Managing Information in the Disaster Coordination Centre: Lessons and Opportunities

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ABSTRACT

The current scope of ICT support for disaster coordination is primarily focused at either the network or data levels. There is significant opportunity for ICT to play an even more important role for disaster coordination at the information level. This paper reviews the information structures and requirements gathered from disaster coordination centres based on exercise observations. Such coordination of information is usually based on national frameworks that document structures, roles, and responsibilities, but are seldom supported by relevant ICT infrastructure or systems. This paper uses the lessons learned from the exercise observations to identify future opportunities for information management software to support disaster centre operations. In particular, the paper introduces a prototypical Crisis Information Management System we are developing to support two challenges: incident notification and resource messaging. The system is based on open standards under development within the OASIS standards consortium, and will be evaluated as part of future exercises.

Keywords

Disaster coordination, incident notification, resource messaging, crisis information management systems.

INTRODUCTION

Recent natural disasters have resulted in a media frenzy highlighting the problems inherent in the disaster management community. One of the most well-published issues lies in the establishment of core data and network infrastructures for disaster response teams (e.g., see (Meinrath , 2006)). However, very little acknowledgement is made of the need for ICT support at the higher information management levels.

The mantra for Crisis Information Management Systems is to "deliver the right information to the right people in the right format in the right place at the right time". These five variables, coupled with the stress of a major disaster, life-dependent decisions, and coordination between potentially hundreds of disparate groups that have never met, make information management one of the greatest challenges for the disaster coordination sector.

This paper will firstly give a background on incident management systems (IMS), with explicit reference to the key IMS in Australia. This is followed by a discussion of the organisational structure commonly used for disaster coordination in Australia. The remainder of the paper focuses on two specific opportunities that we have identified for enhancing the ICT support for information management in disaster coordination centres, based on our observations of cyclone training exercises. We are developing a prototypical Crisis Incident Management System to address these opportunities, and we plan to evaluate this system in future exercises. Our eventual goal is to see such a system deployed in both future exercises and actual disaster situations, to help relieve staff and volunteers of information management tasks that are currently performed manually using basic tools like email and spreadsheets.

INCIDENT MANAGEMENT SYSTEMS

Technology to facilitate crisis management in the emergency sector should support existing processes for managing information and resources in emergencies, enabling greater efficiency and improved decision making without imposing fundamental changes on the way people currently work. The processes used in disaster coordination centres are governed by Incident Management Systems (IMS), which vary across countries, but fundamentally provide a structured and hierarchical "command and control" framework (an Incident Command System – ICS). In Australia, the common IMS is the Australian Inter-service Incident Management System (AIIMS) (Australasian Fire Authority Council, 2004), whilst in the USA it is the National Incident Management System (NIMS) (U.S. Department of Homeland Security, 2004).

AIIMS (and most IMSs) facilitate cross-organisational cooperation by describing common concepts and processes for incident response. Figure 1 shows the AIIMS structure, which captures the management and control hierarchies. These consist of entities such as sections and units with broadly described roles and responsibilities. The AIIMS structure is designed to scale according to the size of the incident. In a very small incident, one person could undertake the role of Incident Controller as well as the tasks of planning, operations, and logistics; however, a medium-sized incident may require a person in each of the 4 roles, while a major incident may require dozens of people to handle the various management functions shown in Figure 1.

These reporting structures promote cooperation at a process level, as they introduce common hierarchical structures and processes across different organisations. However, IMSs do not cover technology solutions (Iannella, 2005) and recent work is now addressing this limitation. For example, the work of (Wang *et al*, 2006) examines NIMS and provides detailed modelling to support workflows across the structures.

