Exploring Service-Oriented C² Support for Emergency Response for Local Communities

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ABSTRACT

The increased impact of natural disasters and terror attacks on our society has augmented the awareness of needs for advances in emergency response. For local communities it is vital to make use of existing resources. Service-oriented technology provides new possibilities for the enhancement of command and control (C^2) systems. However, to gain full use of the technology, it must harmonize with the supported organizations and their work procedures. This paper explores the possibilities and usefulness of service oriented C^2-systems for emergency response at the local community level. The study was performed in five steps: (1) literature study, (2) interviews, (3) scenario design, (4) prototyping service-oriented C^2 systems, and (5) a scenario based evaluation. The results show that service-oriented C^2 systems would support and enhance emergency response at the local community level. Still, several issues that need to be further considered remain, not the least the ability of quality assurance of services.

Keywords

Scenario-driven evaluation, Service orientation, Emergency Response, C^2 systems

INTRODUCTION

Modern society is increasingly dependent on well-functioning infrastructures and citizens expect that the fundamental public services are constantly available and faultless. Recent catastrophic effects of both man-made and natural disasters have brought an increasing awareness of the needs for advances in emergency response. Crisis responses engage several organizations, where heterogeneous groups of distributed actors need to work together, in an intricate flow of activities that are hard to predict in advance, to overview and coordinate (Shen and Shaw, 2004).

It is difficult to predict the time and the location in which a certain kind of crisis will occur. Therefore, it is not possible to build up a sufficient response from scratch. Neither is it possible to have people, equipment and systems ready only to be used in a situation of emergency. Instead, it is necessary to be able to make use of available resources to handle the situation, sometimes by improvising (Mendonca, Jefferson and Harrald, 2007). Modern technology presents new possibilities for enhancements of command and control systems (C^2 systems) for emergency responses (Landgren, 2007; Jungert, Hallberg and Hunstad, 2005). However, technology will not automatically lead to efficient inter-organisational crisis handling. It must be well designed and adapted to fit the prerequisites of the emergency responders (Wybo and Lonka, 2002).

To support interoperability between organizations and/or technical systems, the concept of *service* has been introduced (McGovern, Ambler, Stevens, Linn, Jo and Sharan, 2003). The concept of service orientation within the context of emergency response is aimed to provide increased flexibility in the allocation and use of resources within and between organizations. The emergency responders can then to a higher degree make use of available resources, normally used for other tasks, to handle the situation. However, to develop satisfactory C^2-system support a thorough understanding of the activities, needs and requirements which the system should support is needed (Wybo and Lonka, 2002). In emergency response this work has often been insufficiently performed with the result that many systems do not meet the needs of their users (Wybo and Lonka, 2002). One way to reduce this risk is to involve the users in the development, so that they can provide feedback on early prototypes (Schuler and Namioka, 1993). The objective of the paper is to explore possibilities and usefulness of a concept for service oriented C^2-systems for emergency response at local community level. This is explored through interviews and a workshop. Within the workshop, the concept was explored by use of a prototype system and a scenario. The prototype represents the usage of service-oriented C^2-systems. The scenario is driving the course of events in which needs

arise to order services to solve different tasks. The study was carried out within the Swedish emergency response system.

BACKGROUND

This section presents the service concept, command and control systems (C^2 systems), service-oriented emergency response, and the study setting.

Service

Within the area of software engineering the concept of Service Oriented Architectures (SOA) gained increased popularity in recent years. SOA defines service as "a unit of work done by a service provider to achieve desired end-results for a service consumer" (He, 2003). In this study, a definition based on the SOA service concept is applied, but generalized to cover all types of systems including organizational and not only software. Further, services are seen as the interface between the producer and the consumer. Thereby, it becomes an abstraction of how producers can create value for consumers without specifying how the service is realized. Services can be implemented manually, technically or as a combination thereof. Further, the roles of providers and consumer can be played by humans or machines. Services are described independently of how they are implemented. Each realization of a service has specific properties, which the consumers can use to choose the most suitable realization. Services can be *elementary services* produced by a single unit or *composite services* conducted by several services (Benatallah, Sheng, and Dumas, 2003).

