Requirements for an Earthquake Information Distribution System

Executive Summary

The *Ad Hoc* Panel on Earthquake Information Distribution developed requirements for an earthquake information dissemination service. In the review of current systems, the *Ad Hoc* Panel found many interesting and creative solutions to the problem of distributing earthquake information, but no single existing system that provides the necessary capabilities. The *Ad Hoc* Panel recommends the completion of the requirements outlined here and the development of a system that will serve as a critical component to future applications. The *Ad Hoc* Panel also recommends the USGS management establish a software/systems development policy, for review and adherence to ANSS system-wide standards.

Introduction

The rapid and reliable distribution of accurate information following an earthquake is critical for emergency responders, the media, and the public. For a number of years seismic networks in the United States (and elsewhere) have struggled to develop systems for digital information distribution that satisfy user needs.

The Advanced National Seismic System (ANSS) is an initiative lead by the USGS to integrate, modernize, and expand earthquake monitoring and notification nationwide. One of the goals of the ANSS is to ensure the delivery of timely information in standard formats and displays to users with specific needs for these results and to the public in general. In order to fulfill this goal, the ANSS is working with partners, member networks, and clients.

The California Integrated Seismic Network (CISN) is a partnership among the California Geological Survey, the Berkeley Seismological Laboratory of the University of California, the Seismological Laboratory of the California Institute of Technology, the Menlo Park and Pasadena offices of the USGS, and the California Governor's Office of Emergency Services (OES) in support of integrated earthquake monitoring and notification in California. The CISN represents California as a region of the ANSS.

The *Ad Hoc* Panel on Earthquake Information Distribution (AHPEID) was convened at the request of USGS and OES leadership to review and make recommendations on the development of an earthquake information distribution system. ANSS and CISN have a common interest in a standardized system as competing distribution systems confuse and frustrate users, increase the complexity of operations, duplicate effort and waste federal and state resources. A single, a well-defined data delivery interface will also facilitate the creation of end-user client software and increase the usability of the data products.

This document represents the outcome of deliberations of AHPEID during their July 9 & 10, 2003, meeting at UC Berkeley. The panel consisted of Art Botterell (Incident.com), Ray Buland (USGS), Lind Gee (UC Berkeley), Doug Given (USGS), Jeff Kinder (OES), Steve Malone (University of Washington), Pat Murphy (USGS), Doug Neuhauser (UC Berkeley), David Oppenheimer (USGS), and Dave Wald (USGS). The panel addressed the following issues:

- Review current earthquake information product types, review the users' needs, and assess the strengths and weaknesses of current product distribution systems;
- Define the requirements of a single earthquake information distribution system;
- Recommend steps to be taken to achieve the defined system.

Assessment of information products and current distribution systems

Seismic processing centers produce a wide range of earthquake information products that range from relatively raw products such as waveforms, phase arrival times, and amplitudes to processed results such as hypocenters, magnitudes, and ShakeMaps (Table 1). Higher order products include estimates of the slip distribution, regional stress change, aftershock probabilities, and information on tectonics. Emergency responders, public officials, earthquake engineers, seismologists, the media, and public now routinely use these products.

After a review of the range of applications for earthquake information and the categories of potential users, the panel concluded that a single system should be designed to deliver all products to all recipients. Moreover, the design of the system should easily facilitate the introduction of new and, as yet, unspecified earthquake products for distribution. Rather than considering the type of product to be distributed, the panel evaluated products in terms of attributes such as their size, frequency of distribution, the required bandwidth, the need for rapid delivery and reliability (Table 1). Some of the products listed in Table 1 (unfilled boxes) are more suitable for distribution using specialized applications (e.g., Earthworm, Antelope, etc.) between seismic networks and were not considered for distribution through this system. The panel found that the attributes in Table 1 are more critical to the design of a generalized information distribution system than the characteristics of the consumers of specific products.

