CURRENT AND FUTURE USE OF COMMUNICATION NETWORKS IN EARTHQUAKE MONITORING

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SUMMARY

As seismograph networks become more automated, communication between the various components becomes more important. To ensure timely response to earthquakes, this communication must be real time, or near real time. Typically a combination of systems such as radio, satellite and land lines is used. In many cases, the Internet can be used to great advantage.

This paper discusses the components of an earthquake monitoring network and the types of communication required between these components. It shows that modern seismic instrumentation and computer systems provide some of the required software and hardware but there are still many developments possible in this area.

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1. INTRODUCTION

An important question facing the earthquake engineering community is why do we have seismological networks and what information do we hope to obtain from them. In the past, the answer to this question was simple: to learn about the distribution, mechanism and frequency of occurrence of earthquakes. This is still a valid answer today, but there are not many bodies willing to fund seismograph networks for this reason alone.

Much of the interest in seismograph networks today is for emergency and infrastructure management. This requires reliable and rapid response to any significant earthquake.

2. RELIABLE RAPID RESPONSE

Providing reliable, rapid response after an earthquake requires attention to many factors. The first is the need for a reliable seismograph network. The most cost effective way to provide this is with individual nodes (seismographs) which are as reliable and autonomous as they can reasonably be. More nodes should be installed than the minimum number required, providing a degree of redundancy, significantly reducing the reliability required of each node.

The second factor required is a reliable and rapid telemetry system to transport the data from the seismographs to a central analysis point. For reliability, a variety of telemetry systems should be used so that the response system does not solely rely on any one form of telemetry.

The third factor is a system that can analyse the data and perform event notification. This is usually a standard computer system of some sort, and requires standard precautions such as an uninterruptible power supply.

The final factor for this system is the event notification. The companion paper by Wayne Peck on an “Earthquake Preparation, Alarm and Response System” describes what can be done when an event is notified. The event notification can take a number of forms; systems such as pagers, mobile phones and facsimiles have been used successfully. Again, using a variety of systems is recommended.

3. DATA MANAGEMENT

Providing effective emergency response requires location of earthquakes to an accuracy of a few kilometres. This requires a fairly dense seismograph network and fairly high sample rates (50 or 100 sps). Since one cannot know in advance when an earthquake will occur, seismographs must be sampling continuously. This means that a single seismograph is collecting 50 to 100 MB of data each day. In most cases, it will not be economical to send all this data to a central recording site, therefore the seismograph must have some intelligence so that only selected data is sent. This may be anything from arrival times of suspected earthquakes to the (possibly compressed) continuous waveform of one or more channels of data. A standard telephone line will support the transfer of approximately 20 MB per day.

An earthquake analysis laboratory will typically be receiving data from between six and sixty remote seismographs. It monitors the signal coming from each recorder and determines when an earthquake has occurred. Some systems then determine an approximate earthquake location and magnitude. This information is usually then sent to a seismologist for evaluation before being released to the world at large. Another task often performed at this stage is notification of other seismic observatories, adding the information to a Web site and so on.

To aid reliability, it is suggested that in some cases data from a seismograph should be sent to more than one analysis centre. This covers the case where there is a failure in an analysis centre. It does of course bring up the question of ownership of data.

4. COMMUNICATIONS

Communications are an extremely important part of the operation of a seismograph network. Each seismograph must communicate with the analysis centre, the centre must communicate with seismologists and seismologists must communicate with each other. This paper is primarily addressing the communication between seismographs and the analysis centre.

The problematic (expensive) communication link is when a **permanent** link is required between a seismograph and an analysis centre. This is required when continuous data is required from a seismograph for real time location of earthquakes. The options at present are land lines, (digital) radio and satellite. Each option has advantages and disadvantages that must be weighed up for each site. Land lines are a simple option providing medium speed full duplex communication. However, for many seismograph sites, the cost of such a service is prohibitive (thousands to tens of thousands of dollars per year).