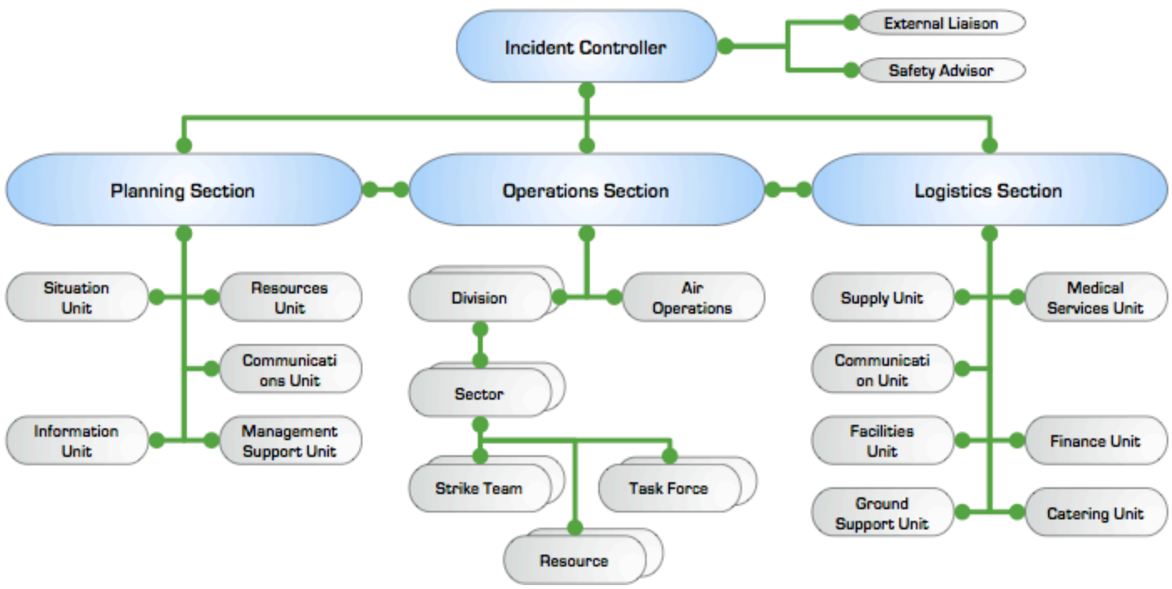

Figure 1. AIIMS structure

DISASTER COORDINATION

In Australia, disaster coordination typically follows a Federal, State, District, Local layered approach in terms of the communications structure. The majority of disaster information coordination is processed at the District level (although this is dependent to some extent on the scale of the incident), and many of the key strategic and tactical decisions are made at this level. District level coordination poses significant challenges as it represents many disparate groups and agencies; these require a great deal of coordination, but often have had little exposure to each other in the past.

Figure 2 shows the structure of a typical District Disaster Coordination Centre (DDCC) and its relationships with the Local and State levels. The DDCC is run by a relatively small core of staff, which is supplemented by a larger group called the District Disaster Management Group (DDMG). The DDMG is made up of representatives from agencies (i.e., any relevant stakeholder group) that play a role in the disaster event. Typically these include government agencies (e.g., Transport, Health, Fire, Police, and Bureau of Meteorology), local councils, and critical infrastructure providers (e.g., telecommunications and energy companies).

