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PACKET RADIO NETWORK FOR VOLCANO MONITORING: AN IMPLEMENTATION ON TAAL (PHILIPPINES)

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ABSTRACT

This paper describes an implementation of a packet radio network on Taal volcano. The network, based on amateur radio hardware and software, allows the Philippine Institute of Volcanology and Seismology (PHILVOLCS) to retrieve real time data from various instruments located on and around the volcano island. The actual list of instruments includes 10 digital seismic stations, 3 tiltmeters, 2 radon sensors, 1 geochemical station (water temperature and conductivity) and an acoustic station. The original features of the network are the use of only one radio frequency simplifying frequency allocation procedures and equipment management, redundancy allowing failures of nodes without loss of data, low power consumption reducing the cost of field power supplies.

The network is linked to the internet by a radio link from PHILVOLCS to the University of the Philippines (UP). This link allows foreign organizations to access the data and provides basic internet services (mail, ftp, telnet, ...) to PHILVOLCS and any user located in the Taal vicinity.

THE VOLCANO

Taal volcano is a 5 km diameter island located 60 km south of Manila and is situated in a 20 km diameter caldera filled by a lake. Its last eruption occurred in 1977 and its history is composed of several deadly eruptions. As such it has been chosen as one of the 10 decade volcanoes by the International Decade for Natural Disaster Reduction commission (IDNDR).

Joint projects between PHILVOLCS and the University of Savoie, France have improved the monitoring of this volcano. Transfer of data between the island and PHILVOLCS main office in Manila has always been a problem due to the lack of existing communications infrastructure on the island.

PACKET RADIO SOLUTION

Radio amateurs have developed packet radio for more than 10 years now and have constituted worldwide network supported by a constellation of satellites. The choice of amateur radio hardware and software was motivated by its low price, proven reliability and large choice.

The basic equipment to access or create a network is a radio, a TNC (Terminal Node Controller) and a computer terminal. The TNC chosen has a 9600 bit/s raw bit rate on his radio port and the radio is a 2 W UHF transceiver. The frequency assigned by the NTC (National Telecommunication Commission) for the network is 424.850 MHz.

A growing community is using the excellent NOS (Network Operating System) of Phil Karn, KA9Q which implements TCP/IP over packet radio. An upgraded version of NOS was used to link PHILVOLCS and the Taal Network to the internet.

TNC+

As suggested by its name the TNC can act as a node and as a terminal simultaneously. The TNC alone acts as a repeater ("digipeater" in amateur radio terms). With a computer connected to its serial port, more sophisticated routing function can be added. Software exist to replace the original repeater function by higher level routings functions but most of the time the terminal function of the TNC is then lost. The igipeating scheme is not efficient in noisy environments if the number of hop between the source and destination is greater than 1. A packet lost on any segment of the link will be retransmitted starting from the source even if it successfully crossed the first segments. Delays and low throughput appear on a digipeater based network.

Most instruments cannot be connected directly to the serial port of the TNC. For volcano monitoring application, it is costly and not practical to install a computer to every node of the network. So another kind of interface is needed.

Most of the nodes of the network will be idle when no measurements are taken. For example the sampling of a tiltmeter takes 10 sec every 15 minutes. Power could be saved by turning off the unused communication equipment during idle time. Less power consumption results in less expensive, lighter and easier design of solar panel and battery power supplies.

To overcome the above problems it was decided to design a special interface board that would connect to the serial port of the TNC and add the following functions:

- packets are acknowledged on every segment to avoid retransmission over the whole link. This is an improvement over the digipeater scheme.
- switching off and on at present time of the radio and TNC to save power.
- provides 3 asynchronous serial ports, 1 synchronous serial port, 16 outputs line, 8 input line, 1 counter input, 3 analog input channel (8 bit A/D converter)
- direct connection of up to 8 *.* A/D converter (21 bit, 2 channels, analog amplifier with programmable gain ranging from 1 to 128)
- monitoring of the power supply voltage (battery level)
- remote modification of the TNC parameters
- additionally a watchdog will reset the board and TNC if the TNC stays continuously on or off for more than 3 hours. This could be due to hanging of the board, the instrument or the master PC. This feature improves reliability of the network.

The interface board is a MC68HC11 microcontroller based with 32 Kb memory expandable to 128 Kb. The TNC is running a radio amateur software, called "The Firmware", copyrighted by NORD><LINK. This software is labelled "free for non-commercial usage". The interface board uses the host mode of The Firmware. The TNC connected to its interface board was named TNC+.

THE TAALNET SOFTWARE

This software is running on a PC (386/33) and implements the master function of the network. It is written in Borland Pascal version 7 and runs in protected mode. It is composed of several units, one unit contains the specific list of commands used to retrieve data from each instrument. This unit needs to be updated when a new instrument is added. Field stations are called periodically. The current setting are the following:

The main 15 minute period is subdivided into three 5-minutes intervals.

At the beginning of the first interval the low frequency data are retrieved, connections are established to the 3 tiltmeters, the 2 radon sensors and the geochemical station. The total call lasts 1.5 minutes so several low frequency instruments can still be added. The second interval is reserved for the call to the acoustic station. This station is composed of a hydrophone located in the main crater lake at a depth of 40 meters and connected to a digital oscilloscope (Fluke Scopemeter PM97) through a set of filters. Taalnet will switch the filters and drive the oscilloscope to perform waveform acquisition at various frequencies. The call lasts from 1.5 to 3 minutes depending on the amount of data to be retrieved. The last interval is dedicated to the call to the digital seismic stations. These stations continuously monitor seismic signal and a triggering algorithm runs concurrently to detect seismic events. Upon detection the event is stored on the on-board memory. A maximum of 32Kb can be retrieved from this station due to limitation in nodes buffer. An external clock sources consisting of an OMEGA signal receiver is needed to insure correct time stamping of the data. Only one station is called at each seismic station interval, so for 10 stations the period is 10 x 15 minutes so 2 hours and 30 minutes. The call lasts from 2 to 5 minutes depending on the number of relays to be crossed. This scheme causes delays in the reception of seismic data but avoid the overloading of the network in case of seismic swarms. Previously the 10 stations were polled for data at each seismic interval. This scheme will be reintroduced when another type of digital seismic station will be available.

