Networked Seismographs: GEOFON Real-Time Data Distribution

Winfried Hanka[1], Andres Heinloo[2] and Karl-Heinz Jaeckel[1]
hanka@gfz-potsdam.de, andres.heinloo@acm.org, jaeckl@gfz-potsdam.de
[1] GeoForschungsZentrum Potsdam, [2]Geological Survey of Estonia

Abstract. A concept for an open manufacturer independent data aquisition, recording and distribution system with real-time data transmission capability over Internet or other TCP/IP links - even weak or dial-up ones - was developped for the GEOFON network. It is already partly implemented and provides real-time or near-real-time data from a substantial part of the network to the GEOFON DC and other data centers.

1 Introduction

Setting up a modern seismological network providing maximum data quality, highest flexibility, standard data formats, up-to-date storage facilities and effective communication protocols is a difficult and normally a very costly task. Only very few commercially available digitizers are capable to resolve the full seismic spectrum and dynamic range provided by a modern VBB (Very Broad Band) seismometer. Companies offering such digitizers are often not capable to provide a complete real-time network solution fulfilling all wishes seismologists have in their mind or such a commercial solution becomes very expensive. Real-time communication for global networks - like in case of the GTSN (Global Telemetered Seismograph Network) or the IMS (International Monitoring System for CTBT verification) - requires normally very expensive satellite links, which are not suitable for pure research VBB networks. An earlier attempt to use the Internet as communication medium - the LISS (Live Internet Seismic Server) of the Albuquerque Seismic Lab - has severe limitatons as it supports only one data logger type and requires very reliable permanent Internet connections which are only very rarely available at remote sites. Thus, up to now, real-time data distribution does not play an important role for global or regional multi-national BB networks as replacement for the conventional tape recording.

Therefore the idea to develop an open, flexible, comfortable, and low cost seismological data acquisition, processing, and communication system with real-time networking capability was born. The Seismological Communication Processor (SeisComP) project is an initiative of the GEOFON Program of GFZ Potsdam with contributions of several other institutions. It relies on commercial VBB digitizers, cheap, reliable and worldwide available hardware (mainly PCs with Linux operating system), the Internet as major communication channel and - as much as possible - on proven open software. The present version of SeisComP consists of four individual software packages for data acquisition, recording and monitoring (station or network processor functionality), real-time communication and user access tools (data center processor functionality).

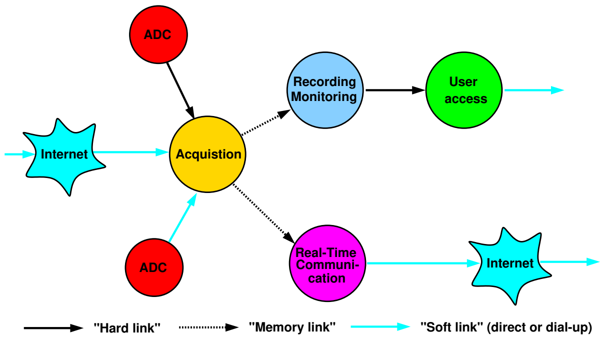

Fig. 1. The basic components of a SeisComP system. The original kernel of the acquisition, recording and monitoring parts of the system is the Comserv software package published by Quanterra Inc & UC Berkeley. Depending on the individual digitizer communication protocols, the connection between the ADC and the acquisition system has normally to be contiguous ("hard link": short term buffered data transfer over serial cables, Ethernet, leased line phone/ISDN lines, satellite links), while the SeedLink real-time communication protocol also supports "soft links" connections (long-term buffered direct or dial-up TCP/IP links). SeedLink e.g. allows to setup the acquisition, recording and user access on separated systems in different locations.

Acquisition, recording and user access of the data from one or more digitizers can take place on the same physical computer (stand-alone mode) or on different SeisComP nodes connected by the real-time communication system SeedLink (networked mode). The network communication is based on dedicated or dial-up TCP/IP links or Internet. At each node of the network, locally acquired data and/or data from other nodes can be jointly recorded and accessed. So the configuration of arbitrary "virtual" real-time networks is easy to achieve.

