five minutes time-window of the seismic signal to download in compressed ASCII format. Using the WiMAX technology the data transfer has been concluded in about six seconds. As comparison, using the 9600 bps GSM connection the same file is transferred in more than fifteen minutes. In this way, it was demonstrated that WiMAX technology can be successfully used for a near real-time remote processing of the data. In a real scenario, this capability allows to integrate the data gathered by the temporary seismic stations with the permanent network ones.



Thirty seconds of seismic signal gathered by the Lennartz M24 station during the test. The oscillations represent a seismic signal generated near the seismograph to simulate an earthquake.



The seismic monitoring system at the Campi Flegrei during the 2004-2006 emergency. Yellow lines represent the possible link between Temporary Seismic Stations and access points (black squares), black ones are the link with the Acquisition Centre.

A REAL CASE SCENARIO: THE 2004-2006 CAMPI FLEGREI CRISIS

In the last unrest episode at Campi Flegrei, ground uplift was recognized starting on November 2004 by clinometric and strainmeter networks. Consequently, eight temporary high-dynamics digital seismic stations were quickly installed to improve the local Permanent Seismic Network. A low-energy volcano tectonic seismic activity accompanied the ground deformation since March 2005. Moreover, a swarm of about 800 long-period events (LP) occurred on October 2006 holding the National Civil Defense's attention.

The Campi Flegrei situation is a typical real case where both Permanent and Temporary Seismic Networks were operating at the same time during a seismic crisis; nevertheless, the different data acquisition has not allowed a real-time integration and analysis of the data. Owing to the high seismic and volcanic risk characterizing this urbanized area, the new communication technologies can be employed to increase both the quality and the amount of useful data. In the Campi Flegrei scenario, the use of WiMAX connection could help in solving this problem allowing a near real-time analysis of data acquired by the temporary stations.

The LOS transmission should be able to allow the direct link between the Temporary Seismic Stations and the Acquisition Center. Nevertheless, in NLOS configuration, the link can be obtained also through a sequence of few radio links (repeaters) in order to reach stations not directly visible. With only three access points (black squares in figure) configured as repeaters, it is possible to cover the entire area and to link the Temporary Stations to the Acquisition Center. Moreover, the transmission *on demand* from a temporary station is a very effective solution because the data are stored on-site: this means that in occurrence of interferences or signal losses during the download, it is always possible to retrieve again the data in a very short time. Finally, the support for QoS provided by the WEIRD system allows also establishing voice and video communications between people on field and scientists in research center.

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