Design Criteria for Public Emergency Warning Systems

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ABSTRACT

This paper describes the development of a public emergency messaging system in Western Australia. A set of design criteria were identified by a review of relevant published literature, a survey of current practice in Australia, and consultation with local stakeholders. The system should support: Multiple Recipients, Multiple Channels, Multiple Hazards, Multiple Stakeholders, Multiple Senders, Multiple Platforms, and Write Once Message Composition. A prototype system was built according to these design criteria, based on the Common Alerting Protocol version 1.0. The design was validated in trials simulating messages sent during a tropical cyclone and a bushfire. A total of 56 trial participants from identified stakeholder groups were surveyed with regard to their experience of the prototype system. Overall, the prototype system functioned successfully and participants reported high levels of satisfaction. The paper describes this research project and the initial stages of the subsequent development of a production system, called APECS.

Keywords

Public Warning System; Government to Citizen Mass Public Warning; Emergency Management.

INTRODUCTION

This paper describes the results of a project to develop a multi-channel Public Emergency Warning System. The research phase was carried out by a team at Murdoch University and was funded by Emergency Management Australia, with in-kind contributions from the Australian Broadcasting Corporation (ABC), Fire and Emergency Services Authority (FESA), and the Interactive Television Research Institute of Murdoch University.

The research project had the following objectives:

- To understand how new media can be used to extend the reach of public information systems and improve community response to emergencies (understanding communities).
- To establish the foundation of an innovative new service with the potential to save lives and property, nationally and globally (emergency management capability).
- To assert the interests of emergency management organizations in the evolution of new national media communications infrastructure (information management and technology).

BACKGROUND

Relevant literature was reviewed at the commencement of the project in order to determine initial design criteria for a Public Emergency Warning System. Reports and documentation of existing warning systems were also consulted. A summary of the criteria follows:

Design Criteria for Public Emergency Warning Systems

Multiple Recipients

A Public Emergency Warning System must by definition reach multiple recipients.

Multiple Stakeholder Groups

The challenge is to reach only the appropriate recipients, as efficiently as possible. (Working Group on Natural Disaster Information Systems - Subcommittee on Natural Disaster Reduction, 2000). A Public Emergency Warning System should therefore have the ability to segment message recipients, geographically, and by user profile.

Different groups of stakeholders have different warning message requirements. They may require different sets and subsets of messages, and they may require messages in different formats. For example, non-english-speaking citizens need messages in a language they understand. Other stakeholder groups have their own requirements: Emergency Managers need to monitor and control published messages; Business Managers may need to be apprised of conditions in several specific locations; Government representatives may need to know of events affecting their jurisdiction; etc. It is important, though, while meeting the differing requirements of diverse stakeholder groups, to preserve message consistency (McLeod, 2003).

Multiple Channels

Multiple channels increase the effectiveness of emergency warnings by extending their reach, and providing the means of confirmation reinforcement. The more channels, the better (Working Group on Natural Disaster Information Systems - Subcommittee on Natural Disaster Reduction, 2000). When people receive news of an unexpected event, they seek confirmation from other sources (Auf der Heide, 1989). If they hear an Emergency Siren, they may turn on their radios. If they receive an email, they may be more likely to perform a web search. If they hear of a cyclone warning on the radio, they may look out their windows at the sky.

In their study of reactions to the broadcast and ensuing panic of Orson Welles 1938 radio broadcast of “War of the Worlds”, Cantril, Wells, Koch, Gaudet and Herzog (1940) categorized listener reactions into four groups:

- Those who analyzed the internal evidence of the information and decided it could not be true;
- Those who checked the information against other sources and concluded it was not true;
- Those who checked the information against other sources and nevertheless concluded it was true;
- Those who made no attempt to check the authenticity of the information.

Some quotes from their interviews illustrate the third category:

> *“I looked out the window and everything looked the same as usual so I thought it hadn’t reached our section yet.”*
> *“We looked out or the window and Wyoming Avenue was black with cars. People were rushing away, I figured.”*
> *“No cars came down my street. Traffic is jammed on account of the roads being destroyed, I thought.”*
> (Cantril, Wells, Koch, Gaudet and Herzog, 1940)

It is important that people do receive confirmation; if they do not, the chance they will disregard the message is increased. The message must also be consistent across channels. Variations in the message create room for interpretation, increasing the chance that the message will be misinterpreted.