2 Data aquisition, monitoring and recording

Kernel of the data acquisition and recording part of SeisComP is the ComServ software package originally developed by Quanterra Inc and UC Berkeley to provide acquisition functionality for data from Quanterra dataloggers on Sun computers. This package was ported to Linux OS to operate on PC hardware. Therefore, all presently available Quanterra dataloggers are supported (Qx80, Q4120, Q730). At GEOFON stations, the data are normally acquired over a RS-232 serial link (hard link, direct cable or arbitrary modem link) using the standard Quanterra comlink protocol. The Quanterra master console is usually connected by a second serial link. The server of the original ComServ package is modified such, that it is possible to acquire data also securely via TCP/IP using the SeedLink protocol (soft link, see below). That allows a combined acquisition of locally and remotely connected digitizers, even over large distances using the Internet. It is also possible to connect to the remote station in dial-up mode on arbitrary schedules.

Beside the original Quanterra dataloggers also other types of digitizers or even arbitrary data sources can be supported by SeisComP. This is done by implementing plugins specially designed for each new digitizer. Presently, this is the case for the Earth Data PS2400 and the Lennartz Electronics M24. The actual plugin talks to the digitizer in its specific transfer protocol and transmits the data and logging information to another program called digiserv, which provides the data in MiniSEED packets to the modified ComServ server. Down-sampling and the generation of multiple data streams for those digitizers which do not support this, can also be performed within digiserv. Normally, it is expected that the digitizers provide correctly time-tagged data already. For the Lennartz M24 digitizer, which does not have GPS timing on board, a GPS corrected real-time clock on the Linux PC is used instead.

Local data recording is essential for stand-alone station processors. The original ComServ datalog client supports only disk storage. A new client, datadump, records on any tape medium and keeps track of disk and tape space. An extended version of the recording and monitoring package, used by SZGRF for the German Regional Seismic Network (GRSN), also supports disk shadowing and automatic CD-R recording.

Data acquisition and recording can be monitored within SeisComP by a number ComServ clients and other tools implemented in the Station Operation Manager (SOM). Among others, the Qplot client provides online monitor plots on screen, files (including web browser loadable gif files) or printer. A Java applet for real "live seismograms" is planned in future versions. Also all kinds of logging and state-of-health information can be displayed in special windows.

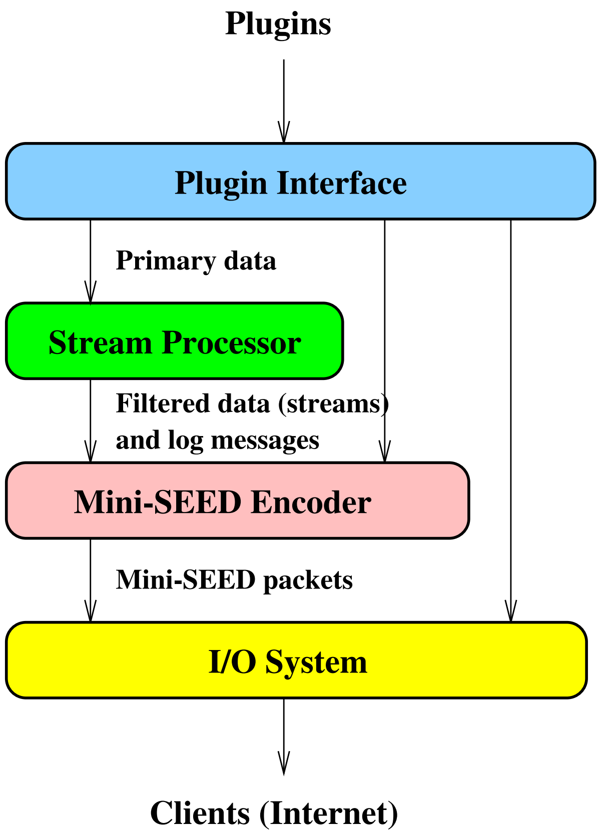

Fig. 2. Data flow in a SeedLink server. With an adequate plugin, SeedLink can in principle support any digitizer type. So far, plugins are made for Quanterra Qx80, Q4120, Q730 - already part of ComServ - Earth Data PS2400 and Lennartz M24. models.