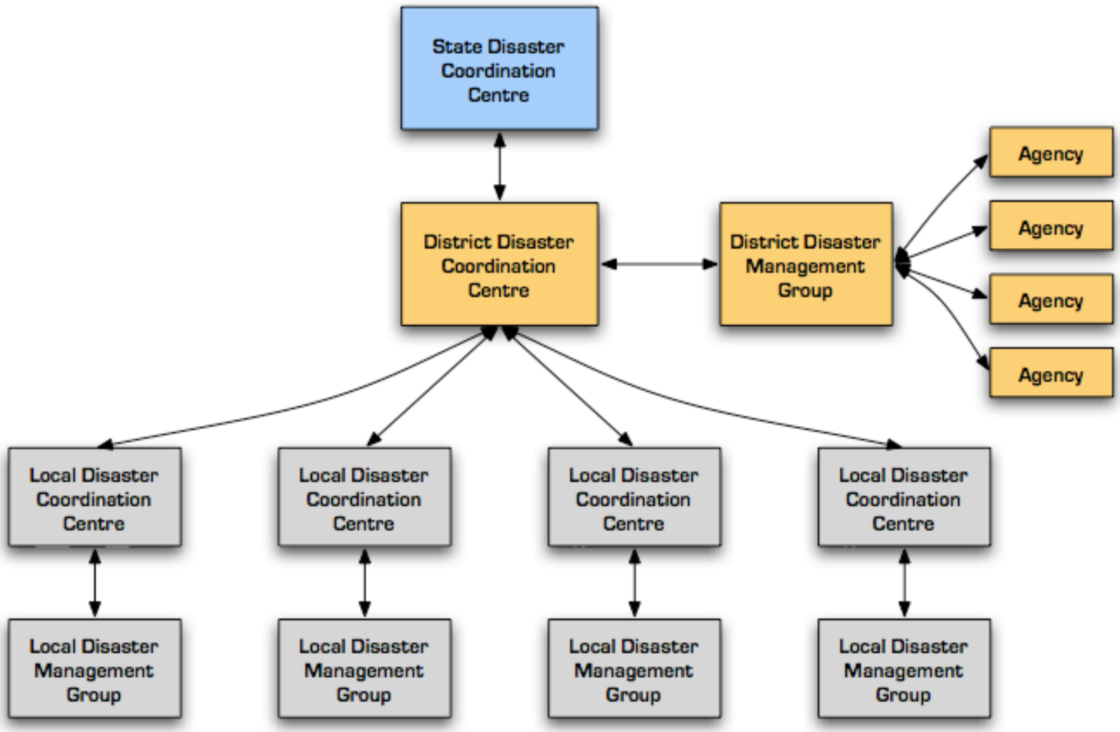

Figure 2. Disaster Coordination Structure

The DDCC structure is replicated at the local level, with a Local Disaster Coordination Centre (LDCC) and Management Group (LDMG). These are focused on local disaster recovery activities. For a small disaster – e.g., local flooding – only a single LDCC/LDMG would be activated. In a major disaster – e.g., a cyclone – the DDCC/DDMG would be set up to handle the coordination across a number of LDCC/LDMGs, including upwards communications to the State level.

The DDCC is responsible for coordinating local efforts when they exhaust their own resources. In these cases, requests for assistance come from the LDCC to the DDCC. The DDCC attempts to resolve these requests by sourcing appropriate resources from known sources, or requesting assistance from the State level. The DDCC follows the AIIMS framework and will typically have an Incident Controller in charge of four sections; Planning, Operations, Logistics, and Administration.

The planning section is responsible for managing and evaluating situation information, and for preparing and disseminating strategies for controlling the incident. The operations section implements the strategies by establishing appropriate operational structures and allocating resources to personnel on the ground, while the logistics section assists by obtaining and maintaining the required resources and services. The administration section differs from the first three sections in that it is not a core part of the AIIMS structure, but rather provides additional support for administrative tasks in the disaster coordination centre, such as documenting all activities in a central operations log.

A key challenge is the level and rollout of ICT solutions to enable the team to effectively share information and to communicate the necessary information to others. This challenge is compounded by the sheer number of different stakeholders involved in disaster coordination, and the heterogeneous ICT systems these organisations already have in place, with which some level of interoperation is desirable. This means that a major feature of Crisis Information Management System (CIMS) is the ability to provide a distributed and seamless service across the range of teams shown in Figure 2.

A key difference with CIMS and current approaches is the focus on distributed information services. A CIMS system should not be a traditional single monolithic system, run by one organization, and requiring all participants to access this one service. This also means that CIMS must interoperate via semantically rich standards and well-known expectations of cooperative functionality.

We are currently developing a framework for CIMS (Iannella *et al*, 2007) that describes the distributed architecture and we have identified these key top-level functional services:

- Incident Management,
- People Management,
- Resource Management,
- Notification Management, and
- Situational Awareness Management.

Our present work has focussed on two of these areas; Notification Management and Resource Management.

EXERCISE USE CASES

We participated in "Exercise Reef Breaker" organised by the Queensland Department of Emergency Services. This four-day event simulated "Cyclone Imogen" heading towards a large regional city with expected damage from storm surge flooding and evacuation of people from many large areas and small towns.

Our observations during these training exercises, which aimed primarily to evaluate DDCC and DDMG operations, highlighted a number of areas in which ICT can play a larger role to improve the effectiveness of communication and information management. We discuss in detail two of these areas: Incident Notification and Resource Messaging.

