Remote Sensing and Satellite Communication on the World Wide Web Platform for Support of Volcanoes Monitoring

Olampi S.[1], Ill D.[2], Carmo P.[3], Guarnieri F.[1]

[1] Ecole des Mines de Paris Pôle Cindyniques, BP 207, 06 904 Sophia-Antipolis, tel: 00 33 493 957 472 – Fax: 33 493 654 304 - Email : samuel.olampi@cindy.cma.fr
[2] INDRA Espacio, Barcelona, Spain.
[3] EDISOFT, Lisboa, Portugal.

Keywords: Remote sensing, satellite communication, world wide web, volcanoes.

Abstract

This paper presents the development and the demonstration of satellite communication networks and remote sensing capabilities thanks to WWW technologies. The application is dedicated to volcano monitoring. It consists of a network of autonomous specialized seismic sensor systems linked through several interoperable communication networks. An implementation and demonstration of this architecture is currently operating. Three European volcanoes are monitored.

1. Introduction

The SANARIS system aims at providing a flexible communications system for telemetry and telemonitoring applications requiring portability and fast deployment of remote acquisition points. Some typical examples of this kind of application are natural risk monitoring networks, as those used to monitor volcano eruptions. These applications are characterized by an absence of infrastructure for communications in the event that close-to-target data acquisition is wanted, which is normally the case. Available communication channels are occupied for other activities (such as emergency management) and the locations with alternative communication infrastructures are far from the points of interest. This lack of infrastructure points to satellite communications as one of the most interesting solutions due to the high coverage of existing geo-stationary communication satellites. On the other hand, the fast deployment requirements associated with these types of applications demand an optimization of the equipment used in the remote terminals both for data acquisition and for communications. This means that an efficient design is needed in all the elements used in the remote terminals (antenna, modem, and related electronics). In such a complex application, many systems need to access the same data, which generally leads to storage of redundant copies on multiple systems. In order to overlap these constraints, the SANARIS system architecture is based on remote sensing derived information supported by satellite communication and World Wide Web technologies (WWW).

2. General Overview of the System

The SANARIS system consists of a network of remote data acquisition points linked to an Applications Control Center (ACC) by means of a Satellite Communications System. The system is divided into two parts: an application part and a communication service provision part.

The application part is at the same time divided into three different parts: a field part, where the data acquisition points are located; a local user part, associated with the application control center; a remote user part, corresponding to the end-users (researchers and/or organisms involved in risk monitoring, prevention, or fighting). The field part is totally application-dependant, but some commonalities can be defined. A Data Acquisition Terminal (DAT) typically consists of a set of sensors associated with the parameters that need to be monitored and data acquisition equipment connected to a computer that controls the different sensors, acquires and stores the different values, and eventually monitors for alarms. Application data and alarms are formatted and delivered to the communications system (remote terminal) for transmission to the applications control center.

The Applications Control Center (ACC) is the entity responsible for the control of the different DATs, for data acquisition, processing, monitoring, storage, and distribution to the end-users. The RACC is the Remote Application Control Center operated by the "Registered Users". The connection to end-users can be done in two different ways depending upon the location of the user: locally or remotely. Local users are those located in the same place as the ACC and are directly connected to the ACC by means of a LAN for the reception of data, alarms, statistics, etc. Remote users are either researchers working in the field interested in sharing data corresponding to different crises worldwide, or organisms with responsibility in the prevention, detection, monitoring and/or fighting of crises. The SANARIS system contemplates the use of the Internet as the communications means to provide remote users access to the application data managed by the agent responsible/owner of the application data network.

The Service part is responsible for providing a data communications service for the control, monitoring, and data acquisition of the application network formed by the ACC and the set of DATs. To provide this service with the required portability and fast-deployment requirements dictated by the applications, it is proposed to use a satellite communications system in order to minimize the need for infrastructure and to provide a flexible, reliable, and manageable mechanism compatible with the application requirements.

3. The SANARIS Application Control Center Architecture: General Overview

By using a powerful communication infrastructure based on network technologies--Internet, CORBA--the SANARIS ACC could be accessible by users distributed in different locations. A three-tier architecture has been chosen for design and development.

