Norwegian National Seismic Network

Technical Report No. 24

Real time seismic network

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Content

1. Introduction

A seismic network are multiple seismic stations that are geographically spread, and where data from these different stations are used and compared to achieve better results than what is possible from single stations alone. The data from all the seismic stations are usually sent to one location, the so-called data centre. Seismic networks are categorized in local, region and global networks after area coverage. Local seismic network usually means stations spanning distances up to about 500 km, these networks are usually country based and run by universities or other national institutions. Regional networks are often based on several local network and countries in cooperation covering a bigger area like the Mediterranean network, MedNet covering the whole Mediterranean sea and the countries around. Regional networks can also be networks covering big countries like USA or Canada, these networks typically have around 500 stations. Global seismic networks are worldwide, and are usually initiated by the international researcher communities or organizations. Today the Global Seismic Network (GSN) is probably the most important global seismic network with 128 stations spaced about 2000 km apart. It offers broadband data from extremely quiet stations, and it is part of a larger Federation of Digital Broad-Band Seismographic Networks (FDSN).[1]

Global networks are often used to study global seismicity, plate tectonics, mantle convection, and earth structures. Local and regional networks are used to study volcanism, seismicity, and structures of a particular region. For these networks the spacing between the stations is less then for global networks, and the earthquakes of interest are closer to the stations, so the detection threshold is lower and location precision is better than for global network.

A special case of a “seismic network” is seismic arrays, where many seismometers are placed within a small area with a geometry chosen for a particular goal. Arrays are often used to locate distant nuclear tests, data are stacked to track the propagation of the wave field across the array, so the direction and the travel time of the wave field are found.[1] Due to stacking of signal small events, often missed by seismic networks, are identified.

In addition to geographical coverage, seismic networks can be divided into real time or none real time, also called dial up, seismic networks. The difference is in how fast data are received at the data centre after it is recorded at the different stations in the network. For a real time network a continuous open communication link between the stations and data centre is needed.

2. Real time versus dial up network

Literary real time seismic networks mean that there are no time latency between and event is recorded at the seismic station to the data are present at the data centre. In practice data latency, delay in time from data are recorded at the stations until it is present at the data centre, up to around 1 minute is still considered to be a real time network. The shorter data latency the better, but as long as the data collecting software can handle these latencies and can compare data from different stations on the fly the network is called a real time or near real time network.

Typically for a real time system continuous data are stored while for dial up networks often only triggered events are sent to the data centre and stored. Dial up seismic networks are typically used in situations where communication is expensive. Usually the data centre dial up the station for example once a day and download all new trigger events from the station since last contact. The communication can also be initiated from the stations. Dial up network are dominating where you have communication types that are paid pr. unit time, real time networks with continuous data stream often demand a payment model with fixed monthly costs or cost pr unit data size which is not too expensive

There are several obvious drawbacks with the dial up seismic network model. It can not be used as an early warning system because of the big data latency. You still have the possibilities to compare triggered events up against other stations, but when you have no continuous stream of data, small events that did not trigger can be lost. These events can be discovered comparing several stations at the same time.

The continuous data stream from a real time seismic network at the data centre, can be used to set up advanced triggering. Different regions within the network could be defined where triggers from several stations are needed to declare an event. Hence a lot of false triggers due to local explosions could be eliminated.

To summarize real time seismic networks have the advantage of fast response and can be used for early warning systems, network problems are early seen, more advanced triggering possible, and real time exchange of data with other networks can be used to improve earthquake location. Disadvantages are higher cost, and more data is lost if no good retransmit system is implemented between the stations and the data centre.

Dial up networks are cheaper to run, less data loss because a lot of memory at the station (usually a PC) is needed, and less processing and storage capacity at the data centre needed because less data is used, usually only triggered events are processed and stored.

The last years drop in data communication costs, especially cheaper telephone line data transfer costs like ADSL, and cheaper satellite costs, has made it possible for more and more seismic networks to move towards a real time network with continuous data collection. Going towards real time seismic network one of the most important decision is choosing the right telemetry between station and data centre.