Incident Notification

All the members of the DDCC/DDMG rely on information to be passed to them to keep them informed of the current status, and to allow them to provide or request information or assistance. This is one of the core aspects of disaster coordination. The predominant means of communicating information in regional exercises are email, fax, radio, and phone. However, email is the most utilised of these, as it is the most pervasive and supports asynchronous communications.

A number of interesting issues arising from the use of email warrant further investigation, namely:

- How do you know the correct recipients of the message,
- How can you deliver the message via other mechanisms,
- What happens if the recipients are not working at the time, and
- What happens if the recipients do not respond?

As part of our demonstrator CIMS, we are developing a notification system that addresses these issues by supporting more flexible routing of information. Unlike email, the system does not require the sender of a message to specify all of the recipients using explicit addressing (although this is still possible). Instead, the system uses a publish/subscribe model which assigns greater control to recipients, who can subscribe to messages that are relevant to their current roles. To support interoperability across the CIMS nodes, messages conform to the Emergency Data eXchange Language (EDXL) Distribution Element standard (OASIS Emergency Management Technical Committee, 2006), which supports message exchange for information systems in the emergency sector. In this standard, the message content is encapsulated within a standard envelope that captures the message metadata, such as the target area for a message (in order to support location-based delivery), information about the sender, keywords describing the message content, and the type and "actionability" of the message (actual, exercise, test, etc.). In the remainder of this section, we illustrate the functionality of the notification system by presenting the prototypical user interfaces we have developed.

Figure 3 shows how a user can describe their profile in terms of three parameters, each one being optional. The first is the type of formal organisational role the user plays, which is chosen from a set of defined terms from the disaster sector. The second is a more general set of disaster-related keywords, again taken from a formal vocabulary. The third is a geo-spatial area, which can either be a named place/region or a set of latitude/longitude coordinates defined by bounding boxes.

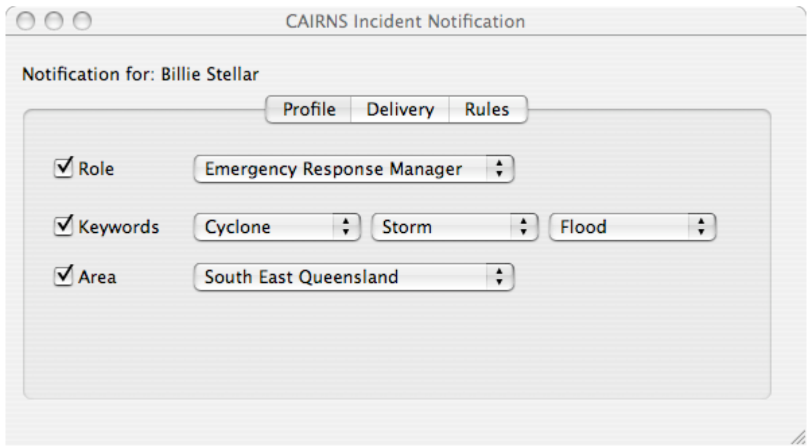

Figure 3. Incident Notification Subscription: Profile

Figure 4 shows how users can define which mechanisms should be used to deliver messages to them. Priorities can be specified, such that lower priority mechanisms are used whenever delivery using the higher priority mechanisms fails. In the figure, the user has indicated a first preference of Web Service delivery (to the given URL endpoint using the SOAP protocol) and a second preference of Email (to the given email address). Also part of the delivery mechanism is a transformation process from the core EDXL format to the format most appropriate for the end delivery system. In some cases, such as EDXL to Email, this is simply a conversion from structured XML to its textual equivalent. In others, such as EDXL to SMS, summarization of the message is required.