A number of earthquake information distribution systems have been developed over the years. Many systems are focused on distribution of data among seismic networks and seismological processing centers (*e.g*., waveforms, picks, amplitudes). However, only a few systems address the issue of distribution outside of the seismological community to the large audience of clients in utilities, transportation, insurance, and life safety fields. The panel focused on reviewing three systems that address distribution to a more general audience, rather than systems that are in use for exchanging seismic data among processing centers: Quake Data Delivery System (QDDS), QuakeWatch, and ShakeCast. QDDS has been used in the seismological community since late 1998, while QuakeWatch and ShakeCast are systems under development.

As part of this review, the panel invited presentations on these systems. David Oppenheimer of the USGS spoke on QDDS, Paul Friberg of Instrumental Software Technologies, Inc (ISTI) spoke on QuakeWatch, and Phil Naecker of GateKeeper Systems spoke on ShakeCast. In addition, the panel heard a presentation by Art Botterell on the Common Alerting Protocol System (CAPS). CAPS is "an open, non-proprietary standard data interchange format that can be used to collect all types of hazard warnings and reports locally, regionally and nationally, for input into a wide range of information-management and warning dissemination systems". Although the charge to the panel did not specifically focus on message formats, the committee sought information on CAPS because information to be distributed through the system might be modeled on, if not conform to, CAPS specification.

All three systems have significant merit, use fairly modern computer science concepts, and are backed by excellent computer engineers. Each provides a service that adds value to seismic information products currently being generated at ANSS network centers. However, each of these systems uses a different mechanism to communicate between the data sources and the consumers of seismic information. Each has been developed at the request of a relatively small subset of the seismic network community to solve a particular problem.

Common to all of these systems was an apparent lack of previous widespread review and limited coordination with developers of related applications. We expect that continued development of these three programs without coordination will cause difficulties for information consumers and network operators who will need to operate different systems to receive and distribute, respectively, similar types of information.

The summary below draws on the review of products provided by the CISN Program Management Committee in its request to the California Office of Emergency Services and the USGS, with the addition of observations from the AHPEID under "Assessment by Committee". Appendix A provides a glossary of acronyms used in this summary.

Quake Data Distribution System (QDDS)

Goal: Rapidly distribute notification of earthquake parametric information from regional seismic networks and NEIC to both sophisticated earthquake recipients and the general public. Subscription to QDDS is self-initiated for users who only need to receive information and requires no intervention by maintainers of QDDS distribution systems. Information delivery is designed to be robust in the presence of network outages and support large numbers of clients.

Description - Stephen Jacobs, a summer employee at the USGS Menlo Park, wrote QDDS in Java during the summer of 1998. Alan Jones, a USGS volunteer affiliated with SUNY Binghamton, enhanced the software and now supports it. Identical software is installed at seismic networks where earthquake information is submitted into the system, at the servers (hubs), and at the clients who receive the information. Configuration of the system specifies who is allowed to submit information to the hubs. QDDS supports the delivery of hypocenter and magnitude messages as well as "addon" message types that provide notification of additional earthquake products specified by URL's. Several client applications have been built on QDDS including the RecentEqs Web pages, EqInTheNews, and teleseismic waveform triggers. More recently, QDDS also feeds the QuakeWatch system (see below). In addition to its use within most seismological processing centers, CBS News and Pacific Gas & Electric integrate earthquake information into their internal systems via information distributed through QDDS. There are presently three distribution hubs (2 USGS and one at IRIS). The source code is open.

Limitations - It cannot pass through firewalls without explicit configuration. This is difficult and sometimes impossible in many organizations. Message delivery is not guaranteed because it transmits messages using UDP. However, QDDS overcomes the unreliability by issuing regular heartbeats to its clients containing the number of the last message issued. QDDS clients use this number to detect and request that the server resend missing messages. Corrupted messages are not detected, although some messages contain a checksum. There are limitations on the file-size of information that can be distributed via UDP. QDDS can only distribute ASCII information. Consequently, it cannot distribute large binary objects like graphics images. The current version has primitive security, but a beta version implements public/private keys. A good interface for the casual user is absent.