3 SeedLink real-time communication

SeisComP nodes can be linked together using the SeedLink server and clients. Server and clients in a SeedLink system are communicating by means of the SeedLink protocol, which is in principle very simple: clients send commands to the server to initiate data transfer, and the server sends back 512-byte Mini-SEED packets with 8-byte SeedLink header. The SeedLink header contains packet sequence number, which is used to resume transmission where it left off: this makes it possible to recover the connection in the case of network errors and also supports non-permanent connections (the "dialup mode"). The SeedLink protocol also provides capabilities to request individual SEED channels by channel name and type - this helps to reduce network traffic if the full set of data is not needed. SeedLink server uses only high-level socket interface, so it can run on any physical communication media which is supported by the underlying operating system; this includes dedicated or dial-up links by phone, radio or satellite modems, ISDN, DSL or Ethernet among others. Both "chain" or "star" type communication models or a mixture of both are supported.

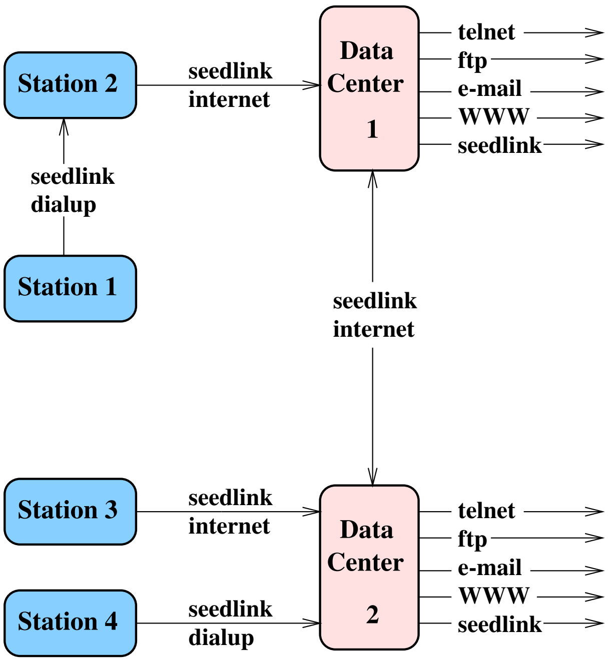

Fig. 3. Example data flow in a SeedLink network using direct and dial-up connections and chain and star type communication models. The SeedLink protocol supports beside secure connections (such as leased phone lines, satellite links,good quality Internet) also slow and insecure Internet connections as well as arbitrarily scheduled dial-up mode over normal phone lines, GSM and ISDN. Support for low-cost "reverse" Internet connections (station connects to the data center through local Internet providers on flat rate basis) and DSL is under construction.

The SeedLink server is designed to support unreliable connections. Some number of recent packets are kept in the main memory for very efficient access, older packets are temporarily stored in the disk buffer. So it is possible to completely recover the connection even if the network is down for a long time. The size of memory and disk buffers can be specified by configuration. No error correction is implemented by SeedLink, however, because the TCP protocol guarantees error-free communication.

The SeedLink concept is not only useful for real-time data exchange between stations and data centers - providing SeedLink access to users in addition to traditional data request methods makes it possible to run applications which require real-time datastreams. Each user can in principle create his own virtual VBB real-time network.

4 User access

Several more standard user access tools are also available within SeisComp. A simple telnet (or terminal emulation) based Data Request Manager (DRM) provides basic services: check for data availability and logging information, selection of data windows, viewing of selected data (using PASSCAL's pql utility) and downloading by ftp or kermit protocols are supported. Since telnet based access is usually not longer possible in firewall environments, a simple web form interface (WebDRM) was developed for data availabilty check and easy access to the data base. Also two email based data request methods are supported: the Swiss AutoDRM (by ETH Zurich and GI Stuttgart) and the IRIS breq_fast. The user access package can also be used independent from a SeisComP station or network setup as an automated data center if the data base is provided in a defined flat-file structure.

