A general system architecture and design for the coordination of volunteers for agile disaster response

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ABSTRACT

In the recent decade the evolvement and widespread success of new technologies in particular in the field of computing power, network bandwidth, mobile networks and wearable devices have prepared the foundation for completely new approaches in crisis management. Currently, we are at the edge that such new technologies for crisis management are becoming a real and practically applicable option, e.g. in the field of alerting, crowdsourcing, and crowdtasking. In parallel, we witness in the recent years that citizens are more and more willing to help during crisis and disasters, thus providing a large – yet unused – potential for agile support in disaster preparation and response. In many disaster situations the emergency personnel reach the limits of their capabilities. In particular during the isolation phase the support of such volunteers can be a valuable benefit for disaster response. With the help of new technologies crisis management can provide current on-site information via mobile devices in real time as well as organize and coordinate the activities of the volunteers at specific locations. In this paper we present the results of the research project ENSURE: a general architecture and a system design for the coordination of spontaneous volunteers for agile disaster response. With the expected broader implementation of such systems in disaster management in the future it is inevitable to elaborate such common technological foundations for practical mass applications.

Keywords

Crisis and disaster management, Response, Alerting, Crowdsourcing, Crowdtasking, Volunteer system, Architecture, System design, System test

1 INTRODUCTION

In classical crisis and disaster management the role of volunteers is mainly limited to the work of volunteer organizations or to the appointment of citizens to support authorities and response forces in cases of large scale disasters. The increasing occurrence of so-called unbound volunteers in recent disaster cases, such as during the flooding at the river of Elbe is currently a major challenge for official disaster response forces but bears at the same time a wide opportunity to massively potentiate certain disaster response actions. In recent years, more and more citizens spontaneously offer impromptu aid when the emergency personnel cannot respond immediately

(Schweer et al., 2014). The challenge is that such unbound volunteers are currently not coordinated and aligned with the strategy and actions of the official response forces. This missing coordination can lead to frustration among the volunteers (Kircher, 2014), may even result in unintentional damages (Schorr et al., 2014) or even to the aggravation of disaster situations e.g., when the volunteers actions contradict with actions of response forces, or when volunteers put their lives or of others in danger. On the other hand, in many disaster situations the emergency personnel reach the limits of their capabilities and in particular during the isolation phase when the response forces have not reached the area of impact yet the support of such volunteers can be a valuable benefit for disaster response. Professional crisis management must be able to integrate and coordinate volunteers in order to benefit from their support and avoid damage and confusion due to poor coordination. Furthermore, it can provide the necessary flexibility for agile crisis and disaster management by overcoming the problem of (re-)allocating response forces in time at upcoming hotspots by using volunteers that are already there.

At the same time the necessary development and widespread availability of new technologies in the field of computing power, ubiquitous connectivity, mobile devices and applications provide today a practically applicable basis for supporting such complex coordination tasks. The wide adoption of mobile devices (smartphones, tablets etc. with the capability of geo-location) and the spread of the Web 2.0 philosophy on the web and in the general public created suitable conditions for establishing the idea of the necessary new approaches in a wide range of application scenarios successfully. These interactive, collaborative, and mobile approaches can help to effectively involve spontaneous unbound volunteers in disaster management in case of an emergency (Reuter et al., 2012). In the field of early warning and alerting the use of mobile infrastructure has become a key technology for effective alerting in particular for individual information needs and response capabilities (Meissen and Fuchs-Kittowski, 2014). Web 2.0 has created concepts of participation, such as crowdsourcing (Howe, 2006), which have facilitated the engagement of volunteers and which have successfully been used in crisis management (Kaufhold and Reuter, 2014; Schimak et al., 2015). In addition, the widespread use of mobile devices among the population offers a high potential to change the way of communicating with citizens in the event of a disaster, and to simplify the participation of the citizens as active volunteers (Reuter et al., 2014). With the help of these new technologies, crisis management can provide current on-site information via mobile devices in real time as well as organize and coordinate the activities of the volunteers at specific locations.

Based on a) the need for volunteer support in certain disaster situation b) the increasing willingness of citizens to support ad-hoc response actions, and c) the availability of necessary new technologies we have developed and practically tested a general approach for volunteer coordination systems in the ENSURE project which results are presented in this paper from a technical point of view. So, it is important to state that organisational, legal, sociological and psychological aspects of volunteer coordination are not the focus of this work. We do concentrate on the technological aspects of providing the necessary functionality through a general, flexible and fast performing system architecture that makes full use of current technologies.