At the beginning of a call an "unproto" (connectionless) packet is sent to synchronise the clock of remote nodes to the PC clock. The unproto mode was chosen to avoid automatic retransmission of these packet without control of the upper layer. A node will read the content of the synchronisation packet and update its clock accordingly. If the packet was delayed due to retransmissions, the node would not be aware of that fact and would update its clock according to a time already elapsed. It is better not to receive a synchronisation packet than to receive an incorrect one.

At the end of each call, Taalnet checks the battery level of the nodes, the correct reception of the synchronisation packet, the next wake time of the node and if it has reset. This information in stored in log files. If the node has reset or if an error is detected the wake configuration parameters will be sent. After no error is detected the node will be turned off. On the Taal network, 2 relays are configured as permanently on to allow communication over the network at any time (see Internet Access).

In case of failure of a link another route, if available, will be tried. The new route will be remembered and tried first on the next call. Taalnet use the Dijstra algorithm to find the shortest route to a node.

The topology and the status of the network is displayed on the screen along with the time remaining before the calls to each node. Different colours show links currently used, links out of order, station connected and station having low battery voltage. When no data transfer is in progress the user can use the Taalgraf (written by Nicolas Poussielgue) option which draws graphs showing the variation of all the parameters measured during the last 8 days. Taalgraft can also be invoked from any computer connected to the LAN (Local Area Network). Early battery problem detection is possible by using Taalgraf daily.

All Taalnet parameters and even Taalnet itself are stored on the file server (see Data Organization). This allow telemaintenance of the network through the internet. People having access rights can remotely change the parameters or update the Taalnet version.

DATA ORGANIZATION

A Sun IPX workstation is used as the central file server for Taal data by running the NFS server. If the LAN is operational the data gathered by the Taalnet software stored on the file server, if the LAN or the IPX is down the data is stored on the local hard disk of the PC running Taalnet. Data will be appended automatically on the file server when the LAN is restored.

Most of the PC's connected to the LAN are running the NFS client software allowing the access of Taal data by multiple users simultaneously. Foreign organizations can also access the IPX through the internet allowing worldwide distribution of the data.

INTERNET ACCESS

The installation of the link to the internet was done in collaboration with ASTI (Advanced Science and Technology Institute) based in the University of the Philippines (UP). Most of the work was done by Denis Villorente of ASTI and comprised mainly in the searching, compiling and testing of different NOS versions followed by correct configuration of the NOS parameters and other UNIX machines on the network. The hardware is composed of a PC with an ethernet board, a 9600 baud TNC, a TEKK radio and a Yaggi antenna at each side of the link. The distance between PHILVOLCS and UP is about 5 km. ASTI is connected to the internet via 64k bit/s leased line. The radio frequency used is the same as the one used for the Taal network. This allows any user in the Taal vicinity to access the internet and theoretically any internet user to access the Taal network but problems appear with heavy traffic. The parameters give priority to the gathering of data from Taal but in case of poor radio conditions (encountered during daytime) the use of the same frequency will cause disconnections on the Taal network and the data currently being transferred will be lost. To overcome this problem the link to UP will be replaced by a public switched telephone link. However the radio interface in PHILVOLCS will be kept to allow users in the Taal vicinity to access to the internet. The PCs are running the grinos (Gerard van der Grinten, PAOGRI) version of NOS.

The PC in PHILVOLCS is also the mail server and users can read and write their mail from any computer running the popmail software and connected with an ethernet board to the LAN. The domain philvolcs.dost.gov.ph" was created with its primary name server consisting of a SUN SPARC 2 workstation located in PHILVOLCS building. This philvolcs domain is not mandatory for the internet connection but to simplify separation between ASTI and PHILVOLCS.

Access to the internet from Taal is done using a 9600 baud TNC, TEKK radio and a computer or terminal. An AX25 connection is established to one of the PCs running grinos. The list of relays used (digipeaters) must be specified with the "connect" command. The user can then read or send his mail or issue a telnet connection to any internet host. To check the latest data retrieved from Taal the user needs to issue a telnet connection to the SPARC IPX of PHILVOLCS. If the user doesn't have its own TNC and radio he can go to any instruments and use the equipment there. Data gathering from Taal is not affected if the communication traffic is kept low. The access from Taal has proven its usefulness by facilitating the maintenance of the monitoring network: a technician or scientist on the field can keep in touch with his team anywhere in the world in case of questions or problems. In case of emergency the network could help to relay information directly to and from the volcano and its surroundings.

SOURCE AND COST OF SOFTWARE AND HARDWARE MENTIONED IN THIS PAPER

nos, grinos: by ftp anonymous to ftp.ucsd.edu, free

popmail: by ftp anonymous to univax.univ-savoie.fr free

nfs: by ftp anonymous to univax.univ-savoie.fr, 20 US$year (shareware)

TNC+ composed of:

TNC-2H (9600 baud): Symek, Germany, 250 US$
TNC interface board: contact the author 350 US$
Radio KS-960: Tekk, USA, 250US$

Taalnet: contact the author, free