Assessment by Committee - Unlike QuakeWatch and ShakeCast, QDDS only performs distribution of earthquake information and conceptually fulfills the requirements for a distribution system. While most of the above limitations could be addressed through product enhancement, the firewall issue greatly hampers its future utility. It has served the community well but should be replaced with the next generation of software. Because QDDS is embedded in many existing real-time applications (see *Description* above), it will require maintenance until it can be replaced.

QuakeWatch

Goal: Provide a user-friendly portal to a wide range of earthquake information products. Combined with CISN Display, it presents a GUI (Graphical User Interface) map display of near real-time seismicity and ShakeMaps, with the capability to proactively notify users of new information. The product is designed to deliver earthquake and product notifications reliably to critical users, such as emergency response centers, utility companies and media organizations. CISN Display also provides "clickable" links that automatically open a web browser and access related earthquake products.

Description - The State of California funded the CISN to develop a replacement for the Qpager (*a.k.a.* CUBE/REDI and RACE) display. The Qpager software runs on a DOS platform, receives earthquake hypocenter information via pagers, and displays earthquake locations and peak ground motions on a map. Caltech contracted with Instrumental Software Technologies, Inc (ISTI) to develop this system. Critical users that have expressed interest in beta testing include OES, Caltrans, Federal Emergency Management Agency, SBC Communications, the Metropolitan Water District of Southern California, Los Angeles Department of Water and Power, and TV stations in Los Angeles.

The current system consists of a server (QuakeWatch), which distributes earthquake information and the client application (CISN Display). At present, the QuakeWatch server receives notifications from QDDS, but QuakeWatch server has plug-in capabilities that enable it to receive data from mechanisms other than QDDS. The client application automatically displays seismicity on a map, with options to open a web browser to view related products for an event, such as ShakeMap, Community Internet Intensity Map, waveforms, focal mechanisms, aftershock forecasts, and other products that may be developed in the future. While not a high-level GIS (Geographic Information System), CISN Display allows users to overlay GIS layers on the seismicity map such as infrastructure, facilities or ShakeMap ground motion contour files. QuakeWatch and CISN Display feature client/server architecture and are written to be platform independent. Messages are XML delivered via CORBA (**C**ommon **O**bject **R**equest

Broker **A**rchitecture) over TCP. The design includes multiple and redundant servers. A beta version of the software is being tested both in house and with a broad user community. The source code is open.

Limitations - The distribution package is presently coupled with the display package, but could be separated. The system is designed to be scaled to any number of clients; however this aspect of the design has not been tested.

Assessment by Committee - This distribution system and client application combines the functions of QDDS and the Qpager display. CISN Display appears to provide users with a good interface for displaying seismicity information and alerting users based on locally specified criteria. CORBA is a modern platform for interfacing with other seismic applications through APIs. Its use of CORBA technology can circumvent all but the most restrictive firewall configurations that limit client-initiated connections to specific ports (such as port 80 for Web browsing). Unfortunately, many potential emergency management clients of CISN Display have responsibilities related to weapons of mass destruction and terrorism planning and response, and have installed such restrictive firewalls. It is unclear if the communications design is sufficiently general to facilitate the transfer of all types of seismic information products. Like ShakeCast, it is a total end-to-end system with poor overlap with other applications.

ShakeCast

Goal: Allow users to reliably and automatically receive and process shaking data from ShakeMap. Users specify the locations of their facilities and set the shaking thresholds (green, yellow, red) in multiple shaking metrics (acceleration, spectral response). Based on user-supplied parametric definitions of damage levels, software can rapidly deliver to end users electronic notification of facilities that may have sustained damage in a prioritized customized, easy-to-use form. ShakeCast meets the needs of sophisticated users who have GIS and require automatic delivery of maps to begin loss estimation. For non-GIS users, the distribution package includes tools for automatically evaluating and prioritizing facility damage.

