

Ad-hoc Community Composition of Rescue Forces in Action Situations

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Abstract: Secure energy and transport networks, Internet and telecommunications, are vital nerves of our highly networked society. Global mobility makes it difficult to combat and natural disasters and technological accidents can cause serious damage in a closer-knit world. In this paper we introduce the challenges in dynamic community composition of heterogeneous rescue forces (culture clash) for rescue and protection tasks and discuss our approach in the context of the "SpeedUp project" how to present a solution for ad-hoc communication, situation-aware representation, tracking and guiding in dynamic inhomogeneous communities.

1 Motivation

Mostly unexpected events like natural causes or major loss are challenges for rescue forces. Within shortest time rescue teams of different public authorities need to sum up the situation, recover injured persons and attend to them, safe the spot, secure evidence, and much more. Rescue forces account for a subset of such tasks and work task-driven according to their organizational structures. Thus typically police, fire service, emergency medical service, and other authorities have separated areas of operation and different objectives. However an interaction and cooperation between forces is important to ensure a fast response to a rescue mission.

According to their tasks every rescue force has a specialized information demand. While fire workers need to know critical places on site and their team leader monitor vital functions, police officers want to gather IDs of involved persons and register any kind of potential evidence for further investigations. Each rescue force can be seen as a community which needs its information to coordinate actions. Information sources and the flow of information is different and depends for instance on type of information, type of situation (context of rescue mission), and organizational structures. In advance official instructions try to define regulations for information needs, flows, and organizational buildups. However every situation has its own instance and specialty. In addition the practical im-

plementation of instructions is often slightly different (and often has a local interpretation too). Generally interfaces to other forces are not defined. In part this leads to repeated information gathering. Information sharing between communities would be preferable since one could see the different rescue forces as a community as a whole.

The first information on a critical event which requires rescue response is typically given via an emergency call. This is an incoming call at an emergency control center¹ providing the service to inform rescue forces depending on the type of event. The received information and potentially further relevant information (e. g. access ways) will be overhanded to the rescue forces. The communication is done using radio. The control center receives status information on rescue forces (e. g. arrived at spot). Quickly the first arrived team sums up the situation and decides whether additional support is necessary or not. The control center is a kind of back office which will care for further resources (e. g. additional man power, tools, special information, food) needed by teams on the spot. Partly needed information is acquired by rescue forces itself. Collected data on site are tried to be gathered at a (local) central point. This is typically done with paper and pencil and blueprints. In an emergency case of a larger scale information is lost, late, incomplete, wrong, or even duplicated and, therefore, may prevent efficient rescue missions.

2 Challenges of IT Support

One consequence which can be drawn from the introducing section is apparent: The field of rescue needs support. Modern IT technology may help if applied in a meaningful way. Investigations of the European Security Research and Innovation Forum (ESRIF) have defined European Research and Security needs in its final report[Eur09]. The working group on crisis management has outlined core challenges, e. g. strengthening response forces, situation awareness and decision making, cooperation, managing resources, and recovery logistics. Information and information flows, communication support, simulation, and training are some of the research and innovation needs. However improvements are partly hard to achieve. Complex aspects need to be taken into account for the implementation of a system and its establishment, e. g.:

- constraints of typical missions,
- clear goals of technology application,
- different organizational structures,
- technological base,
- readiness of use by rescue forces,
- handling, ergonomic aspects

For an identification of effective IT support an extensive analysis of the rescue organizations (static, cultural aspects) and typical processes in rescue including communication is essential. Rescue workers of different organizations cooperating in missions are in the

¹In Germany we have control centers operated by police, by fire service, by medical service or combined versions.

focus of the collaborative project SpeedUp² [Spe10] which has started with such an analysis. SpeedUp seeks for an community focused IT solution by supporting organizational structures and needs as well as improving communication within and between organizations. Rescue workers will be supported in providing better information and, thereby, in coordinating missions more efficient. Figure 1 points out the interplay of organizations, information, and IT with main challenges.