3.1 The three-tier architecture

The three-tier architecture (see figure 1) is used when an effective distributed client/server design is needed that provides increased performance, flexibility, maintainability, and reusability while hiding the complexity of distributed processing from the user.

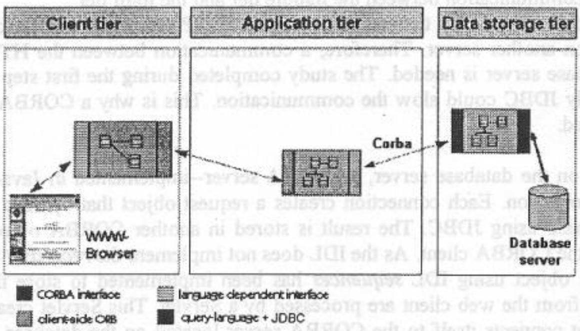

Figure 1: Three-tiers architecture principles.

Thus, in the frame of the SANARIS project, this architecture embraces the following:

- Client-tier: Is responsible for the presentation of data on volcanoes under monitoring, receiving user events, and controlling the user interface. In SANARIS, the data are presented through a web server via an applet and/or HTML pages.
- Application-server-tier: The middle-tier server (or application server) improves performance, flexibility, maintainability, and reusability by centralizing process logic. Centralized process logic makes administration and change management easier by localizing system functionality so that changes must only be written once and placed on the middle tier server to be available throughout the systems. With other architectural designs, a change to a function (service) would need to be written into every application.
- Data-server-tier: This tier is responsible for data storage. Besides the widespread relational database systems, existing legacy systems databases are often reused here.

It is important to note that boundaries between tiers are logical. It is possible to run all three tiers on a single machine. The main importance is that the system is neatly structured, and that there is a well-planned definition of the software boundaries between the different tiers. The functioning of this architecture is based on an HTTP server which is the link between the web client and the other entities--software agent or databases. The requests performed on the web client are sent to a Servlet hosting on the

HTTP server. When the server receives a request, a connection is established either with a software agent using CORBA, which allows heterogeneous components to communicate, or with the database using Java Data Base Connectivity and CORBA. The result of the connection, which can be an answer to a request on the database, is sent to the web client thanks to a Servlet.

3.2 The communication between the middle tier and the third tier

As the applet of the GUI tiers accesses only its HTTP server, it cannot access a database located on another server. Therefore, a communication between the HTTP server and the database server is needed. The study completed during the first step of the project using only JDBC could slow the communication. This is why a CORBA link has been established.

Located on the database server, a CORBA server--implemented in Java--waits for the client connection. Each connection creates a request object that opens a connection to the database using JDBC. The result is stored in another CORBA object that is 'sent back' to the CORBA client. As the IDL does not implement the *recordset* type of JDBC, a special object using IDL *sequences* has been implemented to store the result. The requests from the web client are processed by a Servlet. This Servlet creates a CORBA client that connects itself to the CORBA server located on the database. The result of this connection is sent by the Servlet to the web client using an HTML page.

4. Satellite Communication System Description and Network Architecture

4.1 General overview

The communications network proposed for the SANARIS system is based on the V-SCADA system, a prototype of which was demonstrated within the PlanSAT initiative of the Spanish Administration. V-SCADA is a satellite communications network in Ku-band, which was specifically conceived and designed to meet the communications requirements of telemonitoring and telemetry applications. The most important advantages of the satellite solution are that no infrastructure is needed in the place of the remote terminals, thus making it highly suitable for installation in remote areas and also for rapid deployment.

To minimize the capital investment and set-up time required, the V-SCADA communications system was designed to efficiently cope with existing Ku-band transparent satellite transponders. This required the adoption of advanced digital communication techniques providing high quality and high capacity communications from portable terminals equipped with small antenna dishes. The Band-Limited Quasi-Synchronous Code Division Multiple Access (BLQS-CDMA) technique was selected for the important advantages it provides, especially in terms of system capacity thanks to the reduced carrier power flux density and EIRP requirements and its interference rejection capabilities associated with the direct-sequence spread-spectrum technique.

4.2 Network Management Station (NMS)

The V-SCADA system is a multi-start communications network such that all the transactions to establish communication are done through the Network Management System (NMS) despite the communication origin and destination being remote terminals.