Description - The USGS provided seed funding to develop a system to distribute and automatically process shaking information to critical users, such as emergency response centers, utilities companies and media organizations. USGS contracted with Gatekeeper Systems to develop a system design document and a prototype system. ShakeCast features client/server architecture. The software specifications call for users being able to customize their clients to receive and process ShakeMap data for events of geographical interest or by shaking level. The design includes multiple and redundant servers. The software distribution is based on XML messages via HTTP. The server can operate in two modes: 1) data-push if firewalls are not an issue, or 2) via polling on the standard web server port (80) if a firewall is in place. The ShakeCast specification document includes capabilities to interface ShakeMap data with end-user GIS systems and to redistribute ShakeMap data within an organization. Caltrans has been selected as the first beta user. Several other critical users have asked to be beta testers, including PG&E, FEMA, California Earthquake Authority and SBC. All these users have firewalls, but require ShakeMap to be delivered automatically. The source code is open.

Limitations - The system only supports the exchange of ShakeMap products. ShakeCast requires the existence of an Oracle or MS Access DBMS, which imposes an added cost to the user and which can be difficult to install and maintain. Only Unix and NT systems are currently supported. The ability of the system to scale to large numbers of clients has not been tested. Funding to complete the software has not been committed at the time of this report.

Assessment by Committee - This application combines the functions of data distribution and ShakeMap data processing. Our assessment of the latter functionality is that ShakeCast is well suited to a specific set of earthquake information users and does a good job dividing the responsibility between the seismic networks (produce the shaking information) and the end user (damage estimates). Putting the latter responsibility in the hands of the end user is appropriate as fragility and damage functions are beyond the scope of ANSS and CISN.

To meet the need for a data distribution system, ShakeCast's ShakeMap processing functionality would need to be decoupled from the distribution system. The technology behind the data distribution solves some of the problems of QDDS through a fairly complicated interchange of information via multiple servers and http requests. It would also need to be enhanced to support the distribution of a wider set of products than ShakeMap.

Requirements of an earthquake information distribution system

QDDS provides a model for an earthquake information distribution system that supports multiple applications. However, the rapid expansion of firewalls and the limitations of UDP suggest that QDDS is not a suitable platform for the development of a more generalized system. Both QuakeWatch and ShakeCast have addressed firewall issues using different approaches and each serves as a potential model for a more general earthquake distribution system. However, as discussed above, further software development would be necessary to separate the distribution aspect of both systems from the client application. Based on the review of the current systems and some knowledge of opportunities on the horizon, the panel believes that the community would be well served by the development of a more generalized distribution system to serve as a common layer to all current and future client applications.

The panel extensively discussed the appropriate software design and technology for circumventing firewall implementations. Many institutions operate "stateful" firewalls that monitor the source and destination address of each message that passes. To prevent unsolicited traffic from the public side of the connection from entering the private side, the firewall keeps a table of all communications that have originated from the client computer. All inbound traffic from the Internet is compared against the entries in the table. Inbound Internet traffic is only allowed to reach the computer behind the firewall when there is a matching entry in the table that shows that the communication exchange began from the computer. Communications that originate from a source outside the firewall, such as the Internet, are dropped by the firewall unless an entry in the table is made to allow passage. Many institutions are reluctant to "poke" such holes in their firewall. Accordingly, we recommend that the distribution software design require all data requests to originate from the client.

To address this issue, a new standard called "Web Services" has been developed to enable distributed applications to operate across the Internet using XML messaging. Web Services are a rapidly developing standard, have been endorsed by many of the leading software companies (*c.f.* www.webservices.org), and support communication across operating systems and programming languages. While this approach holds great promise for information distribution, it appears that this technology does not currently support maintaining an open connection to a client. When a client requests information from the server, the server delivers the information and closes the connection. A Web Services implementation would therefore require that the client poll the server at regular intervals to ascertain whether any new earthquake information is available since the last poll. Thus, Web Services would not support an immediate "push" of earthquake information to clients, but would be suitable for clients who could tolerate a few seconds delay and for clients who operate within an environment in which the firewall restricts outbound traffic to port 80 (*i.e.,* web browsing).