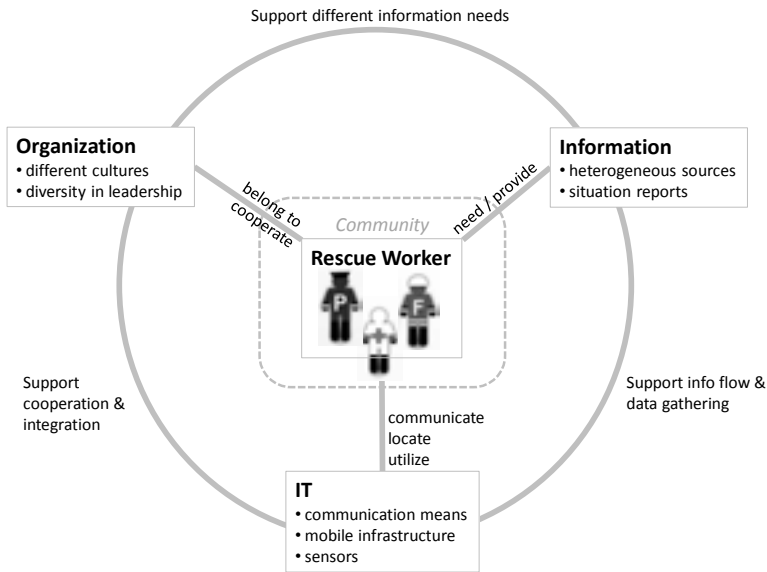


Figure 1: Interplay of organizations, information, IT and challenges with the focus on rescue workers

The main question which rises on the technological level is: How can we move toward a solution which supports various requirements resulting from this interesting application domain and its constraints? The paper outlines relevant fields of research and technology which may lead to an promising architecture if combined meaningful. In SpeedUp some of the ideas will be evaluated and integrated in an suitable framework.

3 The Information Building

Rescue forces have a strong need for any kind of information related to mission in progress. Similar to communities information will be communicate to co-workers. We would like to propose an information building which enables fast information flows, filtering of relevant

²SpeedUp is funded within the Federal Government's program "Research for Civil Security" [Fed10] (call "Rescue and protection of people") by the Federal Ministry of Education and Research (duration: 1 May 2009 - 30 April 2012)

information, and automated information transmissions. Figure 2 presents an overview of related technological fields to cover several informational needs of rescue forces.