The paper is structured as follows: Section 2 presents related work in terms of relevant technologies and related projects. In Section 3 the functional and non-functional requirements are described based on the general use cases for the envisioned solution. Section 4 shows the general reference architecture and its components. Section 5 describes the used implementation and the technology for a pilot system. Section 6 shows the results of the evaluation based on field test. Finally, in Section 7 we draw the conclusions of the presented approach and describe further research directions.

2 RELATED WORK

2.1 RELEVANT TECHNOLOGIES

In order to realize a volunteer coordination system it is generally necessary a) to actively inform the volunteers in time and at their location with individual messages b) to receive information from each volunteer, and c) to support specific tasks of each volunteer. In the context of crisis and disaster management we find the existing technical foundations for such solutions in the field of a) mobile (targeted) alerting systems, b) mobile crowdsourcing/sensing, and c) mobile crowdtasking. In our approach for a general volunteer system we combine existing technologies used in these approaches:

Mobile alerting: Such systems have to be distinguished between broadcast-based alerting approaches (how it is performed e.g. by cell-broadcast systems like in the Netherlands or US) and personalized alerting systems with the ability to address individuals or certain groups with different alert messages (how it is performed e.g. by the App-based public alert system in Germany (KATWARN, 2017)). Along with the increasing coverage provided by new ICTs in the last decade, in particular web technologies, mobile devices and individual messaging, the foundations have been laid for the development of new personalized mobile warning systems. The initial steps towards this type of targeted alerting were described in (Meissen et al., 2014). Also, in (Meissen et al., 2014) a first general reference architecture for personalized alerting system is presented that served as a basis for the implementation of the KATWARN system in as large scale alert system for the public with currently approximately 3 million users (KATWARN, 2017). This system is also providing the basis for the alerting and profile management of the reference architecture and implementation of the general volunteer system presented in this paper.

Mobile crowdsourcing/sensing: Our understanding of the notion 'crowdsourcing' is that a group of people voluntarily collects and shares data and information using widely available mobile devices (smartphones etc.) or/and web applications, where this data is processed and provided via a data-sharing infrastructure to third parties interested in integrating and remixing this data. Concrete projects and applications in disaster management are for instance: InSTEDD, GeoChat, FrontlineSMS , RapidSMS, Outbreaks Near Me, Ushahidi. InSTEDD is a suite of open-source software tools that aims to achieve faster and more coordinated responses to disease outbreaks and natural disasters described in (Fuchs-Kittowski and Faust, 2014). This type of involvement, in which simple, digital information tasks are performed on-site by volunteers, can be described as "Mobile Crowdsourcing" (Fuchs-Kittowski and Faust, 2014) (or "Mobile Crowdsensing", if data is captured using the built-in sensors of the mobile devices).

Mobile crowdtasking: Is a sub-form of mobile crowdsourcing, in which volunteers undertake special physical tasks (such as filling sandbags, providing first aid to injured people, protecting cultural assets, securing dangerous places, etc.) and report on them if appropriate. Two forms of mobile crowdtasking can be distinguished based on the task distribution scheme (Fuchs-Kittowski and Faust, 2014), with one approach being an independent, autonomous task selection and the other a coordinated task assignment. In the first case, the volunteers choose their own tasks from a pool of globally available tasks. In the second case, qualified volunteers are efficiently given appropriate tasks with the aim of fulfilling the objectives of the application as best as possible. In a narrower sense of the term, only the subcategory in which the volunteers are not addressed as a group, but rather assigned individual tasks, is referred to as crowdtasking (Neubauer et al., 2015). The potential of crowdtasking systems remains largely untapped with only a few examples of such systems currently in use to assign real, physical tasks to volunteers (e.g., filling sandbags).

From previous research in mobile crowdsensing and crowdtasking we adopt some general component schemes and approaches for our solution which are incorporated into the general alerting reference architecture used in KATWARN.