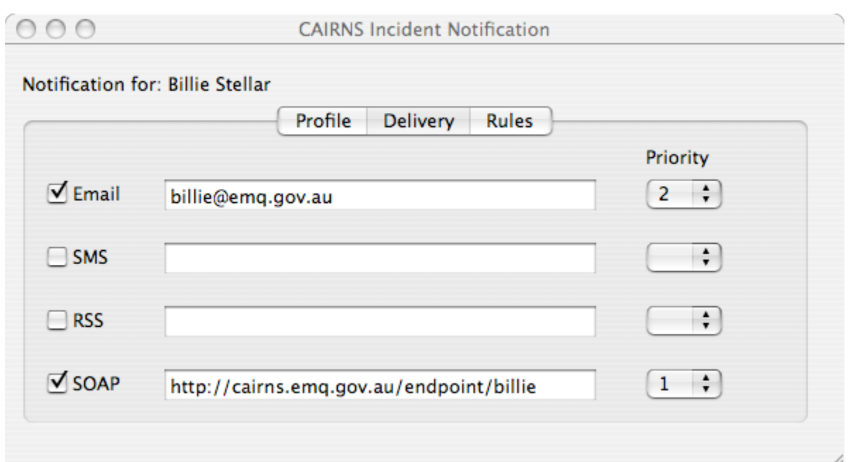

Figure 4. Incident Notification Subscription: Delivery

Figure 5 shows how the user can indicate alternative rules for routing of messages if the user is not available for various reasons. A key aspect of rule processing is the context, as the rules may not apply in all circumstances and the user should not have to re-enter the rules each time the context changes. In this case, the user indicates that the rules apply only during a “disaster” incident. The user also specifies that, between certain times (i.e., work shifts), messages should be redirected to another user. Finally, the user indicates that if there is no response to any messages received by a certain time period, then the messages should be forwarded to another user.

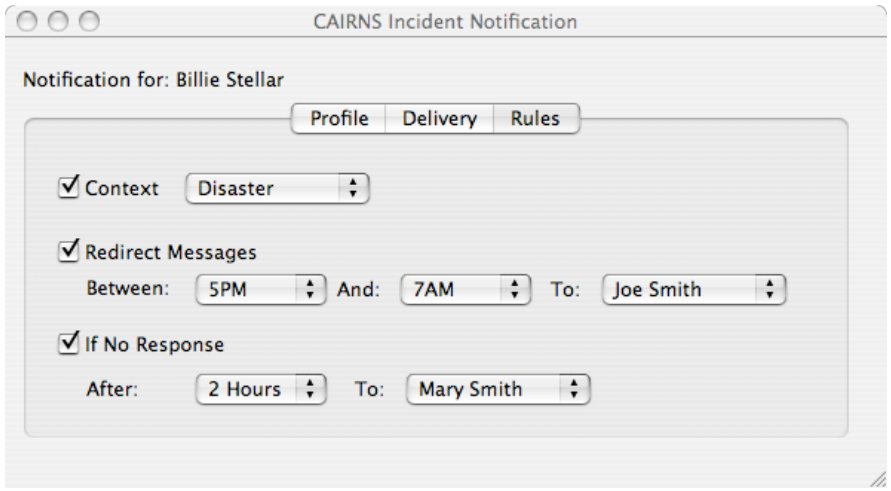

Figure 5. Incident Notification Subscription: Rules

The features described above will improve incident notification for DDCC and DDMG operations significantly. They enable a more managed approach with well-defined roles and rules for the routing and delivery of messages to the right people at the right time. In particular, they provide explicit rules for information management that can be automated by CIMS services, such as routing of messages to the right people in the right area. This cannot be replicated with typical email systems that contain unstructured text as used in emergency management today. The other benefit include less time that emergency team members need to deal with the “administration” of message handling and, hence, more time on responding to the actual incident.

Other related work in this area has approached incident notification from different views, but with the same objectives. Zhu and Zhou (2006) and (Potter *et al*, 2006) describe how to coordinate across “agents”, with support for transferring roles whenever the person responsible for a role becomes unable to fill it. Netten and van Someren (2006) look at machine learning to determine the topics of incident messages that people should be made aware of. These types of approaches can also augment the functions that we are developing in our CIMS.