The NMS is responsible for the overall management of the network, including resource management and monitoring and control of the different network components.

The NMS controls all the network by means of the information sent by a devoted signaling channel, listened to by all the terminals. By means of this channel, the terminals are informed about the auxiliary channels to receive data and the ones used to send data. Groups of terminals can be created to simplify the management, to group those such that their functions and characteristics are similar, or to create better network traffic management. A common address can be assigned to each terminal's group to send broadcast messages common to all of them.

4.3 HUB station

Each sub-network has its own Hub station, responsible for application data transmission between the different remote terminals belonging to the sub-network and the Application Control Center. The Hub station also controls the sub-network by means of the signaling data transmitted and received by all terminals. The Hub stations are designed to be rather small in relation to antenna size, power requirements, modems, and control equipment, so that they can be installed together with the application control Center in the user premises. Figure 2 outlines the equipment that is needed for application control: Hub station, Application Control Center (ACC), local user workstations, and Internet router to provide access to remote end-users.

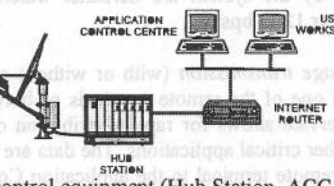

Figure 2: Application control equipment (Hub Station, ACC, User Workstations & IP Router).

4.4 Remote Terminals

Desirable characteristics for a remote terminal are:

- Easy installation and operation,
- Low power requirements and autonomy,
- Small size,
- External interfaces suitable for telemonitoring applications.

Figure 3 outlines the remote equipment to show in more detail the application sensors, data acquisition station, and communication remote terminal.

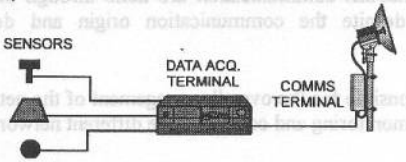

Figure 3: Remote equipment (DAT and Communications Remote Terminal).

4.5 Scalability

The average terminal traffic growing or the number of terminals growing in the network can generate traffic needs involving the growth of network resources to allow for a greater number of simultaneous transactions management. To cope with such requirements, a scalable network is proposed.

A first growing can be done by increasing the available number of simultaneous traffic channels, all controlled by the same signaling channel. That can be done by adding more modems to the HUB and configuring the NMS to manage these new resources.

When the signaling channel does not have enough capacity to manage all the network terminals, it is envisaged to use more than one signaling channel, each one assigned to a terminals group. In this way, sub-networks are created, all them managed by the same NMS and each one having a signaling channel allocated to a lower number of terminals.

4.6 Services

The services provided by the system are hereafter described. In all the cases the transmission rate is 300 or 1200 bps:

- *point-to-point message transmission* (with or without acknowledgement) between the Hub station and one of the remote terminals or between two terminals via the Hub station. This service allows for rapid distribution of sporadic short messages such as alarms or other critical applications. The data are formatted as messages and delivered from the remote terminal to the application Control Center or vice-versa. Data in both directions can be transmitted: inbound data from remote terminal to Hub, and outbound data from Hub to remote terminal.

- *broadcast message transmission* from the Hub station to all the terminals or to a group of terminals that continuously listen to the broadcast channel . This mechanism is used for network control (and in particular setting up of the polling service) and for commanding of the application remote equipment.

- *polling services,* addressing a particular terminal to request data and receiving the response data from the terminal. All terminals can share the same channel in an

Aloha access scheme. The terminal is addressed by means of a broadcast channel and responds through the Aloha shared channel. This is the basic mechanism for the distribution of non-critical data, especially in case they can be allocated in the form of short messages.

- *transparent channel services,* which offer a two-directional full-duplex communication channel between the Hub station and the remote terminals by means of the allocation of two Data Dedicated Channels, one for the outbound data and the other for inbound data. It is also a transparent channel, which means that the responsibility of data integrity control lies with the application. This is the basic mechanism for the transmission of long messages or when continuous transmission for a period of time is needed.

These are the system supported communications basic services. Nevertheless, specific adaptations can be done at the interface level to support the services required by the application each time the application characteristics are supported by the communications system.

