Key challenges in multi-agency collaboration during large-scale emergency management

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Abstract. This paper reports the results of a workshop studying the challenges of collaboration during emergency response in Norway. The findings from the workshop reveal three categories of challenges linked to collaboration both within and across emergency agencies: (1) communicating within and across emergency agencies, (2) establishing and maintaining shared situation awareness, and (3) inter-organizational understanding. Underlying barriers hindering efficient collaboration are identified for each of the three categories. Against this backdrop, the paper discuss opportunities for ambient intelligence technology that can help mitigate the identified challenges.

Keywords. Emergency management, collaboration, ambient intelligence

1 Introduction

In large-scale emergency management, an activity characterized by constantly changing task demands [6, 9], collaboration within and between emergency response agencies is essential. Unfortunately, such collaboration is difficult because of not only the complexity of the incident, but the diverse composition of people and agencies working together, all of whom possess different skills, procedures, knowledge, and competencies. As a result, almost without exception, reports and reflections after disasters express concerns over the emergency agencies' abilities to collaborate. A recent example of this can be found in the concluding report on the terror attack in Norway on June 22, 2011, stating that the various emergency agencies (fire, police, health) were unable to effectively communicate and coordinate their effort [8].

In this paper, we report on a workshop that focused on the challenges of collaboration between and within emergency agencies during incidents in Norway. The workshop was attended by first responders in Norwegian emergency agencies, giving them a chance to provide a bottom-up perspective and practitioner's viewpoint on collaborative challenges. The workshop was conducted as part of the FP7 BRIDGE research project, a 4-year project aiming to develop technology that improves collaboration during emergency response [2].

2 Method

The workshop was one step in the human-centered design approach we are following, the goal of which is to ensure that the design and development of an interactive system takes the needs of its users into account [7]. It was intended to address the common difficulty in that approach of involving domain experts in the innovation process, whether the early phases of context research and idea generation or the later phases of development, refinement, and implementation [4].

In this study, domain experts from emergency agencies were recruited from the Norwegian fire, police, and health services. In total, 10 such experts participated, each having several years of experience in on-site emergency response. Those 10 were divided into 3 groups consisting of at least one member of each agency. Each group was coordinated by a 'facilitator', whose main responsibility was to assign exercises, clarify any methodological issues, and keep on schedule.

During the workshop, the groups were asked several trigger questions about current work practices during emergencies. Two questions were considered to be the most important and were therefore posed to all three groups: (1) How do you set up the emergency organizations on-site, and which roles and responsibilities can be identified? (2) How do you obtain an understanding of the unfolding emergency situation, and how do you maintain such an understanding? The remaining questions were distributed among the groups and addressed communication issues, the decision making process, resource management, risk analysis, and interaction with bystanders, media, and experts.

We used affinity diagramming [5] to form the experts' discussion points into ad-hoc hierarchical groupings of structures and themes, the goal being to highlight relationships between various issues that fell under the topics discussed [1]. The method was enhanced by letting each participant use colored sticky notes indicating their agency (police, fire, and health), as well as two colors to indicate specific information needs and specific challenges. Fig. 1 shows an example of the arrangement of sticky notes. Colour scheme: red = fire, green = health, blue = police, yellow = information need, orange = challenge.

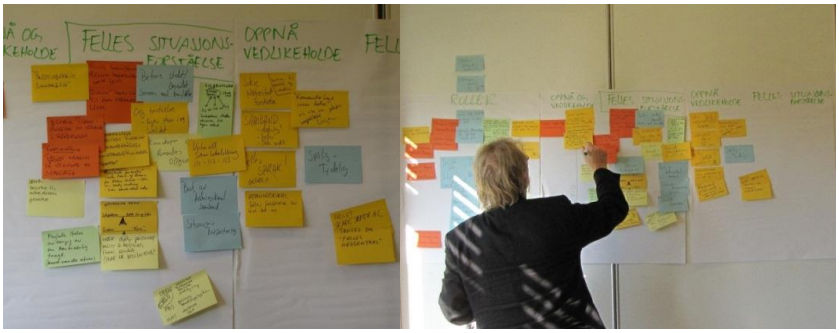

Fig. 1. Domain analysis using sticky notes and affinity diagramming

The workshop followed a common procedure in each group: (1) Facilitator presents trigger question; (2) participants write their responses on sticky notes; (3) iterative posting/diagramming of individual contributions in a shared physical space; and (4) continuous discussion and consolidation of content in relation to other contributions. Group discussions were documented using audio and video recording, and a 'secretary' supported the data collection process by taking notes and pictures. Each group thus produced data in the form of (1) a set of affinity diagrams (one for each trigger question asked within each group) made up of sticky notes describing tasks, challenges, and information needs connected to each given trigger question, and (2) audiovisual recordings of the discussions that took place during the diagramming process.