Other approaches like CORBA (www.corba.org) also enable computer applications to work together on almost any computer, operating system, programming language, and network. CORBA applications are reputedly more difficult to develop, but its accepted use in the commercial sector (since 1994) indicates that it could be applied to the earthquake distribution problem. CORBA has several features that recommend its use for this application. Notably, it supports persistent client-server connections, such that the server can immediately push information to the client instead of waiting for the client to poll the server. By exchanging information over "well known" ports like 80, firewall issues are circumvented.

Below we propose requirements for an earthquake information distribution system that will reliably distribute our products to thousands of users from a limited number of suppliers. We expect that this design will foster an environment in which client applications like displays, local alarm software, and HAZUS can easily and rapidly receive earthquake products. Figure 1 illustrates a schematic diagram of the service.

Dissemination Service

1. The system will utilize enabling technologies based on Internet standards that have received the endorsement of established groups such as the Organization for the Advancement of Structured Information Standards, Object Management Group, and the World Wide Web Consortium. Public interfaces and bindings will be defined and described using XML.

2. The system will receive and rapidly disseminate notification messages in a standard XML format. The system will be neutral to message content and allow an unlimited number of future message types.

3. XML message formats will be designed for the following message types:
   a. Parametric descriptions of the earthquake and ground motions, such as hypocenters, magnitudes, source mechanisms, slip distributions, peak ground motions, early warnings, and related uncertainty information;

   b. The availability of new or updated data sets, images, advisories, and other supplemental representations of seismic events; and,
   c. Updates, corrections and cancellations of previous notifications.

4. Basic data describing seismic events will be included in the notification messages. Extended data sets and binary objects (> 2 kilobytes) will be referenced in the notification messages via Uniform Resource Indicators (URIs) from which the data may be retrieved. (Performance standards for these ancillary services are beyond the scope of these requirements.)

5. The system will support two types of service. A "Subscriber" system will address the needs of users who must receive information as rapidly as possible. A "Passive" system will address the needs of users who operate behind restrictive firewalls or who can tolerate information that is delayed by a few seconds. In all other respects the distribution system and message formats will be identical.

Data Source Functions

1. The data source components will provide the following functions
   a. Registration as one of a federation of authorized sources;
   b. Authentification of servers;
   c. Standard protocols for message transmission;
   d. Messages immediately forwarded to servers, with store (non-volatile) and forward capability;
   e. Guaranteed delivery of messages;
   f. Routine, regular communication between data source components and servers (*e.g.*, heartbeats);
   g. Time stamped log of communication with servers;

Server Functions

1. The server will provide the following functions
   a. Registration of authorized sources (*i.e.,* seismic networks);
   b. Reception of messages "pushed" from authorized sources;
   c. Distribution of information that enables clients to recognize that they have missed messages and to request the missed messages from the server;
   d. A buffer of previously forwarded messages, with configurable length;
   e. Retrieval of a list of recent notification messages on demand;
   f. Retrieval of notification messages on request from any client system (client pull);
   g. Ability to authenticate clients; and,
   h. Logging of all subscriptions.

2. For "Subscriber" client systems, the server will

   a. Utilize enabling technologies (such as CORBA) to maintain persistent connections;
   b. Immediately forward notification messages upon arrival to active client systems (server push);
   c. Close connections to client when necessary; and,
   d. Support automatic subscription to the dissemination service at start-up only for authorized users.

3. For "Passive" client systems, the server will
   a. Utilize Web Services interfaces;
   b. Support regular polling of the dissemination service recent-notice list; and,
   c. Support automatic subscription to the dissemination service (by providing the subscriber's network address and supplemental identification information) at start-up.