2.2 Related Projects For Volunteer Integration

Current projects for an integration of unbound volunteers are Hands2Help (Hofmann et al., 2014), AHA (Detjen et al., 2015), and KOKOS (KOKOS, 2017). There are already some projects based on practical experience such as Ready2Help (Schmidt et al., 2016), ZUKS (ZUKS, 2017), and Team Österreich (Team Österreich, 2017) aimed at the coordinated involvement of volunteers. Within these systems we witness a shift from technically simple solution based mainly on web portals for registration and SMS/email for activation towards more sophisticated approaches with advanced coordination and feedback functionalities based on volunteer apps. Related volunteer systems such as FirstAED (FirstAED, 2017), instantHelp (instantHelp, 2017), or Pulsepoint (Pulsepoint, 2017) (notifies a registered user of an accident in the area according to the user's skills) are also aimed at involving and coordinating volunteers, but they are mainly used for ad hoc lifesaving, i.e., they are specially designed for first aid, and not common tasks in crisis management.

All these approaches so far have the following points in common: they provide methods and tools to recruit a greater number of volunteers, mobilize and activate them when needed, and coordinate their activities. To achieve this, a specific control system is required in order to distribute the tasks to suitable volunteers. A mobile app is also necessary for the volunteer to receive the tasks, coordinate with others, and get involved. However, what is missing is a general reference architecture for such systems and evaluation results for the technical aspects of the system from field studies, which is the main contribution of this paper.

3 REQUIREMENTS

A major part of the interdisciplinary research in the ENSURE project aimed at the identification and classification of appropriate disaster scenarios in order to derive the different requirements for the volunteer system. Whereas from a crisis management the identified scenarios differ based on a variety of significant parameters from a technical system point of view the following three general application categories were of major relevance:

Application Category 1: Long lead-time scenarios for crisis management. In these scenarios we have a long lead-time (days) until the tasks/actions of the volunteers have to be performed. They have in common that we usually have scenarios were professional forces are involved and tasks are preformed under direct control or jointly together. These scenarios are occurring mainly in the preparation and recovery/mitigation, and only partly in the response phase (e.g., during disasters with longer impact time). A typical example for such a scenario in this category is sand bag filling in order to prepare for long-term flooding. From a functional point of view in such scenarios the location of the volunteers is not a key parameter for activation as there is usually enough time to organize transport facilities. However the profile and abilities of each volunteer can be a crucial parameter for activation selection. From a non-functional point of view the performance requirements for such as system have to possibly take a large number of volunteers into account that have to be activated and coordinated. However, most information tasks in these scenarios are not time critical.

Application Category 2: Short lead-time scenarios for crisis management. In these scenarios we have a very short lead-time (hours, minutes) when the tasks/actions of the volunteers have to be performed. They have in common that we usually have scenarios were emergency forces are not yet involved and tasks are preformed in the isolation phase. These scenarios are occurring solely in the response phase. Typical examples for such scenarios in this category are evacuation and first aid scenarios.

From a functional point of view in such scenarios the location of the volunteers is now a key parameter for activation as only close by volunteers can react. From a non-functional point of view the performance requirements for such as system have to send out tasks in almost real-time as every second counts and the robustness of the system has to be on the highest possible level. However, the numbers of volunteers to be informed and coordinated are considerably lower in comparison to category 1.

Application Category 3: Short lead-time scenarios for emergency management. These are scenarios similar to category 2 but for daily applications in emergency management. A typical example is a first-aid scenario with activation of volunteers to use a defilibrator before an ambulance arrives. We have taken such emergency management scenarios into account since it is an important motivation and training factor for volunteers to be activated more frequently than only for major disaster scenarios that possibly occur every decade. Functional and non-functional requirements are similar to the ones in category 2. For the performance aspects the requirements of a higher activation frequency and a 24*7 operation has to be taken into account additionally.

Beside the differences pointed out above the main functional requirements all categories have in common for the effective recruitment, management, activation, and coordination of volunteers are:

- Volunteer registration
- Volunteer profiling
- Volunteer selection
- Alerts and task activation
- Volunteer feedback

In the ENSURE implementation, the system distributes help requests or alert in the event of a hazard or emergency. These requests or alerts are delivered to the volunteers via a mobile app. Volunteers can be activated in two ways: Firstly, the control system can trigger a regional alert to all volunteers in a given area. With this type of alert, volunteers receive a request if they are in the immediate vicinity of the emergency based on their current location (for application category 2+3). Alternatively, volunteers can receive topic-based alerts by subscribing to a certain topic, e.g., “Flooding 2013 – Dresden” or can be selected by their profile (for application category 1).