The collected data was analyzed in four steps. In the first step, the sticky notes were counted, translated, and cataloged using an Excel spreadsheet. Sticky notes that were difficult to decipher were either rejected or (when possible) verified through audio and/or video recordings. Second, any listed tasks and challenges in the diagrams were categorized into respective groups. Third, tasks were further categorized according to which agency they belonged to, and each challenge note was supplemented with an interpretation of it. When necessary, those interpretations were derived from audio and/or video recordings from the diagramming process. Finally, we subjectively categorized the resulting set of challenges, extracting those important to collaboration during emergency response and, within that subset, deriving groups of challenges based on shared themes.

3 Findings

The workshop revealed a wide variety of tasks and challenges that emergency responders face during crisis incidents. It also shed light on challenges related to other aspects of emergency response, such as lack of resources, time-criticality, and hazardous environments. However, in this paper, we have chosen to disregard the latter types of challenges and focus solely on those related to collaboration within and across emergency agencies.

In sum, over 200 sticky notes describing tasks and challenges in emergency response were collected. Of those notes, 87 described challenges linked to emergency response, and of those, 33 described challenges related to collaboration. Additional details can be found in Table 1.

The analysis of the material revealed three overall categories of collaboration challenges: (1) communicating within and across agencies, (2) establishing and maintaining shared situation awareness, and (3) understanding organizational structures. In the remainder of this section, we describe each of these categories in detail, and the barriers in each category that hinder efficient collaboration during emergency response.

Note type	Group 1	Group 2	Group 3	Total (relevant)
Police tasks	35	12	20	67
Fire service tasks	35	8	18	61
Health service tasks	19	5	19	43
Challenges	29	20	38	87(33)

Table 1. Overview of collected sticky notes

3.1 Communicating within and across agencies

Based on the results from the workshop, it is often a great challenge for emergency responders to achieve efficient communication both within and across agencies. Out of the 33 relevant sticky notes, 15 notes described challenges linked to communication. Participants reported that it is generally difficult to exchange information between emergency agencies (particularly with agency representatives at the operative level), and to establish an efficient flow of communication between field personnel.

According to the participants, one main barrier hindering efficient communication is the radio network, because of a lack of radio capacity and other technical problems. During large-scale incidents, emergency agencies make use of a shared radio channel (called the rescue channel) for interagency communication. However, due to the substantial amount of coordination that is required during such incidents (particularly in the initial phase), and the fact that only one user may use the channel at a time, it is often difficult for users to get through with their message.

A second barrier for achieving efficient communication is the common lack of knowledge in how the rescue channel should be used. For example, as explained by one participant, some agencies use the rescue channel for communicating within the agency, even though all agencies have their own dedicated channels for such purposes. The resulting increase in radio traffic can hinder actual *inter*agency messages from getting through

A third barrier for achieving efficient communication is the lack of a common language and terminology across emergency agencies. The Norwegian emergency agencies not only use different terms, they also assign different meanings to the same terms. For example, one participant described a situation where the police requested an ambulance to pick up a patient with life-threatening injuries, describing the situation as urgent. In the terminology of the ambulance personnel, however, *urgent* is not considered to be life-threatening (they use the term *acute* for this purpose), causing them to misunderstand the severity of the situation.

3.2 Establishing and maintaining shared situational awareness

The workshop participants revealed that it is challenging to establish and maintain shared situation awareness among the agencies and actors participating in an emergency effort. Out of the 33 sticky notes analyzed, seven highlighted general difficulties in establishing situation awareness across involved actors, particularly between the three emergency services (police, fire, and health).

Seemingly, the main barrier hindering shared situation awareness is the lack of a common platform for sharing information across agencies. As expressed by one participant, emergency agencies do not have any audiovisual support tools available, and the only means for sharing information across agencies in current practice is through verbal communication, preferably face to face. In addition, there is a lack of resource overview and management (an important component of situation awareness), because devices for sharing information about the position and status of resources are not used in the field.

Other barriers highlighted by participants include information overload, prioritization of information, and obtaining the right information at the right time. Emergency situations develop and change over time, demanding continuous monitoring from emergency response personnel to maintain an up-to-date overview of the situation. One participant explained that getting the right information is an ongoing challenge throughout all phases of an incident, because that information will generally not be available immediately.

3.3 Organizational understanding

The results from the workshop also indicate that emergency agencies sometimes lack a sufficient understanding of the responsibilities, needs, plans, and tactics of their own and other participating agencies, which can have a negative impact on collaboration. Out of 33 sticky notes describing challenges related to collaboration, 11 concerned organizational understanding.

One of the barriers to organizational understanding is the lack of knowledge about one's own as well as others' responsibilities during an emergency situation, which can complicate the coordination of an incident. As an example, one participant stated that the Incident Commander often functions more as a police officer than as a commander for all agencies (which he/she is supposed to be), leading to an inefficient coordination effort focused on police operations.