3. Communication

Telephone lines

Fixed/telephone line is probably most used in developed countries for communication. The problem with using telephone lines up to recently were that is was very expensive. You paid per minute, so it was seldom used for real time network where you demand always on. But with the new ADSL technology for high speed internet at home where a fixed price of around NOK 6000/year, it can now very well be used for real time network. The only problem is that ADSL is not covering the country as good as the normal telephone lines yet.

Exclusively leased analog telephone lines were common to use earlier, but the costs are high at around NOK 15000/year. Also the dynamic range of the signal is low, maximum 12 bits. ADSL or GSM will probably take over for many of these lines in the future.

A major problem with telephone lines is that they are often vulnerable to lightning, high voltage spikes entering through telephone lines destroying telecom equipment and data recorders.

Mobil communication

GSM technology has in only 15 years change the way people communicate in all the corners of the world. The worldwide coverage is extremely good. The problem using GSM technology for data communication was that the high price and slow data through put. But as people demands internet access at a reasonable price on their mobile phones things have changed the last years. New technologies based on the old GSM standard, like EDGE delivers data rates (uplink) at around 70 kbits/s, and at a fixed price of NOK 7500/year. In Norway 98% of the old GSM base stations are upgraded to EDGE technology. This is far from the case worldwide, but GSM base station upgrades are done at a high speed.

Radio link.

Traditional radio links have been the way of transmitting data from the quiet site in the field to the closest village. Today radio link solutions many places have got competition from GSM mobile phone or satellite communication with higher data rate through put. Radio links have fairly high initial costs, put have low running costs when using free frequencies. Drawbacks are high complexity (one needs skilled workers in radio link equipment), low data rates (<10 kbits/s), and problem with frequency interference.

Satellite communication[2]

Two different options are mainly used in seismic networks today:

1) Through service provider
You need a parabolic aerial and decoder at the station (£1500/stations). Service provider has the downlink and your data centre need an internet connection to your satellite service provider. The running cost is around £60-100/month pr station.

2) Nanometrics Libra
Using the Libra system from Nanometrics you have to buy all the equipment from Nanometrics. The equipment is expensive, but probably more robust and uses less power than off the shelf products from a service provider, because it is tested for harsh environment and used in many seismic networks in the world. The equipment cost £8000 pr station, the downlink at the data centre cost £40 000. Running cost is £3000/year for 12 stations.

The advantage with satellite communication is worldwide coverage with high enough data rate for continuous and real time recording. Still the relative high costs, especially the start up costs are major obstacle for many networks.

4. Some real time seismic networks

A survey to get an idea of how real time seismic networks in the world are run, regarding operational methods and challenges, software solutions, archiving, robustness, operational costs is made.

Looking at some good representatives of real time seismic networks in the world I wrote an email with 12 questions, see Appendix, to the following networks:

Canadian National Seismograph Network. Ottawa, Canada. Jim Lyons
Southern California Seismic Network, Pasadena, USA. Egill Hauksson
Pacific Northwest Seismograph network. Seattle, USA. Steve Malone
Northern California Seismic Network, Menlo Park. Project chief David Oppenheimer
Alaska Volcano Observatory, Fairbanks USA. State seismologist Roger Hansen.
Geofon (mainly Pan-European network). Potsdam, Germany. Winfried Hanka

All answered my questions, except the Geofon network responsible. The Alaska Volcano Observatory responsible should come back with a more thorough answer later. Here is my summary of the email replies.

Canadian National Seismograph Network (CNSN)

Started with real time digital telemetry in the mid 1970's with regional networks of short period vertical sensors in eastern and western Canada. In the early 1990's started a major project to upgrade the national network to 3-component digital broadband, with real time telemetry to 2 national data centres. An in-house digitizer was designed and built, also devices to concentrate and forward data streams based on own serial telemetry scheme was developed.

In 2001 the POLARIS consortium came on stream with a planned 90 3-component broadband stations with real time telemetry to a number of university-based hubs. This data is converted on the fly to the in-house CNSN packet format, then processed and event detected just like from the original digital stations.