In recent years, great strides have been made in digital radio technology. Modern spread spectrum radios require relatively little power, no licensing, provide full duplex communications at medium speeds and can be used over distances of up to about one hundred kilometres. Relays for them are also easier than for older types of radios. However, additional power is required for the radio, and a radio mast, lightning protection and so on must be provided.

Satellite communication can provide quite high data rates where this is required. It can also be used in very remote locations. However, there is considerable additional equipment required for a satellite installation and for most users the costs are high. Costs are normally in proportion to the data flow, so there is a temptation to minimise sample rates, dynamic range and number of channels.

5. PROCESSING LEVELS

If there were no constraints on transferring data from seismographs to analysis centres, **all** the information from **all** seismographs would be sent to **all** analysis centres. The reality is that this would be too expensive. To manage this, a number of levels of processing have been introduced. Each level performs some processing on the data it receives and only passes on a proportion of the data to the next level. The idea is that the density of information in the data increases from level to level. Figure 1 shows the different components and how they inter-connect.

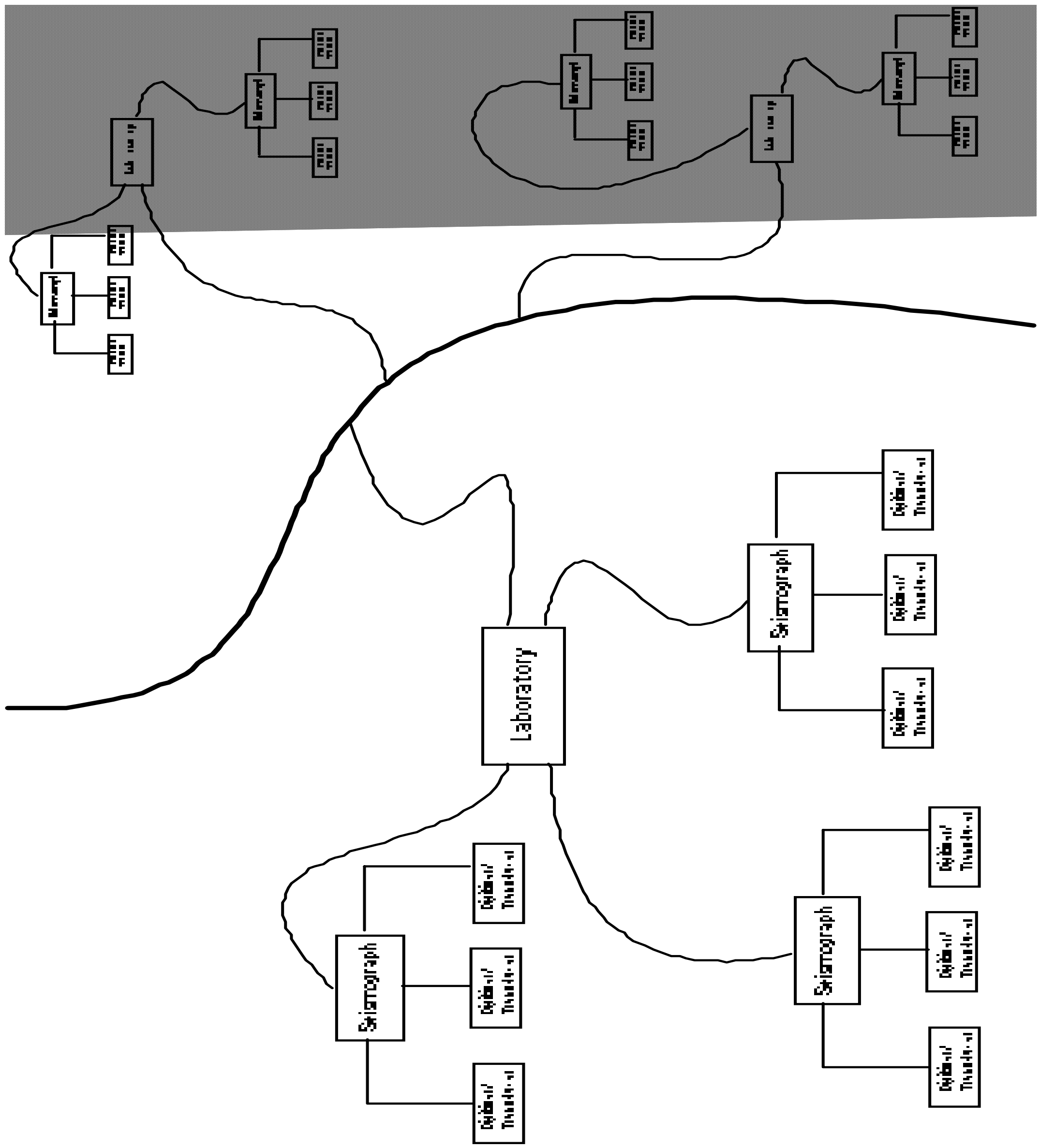

Figure 1: A network of seismograph networks

5.1 Seismograph Level

The bottom level consists of the transducer and digitising system. This system samples the signal at regular intervals and converts it to a digital value. The digitising system may be within a seismograph or external to it. More and more often these days, the data from more than one transducer is fed in to the one seismograph. This may be because both a sensitive seismograph and a strong motion accelerograph are being used, or it may be because motion is being recorded at a number of different points on a structure. In either case, the seismograph can record data from all the transducers, possibly at different sample rates.

Information from this level can be transmitted continuously, or a simple dial-up connection can be used. The optimum solution for most networks is a mixture of the two.

This level allows precise synchronisation of multiple channels, important when studying the response of a structure to earthquake motions or for small seismic arrays. It can also provide short term (hours) recording of continuous data to handle failures in the telemetry system.

5.2 Network Level