5. Volcanoes-Monitoring Application

5.1 End user requirements

The User Requirements highlight four classes of needs:

- *Data acquisition :* The acquisition chain is composed of one or several remote sensors that are linked to one Data Acquisition Terminal (DAT). The DATs are linked to a satellite communication system. All the DATs give their data to the Application Control Center (ACC).
- *Data managing :* Managing all the data coming from the sensors necessitates a database. A database is an efficient way to store and retrieve the data. The data about volcanoes, sensors and working people are thus stored in a Relational Database Management System.
- *Data processing :* Data processing is the analyses done with the data. Because the end-users want to do their own processing, this task is reduced to the simple transmission of the data in raw format, from the database (which is part of the ACC) to the end-users.
- *Project valorization :* The project valorization is the promotion of the SANARIS project itself, the partners, and the work done and in progress.

5.2 The volcanoes under monitoring

Out of the more than 3,000 active volcanoes that are catalogued, fewer than a hundred are equipped with a minimum instrumental and fewer than two dozen have enough scientific technological knowledge available.

An implementation and a demonstration of this architecture is currently running, with three different volcanoes being monitored:

Volcano name	Volcano type	Country
Sete Cidades	Stratovolcano	Portugal
Lanzarote	Fissure vents	Spain
Vesuvius	Complex volcano	Italy

5.3 The SANARIS data storage tier

The SANARIS Database is of a relational database type and will consist of two modules--the Data Entry and Query Modules. These modules provide several functions to the user and give access to the database files in which data are stored. These database files are also linked (relational model).

The data storage tier contains data about volcanoes monitoring in Europe, a map of the region being threatened, and some user information. The database management system used is PostgreSQL.

The general framework of the SANARIS database is the following:

- The Data Entry Module

This module provides options to store and edit data, and options to change program settings. This data collection module has been designed according to the information provided by the SANARIS end-users. A conceptual model of data has been written using the entity-relation formalism.

- The Query Module

The search and retrieval of data from a database is called a "query." Through this module, a search can be conducted on information stored in the SANARIS Database. Simultaneous searches on several files are possible. Complex conditions may be defined, containing several criteria for different parameters. Information from data sets that meets the condition can also be retrieved. Query output can be exported to various file formats, including spreadsheet, text, and database format, or viewed graphically on the monitor or printed. The raw format, asked for by the SANARIS end-users, is also supported.

The SANARIS database is divided into 4 sub-components:

- Data about the SANARIS users,
- General information on volcanoes,
- Information on the sensors network,
- Data given by the sensors.

5.4 The SANARIS application tier

The SANARIS application tier is composed of two major components:

- The Application Kernel : This software forms the skeleton of the SANARIS three-tiers architecture. The program runs on the same computer as the web servers and/or the database, as well as the communication module that manages the data processing and exchanges between these components. When a request is made to a web server, the application kernel handles this request and translates it into a request understandable by the database language, sends the query to the database, receives the answer from the database, analyzes these data, then calls the appropriate function on the client tier to display these data.

- The Communication Module: The SANARIS communication module is a stand-alone program. The purpose of the SANARIS communication module is to provide a way to exchange data between an existing communication system and the Application Control Center. The SANARIS communication module acts as an interface between two systems : one is the SANARIS ACC architecture, the other is the communication system developed by INDRA.

5.5 The SANARIS client tier

In the SANARIS ACC the client tier is divided into two sub-components:

- A Public web client : This set of web pages can be accessible to everyone connected to the HTTP server. The project will maintain a regular web site informing the general public about the status of the project.

- A Private web client : This set of web pages can be visible only by a restricted number of persons (SANARIS end users). Access is by using a login and a password. These pages provide a restricted access to the data-storage tier (database, for example, to make a query) as well as to the application tier (in particular the communication module, to send or retrieve a sensor file that can contain configuration information or raw data)

6. Conclusions and Perspectives

The present paper has briefly described how both satellite communication and WWW concepts and technologies can improve decision-making in natural hazards prevention and fighting. Nevertheless, this paper indicates only some main problems and criteria for the development of cooperative Decision Support Systems. A pilot application has validated the methodological and technological approach. As far as further development is concerned, it has been planned to:

- implement these technologies in the field of other natural hazards (e.g., fire, flood …).
- enter, as soon as possible, the project into the commercialization phase.