Many people, including those living in remote communities not served by local radio or television broadcasts, will turn to the internet to verify unexpected news. However, it is difficult to predict where on the web people will look for emergency information. Sites run by emergency services, local councils, police services, are among many possibilities. These examples, however, are of a type that, in an emergency event, may not have resources available to keep their website up to date. To facilitate a consistent, timely message across these many sites, a web applet can be built to be incorporated into existing website pages. The applet automatically displays recent headlines with links to message details. Such an applet could be incorporated into the websites of the various organisations people might look to for information during an emergency, including local councils, police, volunteer agencies, etc. The applet might be configured to show only headlines matching specific criteria, for example location or type of emergency event.

Another reason for multiple channels is system redundancy. More channels means less chance the message will be delayed (McLeod, 2003). It is important however that increasing the number of channels does not lead to a “scattergun” approach to message publication; rather, diverse channels should be used to facilitate targeted delivery of messages, using channels to deliver messages to specific groups, such as voicemail messages to the blind, or SMS to the deaf (Working Group on Natural Disaster Information Systems - Subcommittee on Natural Disaster Reduction, 2000).

Multiple Hazards

There are a number of reasons to design a public warning system to handle multiple types of hazard. Hazards are by definition unpredictable; so it is important to build as much flexibility into a public warning system as possible (without diluting efficiency or effectiveness). Hazards may arrive in multiples; an earthquake and a fire, for example, or a cyclone and a chemical spill. Ideally, citizens would be able to rely on a single warning system for all hazard types and combinations, with no uncertainty as to whether they were attending to the correct source. This requires a high level of cooperation and coordination between agencies and an integrated public alert system.

Multiple Senders

Typically many agencies cooperate in response to an emergency, and communication with the public is one aspect of the response that must be coordinated among the agencies. The content of warning messages may originate with different responding agencies, but it is important that messages to the public are consistent with one another, and their dissemination coordinated to achieve the best effect. Inconsistent messages will lose credibility; too many messages will lose effect; too few messages will have inadequate impact.

In the event of an emergency, the Western Australia State Public Information Emergency Management Support Plan specifies that a designated Hazard Management Agency will manage the public information function for the overall emergency operation. However, the plan also states that, *"as a principle, each agency may address the public and the media but only on issues which are their responsibility. Matters that are not their direct responsibility should be referred to the appropriate agency or the Emergency Public Information Coordinator."* In addition, *"all agencies are to be kept informed of information provided to the media and public"* (Western Australia State Emergency Management Committee, 2002). This is in line with recommendations from the literature:

> *For example, the determination that adverse weather will lead to unusually heavy rainfall is usually made by the Weather Bureau. This might alert the local flood control authorities to the possibility of flooding and the subsequent detection of impending dam or levee failure. The decision to issue an evacuation directive might then come from the sheriffs department or the office of the county executive. But the conveyance of the message to the public is often carried out by local commercial radio or TV stations."* (Auf der Heide, 1989)

In large, rapidly emerging emergency events, coordination between responding, supporting, and managing agencies requires a high level of overhead, and maintaining this effort in the context of an emergency can be problematic. The need for a reliable, coordinated approach to disseminating information originating from diverse hazard management agencies has led emergency professionals and incident inquiries to call for a centralized entity with this responsibility for public warnings (McLeod, 2003).

Multiple Platforms / Applications

A multiple-channel warning system must interoperate with existing communications systems that might include voice, fax, email, SMS and TV, among others. Warning systems should be able to connect to existing databases of messages and message recipients, to minimize duplication and the chance of relying on outdated data. The Common Alerting Protocol (CAP) message format is a published open standard enabling communication between diverse systems in a Public Emergency Warning network (Oasis Emergency Management Technical Committee, 2005).

Public Emergency Warning Systems based on published open standards like CAP are positioned to gain maximum effect from existing systems and infrastructure, and to lower the long-term cost of system maintenance and development. This holds true whether system development is carried out in-house, or out-sourced.

When warning systems are developed in-house, open standards-based implementation increases the chance a system will be able to take advantage of future developments in related technologies. Public warning systems are being improved continuously, around the world; open standards-based implementation increases the chance that an in-house system will integrate with systems representing the latest best-practice, developed elsewhere and available off-the-shelf for much less than the cost of bespoke development. Open standards based implementation also facilitates making in-house systems available to other agencies with similar public warning systems needs, and multi-agency cooperation in development of common public warning systems. When system development is outsourced, open standards-based implementation is a means to preserve independence from third-party systems vendors, which proprietary implementations may compromise.

Write-Once Message Input

Public warning systems should be “write-once, multiple message output” in order to reduce errors, and to preserve the consistency and authority of messages. Additional functionality must not come at the cost of increased complexity; public warning systems must be easy to use. To this end, public warning systems should be as automated as possible, supporting multiple recipients, multiple stakeholder groups, multiple hazards, multiple senders, and multiple platforms / applications without requiring any emergency warning to be written more than once. Any increase in operational complexity has the potential to introduce errors, with the cost potentially measured in lives.