The middle level involves information from a number of seismographs being sent to an analysis centre. In many cases this is a one way communication link, to minimise costs. However, if two way communication is provided, it is also possible for the analysis centre to provide information to the recorder. This could be used for example to notify the recorder that an event has occurred which it did not detect, it would then record its data for that event in permanent storage. In many cases this data includes more channels, is at a higher sample rate and greater dynamic range than that telemetered to the analysis centre.

The communication at this level consists of moderate data rates, of the order of one kilobit per second. This can be achieved using radio, landlines or satellite telemetry. The optimum solution varies from site to site and country to country. A mix is often best.

This communication network topology is usually a star shape, all sites communicating with a central hub rather than a more general inter-connection. In some situations, data from two or more sites may be concentrated in to a single link, but the overall structure remains the same. Assuming the hub is operating, it is possible for all sites to communicate with each other through the hub although this is not often done in practice.

The analysis computers' task is to determine when an earthquake has occurred and perform the appropriate notifications. This usually means paging the on call seismologist who will then verify the information from the computer. He or she would then notify the appropriate emergency management authorities if relevant. Another important task of the system is to notify staff of any failures in the system.

An advantage provided by this level is much improved earthquake detection reliability when using a network of seismographs rather than a single seismograph. Local noise at any one seismograph will not give a false indication from the system as a whole. The other service is the ability to provide rapid information for emergency response after a significant earthquake.

5.3 Internetwork Level

It is proposed that another level is often appropriate above the individual analysis centres. It is quite possible that for one of any number of reasons, an analysis centre may be out of operation for a period of time. Since this is the hub of activities, it means that the functions performed by that network are not available. It is important however, that if the seismographs are autonomous, they will continue to operate unaffected.

To overcome this, it is suggested that analysis centres should communicate with neighbouring centres. This has not been implemented to any extent yet but is an area of active development. The availability of the Internet as an appropriate communication medium for this level has spurred activity. It opens up a number of possibilities:

- Neighbouring networks would be able to determine that an analysis centre was not operating and notify people as required. The neighbouring networks could then perform some or all of the tasks of the failed network.
- Trigger time and/or event data could be exchanged between networks providing more reliable triggering for all networks.