Service-oriented emergency response

The service-oriented emergency response concept is based on the principle that organizations, units and technical systems provide information and capabilities as services that other organizations, units and technical systems can make use of. Thereby, it is possible to exchange information, to make use of resources and to combine those to handle different situations. Hence, commanders are provided the possibility to rapidly retrieve information and make use of existing capabilities, even though those resources may belong to another organization. The service-oriented emergency response concept embraces, thereby, inter-organizational collaboration.

The concept of service-oriented emergency response presumes that organizations and autonomous systems are connected to a common information infrastructure, which functions as a virtual market-place for the exchange of capabilities and information as *services*. Organizations that ought to participate are such as officially established emergency call centers, emergency service providers and operators, voluntary organizations, authorities, and scientific expert organizations relevant to the emergency response field. Commercial and voluntary actors can offer services via the network, without necessarily having the right to make use of other services provided. The adoption of the service-oriented concept would not enforce any new nor restrict any existing organizational structures or work procedures. On the contrary, it allows for high flexibility on how to organize and carry out emergency response. From a technical aspect, the envisioned concept can be based on current web-based technologies. Further, emergency response organizations will be able to connect their own systems, via an interface, to the network and seek out relevant services. These connecting emergency response systems can be anything from a browser to an advanced decision-support system or autonomous systems integrated to provide services, e.g., cameras for traffic surveillance and systems for weather forecasts.

Emergency response and C^2 systems

Extensive emergency response is a complex activity, involving coordination of activities performed by several actors with different education and expertise, from different organizations with different work cultures, and using diverse technical systems. Further, actions must be taken and resources used in the right sequence so that the outcomes of actions can be used by other resources to perform their future actions (Shen and Shaw, 2004). To have shared situational awareness is essential for efficient emergency response, e.g., to be able to make the correct decisions about possible alternative actions. Situational awareness includes organizational awareness, which refers to understanding of the available resources and how they can be used to handle the emergency (Oomes, 2004). A lack of organizational awareness results in inefficient emergency response, so that the correct resources may not be used, or that the necessary actions are not performed because it is not known what resources are available. Thereby, the development of sufficient C^2-systems for emergency response is complex and difficult.

In general, C^2 system refers to the equipment, facilities and personnel including the commanders require for effectively commanding and controlling the management of handling the crisis situation. In this paper, however, C^2 system refers to the technical part, i.e. the information systems support. Well developed technical support for C^2-systems need to:

- support inter-organizational collaboration and the coordination of the responders' activities,
- meet the requirements of communication, exchange of information and use of resources outside the own organization,
- not only be used during crisis situations but on a regular basis since managers and responders need to be familiar with the C^2 systems,
- be adoptable so that they can be adjusted to unexpected situations (Levchuk, Yu, Levchuk, and Pattipati, 2004).

In the workshop, the two first requirements where focused upon and evaluated.

Study settings

The core of the Swedish emergency response model is the existing resources in the everyday business of the involved organizations, which can be complemented with supplementary resources when necessary. It is stated by Swedish law that emergencies should be handled at the lowest possible level of the social structure. Thus, the local authorities obtain a key role. If needed, it is possible to complement the local resources with the capabilities available at the regional and/or national level. In Sweden, there are six main actors active at the local level; (1) The Municipality Administrative Office (MAO), (2) The County Administrative Board (CAB), (3) The County Council/Medical Service, (4) The Police Force, (5) The Fire Department, and (6) SOS Alarm. SOS Alarm is responsible for handling emergency calls and coordinating ambulance transportations. It is a public service enterprise that is owned by the government, the county councils and the municipalities. The MAO is obligated by two compulsory responsibilities at the local level. The responsibility of *operations* implies that authorities and organizations are forced to maintain their regular activities even during emergencies. The responsibility of *area* implies responsibility for coordination of emergency response in the local area, concerning preparation as well as operation. The CAB gives support to the local authorities when handling emergencies and is responsible at the regional level. Moreover, the CAB should work for collaboration to the greatest extent possible. The County Council is obliged to maintain preparedness for disaster medicine and traumatology. There is always a person on duty, responsible for coordinating the medical resources at both the local and regional level. The Police Force investigates all emergency calls the Fire Departments are responding to as to determine whether they have any criminal causes. The Fire Department is responsible for prevention, limitation and handling of accidents affecting humans, property or the environment irrespective of cause.