Other related work has been done in the area of public alert systems. For example, (McGinley *et al*, 2006) trialled a public warning system in which participants (including the public, business owners, media representatives, etc.) could elect to receive public warnings via voice messages, SMS, email, fax and Web pages (or several of these channels). The prototype is now being developed into an operational system called APECS. The system uses the Common Alerting Protocol (CAP) (OASIS Emergency Management Technical Committee, 2005) a standard for emergency alerts and public warnings produced by the same OASIS consortium group responsible for EDXL. Our incident notification system will be similar in some respects, but broader in scope. It will support communications within and between organisations involved in disaster coordination, as well as public warnings.

Resource Messaging

The other main goal of our CIMS is to support the management of resources during disasters. Resource management tasks – i.e., handling resource requests, returns, approvals, notifications, and statuses – are amongst the most crucial and challenging aspects of disaster coordination (Henricksen and Iannella, 2006). Our observations at training exercises suggest that large efficiency gains could be made by automating the information management tasks surrounding resource management. The mechanisms that we observed in use for communication of resource-related information were essentially the same as those for incident notification in general (i.e., email, fax, radio and phone). Again, the predominant mechanism was email. During the exercises, all resource requests were triggered by messages (exercise serials) received by email. An example serial is shown in Figure 6; this requests a tanker of fuel for refilling emergency services vehicles.

The volume of emails exchanged during the exercises was very high, meaning that messages could sometimes be missed. In addition, tracking the progress of a particular issue or request could require searching through a large number of emails (although an effort was also made within the disaster coordination centre to centrally record all requests and actions taken in the operations log – this required manual transcription of the information into a spreadsheet by the administration person). As messages were sent to people's personal email addresses, information about the progress of a particular issue could become unavailable when the shift ended and another person took over their role.

Some emergency information management software already supports basic forms of resource management. For example, WebEOC (Emergency Services integrators, 2007) enables users to track the deployment status of resources, manage and search a resource inventory, and log donations and requests for assistance. However, this software is not scalable (for example, logs are flat structures that become unwieldy for large incidents), it is centralised (a single Web-based system that everybody must log into), and it is not based on open standards that support interoperability. In contrast, our CIMS builds on open standards, allowing for easier integration with other software that is already place, and removing the requirement for all organisations involved in disaster response and recovery activities to adopt the same software.

EXERCISE REEF BREAKER SERIAL

To:	**Townsville-Thuringowa LDMG**
From:	QFRS
Issue:	Time delays being experienced by emergency service crews waiting for fuel at the BP service station due to a large number of community members queuing for fuel supplies.
Request:	25,000 litres of diesel and 10,000 litres of unleaded petrol in a tanker that is equipped to pump fuel into emergency services vehicles directly from the tanker. The tanker would need to be located at Townsville City Council depot for approximately one week depending on fuel requirements.

Figure 6. Email Request for Resources

The standard that underpins the resource management functionality is the EDXL Resource Messaging (EDXL-RM) (OASIS Emergency Management Technical Committee, 2007) standard. We are currently contributing to the development of this standard within the OASIS Emergency Management Technical Committee.

When completed, the standard will provide a set of XML message formats for:

- requesting resources and responding to resource requests;
- requisitioning and committing resources;
- requesting resource information and responding to requests for information;
- offering unsolicited resources;
- releasing resources;
- requesting the return of resources and responding to return requests;
- requesting quotes and responding to requests for quotes;
- requesting and notifying resource deployment statuses; and
- requesting extended use of a resource and responding to extension requests.

The CIMS we are developing will provide a set of user interfaces for composing, sending and receiving resource messages, as well as tracking the status of requests. The EDXL-RM standard provides a mechanism for linking together related resource messages (using message and sequence identifiers) in a more effective way than is currently possible with email. Thus, the software can automatically track and display the progress of each request and group together the thread of messages related to that request. The CIMS also provides flexible routing of resource messages – without the sender always needing to know the most appropriate people or organisations to respond to a given request – using the publish/subscribe notification scheme described in the previous section.