Total number of stations: 265
Number of HBB stations: 79
Number of BB stations: 105
Number of ESP stations: 50
Number of SP stations: 19
Infrasound stations: 20

Estimated daily aggregate input rate: 5440.6 MB/24 hr

Average data availability for the entire CNSN network last year: 96.2%
There are many causes of failure. Data telemetry problems are probably highest cause of data loss. Many complex telemetry paths with both UHF radio and VSAT to a satellite service provider in a distant city, then conversion to IP. Then high speed internet connection, T1, to the data centre.

Average data latency is 10-20 seconds at which time data is available for processing. Physical archiving occurs somewhat later. A drop-dead time of 2 minutes, is used to wait for late arriving data, then give up and start processing.

The CNSN packets contain compressed seismic data plus state of health info in headers.

Most BB stations have at least 6-hour buffers, some SP stations only have 20 minutes. Digitizers are designed to push data on start-up. CNSN protocol also has a retransmission request provision, the acquisition system automatically request missing data.

Dividing the total yearly telecoms budget by number of stations gives a value of ~$2000 CAD (NOK 12000).

Data quality is monitored by operational staff, they check for timing errors or need to re-centre the seismometers. Power Spectra Density (PSD) plots for previous 24 hours are generated automatically and scanned to compare to the 5-95% and typical noise curves as displayed in the station book. PSD plots give a measure of the site noise as a function of the frequency, both natural background noise and noise due to equipment.

The input data is CNSN packets. In the mid-1990's CNSN experimented with using SEED for output/archive format, but backed away as the SEED specifications was still evolving at the time, and one lost the state of health info and good data compression. An in-house format called Canadian archive (CA), which comprise typically a network half-hour of data. Each component comprises a simple header followed a concatenated stream of CNSN packets. From here one can convert to SEED, GSE2.0/IMS, and several other formats on the fly as needed for external users.

For data processing the eastern office uses a suite of in-house software for all phases of processing, from data acquisition through analysis, archiving, and database storage of derived parameters. The western office has purchased Antelope, and is in the process of a long, slow conversion to it for at least the analysis portion.

Southern California Seismic Network (SCSN)

The SCSN has been a real time seismic network since the late 1970's, and SCSN operates approximately 300 stations and import data from another 100 stations.

The approximate station uptime is between 95% to 100%. Major cause of data loss is data communication not working, and access to remote site not available for long periods of time.

Continuous data in the miniSEED format is transmitted from the stations. State of health is also transmitted. Data latency in the network is a few minutes. (time for data from recorded at station to received at data centre). In case of communication loss the stations have local storage, but retrieval is not automated yet.

Average yearly communication costs for a station is approximately US$ 1800 (NOK 12000) + maintenance.

The quality control of the data is done by automatic processes and local operators.

Around 3 GB of data are collected every day (1.1 TB/year).

The data format used is miniSEED, and the format is used for data acquisition, data processing, and data archiving.

The SCSN uses the COMSERV for data acquisition and data collection. COMSERV is an open-standards suite of software that runs on Solaris systems for real-time acquisition of seismological network data from Quanterra digitizers. For data processing Earthworm and in-house software is used. Oracle is used for the database.

Pacific Northwest Seismograph Network (PNSN)

The seismic network has been a "real time" network since the beginning in 1969, but for much of this time, and still many of the stations are analog. In the start the data was recorded on film, from 1980 the data are digitized at the network center in Seattle. These stations are much lower quality than the purely digital stations that have been installed since 1992. Of digital stations there are now 90 strong motion sensors and 30 broad band stations.

There are not very good record of exactly “up-time”, but the estimates are that between 90 and 95% of the stations are operating at any given time. That means that of the ~250 stations that are recorded like 20-25 may have problem.

Loss of stations or repeaters due to all sorts of things including power failure, antenna damage, vandalism, lightning strikes, volcanic eruption, telephone company or internet routing problems. For the digital stations a common problem is firewall changes for stations on commercial internet that blocks the connections. Most problem is during winter with high mountain stations. Some stations can only be reached 5 months of the years, unless hiring expensive helicopters. The central recording/processing system is very robust, measured down time for this system to 1 hour per year for the past several years. There are duplicate parts of this system, and usually things are fixed very quickly.

Transmission latency is 1s for analog telemetry, and from 2.5-5s for digital stations.