Another relevant barrier is the lack of understanding of other agencies' needs during an emergency effort. Each of the three emergency agency functions as a separate organization with specific tasks and responsibilities, and participants expressed that the three often have different opinions regarding how a situation should be resolved. Despite that, efficient emergency management and collaboration requires the leaders of those agencies to have a shared understanding of what the other agencies need in order to do their job.

A third barrier related to organizational understanding is the lack of congruent planning and common tactics across agencies. In today's practice, emergency agencies

have different sets of plans for how to manage a given incident scenario, and unfortunately, those plans do not match each other. That can negatively affect the development of strategies and tactics, resulting in time loss and misunderstandings during an emergency situation.

4 Discussion

Efficient collaboration during emergency response in large-scale incidents requires a clear understanding of roles, responsibilities, and tasks among the involved actors; simple sharing of relevant information; and a common and shared understanding of the situation at hand. In this section, we discuss opportunities for technology that can help mitigate the challenges of collaboration during emergency response.

4.1 Mitigating communication challenges between and within agencies

The challenges described in Section 3 indicate a clear need for better technology to support intra- and inter-agency communication during emergency response. One approach could be to supplement verbal communication with electronic messaging tools. Those would have the potential to reduce not only the need for verbal communication, but also the risk of information overload, because a message would be directed only to the person or persons the user specifies rather than blasted to everyone.

Another, more advanced option is to use artificially intelligent tools (e.g., software agents) to automatically handle parts of the coordination required during an emergency situation. For example, wearable sensors and smart devices could collect information about the status and environmental conditions of field responders and then send that information on to software agents. The agents could then compare that information to the parameters of different tasks that agency leaders are trying to coordinate, highlighting those personnel and teams best-suited to a given task.

Along the lines of the latter option, the Resource Manager, currently under development in the BRIDGE project, aims to support automatic allocation of personnel and equipment during large-scale incidents. Based on the position, capabilities, environment, and status of available resources, the Resource Manager will be capable of determining which resources are best-suited to handle a given task. The selected resources (or the personnel in charge of them) will then be notified of the assignment automatically on a handheld device, which they must confirm or decline. Notifications of confirmation or decline are sent back to the commander who issued the request.

Finally, one of the key challenges in communicating during emergency management is that the network capacity is limited and easily overwhelmed. That is a crucial resource for sharing information between emergency personnel. To reduce the need for high-bandwidth networks, the amount of information that responders must transmit should be reduced. That could be done by moving processing power out to the sensors, letting them do the main analyses and transmitting just the results. That will also reduce the need for bandwidth so that potentially also the TETRA-based com-

munication infrastructure used in several European countries could be used to exchange the most critical information when necessary

4.2 Mitigating the challenges of shared situation awareness

The lack of a shared situation awareness is inherently linked with the lack of efficient communication during emergency response, and hence could also benefit from the technical solutions described in Section 4.1. Still, there is always a limitation with respect to how much information one person has time to communicate to another. To bridge that problem, we see an opportunity for the use of sensors, smart devices, and intelligent agents that unobtrusively collect relevant data and broadcast it to a central repository, where it is accessible by those in need of that information. A concept currently under development in the BRIDGE project, called the *Master*, aims to realize that idea by providing a common operational picture that supports the three levels of situational awareness proposed by Endsley [3]: (1) "Perception of the elements in the environment"; (2) "comprehension of the current situation"; and (3) "projection of future status". To achieve an up-to-date operational picture, the Master draws information from sensors and smart devices that track the position and status of resources, victims, and triaged patients. The operational picture can be accessed on any kind of device (e.g. pc, surface tables, tablets, mobile phones), and allows each user to filter out the information he/she needs. Unlike other available software with similar capabilities, the Master enables sharing of information across all involved parties, making heavy use of sensors that are deployed directly in the field or attached to the equipment and clothing of emergency response personnel and victims.

4.3 Mitigating the challenges of organizational understanding

In contrast to the challenges addressed in Section 4.1 and 4.2, the challenges of organizational understanding are not necessarily solvable by new and better technology. Instead, we see a clear need for better training and education, giving the first responders a clear understanding of the responsibilities, tasks, and roles of not only their own agency, but of all the three main emergency agencies.

5 Conclusion

The results of this workshop revealed three key challenges in emergency response that, at least in Norway, create problems for multi-agency collaboration: (1) efficient communication between participating actors, (2) establishing and maintaining a shared situation awareness, and (3) achieving organizational understanding. The first and second challenges both deal with information exchange in different ways, raising the likelihood that advancements in ambient intelligence can mitigate them – in particular, the interplay between wearable sensors and smart devices and intelligent software agents. The third is more of an educational issue, however, and not easily addressed through ambient intelligence technologies.

Acknowledgements. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n°261817, the BRIDGE project (www.bridgeproject.eu) within the Security Programme SEC-2010.4.2-1: Interoperability of data, systems, tools and equipment. We also owe our gratitude to the participants that took part in the workshop. Without them, the research reported in this paper would have been impossible.

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