4. The dissemination service will report to the system operator(s) any loss of communication with authorized data sources for more than a configurable interval of time (e.g., 5 minutes) and, likewise, any loss of communication with clients for more than a configurable interval of time (e.g., 20 minutes).

5. The dissemination service will delete or cancel any subscription for a client that has not communicated for more than a configurable interval of time (e.g. 1 hour). The client will automatically re-subscribe when it reestablishes connection. All canceled subscriptions will be logged.

6. A separate monitoring system will detect any failure of the dissemination service, log it, and optionally report it immediately to the system operator(s) via a configurable notification service.

Client Functions

1. All client systems will provide the following functions:
   a. Automatic subscription to the dissemination service (by providing the subscriber's network address and supplemental identification information) at start-up;
   b. Cancellation of subscription at shutdown;
   c. Initiation of all data requests;
   d. Polling of the dissemination service recent-notices list at start-up and whenever no new messages have been received for a designated period; and,
   e. Automatic re-subscription and retrieval of any missed messages whenever a communication failure is detected, either by a mismatch between local records and the retrieved recent-notices list or by receipt of an out-of-sequence notification message

2. "Subscriber" client systems will provide the following additional functions:

   a. Utilize enabling technologies (such as CORBA) to initiate and maintain persistent connections
   b. Reception of new notification messages pushed from the dissemination service.

3. "Passive" client systems will provide the following functions using Web service interfaces
   a. Regular polling of the dissemination service recent-notices list (typically every 5 minutes)

4. Each client system should provide a mechanism for detecting failures of communication with the dissemination service exceeding some configurable interval, log failures, and optionally report it immediately to its system operator(s) via a configurable notification service.

Performance

1. The dissemination service will be provided using facilities sufficient to transmit new notification messages to up to 1,000 subscriber client systems within 2 seconds in 99.99% of instances, while also responding to queries for the current message list and individual messages at an average rate of up to 66 queries per second (e.g., 10,000 passive clients polling at 5 minute intervals and retrieving one new message) within 5 seconds in 99.9% of instances.
2. The dissemination service will maintain overall availability of 99.999% at the specified performance levels.
3. The dissemination service will be implemented in a manner that will permit future expansion in client capacity up to at least 10 times the initial specified load while maintaining or improving the specified performance standards.

Other

1. The dissemination service will utilize redundant facilities at physically dispersed locations. All efforts will be made to eliminate single points of failure. The failure of a server may degrade system response time, but will not affect the completeness of information distributed through the service nor affect the ability of data providers to supply data to the service.
2. The protocol will support digital signatures for authentication of distributed messages and assurance of data integrity.
3. The protocol will require digital signatures for authentication of messages received from data providers (*i.e.,* seismic networks). Unauthenticated messages will be logged in an error file and rejected without further action.
4. For demonstration purposes, reference client implementations using both subscription and passive modes and user-configurable email outputs will be provided as open-source products available to the public at no charge.
5. All interfaces used in this system will use Internet standards for "push" and "pull" transactions and will be documented.

6. Daily logs of distribution activity, error conditions, and configuration parameters will be created. Verbosity of logging will be configurable to assist in debugging.
7. Distribution system will automatically delete files and data older than a configurable interval.
8. Client systems will receive software update notifications and will notify administrator via email when software updates are ready to be installed.
9. Data distribution administrator will have the ability to configure who can be a data provider.
10. Registration occurs at a subscription web site in fashion similar to following:
    i. User's existence is verified by sending e-mail containing verification link to click.
    ii. Click completes registration, generates key file and sends it to user
    iii. User gets key file puts it in place client software will find it.
    iv. Server enters key entered in dbase
    v. Key made known to all cooperating server instances (replication?)
11. All messages will be distributed to all recipients in the initial phase of development. Subsequent phases should support the subscription to particular message types.
12. Additional Web services such as data-correlation, analytic and archival services may be compatible with the dissemination service, but are beyond the scope of its initial implementation.
13. Source code should be in the public domain (*i.e.,* "open source"). Reliance on proprietary software packages should be minimized.

