Low-Cost Continuous Seismic Acquisition Solution Utilizing Open-Source Software

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Summary

Continuous monitoring of regional seismicity is important for locating earthquakes and the mitigation of earthquake hazards. In Saskatchewan, this is currently only performed by our group at the University of Saskatchewan. We aim at a robust, low-maintenance and low-cost solution with full automation of data acquisition, archiving, and processing. This is achieved through building inexpensive multichannel digital data loggers and utilizing open-source software to transmit the continuous records over a TCP/IP network connection.

The system consists of three components: acquisition data server (located near the geophones), data relay program (located in the data centre) and client programs used for displaying, processing, and saving the data. Various clients are available, from simple display tools to a direct feed into the IGeoS processing package. This allows practically unlimited flexibility of processing applied to the real-time data stream, from immediate archiving to creating ring buffers, identifying events, or producing various data displays. Web server is used to display system status and set acquisition parameters. Currently, the system has two operational stations near Saskatoon, Saskatchewan, with more stations planned.

Introduction

As a seismic monitoring system operated by a small University group with, our hardware/software solution is designed to be a reliable and fully automated hardware and software combination for collecting, transmitting, processing and storing seismic data. While use of the system has been focused on a serving as a regional (1Hz) seismograph, the network design and concept of direct feed into processing should also work well in reservoir monitoring. The modular approach (server, relay and client) and documented interface allow new clients to be written to integrate real time data in other applications which could be useful even outside of the seismic community.

Considerable effort was spent to ensure that the system uses a minimum of network bandwidth which makes it suitable for slower internet links found in remote locations. To keep operating and maintenance costs at a minimum, the data is processed without the need for an operator and events are automatically identified. Most significantly, the data can be loaded directly into a full-featured geophysical processing package (IGeoS). This allows a great deal of flexibility in the processing scheme. The software is open-source (Linux-based), and the hardware is build from standard computer components and an inexpensive commercially available 24-bit A/D system with GPS timing.

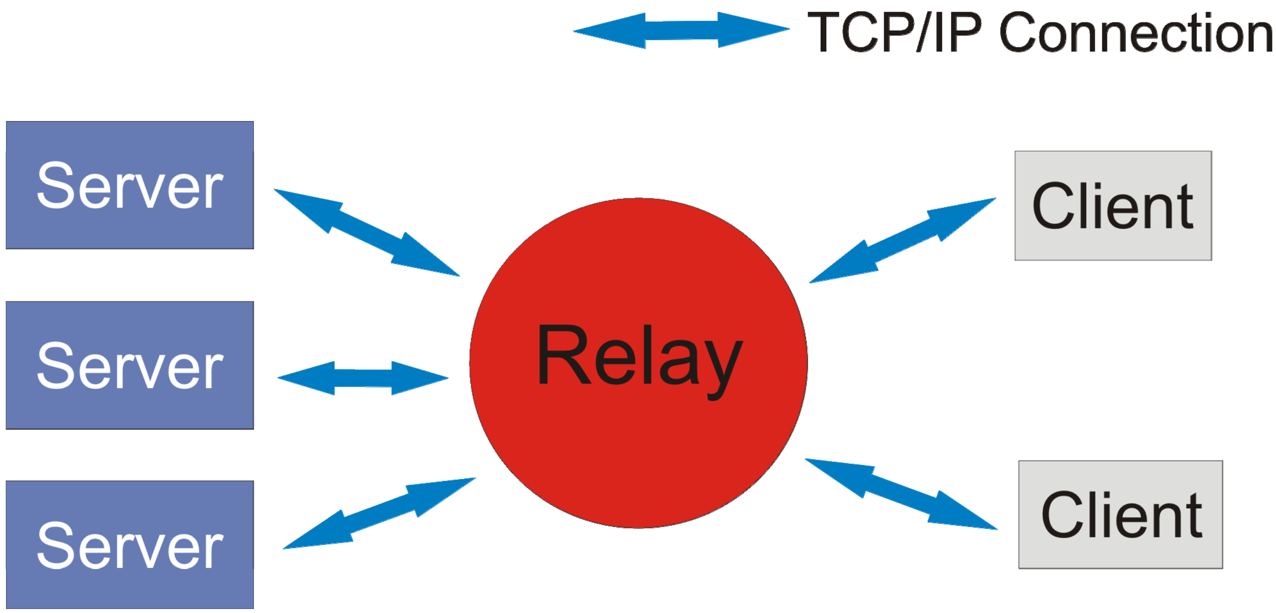

Figure 1: Network design

Three distinct components comprise the software: server, relay, and client (Figure 1). Communication is handled over a standard TCP/IP network connection. The server component is located at site of the data acquisition and transmits the digitized data to the relay. Multiple servers can connect to a single relay which can pass the data unaltered to the clients or first perform some timing synchronization. Clients can connect to the relay and retrieve a list of available servers. They are then able to specify which servers to receive the data stream from.