METHOD AND MATERIALS

This study was performed in five steps (1) a literature study, (2) interviews with emergency response representatives, (3) design of a local crisis scenario, (4) design of a prototype that support service-oriented C^2 systems for emergency response, and (5) a scenario based evaluation of the concept.

The literature study included the structure of the emergency response system in Sweden and the assignments of different crisis organizations. The study focused on the six main crisis organizations and the documents available on emergency response management at each organization. The literature study was followed by study visits at the six organizations (about half a day at each organization) and by one and a half hour semi-structured interviews with representatives from each organization. Notes were taken down both at the study visits and the interviews and the interviews were further tape recorded. Three researchers participated in the collection and analysis of data. Based on the merged results from the literature study, study visits and the interviews the researchers identified examples of services that could be of use in local emergency response. From the services, a preliminary model for service-oriented emergency response was developed. To explore the service-oriented C^2 systems for emergency response a scenario and a prototype in HTML were developed.

The scenario was created to lead a crisis situation story in which the emergency actors were supposed to make use of different services to perform their tasks. Thereafter, a prototype was developed to illustrate how these services were used. Both the prototype and the scenario should be seen as examples of how the concept can be applied in local emergency response, rather than covering all services possible as related to emergency management.

A one day workshop was finally performed, in which the services were validated. In the workshop, five representatives from five of the six main local emergency response organizations participated[1]. During the workshop, the three researchers presented the scenario to the representatives who continuously had the possibility to comment on the scenario and the use of services. Their comments were collected by note taking and tape recording and subsequently analyzed by the researchers together.

Scenario

The scenario takes place in a middle size Swedish community (about 150000 inhabitants) in 2009. The stores are open until 8 pm and the Christmas shopping is intense. A truck with propane is heading south on the highway but overturns. A bus with 25 passengers run into the truck and an additional 10 cars are involved in a multiple collision. Propane leaks out on the drive lane and starts boiling. The scenario thereafter describes how the engaged organizations handle the situation through collaboration by ordering services from each other and other resources available within the community.

Within the county, a service-oriented information infrastructure is available, where actors can both offer and order services. By use of specific services it is possible to set up a common distribute staff team with representatives from the engaged organizations. The staff team is responsible for the coordination of tasks and resources among the different organizations. To support their work the staff team has access to technical C^2 systems support with unlimited functionality regarding communication and information exchange. Moreover, there exists a function that selects, analyzes and aggregates information received or collected to an operational picture.

Prototype

Prototypes can be used to present how a technical system can appear/work. Prototypes highlight and demonstrate specific properties of systems where more in-depth knowledge is needed. Moreover, prototypes provide the means for evaluating solutions (Houde and Hill, 1997). In specific, they provide hands-on-experience, which makes it easier for the users to take an active part in the design of the system. Further, prototypes enable the evaluation of several different design options (Jacobson, Christerson, Jonsson and Övergaard, 1992).

The prototype developed to support the scenario during the workshop was strictly service oriented, i.e., all user interactions involved the use of services. The use of a service was performed in the following; (1) the operator selected the service to use, (2) provided the requested input, and (3) submitted the service request. The implementation was made in HTML and executed in a standard web browser. All the service examples that had been identified from the data collection were implemented in the prototype. Below, examples of services are presented.