FINDINGS AND RECOMMENDATIONS OF THE AHPEID

All of the systems reviewed by the *Ad Hoc* panel have interesting and different solutions to the problem of earthquake information distribution. Each system has its strengths and weaknesses. The *Ad Hoc* panel recommends the Internet standards approach is most likely to address the growing issues of firewalls while providing the necessary infrastructure upon which many useful applications may be developed. The *Ad Hoc* panel makes the follow recommendations for the system:

- The specifications in this report should be expanded and used to develop and deploy a new distribution system within one year (*i.e*., by July 2004). Sufficient resources should be made available to complete this project and maintain the software and hardware infrastructure that results from it.
- When completed, future USGS/ANSS/CISN-funded products should be directed to utilize this distribution system.
- The development of an XML messaging standard for earthquake information should be a high priority. The standard should receive input from a wide working group that includes IRIS, QuakeWatch, and ShakeCast developers. The Common Alerting Protocol (http://www.incident.com/cap/) should be considered as a basis for notification messages.
- Support for the maintenance of QDDS should be continued until a replacement earthquake information distribution system is completed. No further development for QDDS is recommended. However, since QDDS already meets some of the

recommendations by the committee, its Java code should be analyzed and reused, if appropriate.

- Support for continued development of ShakeCast and QuakeWatch/CISN Display is recommended, but with an emphasis on the application aspects of the systems. Both projects should be transitioned to use the replacement earthquake information distribution system when it is completed.
- The federated nature of the ANSS creates complications for earthquake information in terms of a single, unchanging “handle” or event ID number for an event. It is necessary to develop an earthquake view-association service to provide this capability.
- An application should be developed that provides users of earthquake information the ability to locally generate email notification based on their individual requirements. The application should receive its data from the proposed Earthquake Information Distribution System. The software should be freely available for download by users.
- Data providers (*i.e.*, seismic network operators) must strictly adhere to XML definitions. An interface that translates standard earthquake formats such as summary cards into XML should be developed for data providers.

In terms of coordination of products, the *Ad Hoc* Panel recommends

- Establish an integrated portal where all products and applications are available.
- Develop brochures or fact sheets to describe different client applications and their use.

Finally, although the ANSS is still in the early stages of development, it is critical that the USGS management establish a software/systems development policy, which requires appropriate review and adherence to ANSS system-wide standards for any development done by USGS staff and/or funded by USGS funds. This certainly could slow some development efforts now but in the long run will prove to be far more efficient and cost effective than the current ad hoc policy. At the heart of making such a policy effective must be the fundamental system-wide standards to which software must adhere. These standards must be the first and top priority for development. A systems engineering effort should be started immediately to develop these standards. Those doing this engineering MUST include experts from outside the USGS or their supported university networks who have general expertise in modern computer networks, systems engineering, distributed databases and information distribution.

Table 1: Seismological Products

Filled box = products for "distribution system"

	frequency (per day)	size (Kbytes)	rate (bps)	Speed of creation	type info distributed
Early Response					
Arrival times	40000	0.1	379	secs	
Amplitudes	40000	0.1	379	secs	
Early Warning	0.02	1	0	secs	data
Hypocenter	200	1	19	secs to mins	data
Magnitudes	300	1	28	secs to mins	data
Source Mechanism	20	3	6	mins	data
Later Response					
ShakeMap	0.7	35000	2323	mins	URI
Ground motion values	0.7	50	3	mins	URI
Slip distribution	0.05	100	0	tens of mins	URI
Aftershock Probability	0.2	3	0	tens of mins	data
Stress Change	0.05	100	0	tens of mins	URI
Felt Reports (CIIM)	0.7	15000	996	mins to days	URI
Supplemental Info					
Tectonic Summary	200	5000	94815	tens of mins	URI
Event Summary	0.1	5000	47	mins to days	URI
Waveforms					
Triggered	4000	0.1	38	mins	URI
Continuous	-	-	-	secs	-
Internet Quick Report	0.02	5000	9	mins to days	URI
Summary Products					
Catalogs				mins to days	
Processed waveforms				days	
Metadata					
Station					
Site					