Message consistency is important. All messages are subject to interpretation by recipient citizens, and citizens look to other sources for validation (Vogt and Sorensen, 1994), (Auf der Heide, 1989). When different sources provide different variations on a message – even in wording only – the message can be diluted rather than reinforced. For this reason FESA-WA has an agreement with ABC radio to read bushfire bulletins on the air verbatim. Bureau of Meteorology staff recount incidents of commercial “Disk Jockeys” transforming cyclone warnings into casual, between-track banter, reducing their effectiveness. Although it cannot in the end control the delivery of an on-air presenter, a “write-once” system does help to preserve consistency across channels.

Role of Authoritative Centralised Emergency Warning Websites

One way Hazard Management and related Agencies have responded to this challenge is by establishing authoritative web sites aggregating emergency warnings from diverse sources. These sites provide a place internet users can go to validate emergency warnings.

Authoritative emergency warning web sites, however, are only part of the solution. When a member of the community receives notice of an imminent cyclone or tsunami, they are likely to refer to websites of familiar local organisations for confirmation of unexpected information. Examples include local surf club, volunteer fire-fighting organisation, or city council websites. These are sites a community member may already refer to regularly for local information. Currently, these are sites that are likely to contain no mention of an emergency event. When there is information about the event, it is likely to be outdated, or inconsistent with other sources. The lack of participation of local community websites in the larger emergency warning network constitutes a real increase to public risk.

However, local community website providers do not currently have sufficient time, money, personnel, or organisational infrastructure to participate in emergency notification networks. This situation can be addressed by increasing the amount of resources available to local organisations for the purpose of participating in emergency warning networks, or by lowering the threshold of resources required to a level where local organisations can participate with current available resources.

RESEARCH PROJECT OVERVIEW

Aims and Approach

The research project involved the development and trial of a prototype multi-channel Public Emergency Warning System. The project was carried out at Murdoch University by the authors. It was funded by Emergency Management Australia (EMA), with in-kind contributions from the Australian Broadcasting Corporation, FESA Western Australia, and the Interactive Television Research Institute of Murdoch University (ITRI).

The initial project objective to explore uses of New Media in Public Emergency Warning Systems was reformulated as the research question: “What are the design criteria for an effective and extensible multi-channel Public Emergency Warning System?” This formulation removed the emphasis on New Media delivery channels, allowing them to be considered alongside of existing delivery channels as part of an integrated system. The researchers approached the problem from the point of view of the Human Computer Interaction discipline.

Information concerning system requirements was collected through interviews and workshops conducted with stakeholders. These consultations focussed on describing the following aspects of the system:

- Users
- Tasks
- Equipment
- Organizational environment
- Technical environment
- Physical environment

Stakeholder Groups

Relevant policy and procedure documents identified in the course of these interviews and workshops were assembled and examined, as well as logs of public communications from actual bushfire and cyclone incidents. Table 1 below describes the stakeholder groups represented in the consultations:

Group	Description	Examples
Citizen	A Citizen is a member of the general public.	Citizens currently well served by existing communications media Citizens currently not well served including: • non-English speaker; • resident of a remote community; • disabled person.
Emergency Manager	An Emergency Manager is someone wholly or partly responsible for the management of a organization involved in emergency procedures. They are interested in maintaining a clear overview of relevant developments and have authority to override decisions of those under their command.	Manager of a Local Hazard Management Agency Manager of Regional Hazard Management Agency Manager of a collaborating agency
Business Manager	A Business Manager acts on behalf of an organisation with a particular interest in an emergency alert (due to possible significant impact due to the nature of their business and/or geographic location)	Car Dealership Officer Mining Company Officer Forestry Company Officer Utility Company Officer
Government Representative	A Government Representative is a member of government or someone working for the government.	Civil Servant Local Councillor Member of Parliament Minister Premier Prime Minister

Group	Description	Examples
Media Agent	A Media Agent is any member of the media, representing (acting for) a media organisation to publish an alert message.	Television Journalist Radio Journalist Print Journalist Automated Radio Station New media producer (e.g. web master)

Table 1. Project Stakeholder Groups

Trial of Prototype System

The results of the stakeholder consultations were synthesized into a set of high-level design criteria. A Public Emergency Warning System should support:

- multiple recipients,
- multiple stakeholder groups,
- multiple channels,
- multiple hazards,
- multiple senders,
- multiple platforms / applications and;
- write-once message input;

  while,

- minimizing complexity of operation,
- facilitating authorisation and coordination of messages,
- preserving consistency of messages, and
- minimizing cost of maintenance and development.