What kind of data is transmitted depends on the remote data logger. Most have some kind of “state of health” parameters. The data loggers that are used in this network include: Reftek 72-0A, Kinemetrics K2, Terra Tech. IDS 18 and IDS24, Guralp CMG-5T and -6T. Most of the data loggers have some hours of local buffer and can retransmit if connection is lost for a short period.

Telecommunication costs are $200 a year for analog telemetry. Many of the digital station are located close to public works buildings, school, and power companies. Deals where cost are close to zero are made, but one is committed to provide information and resources on earthquake and seismic events, which take staff time of the network personnel.

Both automatic and human inspection is used to monitor data quality. State of health is monitored on most digital stations and alarm threshold are used for a variety of possible problems. Alarms are sent by SMS or email for certain time of problem. The analyst reviews all channels (>700) at least twice a week for data quality and gives a report to the technical staff on problems observed.

All continuous data are sent to the IRIS DMC with 30 minutes latency where it lives on their BUD system for access by anyone and for permanent archiving. Triggered data are saved locally and later sent to IRIS DMC. Total network volume at IRIS DMC is about 5GB/day, the NPSN network save locally about 1.5GB/day.

Data format for acquisition is determined by the data logger, all incoming data are transferred to Earthworm Trace_Buf format, and lives in this format in wave-server and auto processing system.

For triggered data made by the Earthworm system the format used is “UW2” format. The software “xped” is used for analysis. All of the data is in flat files, there are not yet any real database management system which is a big weakness. The manual processing and scientific analysis system is a mix of lots of locally written software plus some other odds and ends. Some ideas are taken from SeisAn.

In general a real time system is preferred over a dial up. NPSN ran a partial dial-up system for a while, that dial up system took a lots of staff time for its care feeding. the real time system takes care and feeding too, but it seems that once going there are fewer repeating sorts of problem. Also when there is a problem at the remote station you know about it right off.

Northern California Seismic Network (NCSN)

The Northern California Seismic Network in Menlo Park began recording analog data on film in 1967, on magnetic tape in 1977, and with real-time computers in 1981. Today there are 423 stations, and also import data from another 141 stations operated by other agencies (California Department of Water Resources, Pacific Gas and Electric, University of California Berkeley, Caltech, etc..)

Tracking of uptime is not done in the network, main reason is that network was mostly analog until 2000, so it was impossible to monitor station uptime because the digitizer outputs data even if the analog station is down. We now have 161 digital stations, so it is possible to monitor uptime, but we have not decided how to do this yet.

We have 4 technicians to maintain these stations and 2 technicians to maintain microwave, radio and satellite communications. We attempt to prioritize the work. If a digital telemetry "trunk" link goes down (e.g., a satellite hub or a microwave repeater), we generally repair it within 24 hours. Next in priority is a digital station. After that, analog stations. Some of the stations are inaccessible in the winter time, so they can be down for months. Since the network utilizes different types of telemetry that overlap, an outage at a single station does not generally compromise our detection capabilities. The real-time environment is fully redundant, so we are always "up" even if some stations are down. I think in the past 10 years we have been off the air only once for about 3 hours due to a DNS failure. I get very unhappy if our central processing software goes down.

The network does not track how much data are lost per year. Many of our stations transmit data into a local, unattended "hub" that can buffer the data even if the telemetry to Menlo Park is down. When the link comes back up, we can retrieve the data from the hub. Some of our data loggers have built-in memory that also enables us to recover late data if within the memory interval. When a telemetry link fails, we always try to recover any event waveforms, but we do not attempt to recover continuous waveforms. It is physically impossible because we do not have sufficient bandwidth to send real-time and historic waveforms simultaneously.

The major factor of data loss is that the battery on many stations dies earlier then expected. Most sites are remote and are powered by batteries that are charged from solar panels. Sometimes winter storms can temporarily bury solar panels for days, and stations go down. Vandalism is a problem occasionally. Hardware failures are probably the most common problem. Water, wind, and animals can destroy equipment. Finally, we have increasing problems with radio interference as cell phone companies expand service and locate on the same mountain tops where we have our telemetry sites.

