# Systematic First Response Use Case Evaluation

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***Abstract*—Efficient communication architectures are vital for handling larger scale disaster management, and existing communication mechanisms have several shortcomings due to the heterogeneity of the first response groups. In this paper, we present requirements leading to FRCS, a sandbox environment for simulating all kinds of communication approaches in a first response scenario. Through extensive telephone interviews and from existing reports, we have identified several use cases which a first response system must be able to handle. Only by combining both, a unified infrastructure scenario and standardized use cases, becomes a fair evaluation of different kinds of first response solutions possible.**

## I. Introduction

Efficient communication architectures are vital for handling larger scale disaster management, and existing communication mechanisms have several shortcomings due to the heterogeneity of the first response groups. The need for reliable first response communications was one of the findings of the 9/11 attack on the Pentagon: [1] *"In the first few hours, foot messengers at times proved to be the most reliable means of communicating."* In this paper we present the requirements leading us to develop a first response communication sandbox, which is intended to simulate the situation after the existing communication infrastructure has been heavily damaged. Besides the massive overload in case of a disaster, interoperability between rescue groups is nearly impossible due to different radio frequencies and communication protocols [2]. In order to get realistic requirements and address the needs of first response helpers, we analyzed findings of disaster reports and interviewed first response helpers. This paper is organized as follows. Section II presents actual use cases which our infrastructure should be able to handle. In section III we present our evaluation methodology. Section IV discusses related work and section V concludes the paper.

## II. Identified Use Cases

We now present the basic requirements and use cases for a first response communication system. Both the requirements and use cases system from the results presented in the literature [3] [4] as well as extensive telephone interviews we conducted with professionals working on first response. Our First Response Communication Sandbox (FRCS) [5] is intended for simulating distributed rescue communication. The first response team on-site needs needs a reliable group communication system for establishing communication which supports the organizational hierarchy [6]. On-site communications refer to the communication needs of the first response team. They take place mainly over wireless links and between small handheld devices carried by the personnel. In addition, there could be some servers handling other tasks. Our goal is to augment or replace foot messengers with a distributed communication system. Based on extensive telephone interviews, we have identified several use cases which our system would need to address. These are listed in table I. We also provide an example for each use case. The use case *Broadcast/Multicast* is necessary for sending important messages to a group of users. The challenge for broadcasting information is to reach every node regardless of its current position and its connection point. The use case *Shift Change* occurs regularly if one rescue team needs rest and their roles are taken over by another team. The communication system needs to ensure that roles, open tasks, and solved issues are seamlessly picked up by the new team. In the use case *Locality Awareness*, a digitally marked spot is visible to all members of the network. If another team approaches e.g. a bridge it will be notified before it attempts to cross the bridge. The *Resource Awareness* use case ensures the optimal utilization of the available hardware. Communication is heavily influenced by heterogeneous hardware with dynamic fluctuation of resources. The area which a first response team is able to observe visually is limited. Use case *Active Search* covers the need to search for people based on their roles, distinct persons, or digitally marked tools. *Hierarchy Maintenance* is crucial to the success of first response. Strict hierarchical decision making and reporting has become the standard organization for disaster management. Nevertheless, loose cross-organizational communication can be established using P2P communication all the while maintaining the strict intra-organizational hierarchy.

## III. Use Case Evaluation Methodology

A communication system for on-site communications for first response has a relatively small amount of users, on the order of a few hundreds or a couple of thousand at most. Furthermore, we expect the churn to remain at moderate levels for most of the nodes. Evaluation of a first response solution needs to cover both, the actual performance of typical use cases needed in catastrophic situations and a unified disaster scenario in order to create comparable results. In order to get a fair reliability comparison of the different use cases, we introduce a metric for each use case. The metric is completely independent from the chosen communication technology and software.

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| Name | Description | Example |
|---|---|---|
| Broadcast/Multicast | Messages need to be sent to groups of peers, optionally with acknowledgment. | Operation Control sends evacuation message to first response team |
| Shift Change | Immediate churn occurs, due to massive logins of new shift and leaving peers of old shift | Firefighter team A needs to rest and responsibility is taken over by firefighter Team B |
| Locality Awareness | Mobile user enters a certain area and is automatically receiving location aware news | A medic is walking toward a building and receives a warning not to enter the building |
| Resource Awareness | Additional hardware is provided, the network adapts to the new resources and optimally utilizes the additional hardware | Operation control provides additional hardware, the network restructures itself using the new hardware for stabilizing the overlay |
| Active Search | Search for an object, optionally within location range | A first response team is searching for an available medic nearby |
| Hierarchy Maintenance | In all catastrophic scenarios there is a strict organization hierarchy for all helpers. | A new team at the site it is immediately assigned to a supervisor and is able to receive orders |