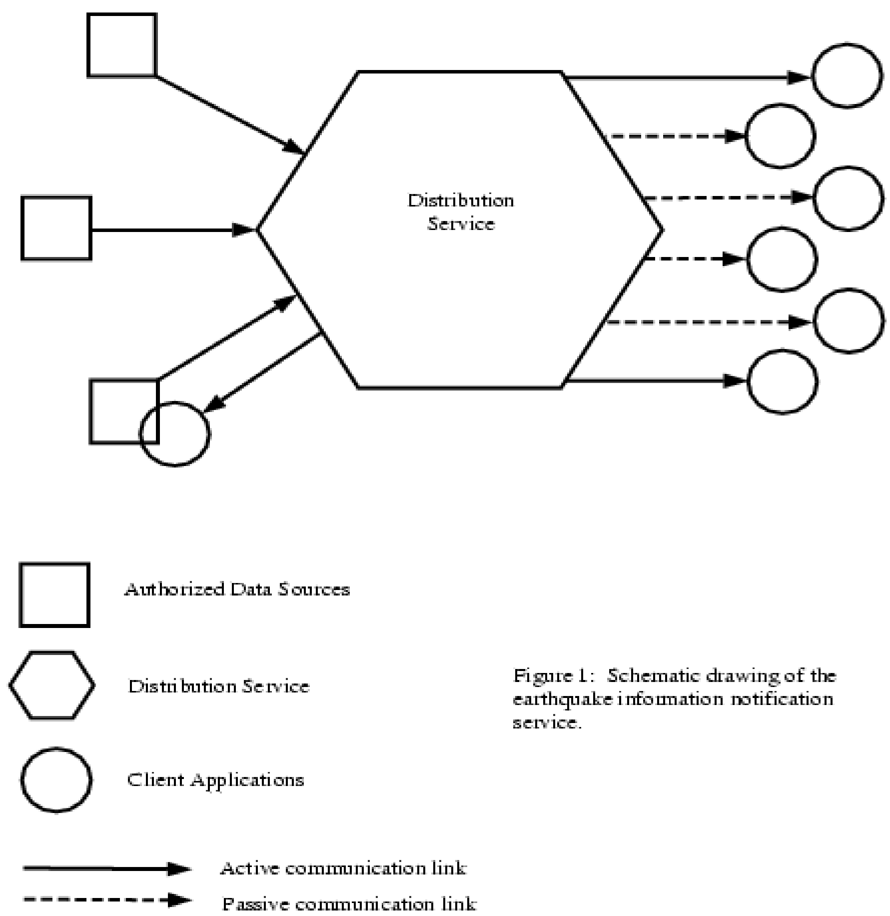

Figure 1: Schematic diagram of the distribution service showing data sources and active and passive clients. The number of servers and the connections between the data sources and among the servers is left blank to avoid implementation issues.

Appendix A: Common Acronyms

AHPEID	*Ad Hoc* Panel on Earthquake Information Distribution
ANSS	Advanced National Seismic System
API	Application Program Interface
ASCII	American Standard Code for Information Interchange
CAPS	Common Alerting Protocol System
CISN	California Integrated Seismic Network
CORBA	Common Object Request Broker Architecture
DBMS	Database Management System
GIS	Geographical Information System
GUI	Graphical User Interface
HAZUS	Hazards United States
HTTP	Hypertext Transfer Protocol
IP	Internet Protocol
OES	Office of Emergency Services
QDDS	Quake Data Distribution System
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
URI	Universal Resource Indicator
URL	Uniform Resource Locator
USGS	United States Geological Survey
XML	Extensible Markup Language