- *Activate emergency team.* Result: an emergency team is put together and sent to the location given.
- *Activate operational picture function.* Result: a group or a system that selects, analyzes and aggregate received or collected information to an operational picture is activated.
- *Activate staff team.* Result: affected persons are called to form a staff team for the crisis. A mandatory receipt from the responders is possible.
- *Activate virtual staff room.* Result: a virtual staff room is set up with suitable characteristics. Depending on the characteristics of the crisis, specific persons are sent invitations to join.
- *Order mobile disaster medical care.* Result: accessible mobile disaster medical care is identified and the units best suited are allocated for future use.
- *Guarding.* Result: A given area/object is guarded during a given period of time.
- *Inventory and reservation of medical care assets.* Result: accessible assets, physicians, nurses, beds, medical equipment etc, are reserved at specified organizations.
- *Communicate information.* Result: a text message is sent to a mobile phone, computer, or mini call. Receipt on reception is optional.
- *Identification of vehicle and cargo.* Result: information about a specific vehicle and its cargo.
- *Collection of incident related information.* Result: information regarding an incident in a specified area.

[1] The representatives from the Police Department was unable to participate

- *Collection of information regarding an object.* Result: access to information.
- *Position of mobile phone.* Result: the geographic position and/or directions are provided.
- *Route plan.* Result: the best alternative transport routes are presented.
- *Patient transportation.* Result: transportation of patients from the specified location to another.
- *Send sms warning.* Result: sends a sms message to all mobile phones within the specified area.
- *Control of traffic signals.* Result: possibility to control the traffic lights of traffic junctions or routes.
- *Establish a roadblock.* Result: a roadblock is established at the specified location.

RESULTS

In general, the workshop participants strongly approved of the service-oriented concept. In particular, they recognized that an increased exchange of computerized information can meet current problems caused by that the organizations use different terms with slightly different meanings. It is vital that participating organizations obtain the same perception of a situation, based on the description of this situation. The participants thus stated that a common terminology is of importance for the description of services. The terminology bridge between organizations is thereby essential to consider during the development of technology for inter-organizational crisis management.

It was agreed among the participants that the current collaboration between the operative units in the field works well. However, as soon as the headquarters are involved it becomes more difficult. The engaged organizations' headquarters do not have sufficient communication with each other. This means that they lack a shared operational picture and thereby also lack the common situational awareness which the participants stated were so important. Today, each organizations' headquarter create their own operational picture based on information from their own units in the field. This information is influenced by the scope of the organization activities and often varies from the information communicated in other organizations. There is an embryo to distributed collaboration between the tactical headquarters today; where the communication is performed via e-mail and phone. A more extensive support such as a common virtual headquarter with communication and information exchange features, including text, sound, and pictures, as presented in the prototype and scenario, was seen as interesting. For instance, photos from the scene of the incident will be useful for the healthcare unit in judging what kind of injuries to expect and hence to be better prepared. Such photos might be available at an early stage within some of the other organizations. In general, access to a common service-oriented information database will enhance information availability.

The participants expressed a concern for the sharing of information, i.e., they thought that it will be hard to judge the trustworthiness of information. It was seen as necessary to be able to estimate the quality of information but also of services in general, i.e., to know about flaws and shortcomings. This, since the information should be able to be used as basis for critical decisions that can have far-reaching consequences. Further, it is also important to be sure of that used services provide the expected result. Hence, it was stated that some sort of quality assurance mechanism of information and services is needed. This was found especially important since according to the service concept it is not necessarily known who the producer of the service is. The choice of services can solely be based on the descriptive information presented for each service.