The general non-functional requirements were postulated with respect to established requirements for IT applications in disaster management in the literature (Mauthner et al., 2015), namely:

Efficiency and safety: the volunteer system shall be applicable for mass application with hundred thousands of users and capable of providing tasks and alerts in a short time without demanding massive hardware investments. All personal information processed by the system shall be protected from misuse.

Clarity and usability: the volunteer system shall be easy to use without training. All information provided by the system in particular alerts and tasks shall be clearly understandable.

Reliability and availability: the volunteer system shall be robust in operation with a minimum of failure and maintenance time.

4 ARCHITECTURE

Figure 1 shows an overview of the general architecture for volunteer systems developed in the ENSURE research project based on the envisioned functional and non-functional requirements. The later had a strong influence on the architecture in particular to ensure efficiency, safety, reliability and availability.

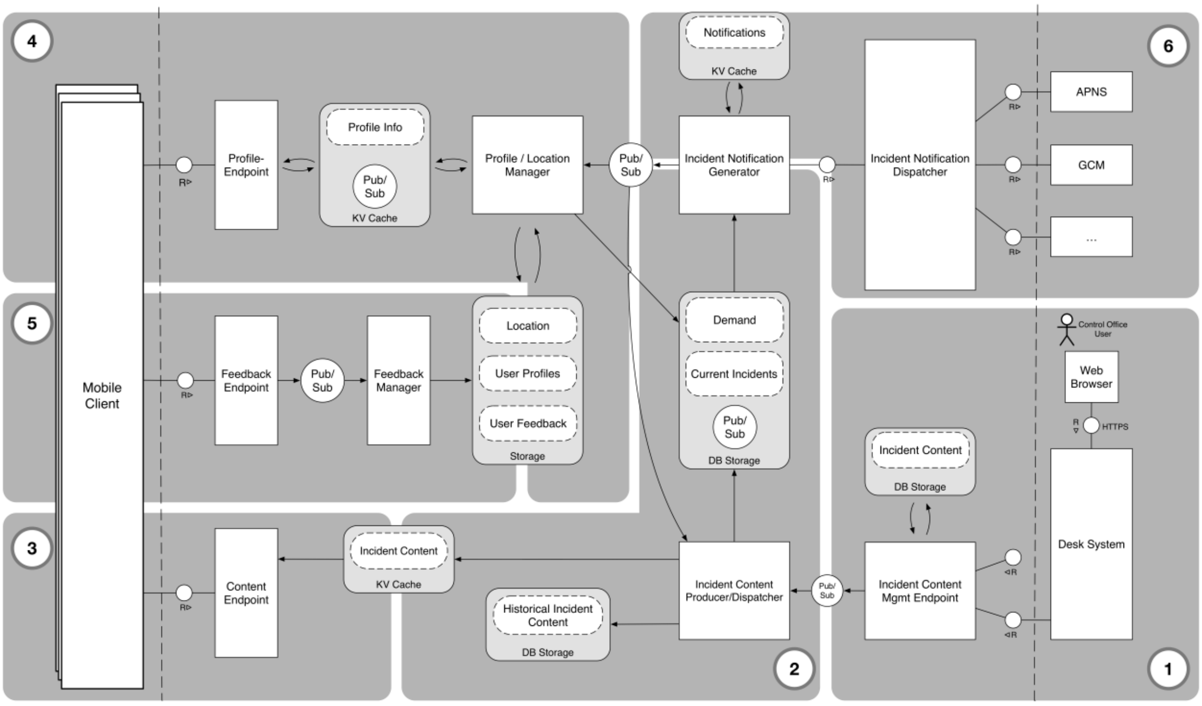

Figure 1: ENSURE General Architecture

This general architecture consists of the following major components:

1) Incident Manager: is responsible for managing incoming events (alerts or requests from the control system). It accepts event messages (raw events) via different external interfaces and saves them persistently in the *Incident Content Storage*. New or updated events are forwarded to the *Incident Content Producer/Dispatcher* and thus to the *Distribution System*.

2) Distribution System: has two main tasks a) it prepares the raw data of the incoming events and b) it is responsible for the distribution of events within the system. The processing is performed according to how the information will be further distributed. The system stores the data required for sending the notifications in the *Demand/Incident Storage* and informs the *Incident Notification Generator* about the new or updated event. It also generates the data required by the end users for the textual and graphical processing on their devices. This data is made available for retrieval via the *Incident Content Cache*. The *Incident Content Cache* serves as a buffer for content to be delivered (e.g., events such as alerts or inquiries, additional information). The *Demand/Incident Storage* maps subscriptions from system users and event messages in a high-performance runtime model that facilitates efficient matching between both types of information.