Figure 7 shows a sample user interface for formulating a resource request. The request shown here is based on the email serial from Figure 6. In this case, the recipient of the message is explicitly specified, but in other instances it may not be (instead, routing based on keywords, role or geographical area can be performed as described earlier). A request can contain multiple items (here, a tanker, diesel and unleaded fuel). Each item has a requested quantity, as well as detailed information such as a textual description and special characteristics including credentials and certifications. The detailed information is not visible in the figure, but can be revealed and modified by pressing the "edit" button beside the relevant item. The right hand side shows the requested schedule – that is, requested arrival and return dates and times, and the requested location. Other types of schedule information can also be specified for other message types – for example, the current location of the resource or the date and time a resource will become available.

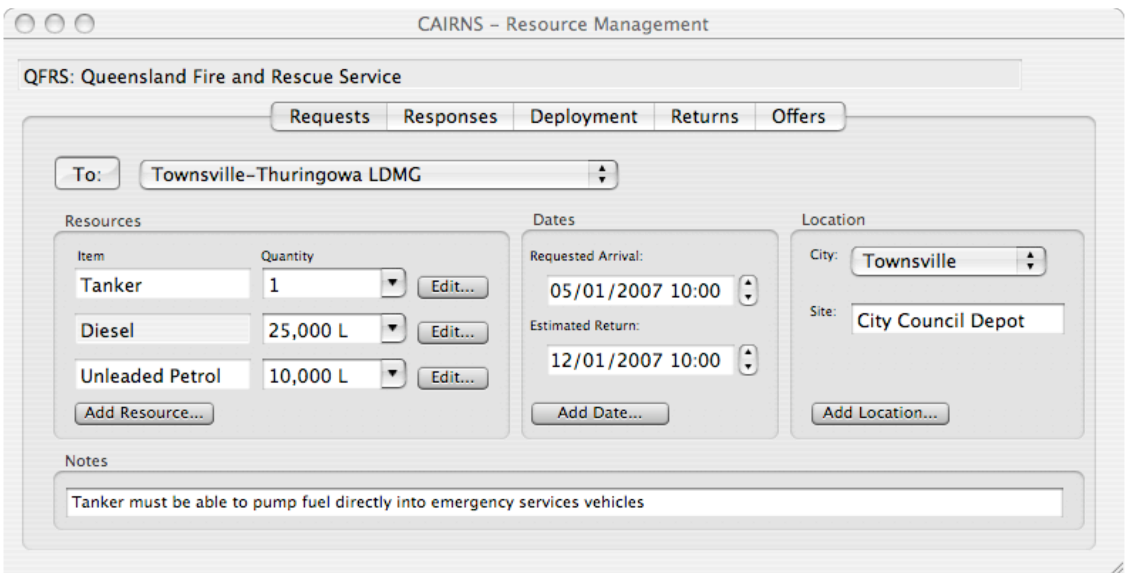

Figure 7. Resource Messaging: Request

Figure 8 shows a high-level view of the resource message routing. In this example, the DDCC generates a resource request, which is transformed into an EDXL-RM "Request Resource" message by the Resource Messaging software, and then passed to the publish/subscribe infrastructure as the payload inside an EDXL Distribution Element (EDXL-DE) message. The EDXL-DE message captures the metadata required for routing the message to its destination(s); as discussed earlier, this metadata may include explicit target addresses, geospatial areas and keywords. In the example, the message is routed to two agencies that may be able to respond to the request. Agency2 responds with a resource offer, which is transmitted back to the DDCC as an EDXL-RM message within an EDXL-DE envelope as before.

EVALUATION AND FUTURE WORK

The CIMS we have described is being developed in response to requirements identified through our observations at cyclone training exercises, and we plan to demonstrate and evaluate the system as part of future exercises. Although the true impact of the system will be felt only when it is deployed for an actual disaster, its use during exercises will still be crucial. Based on the results of evaluations during future exercises, we plan to make refinements to the system, as well as to identify any necessary modifications or extensions of the EDXL Distribution Element and Resource Messaging standards.

We intend to run our CIMS in parallel with existing operations during future exercises, and based on formal user feedback via interviews, and informal feedback we will measure the qualitative success of the experiment. Additionally, we can formulate quantitative measures via tracking the timeliness of incident message handling and resource request and allocation times.