The "data latency" from the field to when received in Menlo Park is on the order of 1 sec except for data transmitted via the Nanometrics satellite system. The latter data can have a maximum latency of ~5 sec, which corresponds to the frame size of the data packet. There is another 5 minutes until we make the data available to the public at the NCEDC. It may take longer time if a major earthquake with many aftershocks. In that case the system can fall behind.

Only waveforms and derived parametric information (phase, amplitudes, durations, etc) are archived at the data centre. "State-of-health" information from the station is sent to our central processing facilities in Menlo Park, but we do not archive that information at the data centre. We do use it to monitor whether the station is operating correctly using a program call SeisNetWatch that is available from ISTI.

To be able to do retransmit if communication is down, unattended Earthworm hubs that locally buffer the data on a waveserver for 6 days. They also locally pick/associate/locate earthquakes. If the telemetry link comes up within 6 days, picks are forwarded to Menlo Park, and then we can easily recover all of the event waveforms. The remote hubs also save event waveforms for earthquakes that it detects, in case the outage persists beyond 6 days. We delete these remote, event waveform files every 30 days.

Some of our data loggers also have on-board storage, but it varies with the type of equipment. The K2, Reftek ANSS-130 data loggers store triggers, while the Nanometrics data loggers (Trident, Lynx, HRD24) have ~3 hours of onboard memory for recovery of missing data samples.

The average cost to operate the 423 stations (not including salary) is $957/year/station. That includes telemetry, maintenance, computers, travel, fuel, software, repairs, etc.

We try to invest in hardware that utilizes our telemetry infrastructure (e.g., spread-spectrum radios that transmit to our digital microwave network that comes into Menlo Park). While there are start-up costs, this eliminates recurring telemetry costs. When that is not possible, we have to pay for commercial telemetry, as shown below.

DSL - $1000/yr/station (half of this cost is the proportional cost of a private T1 line that we lease so that we do not use the public Internet). Sample rate is typically 100sps, 3 channels in urban locations

Frame relay - $1500/yr/station. "T1" issue applies in some cases as described above for DSL. Frame relay has a mileage charge that makes it more expensive. Sample rate is 100sps, 3-6 channels in urban or rural locations

Satellite - $1100/yr/6-ch station at either 50 or 100sps.

T1 to a remote Earthworm hub - depends on distance. ~$5000/year

The cost/station estimate that I provided does not include data archiving at the University of California Berkeley Northern California Earthquake Data Center. It only covers non-salary costs for station operations and maintenance, telemetry, data processing, up to the point when we forward the data to the data center. Data archiving costs are paid by the USGS under contract to UC Berkeley. Also, the cost estimates do not include USGS "overhead" of 43%.

We perform automated data to recover missing data samples if they arrive after we sent the waveform data to the data center. We use SeisNetWatch to alert us when a station is not functioning properly, and our analysts use trouble-ticket reporting software to log stations that have problems such as malfunctioning seismometers, radio interference, etc.

Total daily stored date: Continuous waveforms compressed using Steim2 = 4.8 GBytes/day

For data acquisition we operate data loggers made by Nanometrics, Reftek, and Kinemetrics. They all send data using different formats, so we acquire the data using their server software and then retransmit to our processing environment in a common Earthworm "tracebuf" format. Later we archive the data in miniSEED.

For data acquisition vendor software for commercial data loggers or Earthworm software for analog stations are used. We archive data using software developed for the Northern and Southern California Data Centers. For data processing Earthworm and California Integrated Seismic Network (CISN) software are used, which was developed for the TriNet project in southern California

Alaska Volcano Observatory

We rely heavily on a commercial product for our real time seismic network operations. We utilize the Antelope system that can be found on the web at: www/brtt.com or www.kmi.com noted as their "aspen solution"

5 Suggestions for NNSN becoming a real time network

The National Norwegian Seismic network has around 30 stations, today it is possible to have real time communication with 9 of the stations: SNART, OSL, STAV, BER, FOO, MOL, STOK, TRO, BJO, (may be also KONO and KBS which also are part of the Global Seismic Network).

The major obstacle upgrading the NNSN to a real time seismic network is that the current in-house data collecting software (SeisNet) is not written for real time data collection. Upgrading the in-house software will probably not be a good idea since there are already two advanced software package written for this task.