Server

The data acquisition server program is automatically started on boot, makes a network socket connection to the relay program and begins to communicate the digitized values, time marks and GPS coordinate and time strings as they are retrieved from the hardware. Timing data may arrive significantly before or after the samples which they describe, and thus it is necessary to synchronize the data before it is used. However, in order to keep the server as simple and robust as possible, the synchronization is done off site, by the relay or client programs.

If the network connection is broken, the data can be stored locally for later transmission or retrieval via a web browser. When the network becomes available again, the connection with the relay is reestablished automatically, and the transmission continues. After a network outage, the stored data may be sent concurrently with new data until the system is again working in real time. Optionally, the server can back up all data to a local disk in addition to transmitting it.

To monitor the state of health (currently temperature) of the system, we use the 1wire devices from Dallas Semiconductor. A model DS9097 serial to 1wire adapter is used and a DS18S20 digital 1wire thermometer. The server software polls the thermometer at a configurable interval and transmits a “state of health” package to the relay which includes the time and temperature. If the temperature is outside of the configured high or low alarm points an email is also generated and sent to the specified addresses.

Relay

The data relay program runs continuously at the data center computer and accepts network connections from all data servers and from clients in the system (Figure 1). It has two main functions: re-distributing data and synchronizing the timing. It acts as a distribution point for the data which reduces the load on the internet connections from the servers. With this design, only a single stream needs to be sent from the remote site regardless of how many clients are receiving the data. Communication is formatted using a small set of XML tags.

Each server makes a connection to the relay, identifies itself as a data source and provides site information. The available site names are then transmitted to any clients that connect. Clients connect to the relay and specify what type of data (e.g., raw or time-synchronized) they expect.

Synchronization is accomplished by creating a data queue for both the time marks and the corresponding data packets in the relay.

Clients

Implementation of a client for this system is relatively simple: the program must only be able to make a socket connection over a network to the relay and send and parse a few XML tags. We have written a simple client which displays the real-time data from selected channels. Another client program send the real-time data into the IGeoS processing package (formerly SIA, Morozov and Smithson, 1997; Chubak and Morozov, 2006), which allows to perform any standard seismic processing and leverage the more than 200 tools currently in the package. Because the data is fed directly into a processing package, the result is limited only by the selection of tools made by the user. For example, we use processing flows which save the data to a RAID concurrently with performing filtering and preprocessing and applying an STA/LTA (Short Term Average / Long Term Average) event detection. IGeoS client processing flows can also use 3D OpenGL visualization or PostScript to display the data , and to produce various types of file outputs, such as formatted in ASCII, SAC, or SEG-Y.

Current Installation

Mining and other human activities account for many of the seismic events in Saskatchewan. These are of interest to the public and in many cases to the exploration community as well. The first system we installed is located on the Whitecap Reserve south of Saskatoon, SK in response to concerns that seismic activity from a nearby military base might be affecting the structural integrity of the buildings (Figure 2; Morozov et al., 2007). A second station is located a the UofS Geophysics test site east of Saskatoon. From this location we have recently recorded a large, m_b=3.2, seismic event near Esterhazy, SK (Figure 3). We are currently looking for a site for the third station of the network, which is necessary for accurate event location (Figure 2).

Figure 2: Current and proposed locations of the UofS regional monitoring stations.

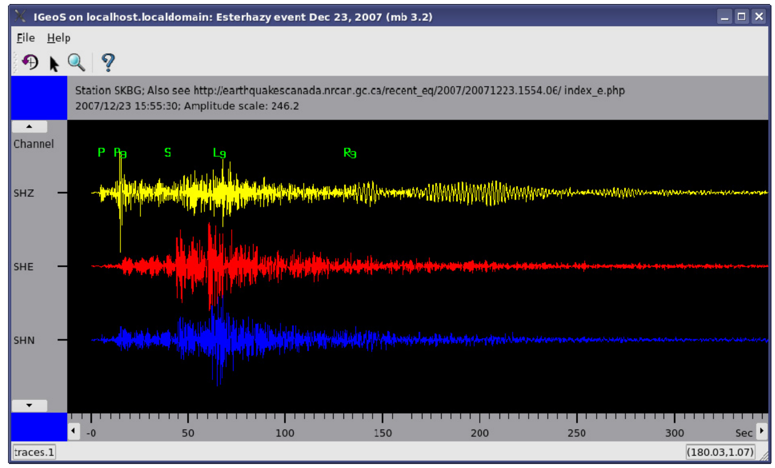

Figure 3: Esterhazy, SK mine event on Dec 23, 2007 recorded at station SKBG in Figure 2.

Conclusion

While network monitoring systems are not new, we believe that the use of open-source software combined with commodity hardware provides low-cost and robust solution for remote seismic acquisition. The unique (to our knowledge) integration of the data stream into a processing package provides features and flexibility not found in other systems. Finally, as a complete solution for seismic monitoring it is necessary only to provide the appropriate hardware and a location with power and internet to begin collecting and analyzing data.

References

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