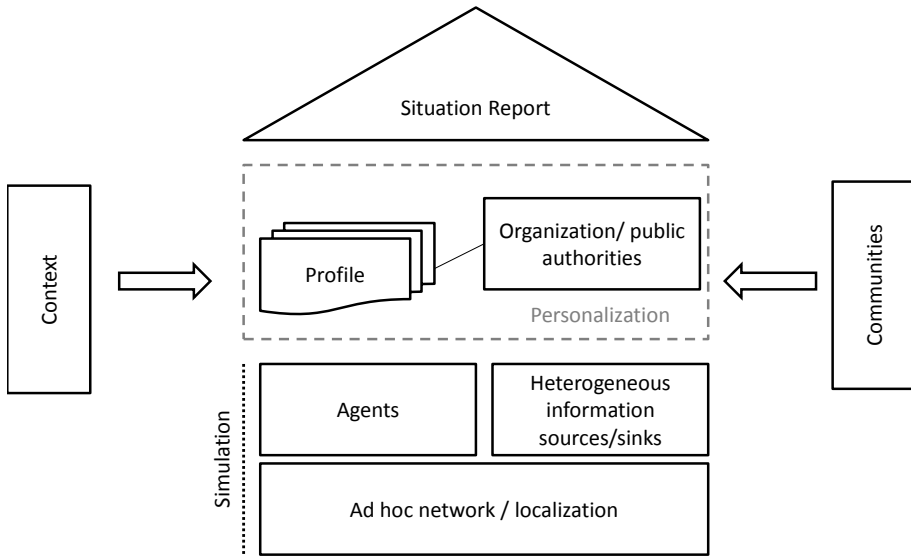


Figure 2: The information building: A technological landscape

As a prerequisite for an information flow a technical infrastructure has to be available or established. For the transmission of information devices need to be networked using ad hoc networks or if available public infrastructures like cellular networks. Localization of rescue forces and geotagged data is very helpful for further processing. A sophisticated transport of data and information as well as an seamless integration of data resources via standard interfaces is essential to cover a flexible usage of the whole system. The application of mobile software agents is promising therefore. This opens also the chance to establish a simulation system on basis of software agents for training purposes. The information flow will be accompanied by agents with the goal to deliver data to organizations and rescue workers with different roles. Which information is delivered and accessible for organization and rescue workers is guided by policies and profiles. Information needs are different for involved organization: they are task (context) and role dependent. The knowledge which is gathered during a mission should be shared by the community of rescue workers mostly independent of their organizations. This information building shows technical solution fields which will be examined in more detail toward a precise supporting solution.

3.1 Localization of Objects

Any rescue activity is usually map-driven. Therefore, it is essential to be informed about the current position of any interesting object. Objects are persons, materials and environments, where persons are rescue teams and victims (injured persons); materials are rescue vehicles and equipments; and environments describe to given local situation. Any of this objects can be associated with geo-coordinates within a certain area.

3.1.1 Network Support for Localization

There are typically four types of networks which can be primary or secondary used for localization of objects:

- the Global Positioning Satellite Network (GPS),
- the permanent mobile phone network (GSM/GPRS/UMTS),
- the special rescue forces digital network (TETRA)³,
- permanent and ad-hoc meshed wireless networks (WLAN/Bluetooth).

All of these networks can be extended by additional base stations on demand with local resources, mounted on vehicles to support two goals: extend the communication capacity and increase the accuracy of localization. To incorporate different localization technologies the exact position (geo-coordinates) of any type of base station is required. Furthermore, special rescue communication devices, called multi-functional devices with multiple communication interfaces devices can act as mediator. For example, the exact position of such a movable device is found by GPS, while it acts as WLAN base station too.

3.1.2 Accuracy of Localization

GPS provides a localization accuracy of about 5 m, GSM using triangulation of about 50 m assuming multiple cells are receivable. Both holds for outdoor localization. GPS is not available in most indoor cases. However, active and passive repeaters might help slightly in rooms with non-metallic covered windows. Risky buildings with fixed and dense WLAN infrastructures could be modeled in advance for exact positioning. Ekahau systems reach accuracies down to 1 m there. Installed Bluetooth tags can enrich this as they operate in the same radio frequency band as WLAN. The following chapter will introduce, how ad-hoc mobile networks can overcome at least some issues.

Areas can be marked as dangerous by modeling polygons. As soon as an unauthorized rescue person is about entering such an area an alarm on the multi-functional device is generated or a special communication channel is established. The entire scenario should be given such a polygon as border to detect new incoming our leaving outgoing resources.

³The new federal German communication network of "Behörden und Organisationen mit Sicherheitsaufgaben".

3.1.3 Tagging

As the number of multi-functional devices is limited, permanent tags - applicable indoor and outdoor are introduced and attached to any interesting (semi) static object in the rescue scenario. There are two types: passive and active tags. Passive tags might be simple 2D-barcodes as self-adhesive labels, scanable by the camera of the multi-functional device. The tags are attached manually to objects by rescue workers, scanned at the moment of attachment and stored with its unique ID and geo-coordinates in the central database of the coordination team. Although QR-codes are currently the most spreaded barcode labels, ZigBee codes are recommended, as they have the charm to combine machine and man readable parts within one label. To omit the time consuming photo process, RFIDs in combination with visible tags are recommended. If static, later on such tags can be used as reference points. [ELAS09]

Active tags are either long range interactive RFIDs or Bluetooth tags. In contrast to the passive tags there is no need for active scan as they are recognized automatically by multi-functional devices from a certain distance. The interaction can be controlled by shaking or turning the device in a defined pattern.