5 SeisComP implementations

Presently twenty stations of the GEOFON network are equipped with SeisComP PCs in connection with Quanterra dataloggers or digitizers (Fig. 3). Seventeen of those transmit their data already in quasi real-time to the data center in Potsdam. Up to 15 more stations will follow in the next 1-2 years. Also all not GEOFON supported stations of the German Regional Seismic Network (GRSN) and other similar BB stations in Germany were upgraded to SeisComP systems by SZGRF in 1999. SeedLink real-time data transmission is in test there as well. Two more new local networks in Germany based on SeisComP technology will be installed in 2001: one with 5 stations in the Ruhr mining area (based on Earth Data digitizers) and one with 15 stations in Bavaria (using Lennartz digitizers). The complete 8-station Israelian BB network (including the non-GEOFON stations) runs on SeisComP. Several test installations are made in different countries and more implementations are underway.

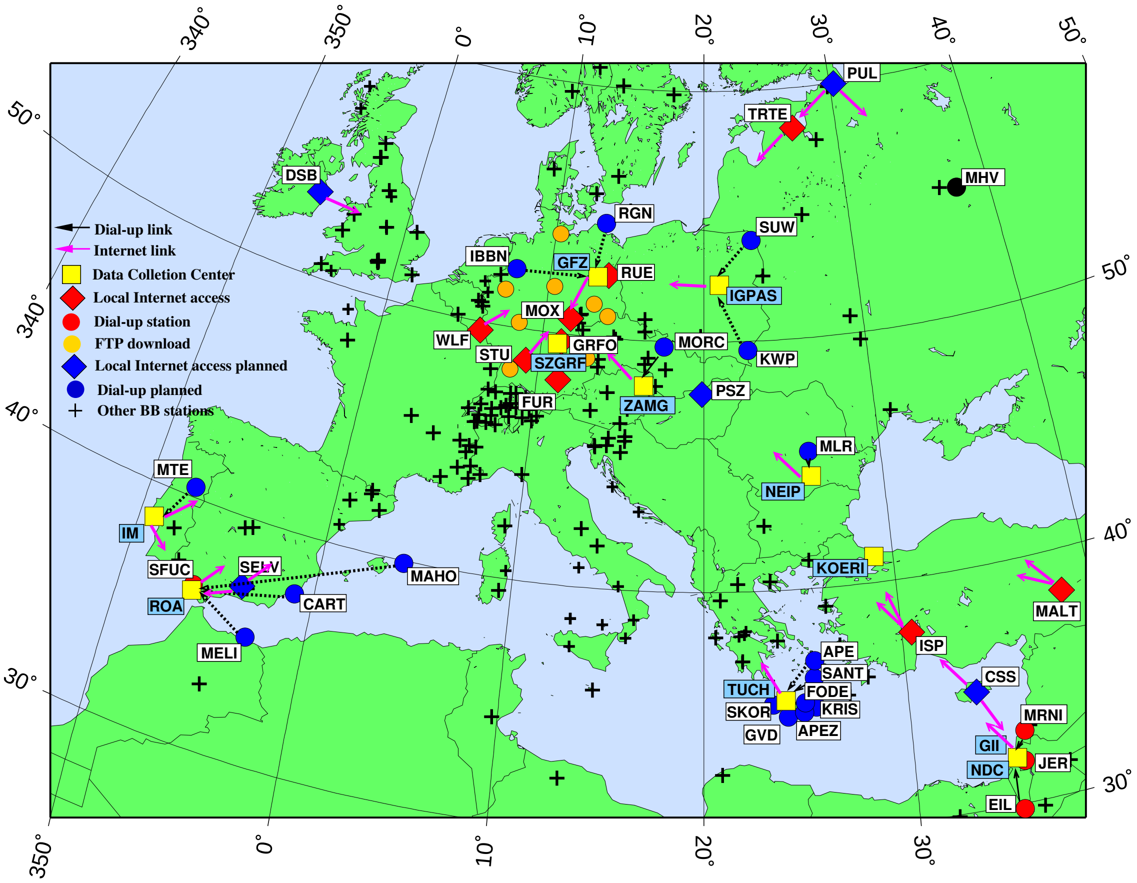

Fig. 4. Major SeisComP installations in Euro-Med area, mostly at GEOFON stations. Dial-up stations are those not directly connected to the Internet but to a data collection center, regardless of the nature of the actual link. Local Internet access can also involve a short-distance dial-up line, but it does not include a DCC. There are more installations existing or planned outside this map (Greenland, Spitzbergen, Hawaii, Nicaragua, Chile, Antarctica).