A prototype Public Emergency Warning System designed according to these principles was built and trialed. Simulations were carried out in two Western Australian communities, based on sequences of warning messages used in actual events affecting the communities in the past. Simulations were based on cyclone warnings in the Pilbara region, and bushfires in the Darlington region.

Through citizens committees, local hazard management agencies, and word-of-mouth, participants were recruited who, in an actual emergency event, would wish to receive messages. Persons interested in participating in the trial were asked to go to a dedicated website, where they were provided with background information on the trials, and then, after indicating their consent to proceed, asked to provide demographic data and specify their preferences for receiving messages during the trial – i.e media channel, types of messages, etc. A total of 20 people registered to participate in the cyclone part of the trial and 43 people registered for the bushfire part. Of these, 7 people participated in both trials, yielding an overall total of 56 participants, of which 70% were male and 30% female. Participants categorized themselves in terms of defined stakeholder group, as follows:

Stakeholder Group	Number	Percent
Resident	23	41%

Business Owner	3	5%
Media Representative	2	4%
Government Representative	6	11%
Emergency Professional	19	34%
Other	3	5%

Table 2. Trial Participants by Stakeholder Group

The cyclone message sequence consisted of 16 messages sent from 16th to18th June, 2004. The sequence was based on actual messages sent by the Bureau of Meteorology during Tropical Cyclone Inigo in April 2003. The bushfire message sequence consisted of 14 messages sent from 30th June to 1 July 2004. The sequence was based on actual messages sent by FESA during a bushfire in the Boya area in February 2004.

Participants were asked to record details of the emergency messages they received, along with any comments or suggestions regarding the system, in a supplied message log. They were asked to return the completed logbooks in supplied postage paid envelopes at the conclusion of each message sequence. Participants returned a total of 566 completed logbook pages, each representing a received message. After the trials, a telephone survey was conducted of all participants with regard to their experience of the system including their satisfaction with the idea of multiple messages channels and suggestions for improvement.

Results

A total of 56 participants registered for the trials and completed pre-trial surveys. Of these registered participants, 35 returned logbooks reporting details of 566 instances of received alerts. A total of 42 participants were able to be contacted to complete telephone follow-up surveys. 38 registered participants reported that they did receive alerts during the trials. Of these, 31 completed follow-up telephone surveys. The follow-up surveys indicated that the most common reason for not receiving alerts was inability of access alert channels due to travel.

The trial system delivered messages across Voice, SMS, email, fax, and web pages. A total of 27 (87%) of the 31 participants completing the follow-up surveys who said they had received alerts reported it was useful to be able to receive alerts over several channels. Although SMS messages contained substantially less information (limited to 160 characters), more participants said they would use that channel than other listed channels (excluding web pages, which were not listed as a response choice). Participant comments suggested they would use the SMS messages as a trigger to seek more detailed information.

Figure 1 shows a summary of responses (by the 31 participants contacted by telephone survey who reported receiving alerts) to the question "In a real system, which channels would you use?" Also, 30 (97%) of these participants said it was useful to choose when (i.e., under what conditions) they would receive alerts.

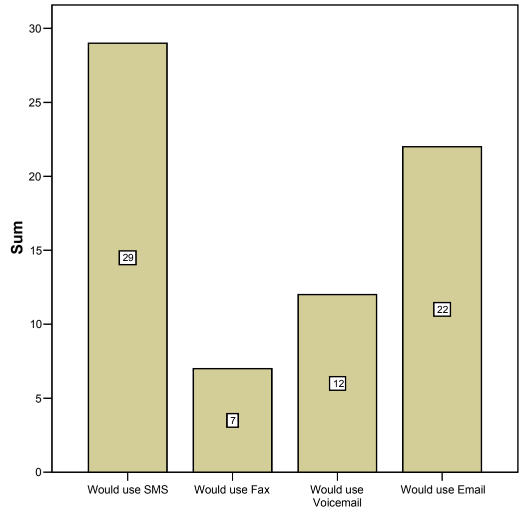

Figure 1. Responses to the question "In a real system, which channels would you use?