3.2 Mobile Assistants

The combination of personal mobile devices and wireless ad-hoc networks allows the concept of mobile emergency ad-hoc information system, consisting of a highly dynamic, decentralized and self-organizing network of autonomous and mobile devices that interact as peers. Each mobile device represents one or more rescue units using information, feeding data or being a peer. According the rescue task such a mobile ad-hoc network must be self-organizing to be a benefit for rescue and protecting people. Thus, researchers and developers have to deal with a new set of problems peculiar of these systems, due to user and device mobility, variable bandwidth, transient loss of connectivity and no centralized structures. It is evident that, for these classes of systems, applications cannot be designed according to the conventional architectural paradigms.

Based on an emergency call rescue forces move out. The received information and potentially further relevant information like access ways will be overhanded by the emergency control center using radio. Arrived on site the first rescue team tries to get a situation report for starting rescue operations. In contrast to an individual case of an emergency the first team is exposed to a situation of radical change by making the critical decisions with far-reaching consequences. Proceeding as an individual case of an emergency rescue operations may fail to tactical procedures at the expense of human life. So the first rescue team plays a decisive role for the entire occurrence. In the first instance they have to supervise and arrange. Afterward they can save human life. Otherwise, the order is missed and there is no on-site management organization. This and the overall chaos will make future rescue operations difficult or impossible. [PMU01] Situation reports therefore have great importance. According them emergency forces initiate rescue activities immediately. Situation reports are continuously issued by on-site management. Started by the first rescue

team these reports are overhanded to the next levels of on-site management organization. Thus, we have a highly dynamic situation and management. Moreover, gathering all relevant situation data is done by radio or in a paper driven process. Disappearing of data is unavoidable. On-site command control assistants try to manage paper and information flooding. Heading this way first integration of mobile IT in Germany demonstrates significant advantages. So rescue units have identified that they could save radio effort, obtain clean data sets and keep calm. But mobile IT is a mixed blessing. Using mobile technology device mobility denotes wireless networks and no centralized structures. Furthermore, integrated rescue mobile technology requires easy to use and self-organizing structures. On site there is no time for (re)configuration or management of connectivity.

According common rescue operations let us assume we have command control assistants in software form supporting connectivity management, configuration and self-organizing IT structures. Software command control assistants mean a multiplication of command control assistants able to organize network, command and information structures. Erfurth et al. [EKR⁺08] present mobile assistants as one way to support networked worlds. In understanding of Erfurth et al. mobile assistants are similar to (mobile) agents. Therefore, a mobile agent is a special kind of software which can execute autonomously. [BR05] Once dispatched, it can hop from peer to peer performing data processing autonomously, while software can typically only execute when being called upon by other routines. Therefore, it seems to be that mobile agents are meant for supporting rescue forces in autonomous self-organizing networks. Self-organizing networks mean ad-hoc networks ready to use for rescue units at all times. Specifically for the rescue operations we need mobile ad-hoc networks (MANET). But rescue units pay no attention to organization and communication within the network. This part is done by mobile agents. So we call such a mobile agent mobile ad-hoc network 2MANET.

3.2.1 Mobile Agent Mobile Ad-hoc Networks

In general, mobile ad-hoc networks (MANET) are communication networks built up of a collection of mobile devices which can communicate with each other via wireless connections. [BSF08, SGF02] Peers can join or leave at any time. Routing is the task of directing data from a source peer to a given destination. Based on no fixed infrastructure all peers are equal and there is no centralized control or overview. So the routing task is quite hard in mobile ad-hoc networks. Peers serve as routers for each other, and data packets are forwarded from peer to peer in a multi-hop fashion. Due to the mobility of mobile peers and the lack of centralized structures, routing algorithms should be robust and adaptive working in decentralized and self-organizing way. [QW01, CDG05]

The new challenges include:

- the variety of communication channels;
- the communication bandwidth per channel is quite different;
- the communication bandwidth for wireless network is much lower;
- the environment is more unreliable, causing unreliable network connection and increasing the likelihood of input data to be in faulty; and

- fixed routing is impossible.