In case of emergencies, each organization has its own internal chain of preparatory activities that need to be executed. The representatives stated that it is important that they are provided with information that something has happened as soon as possible. This implies the need for alarm functions but also for a function to be able to roll-back those alarms that after a while show to not be as serious as first was presumed. Further, it is essential that the communication between the organizations helps to reduce the spreading of contradictory information that can lead to rumours. Shared services for communication with the media and the public were asked for as were services to be able to inform the other engaged organizations of what information has been given to the public. The participants also asked for a function for communication with relatives, for instance a common phone number to which relatives with questions can turn to. This function can be fed with information from all involved organizations. Further, the participants stated the importance of being aware of that certain information is missing, since this makes it possible to focus on other issues until sufficient information is available. Hence, they stated the need for a function for informing each other that about the lack of information.

An important feature of service-oriented C^2 systems is the ability to strengthen the organizations with external resources. For instance, each hospital currently has its own system to provide information on available beds, which cannot communicate with other similar systems. Instead the regional healthcare management calls each hospital to

obtain the information. The representatives for the regional healthcare stated that it would be preferable with a single system that could provide this information for all the hospitals. However, even within the healthcare organizations themselves, difficulties with unambiguous usage of terms exist. An example is the term "available bed". For some organizations a bed is marked as occupied for a whole day even though it in practise is used only part of the day. Meanwhile other organizations update the status of beds two times a day. Moreover, a common C^2 system to handle resources is also needed to overview, e.g. medical equipment, if there is a need to move some of the medical treatment to the scene of the incident. This need for exchange of information and resources is acknowledged by the participants but has not been thought of as requiring a service. However, according to the definition used here, it is a typical service. In the study, the need is represented by the service "Inventory and reservation of medical care assets".

The fire brigades use several different types of external resources and information. Many of those are found via the Swedish Rescue Service Agency and the yellow pages, but also via several other sources such as public authorities like the local building committee. More and more of this information will be available online and a support to find the information would be useful.

The participants finally experienced that their organizations to a large extent already work and think in terms of services even though they do not use the term service. This indicates that service-oriented C^2 systems have potential to support emergency response as it is currently performed within local communities, and also that service orientation of C^2 systems, enhancing interoperability between engaged organizations and actors, would solve some of the existing needs of support.

DISCUSSION

The use of the concept of service is gaining ground in several areas. In software engineering, it has become a way to attain interoperability and, thereby, achieve reusability and make complex system less complex by modularity. In service-oriented crisis management, interoperability is also desirable but more to obtain adaptability to the situation and to increase the ability to work together, exchange information and make use of existing resources, including those not primarily intended for emergency response. To build service-oriented C^2 systems is technically feasible. However, to gain full potential out of such systems they must harmonize with how the management within emergency response is performed.

During the workshop it become evident that service-oriented C^2 systems will reflect and support the way that emergency responders work and would like to work a local community level. None of the service presented were stated to be inadequate, meanwhile several additional services were asked for. For instance, the healthcare representative stated a major need for support to find and allocate hospital beds, health care providers and medical equipment.

The participants at the workshop expressed a fear that the use of different terminologies in the organizations may be hinder to the concept. This issue must be further considered, especially if information shall be exchanged more freely among the organizations. Since development of common terminologies has been shown so difficult, it is possibly a better approach to make use of ontologies to bridge one terminology into another automatically (Namyoun, Il-Yeol and Hyoil, 2006).

By providing an interface, e.g. services, it is possible to integrate different systems into one. For instance, the fire brigades currently have several systems to search for resources, e.g. a national database, the yellow pages, own maintained databases, and paper based systems. Regarding resource allocation, the main advantages of a service-oriented C^2-systems are that (1) the resources will be found within one of the systems integrated in the C^2-system, (2) it is the producer of service that makes their services available to the systems, not organizations/authorities that are responsible to keep a resource database updated, and (3) it is possible to directly request the resources and information via the system. The system automatically finds those suitable resources that are available and there is, thus, no risk of wasting time needing to turn to different persons or function to find the proper resources.