We expect that the impact of the CIMS will be to help simplify the running of future exercises by facilitating information management, making it less likely that information will be lost, and minimising the need for manual tasks such as tracking the status of requests and filing information. The CIMS will also make it easier to capture and analyse information exchanged during the exercises, as message traces can be generated by the publish/subscribe system in a way that it not currently possible with email, fax, phone and radio exchanges. Finally, the use of the CIMS in exercises will allow the disaster coordination centre staff and volunteers to become familiar with the software, facilitating later use of the system in actual disaster situations.

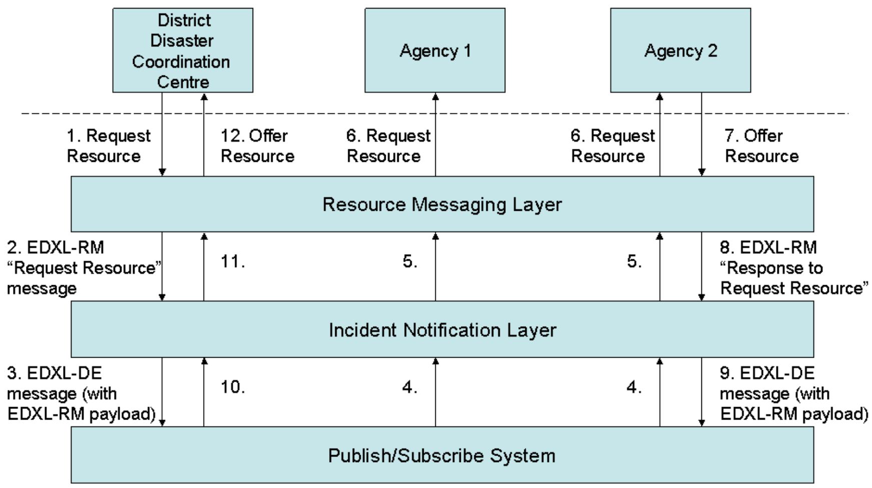

Figure 8. Resource messaging example. Each resource message is routed by the publish/subscribe system in an EDXL Resource Message (EDXL-RM) packaged within the EDXL Distribution Element (EDXL-DE).

Today, many (or all) of the software tools used in disaster coordination centres are those that staff employ on a daily basis, including email, spreadsheet, word processing and database tools. To leverage the clear advantages of familiarity, we plan to explore ways in which the CIMS functionality – for example, the publish/subscribe notification system – can be used by those working in the emergency sector in their daily jobs, to help ensure the uptake and success of the software when a disaster occurs. As another area of future work, we plan to extend the CIMS to provide additional information management functions, such as support for managing and integrating situation reports.

There will also be a number of non-technical challenges to CIMS adoption. In particular, this would be the result of the different cultures of sharing across the agencies involved in emergency response, including cross-jurisdictional politics. One area would be the sharing of terminology across such a wide group of teams and agencies. Technically, mapping via ontologies is possible, but this needs to accepted and driven by the teams themselves. Additionally, the current OASIS standards are not yet fully tested in real incidents, and will need to prove themselves capable of addressing such operational needs.

CONCLUSION

Disaster coordination poses many challenges and opportunities for the ICT sector. We are now seeing more recognition that, to better manage the incident, we need to better manage the information. Crisis Information Management Systems are now the emerging response from the ICT sector to help support the information-rich needs of disaster teams. CIMS need to work within the current IMS frameworks and not challenge the existing working patterns. They need to support interoperability, in order to enable cooperation between a large number of organisations and integration with these organisations' existing ICT systems.

Our current work focuses on two areas that are the foundations of CIMS software: incident notification and resource messaging. We are in the process of developing software that supports these two areas, and have developed sophisticated interfaces and information models to capture the information management needs of these two functions. This work builds on open standards, including the OASIS EDXL Distribution Element and Resource Messaging standards, to promote interoperability. This will help CIMS to support the disaster response effort and meet the needs of the federal, state, district, and local layers in the IMS structures by enabling distributed sharing of information and coordinated resource management. This will be a major step forward in the ICT support for crisis management and move closer towards "delivering the right information to the right people in the right format in the right place at the right time".

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