Participant comments regarding the content of trial messages included:

- Messages should be in every-day language.
- Messages for evacuation need to include where to go (and perhaps route to use).
- Subscription interfaces should tell users the different information they can receive on different platforms (the trial did not), enabling users to better manage their information.
- Some messages (e.g. SMS) lacked some aspects that were expected (e.g. cyclone category; instructions of what to do).
- Participants liked receiving good news (e.g. all clear) as well as bad.
- Participants liked receiving exact locations of cyclone or fire and direction/speed of movement.
- Size of fire should be included.
- Distance and direction of cyclone from nearest town would be useful.
- Links to other information sources (and communication channels) should be included where possible.
- Some messages were considered too long (e.g. for voice mail).
- Spelling and grammar should be carefully proofread before sending - there were mistakes.
- Keep faxes to one page long.

Participants were asked to complete the following statement for each alert they received: "If this had been a real alert, I would have taken these actions…" Based on these responses, participants were categorized according to their intentions to a) seek further information from other sources, and b) relay the information to others. Of the 35 participants returning completed logbooks, 18 (51%), indicated they would seek further information from other sources; 12 (34%) indicated they would relay information to others.

The Public Emergency Warning System design criteria developed in the initial stages of the project were validated by the results of the trial of the prototype system.

DEVELOPMENT OF WESTERN AUSTRALIA EMERGENCY WARNING SYSTEM

Following the success of the research project, the state government of Western Australia commissioned the development of a Public Emergency Warning System based on the criteria validated by the trails of the prototype system. The system takes a "whole of government" approach to establish a resource that will facilitate dissemination of public emergency warning messages and coordination of messages among various responding agencies. The first author (through his company, Ovis Pty Ltd), with assistance from the other authors, was successful in being awarded the contract to develop the production system, The system, called APECS, will be operational in the second half of 2006.

In consultation with the Western Australian Police Service and the Fire and Emergency Services Authority of Western Australia, the prototype system was extended to include the components described in table 3. The design criteria described in this paper proved a useful framework for stakeholder communication and system specifications.

Extension	Description
Public dial-up telephone message service	Members of the public can phone to access the latest system alert, alerts for a specific postcode, or general safety information. This functionality reduces the number of update message broadcasts required by establishing an on-demand source for updates, after the initial alert has been issued.
Recipient response capture	Telephone message recipients can register responses using their telephone keypads. This may be used, for example, to acknowledge message receipt or to request special assistance.
Reporting and auditing	Message broadcasts and responses can be monitored in real-time. All messages and actions are logged and archived for post-hoc analysis.
Response team callout	Messages can be sent to predefined groups of recipients for emergency response callout. Recipients can register their availability using telephone keypads and responses are monitored in real-time.
Workflow support	A “wizard” style user interface is employed to support complete and consistent messages. A detailed user rights schema allows granular control of user access to system features.
RSS datafeed subscription	The system publishes alerts via RSS newsfeeds, enabling small websites (such as surf clubs) to participate in the emergency alert network by including the latest alerts on their pages. Alert subscriptions can be filtered by postcodes.
Public telephone number and cadastral databases	The system extracts telephone numbers for voice messages from the Australian public telephone number database based on geographic information in the Western Australian cadastral information database.

Table 3. System Extensions in APECS

Qualitative data including participant comments in logbooks and follow-up telephone surveys indicated a need for messages confirming that no emergency was extant, and that the Public Emergency Warning System was nevertheless in place and functional. For example, some participants said they would like to use the system to confirm that a smoke plume in the horizon was a controlled burn. These comments contributed to the development of "pull"-type communication channels in the system, in the form of a dial-in telephone message service and RSS news feed.

CONCLUSIONS

The design criteria for Public Emergency Warning Systems described in this paper have been preliminarily validated from the point of view of message recipients in trials based on simulated emergency events, and from the point of view of message originators, in the commissioning of an actual system. Final validation must wait until after the APECS system has been used in several actual emergency events.

The first advantage of a multi-channel Public Emergency Warning System is the ability to extend the reach of alert broadcasts. A secondary, but critical, advantage is that coordinated messages delivered over multiple channels make it easier for recipients to confirm and authenticate information, increasing the chance they will interpret the message correctly, and take appropriate action.

Participant comments from the trial indicate a need for non-emergency messages for the purpose of i) confirming that the system is operational and ii) confirming that no emergency is extant at the time. The requirement to avoid "message fatigue" and preserve the impact of actual emergency messages among recipients suggests that these messages should be "pull"-type in nature. The researchers have adopted the term "negative-confirmation" to talk about this class of messages, and believe the case for them is strong enough to warrant their inclusion as an additional design criterion for Public Emergency Warning Messages.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of Emergency Management Australia, the Western Australian Fire and Emergency Services Authority, the Australian Broadcasting Corporation, the Western Australian Police Department, the Interactive Television Research Institute at Murdoch University Perth. We would like to thank Jenelle Provost, Rick Corkill, and Art Botterell specifically for their encouragement, support and guidance.

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