A consideration raised during the workshop was that whether it should be possible to request services without knowing the identity of the producer, e.g. if a system should automatically select the producer of the requested service that best fits the needs of the consumer. A difficulty regarding this is the act on public procurement that the authorities have to take into account and the liability to pay compensation that follows with responsibility. This might imply that the producer of a service must be known and be certified. Further, if the source of information and

resources is not known this has consequences for quality assurance of the resources and the information. Hence, some features that facilitate the evaluation of the quality of the services must be added to the system.

Service-orientation enhances the possibility to exchange information and, thereby, enhances more integrated collaboration. A need stated at the workshop concerned the headquarters. In the scenario a virtual staff room was presented to support an integrated, but in the same time distributed management of the emergency response. In the virtual staff room the shared operational picture is a core component; but also features for, e.g., text, audio and video links for communication and possibilities for information exchange is vital. At the core of the idea with the virtual staff room is to support close collaboration while the participants physically remain in their own organization. The benefit of this way of working is for the organizations to have closeness to their own resources and direct access to their own support systems, and not have to work in an unfamiliar environment. However, to get a virtual staff room for distributed command and control to work requires that the commanders regularly meet physically and practice in the virtual environment.

To have a shared situational awareness is vital in emergency response. This shared awareness is based on a shared operational picture. A service introduced during the workshop was the *Activate operational picture function.* This service purpose was to collect and aggregate information about the situation to an operational picture, which the emergency organizations could use. In the scenario, it was not stated how this service was realized and which organization that should have the responsibility for the operational picture. Comments on this service was that it would be highly appreciated, but in the same time implementing it may result in political difficulties since none of the participating organizations is in charge over the others. The natural choice may have been SOS Alarm since they are the one that receives the alarm calls and, thereby, in the early critical stage posses the information about the situation. However, a severity is that SOS alarm is a commercial organization, which means that such new tasks must be purchased. Still, the outcome of the workshop point at there is a major need to obtain a shared operational picture between the headquarters.

Furthermore, who should have access to what services in the system, including different levels of secrecy? Likewise, who should be able to offer services in the system? Here, the aspects of authorization and access control for both intra- and inter-organizational perspectives are important. Also, who will decide what services will be accessible in the system? These questions are essential in relation to quality assurance which is an important aspect, not the least to differentiate the system from the Internet.

For the commanders, the possibility to combine different services to obtain a new service provides higher levels of flexibility, adaptability and re-usability. As was confirmed in the workshop, the service-orientation provides a support to work with emergency response that is wanted, even thought the concept of service not has been used. Hence, well designed service oriented C^2 systems can enhance emergency response at local community levels, increase the possibility to work more integrated and to make use of resources already existing in the society.

FUTURE WORK

In the ensuing work, a more solid needs analysis will take place. In this study, examples of services were directly identified from the data in order to illustrate the concept. In the needs analysis, needs will first be established, prioritized and then transformed into corresponding services. Based on this, the prototype will be further developed into a demonstrator where a sub-set of the highest prioritized needs/services will be implemented. The demonstrator will be tested, used and evaluated by the local municipalities in the county of Östergötland, Sweden. The demonstrator will also be demonstrated for the Swedish Emergency Management Agency (KBM) and for the Swedish security industry, in order to pave the way for the realization of future products.

In Sweden, there is currently work taking place at national level to identify service-based models for crisis management organizations and authorities. The work is initiated and lead by the Swedish Emergency Management Agency (KBM). The idea is that the organizations shall describe themselves in terms of service providers and present their services. Also private entrepreneurs are encouraged to describe and provide commercial services to be used in a crisis situation. In this manner, the Swedish emergency response model is already starting to incorporate aspects of service-orientation, thereby paving the way for organizational implementation of the concept. Again, the idea is not to build up anything from scratch or add extra work to the organizations, but rather to use existing resources in innovative and sometimes improvised ways. Thus, the possibility of the concept to be accepted by and integrated in the Swedish emergency organizations is enhanced.

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