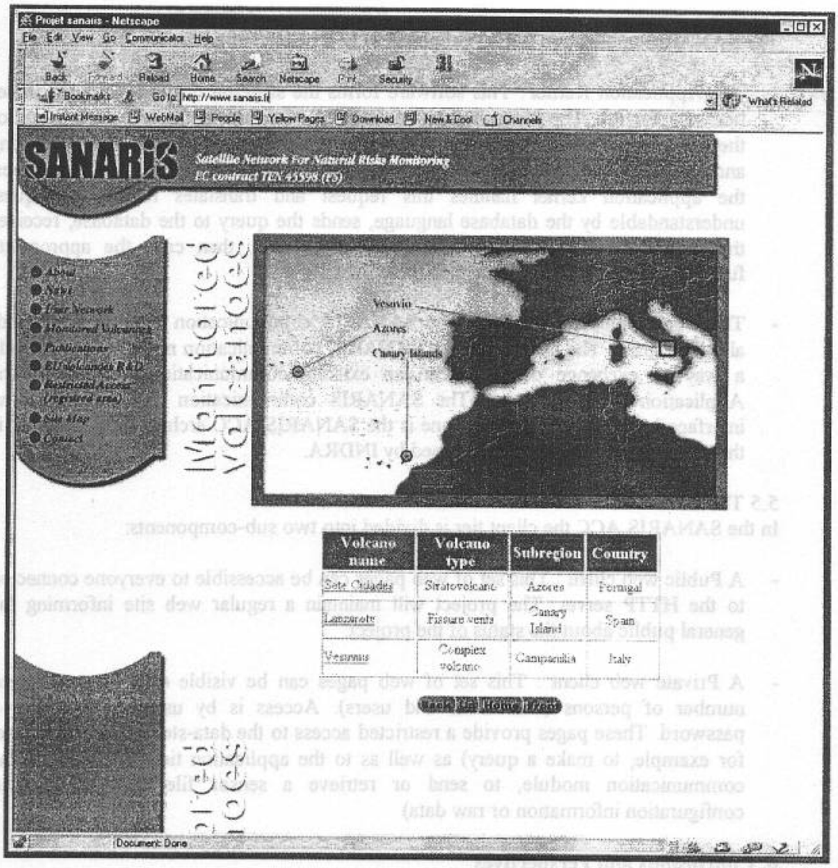

Figure 4 : SANARIS client tier.

7. References

A. Ferigle, "*V-SCADA. Red de Comunicaciones via Satélite para Telemedida y Telecontrol*", Jornadas PlanSAT, Nov. 1997.

R. De Gaudenzi, L. Guzmán, A. Zarembowitch, "*ARCANET: A Ku-band CDMA VSAT Network for High Quality Telephony to Portable Terminals*", IEEE ISSSTA, 1996.

R. De Gaudenzi, C. Elia, R. Viola, "*Bandlimited Quasi-Synchronous CDMA: A novel Satellite Access Technique for Mobile and Personal Communication Systems*", IEEE Journal on Selected Areas in Communications, Vol. 10, No. 2, Feb. 1992, pp. 328-343.

Harris, AJL, AL Butterworth, RW Carlton, I Downey, P Miller, P Navarro, and DA Rothery (1997) Low-cost volcano surveillance from space: case studies from Etna, Krafla, Cerro Negro, Fogo, Lascar and Erebus, Bull. Volcanol., 59: 49-64.

Francis PW, G Wadge, and PJ Mouginis-Mark (1996) Satellite monitoring of volcanoes, In: Monitoring and Mitigation of Volcano Hazards, R Tilling and R Scarpa (editors) Springer-Verlag Press, N.Y., pp. 257-298

Self S. and PJ Mouginis-Mark (1995) Volcanic eruptions, prediction, hazard assessment, remote sensing, and societal implications, US National Report to International Union of Geodesy and Geophysics, 1991-1994, Rev. Geophys. Suppl., 33: 257-262.

8. Acknowledgements

EC Contract TEN 45598 (FS). Commission of the European Communities, Directorate General Information Society, Information Society Technologies: Technological Developments of a Generic Nature and Horizontal Actions. Trans-European Telecommunication Networks.