The freeware package Earthworm developed by USGS and many independent contributors, today handled by ISTI Inc. The second one is the commercial software package Antelope from Kinemetrics. The price of the Antelope depends on the number of stations, but will probably be over $ 100 000, a second option is to lease the software. Earthworm is more of a pure data collection software, with no graphical interface, only pulling data from the stations to the data centre, but with triggering possibility and some automatic phase picking algorithms. The Antelope system is both a data collection and data processing software with a graphical interface where analysts can pick phases, locate and determine magnitude of earthquake, and plot them on maps. The data collection part of the program is also probably more advanced than Earthworm with support for state of health messages, and quality control of the data.

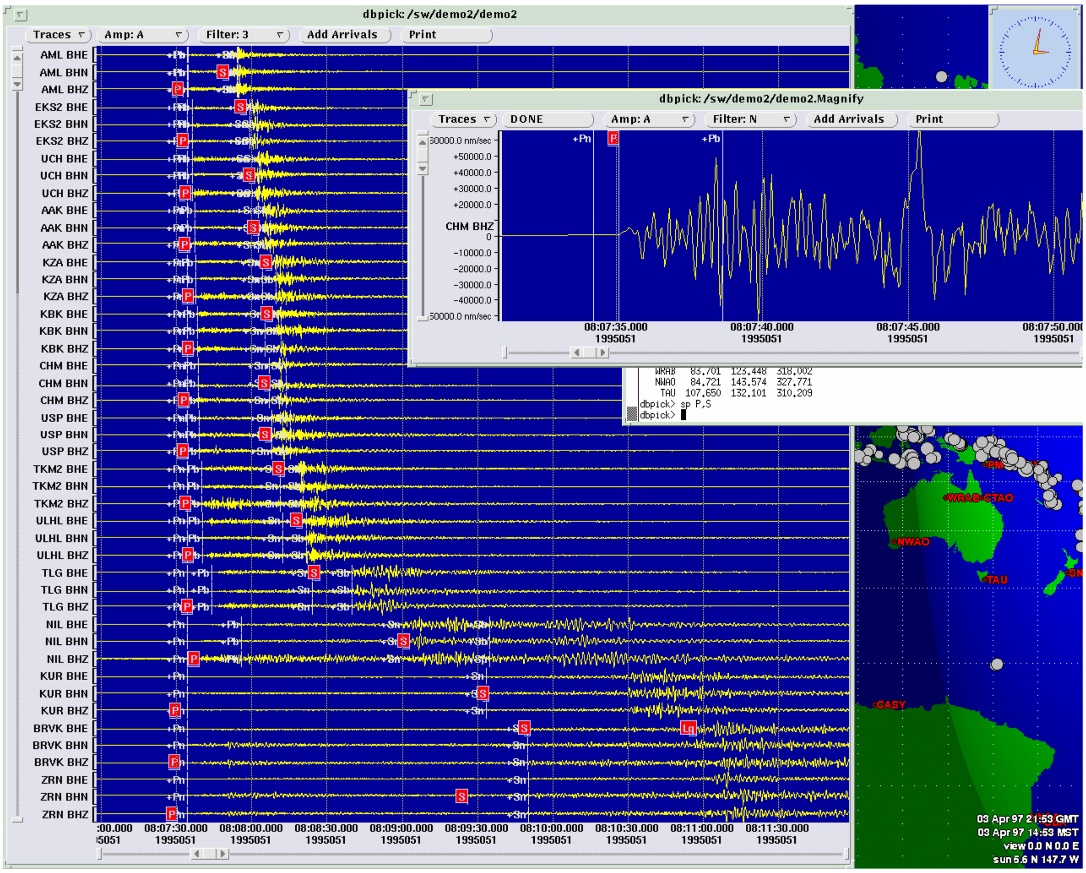

Figure 1. Screenshots from Antelope software

The first step in going to a real time network is to test the software solutions for collecting data on the data centre. Earthworm is today running on test, but the Antelope software should also be test, by asking for a free demonstration version. The 3rd options would be to upgrade the in-house SeisNet data collecting software used on our dial up solution today, but this would take longer to implement, and has not the advantage of standardization. Using the same software as other networks would help exchange data and collaboration.