Many MANET routing algorithms have been proposed. In the literature, the classical distinction is between table-driven and demand-driven algorithms. Table-driven algorithms, such as DSDV, are purely proactive: all nodes try to maintain routes to all other nodes at all times. This means that they need to keep track of all topology changes, which can be difficult if there are a lot of nodes or if they are very mobile. Demand-driven algorithms, such as AODV, are purely reactive: nodes only gather routing information when a data session to a new destination starts, or when a route which is in use fails. Reactive algorithms are in general more scalable since they reduce routing overhead, but they can suffer from oscillations in performance because they are never prepared for disruptive events. In practice, many algorithms are hybrid (e.g. ZRP), using both proactive and reactive components.

The advantage of this kind of network is, that it does not require or even need any kind of infrastructure, like a base station in a cellular network. Therefore ad hoc networks are best suited for an environment, which is not able to provide any kind of infrastructure like for disaster recovery.

In traditional distributed networks, data are collected by source peers, and then transmitted to a higher-level processing peers which performs data fusion. During this process, large amount of data are moved around the network, as is the typical scenario in the client/server paradigm. [TZA03]

By transmitting the computation engine instead of data, in our understanding mobile agents as a special kind of software which can execute autonomously, the new formed Mobile Agent Mobile Ad-hoc Network (2MANET) offers the following important benefits:

- Network bandwidth requirement is reduced. Instead of passing large amount of raw data over the network through several round trips, only the agent with small size is sent. This is especially important for real-time applications and where the communication is through low-bandwidth wireless connections.
- Stability. Mobile agents can be sent when the network connection is alive and return results when the connection is re-established. Therefore, the performance of 2MANET is not much affected by the reliability of the network.

In our research we pursue a two way strategy. In the field we are dealing with mobile devices be part of the rescue operations. In contrast most of the time we only carry out experiments under lab conditions. Research under rescue conditions in action seems too great a risk for rescue forces in workaday life therefore we use exercises of precautionary measures in the field. Figure 3 presents a snap-shot of 2MANET rescue scenario in an exhibition hall. Each spot symbolizes one rescue staff member in action and the way covering his distance as light gray line. Other colors are indicated as follows: Red colored spot means the starting point for data. The destination is marked by green spot. Blue colored spots are whistle stops attended on the way.

The data way or the way of an agent depends on the environment availability (communication channels, communication bandwidth, peer reliability, services, etc.) per peer part



Figure 3: Mobile Agent Mobile Ad-hoc Network simulation

of that highly dynamic network occurrence (in contrast a MANET is ad-hoc network in a fixed configuration). As preliminary research result we combine conventional methods of MANET hybrid routing policies, time-based memory of whistle stops, cloning strategies and decision making on peer site. This complex process is done within each agents supported by peer services. [DCG] It is the way to achieve emergency force demands of ad-hoc community composition. Depending on chronological situation on site data are information addressed to different emergency units in variable transmission. So figure 3 presents three heterogeneous communities (in the area of D03, E07 and E02) composed by firefighter, rescue service and police force. Based on the situation they are interested in differend information maybe regulated by law. Therefore, we form a metalevel as an ad-hoc community upon on site heterogenous forces. An ad-hoc community composition of rescue forces defines a situation driven need for information regulated by operation and/or by act of law.

3.3 Personalization

In our rescue force scenario, understanding the situation is a key priority for rescuers. Communication between actors is important for coordinating actions in place.

A lot of information is collected via radio communication or telephone and is written down on sheets of paper. Information can get lost, written down twice or inconsistently, and sometimes come to late to the people who urgently need this information. Besides, a huge

amount of information is collected, e.g. in the control, and rescuers face an information overflow and have to figure out relevant information.