6 Outlook

So far only high-power standard office-type or industry PC hardware is used in SeisComP installations. A low power SeisComP PC version based on embedded PC104 boards has been developped at GFZ and is commercially available now. The first GEOFON stations are just being equipped with the first recorders. Together with low-power digitizers (such as the Earth Data PS2400 or the new Q330 by Quanterra) and modern radio communication equipment (wireless LAN, "bluetooth"), this development will allow to use SeisComP in remote field installations where minimizing the power consumption is critical, but where advanced recording or networking capability is still important. Since the new GFZ field datalogger, manufactured by Earth Data, is using a newer version of the PS2400 digitizer unit and also a PC104 based Linux system for recording, it can easily be supported by the SeisComP software as well. That will allow in future temporary experiments with low power equipment following the same networking, monitoring, processing and archiving strategy as used for modern permanent real-time networks (e.g. in connection with a mobile satellite hub for the field data collection center).

A major future SeedLink improvement will be the support of reverse Internet connections. That means, the data center will not connect to a station as in standard mode, but the station will connect to the data center via a local Internet provider. Thereafter, the data center will request the next batch of data in the dialup mode as usual. This would allow to perform near-real-time data distribution at lowest possible costs, even take advantage from Internet flat rates. Only this measure will open SeedLink communication for the majority of GEOFON stations, where direct Internet access is not possible and long-distance dial-up calls are too expensive to be able to download all available data.

A special SeedLink plugin will be designed to support the transfer of arbitrary data files. That will e.g. allow to access non-SeisComP stations with DRM or AutoDRM functionality and feed conventionally retrieved data records into the SeedLink near-real-time distribution scheme. This feature can also be used to replace ftp data transfer of arbitrary files where unreliable Internet connections or security problems will not allow standard ftp usage.

Java based web tools are planned for easy SeisComP installation, configuration and monitoring over the web and across the network.

An event detection client will be implemented in the recording and monitoring package to provide event triggering capability for those digitizers, which do not provide this feature onboard.

The IRIS NetDC networking protocol for DC-DC data exchange will be integrated in the user access package. Intensive discussion and several developments regarding real-time data distribution are going on within the IRIS community (Ahern, 2000) as well as in Europe. It is planned to closely coordinate with these efforts and to integrate the SeisComP concept in an even broader context. Within the just started, EC funded MEREDIAN project (van Eck, 2000) it is planned to implement a real-time data exchange structure in the European-Mediterranean area mainly based on the SeedLink protocol.

7 Conclusions

The SeisComP concept has been proven to provide an open, flexible and comprehensive solution for a manufacturer independent low-cost networked VBB seismological communication system. It includes software packages for data acquisition, recording, monitoring, real-time networking across all kinds of TCP/IP networks and sophisticated user access. It has been successfully installed in the GEOFON and co-operating networks and provides a number of new features, including real-time data distribution. Besides its advantages in terms of improved network operation - easier maintenance, more complete data basis, faster data quality checks and failure detections - SeisComP offers new possibilities in the usage of regional or even global VBB data for automated near-real-time applications like quick epicenter localization and magnitude determination as well as quick moment tensor computation. This would substantial improve the rapid warning capability of the public after larger earthquakes. Substantial improvements of the package are planned within the MEREDIAN EC project.

Acknowledgement. The SeisComP project is supported by the GeoForschungsZentrum Potsdam and the European Commission within the ORFEUS coordinated MEREDIAN project (contract no EVR1-CT-2000-40007). Contributions were made by the Geological Survey of Estonia, the German Central Seismological Observatory Erlangen, Stuttgart University and Lennartz electronic GmBH.

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