A problem for us is the integration between the data collecting software at the University in Bergen and the software on our stations. We mainly use the in-house Seislog software for data acquisition, this software is not ready for pushing data in real time to the data centre. It is also not straightforward to replace Seislog with other software, because our digitizers are mainly old Nanometrics RD3 for which there are not many options to Seislog. Most data acquisition software comes with the digitizer vendor, either free or at an extra cost. We use Nanometrics, Guralp, Earth Data, and Sara digitizers. There is today not a single software that support all these digitizers, and can push data in real time to an Antelope or Earthworm system at the data centre.

An upgrade of our in-house Seislog to push data to an Antelope or Earthworm system, with retransmit possibilities, could be the way to go. An alternative is to use the SeisComp software, it support real time pushing of data using the Seedlink protocol. The SeisComp software supports all of our digitizers except the Nanometrics RD3. Ten of the stations could be upgraded from the older RD3 digitizers to the newer Earth Data PS2400 digitizer. NNSN has today 10 unused Earth Data PS2400 digitizers.

Going from a dial up based network to a real time continuous data also means equipment upgrade at the data centre at University of Bergen, at least big storage capacity is needed, with full backup system. If 40 stations all with 3 components and 100 SPS are collected continuous. With good compression one can come down to 1 Byte per sample. For this network 40*3*100 SPS*(3600*24) sec/day = 1036*10^6 samples/day, which equals 1036 MB/day. Hence at start up the data system needs to handle storage of 1 GB/day.

From the around 1 GB/day of raw data from a full real time NNSN network, earthquake parameters have to be extracted from both human inspection and automatic algorithms. The overwhelming data coming in every day, will probably change the life of the analysts. Training and new tools are needed.

Both Antelope and Earthworm are original written for the Solaris operative system, running on Sun Sparc workstations, and hence works best on this platform. A Sun workstations should be used for Earthworm or Antelope, with a backup software system set up on a second workstation for fast start up if the primary workstation fails.

The storage system, for archiving of the data, should be operating system independent, so that changes in the platform of the data collection software, would be seamless. Hence a NAS (Network-attached Storage) system is recommended for archiving.

The waveform files are recommended to be stored directly on the hard disks, so called flat file structure, using some kind of directory tree to categorize. They represent so much data that they would only slow down the database if they are to be embedded in the database itself. There should be a relational database containing earthquake parameters like hypocenter and magnitude, operational information like instrument response or state of health, link to the waveform data, and so on. A relational database would ease searching, backup, and publication on the internet. Both Antelope and Earthworm have some database support. For building your own database the IRIS Data Management Center (DMC) provide a good starting point on how to set up your own database.[3]

7 Cost example of a real time NNSN network

A budget of the communication cost for 2 satellite stations (MOR8, HOPEN), 4 free internet (OSL, BER, STAV, TRO), 9 ADSL stations (SNART, FOO, MOL, BLS, NSS, DOMB, ODD, ASK, EGD), and 6 GSM Edge stations (KMY, RUND, FLO, KONS, SUE, HYA) will be set up.

The 2 stations needing satellite communications are excluded from the budget due to too high start up cost for only 2 stations.

Start up cost for new comm. equipment.
For ADSL stations 4 new PC needed (BLS, RUND, ASK, EGD)
For Edge stations 2 new PC needed (SUE, HYA)
6 PC at NOK 6500 = NOK 39 000
6 GSM Edge routers (also VPN clients) to keep link up from station side.
6*NOK 6000 = NOK 36 000

Running cost communication
9 ADSL stations 9*NOK 6000/year = NOK 54 000/year
6 GSM Edge stations 6*NOK 7500/year = NOK 45 000/year

Travel/station upgrade costs
NOK 5000/station*8 (BLS, NSS, DOMB, ODD, KMY, SUE, HYA, Nordland)
= NOK 40 0000

So upgrading to a real time network of 19 stations are roughly estimated to cost at start up NOK 115 000 with a yearly communications cost of NOK 99 000.

The numbers probably represent minimum costs. In my survey among other networks the average communication cost was around $1500/year pr station (NOK 9000).

Maybe a new Sun workstation is needed for running the data collection software, plus software licences needed. Added data storage capacity are also probably soon needed.