TABLE I
USE CASE TABLE

| Name | Evaluation Criterion | Formal Description |
|---|---|---|
| Broadcast/Multicast | Average success rate | $\frac{1}{n}\sum_{i=1}^{n} b_i * p_i$, b=1 if peer $p_i$ received broadcast, otherwise 0 |
| Shift Change | Average recovery time for shift changes. | $\frac{1}{n}\sum_{i=1}^{n} r_i * p_i$, r=peer recovery time |
| Locality Awareness | How long does it take until a first response helper receives new information for his area | $\frac{1}{n}\sum_{i=1}^{n} l_i * p_i$, l=delay between event and notification |
| Resource Awareness | Relative resource utilization ratio of mobile peers | $\frac{\sum_{i=1}^{n} m_i * u_i * p_i}{\sum_{i=1}^{n} u_i * p_i}$, m=1 if peer is mobile, otherwise 0, u=resource utilization |
| Active Search | Success rate of search | $\frac{1}{n}\sum_{i=1}^{n} s_i * p_i$, s=1 if searching was successful, 0 otherwise. |
| Hierarchy Maintenance | Average restructuration time | $\frac{1}{n}\sum_{i=1}^{n} h_i * p_i$, h=delay of peer integration |

TABLE II
USE CASE VERIFICATION TABLE

Table II shows the basic evaluation methodology for each use case. Nevertheless, a comparison is only possible with a "standardized" disaster scenario. Otherwise the results would vary depending on the number of communication devices, network coverage, movement speed, ressources of the devices, etc. In order to overcome these numerous configuration discrepancies, we propose a standardized scenario setup description [5]. The combination of the proposed use cases and the standardized scenario setup simplifies comparison between different first response communication approaches. We defined both a set of necessary use cases and a scenario description for first response situations. With both requirements met, a fair comparison of first response solutions is possible. We have strong confidence in our use case definitions, though we did not succeed in defining an agreed standardized disaster situation for evaluating first response communication approaches. Nevertheless standardized evaluation scenarios are likely to evolve, and with our proposed scenario description, this process can be accelerated.

## IV. Related Work

A P2P requirement analysis is done by University of Virginia [3], they identified three main issues in current first response approaches and developed a prototype for a P2P based first response solution. Nevertheless their approach focuses mainly on usability for the first response team, while our contribution sets the base for a fair comparison. Further implementation of their P2P solution [3] is done using hypercast, GPS capabilities, multicast streaming video and access control mechanism. Nevertheless the goal was to develop a prototype, large scale simulations were not conducted.

## V. Conclusion

Working communications are extremely important in disaster management and first response scenarios. The heterogeneity of devices means traditional communication systems have to overcome several hurdles to be effective. In this paper, we outline the main requirements of a communication system for first response scenarios. These requirements are based on reports and extensive telephone interviews with rescue professionals. We then designed FRCS in order to evaluate proposed solutions and create new approaches for tackling communication in first response situations. Both pieces, the collected use cases combined with the FRCS puts us in position to evaluate and compare different disaster management solutions under exactly the same laboratory conditions.

## References


[1] Prepared by Titan Systems Corporation, "Arlington county after-action report on the response to the september 11 terrorist attack on the pentagon," 2002.

[2] Art Botterell and Ronja Addams-Moring, "Public warning in the networked age: open standards to the rescue?," *Commun. ACM*, vol. 50, no. 3, pp. 59–60, 2007.

[3] A.S. Bahora et al., "Integrated peer-to-peer applications for advanced emergency response systems. part i+ii. concept of operations," in *SIEDS, 2003 IEEE*, 24-25 April 2003, pp. 255–260.

[4] J. Rosen et al., "The future of command and control for disaster response," *Engineering in Medicine and Biology Magazine, IEEE*, vol. 21, no. 5, pp. 56–68, Sept.-Oct. 2002.

[5] D. Bradler, J. Kangasharju, and M. Muehlhaeuser, "First response communication sandbox," *in submission*, 2007.

[6] B.S. Manoj and Alexandra Hubenko Baker, "Communication challenges in emergency response," *Communications of the ACM*, vol. 50, no. 3, pp. 51–53, 2007.