Our research therefore focuses on new ways of offering information to the rescue force members. The rapidly increasing amount of data available needs accurate compilation depending on local workflows and the individual needs of a rescuer. Giving all information to all rescuers in an emergency situation will not be appropriate for huge amounts of data. The information should be offered according to the current place of the rescuer and near real-time. Furthermore, it is important to consider the rights of involved rescuers to receive certain information. E.g., policemen are allowed to get statistical information about the number of persons injured, but no details about concrete injuries of a certain person. Organizational aspects also play an important role in information allocation and filtering. Members within the same rescue force on different organizational levels, and members of different rescue forces have different information needs, goals and tasks to perform according to their location.

Therefore, legal, organizational and situation dependent rules have to be defined to make sure that the right information comes to the right people. A personalization of information is important. In contrast to customization, where users specify their preferences manually, automatic personalization means automatic adaptation according to user profiles. Personalization is a data-intensive process and is based on the characteristics of the user (user data, usage data) and the user's context in which he/she is located or a certain action is performed. In our context, several types of personalization can be applied: personalization of content, structure or modality (Fig. 4).

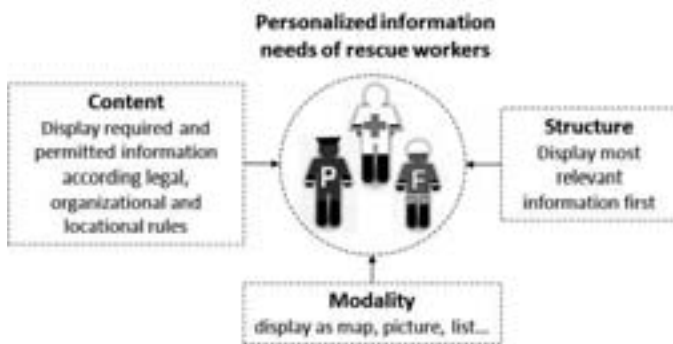


Figure 4: Different forms of personalization

Personalization of content means the automatic tailoring of information according to users' profiles, that include needs or level of expertise. Relevant information can be retrieved and the content can be selected according to the special location or context of activities that have to be performed at a given point of time. [MC00] If all information would be recorded electronically via a central database, it could be distributed with the help of a personalized approach. In our scenario, e.g. special alarm words can be used to assign information to a certain person (like information including the word injured people should first go to

emergency medical service units). Another possibility is a semi-automatic personalization approach, where people writing down their information electronically decide via click for which group of people this information should be relevant. People that receive this information can mark information that is unimportant for them, so the system can learn from user's needs and can better decide about relevant information for a specific user.

Personalizing the structure of an application refers to altering the location of content including text, images or links. This helps to identify important information, but can also facilitate a personalized navigation. [SC02] In rescue situations, relevant information have to be easy to identify. Therefore, information relevant to the exact place of the rescuer, and among these the most urgently things to be done should be displayed at first sight.

The personalization of modality enables changes from text to other types of media to present to the user. [ABD⁺04] These could be images, videos, maps or audio, if they are available in the system. The selection of the modality can be done according to the kind of content, or the user characteristics. For quick decision making in rescue situations, maps to visualize places of injured people is easier and quicker to understand as a long textual description.

4 Conclusion

In our paper, we introduced relevant fields for an ad-hoc community composition of rescue forces. For implementing an overall system, we have to consider the complex application domain. The understanding of processes and organizational cultures of different rescue forces defines the basis for an successful IT support. In this context, the SpeedUp project tries to integrate the users to evaluate relevant technologies and their possible implementation in rescue scenarios.

Due to different organizational structures of rescue forces and federalism in Germany, the requirements for an overall system are quite diverse. Therefore we need flexible technologies to support a lot of scenarios - starting from small action situations to major incidents. Our paper discusses a first approach to combine relevant technologies and research paradigms on different levels to outline an overall system.

In order to introduce such a system, rescue workers have to become familiar with the handling. Therefore, it is essential to simulate different rescue scenarios in a training phase. Our approach allows authentic training using the same system by simulating an infrastructure and scenarios with the help of mobile software agents. Scenarios can be displayed several times so that rescue workers can learn from different decision situations. With this focus the proposed system is promising to achieve acceptance of rescue forces.

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