8 Conclusion

Today there is a trend towards real time communication, and combined with the adaptation of standards for data formats, seismology is moving towards a situation where data from local, regional and global networks can easily be combined eliminating the distinctions between networks.

When building a new or upgrading a seismic network today, the network should be real time recording continuous data. This enables you to exchange data with other seismic networks in real time, making your own network better.

Upgrading a network from a dial up based to a real time network, one should first define the goals of the network. Is it a warning system where fast response is essential, or is the main output seismicity maps, then data availability is more important. If the budget to run the network is tight and staff limited, one need to focus on total cost of ownership (initial cost, maintenance, training). If collaboration and data exchange with other networks is very important, standardizing hardware and software is more important. Or if it is primary a research network then other needs may apply.

Both the commercial Antelope and the free Earthworm should be tested collecting data from a couple of stations over a period of 2-3 months. The software best filling our network needs should be chosen.

For telemetry: testing of GSM Edge based solution should immediately start. The hardware (GSM Edge routers) should be tested for stability over 2-3 months before employed at the stations. As was the chase for our ADSL solutions there are probably going to be some start up problems. If GSM Edge solutions turn out to be as stable as ADSL solutions, it should be preferred over ADSL solutions, because it is more immune to lighting problems and can be deployed over almost the entire country.

Prices for a new data storage system (NAS based) with backup should be collected. It should also be investigated if the Antelope or Earthworm software needs to run on a new Sun workstation, or can use some of our old. At least there should be a backup workstation with the software installed, so a minimum of data is lost if the primary workstation fails.

References

1) Stein S. & Wysession M. (2003) An introduction to seismology, earthquakes, and earth structure. p407-410.

2) Satellite communication information provided by Lars Ottemöller BGS, Edinburgh (UK).

3) IRIS DMC. Database structure. http://www.iris.edu/SeismiQuery/SQ_tables.html

Appendix

My email with 12 questions sent to different seismic network responsible.

Southern California Seismic network. Jeroen Tromp Director of Seismo lab (jtromp@gps.caltech.edu), he forward to Egill Hauksson.
Canadian National Seismograph Network. Jim Lyons jlyons@nrcan.gc.ca
The Pacific Northwest Seismograph network (PNSN). Steve Malone, steve@ess.washington.edu
USGS Neic. William Leith, wleith@usgs.gov. He forward to
Northern California Seismic Network. David Oppenheimer, oppen@usgs.gov
Alaska Volcano Observatory. Dr. Roger Hansen, roger@giseis.alaska.edu
Geofon. Winfried Hanka, hanka@gfz-potsdam.de

Dear responsible for the real time seismic network.

I am working at the University of Bergen in Norway, we are running the National Norwegian Seismic Network.

I am writing a report on real time seismic networks, because we are in the process of moving from a dial up based network, where only triggered events are transmitted, to a real time seismic network with continuous data recording. Hence I want to investigate some of the existing real time seismic networks in the world.

Hope you can help me, or know anybody that can help me. Thanks in advance.

Here are my 12 questions.

Age/Size
1) How long have your network been a real time seismic network, and how many stations contribute to the network?

Stability/Robustness
2) Approx. what is average uptime (running hours/hours in a year) for a station in your network?
3) How much data are lost in a year in the network (lost GB/potensiell GB in a year)?
4) What are the major factors for loosing data?

Communication
5) What is average time from an event is recorded at the station to it is stored at data centre (data latency)?

6) What is transferred from the stations to the data centre? Are also other data like quality control parameters e.q. for noise/timing problem transferred?
7) If communication to a station fails, are there storage buffers on the stations, and can data be automatically retransmitted at a later from the station.
8) What is average running cost of communication for one station in the real time network pr year? (Pure communication cost + maintenance, not start up costs)

Data centre
9) How is the quality of the data controlled at the data centre or/and at the stations, automatic algorithms or human inspection?
10) How much data are stored every day (in Gigabyte)?

Software
11) Do you have any preferred data format for: A) data transmitted from station, B) for data processing, and C) post processed storage?
12) What software is mainly used for A) data acquisition B) data collection, and C) data processing?