3) Content Manager: provides the interface through which to query content. This includes queries of processed events and relevant additional information. The data is taken from the *Incident Content Cache*. The *Content Manager* is designed for maximum scalability and employs dynamic load distribution.

4) Profile/Subscription Manager: presents the interface through which the user can query, add, or modify profile information. Similar to the *Content Manager*, the *Profile/Subscription Manager* uses a dynamic load distribution in order to enable, among other things, multiple profile updates within a short period of time. The Profile Manager retrieves answers to queries from the *Profile Info Cache*, which holds frequently-requested data as well as last-changed profile information in a high-performance key-value cache. The *Location Manager* is responsible for managing all profile-related data in the system. User inquiries are forwarded to the manager if they cannot be answered directly from the *Profile Info Cache*. All data is persistently stored in the *Location/Profile/Feedback Storage*. Changes to subscriptions are also send to the *Demand/Incident Storage* and forwarded to the *Incident Notification Generator* to check if a notification is required.

5) Response Service: processes all user feedback (task accepted/rejected, feedback after completion of a task, as well as feedback regarding the basic profiling). It is received and forwarded to the *Feedback Storage*.

Furthermore, the content management system can access all feedback information over this endpoint and prepare it for the dispatchers or use it as filter parameters (profile extensions) for the volunteer search.

6) Notification service: The *Incident Notification Generator* is responsible for matching subscriptions (current position, profile of user) and events. The service has access to the *Demand/Incident Storage*, a special runtime database in which the subscription and event data have already been combined. The main task is to retrieve the device addresses of the relevant volunteers for each of the event messages and send these data to the *Incident Notification Dispatcher*. In addition, this component has a store in which the notification statuses of the individual devices/users are held. The *Incident Notification Generator* also informs other system components of which devices are expected to send queries in the near future before triggering the notification delivery. This makes it possible to prepare the system so that requested information is more readily available. The *Incident Notification Dispatcher* is responsible for sending the notifications over different channels. It receives the event messages generated by the *Incident Notification Generator* along with the corresponding device addresses and sends the notifications.

5 IMPLEMENTATION

Based on the reference architecture a pilot system was developed during the ENSURE project that is fully operational with end users for test and evaluation purposes. It was developed in an iterative approach over a time line of two years taking all functional and – in particular – non-functional requirements into account. In each iteration, new functionality is added to the system and evaluated. The operational system consists of the following main subsystems:

Backend system: Based on the reference architecture described above an implementation was performed. Figure 2 shows a simplified logical architecture of the implementation, which also leaves out non-functional aspects.

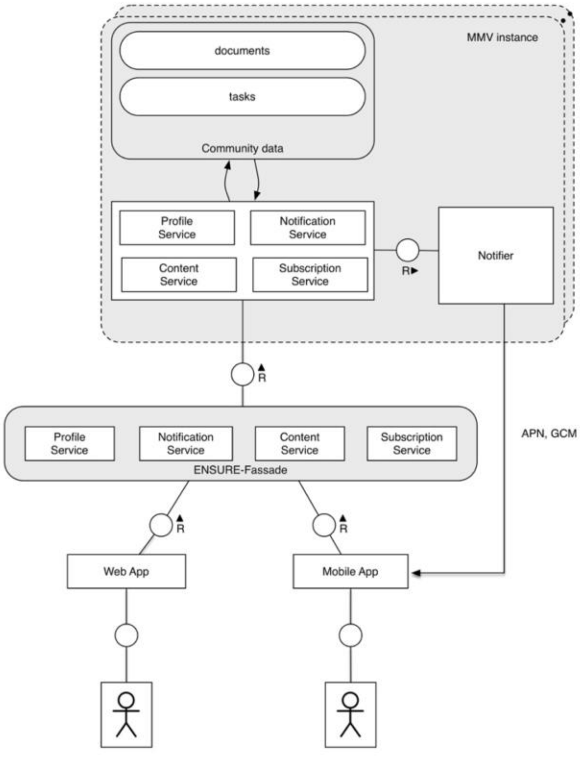

Figure 2: Logical view on the implementation architecture of ENSURE

The backend is responsible for the core processes of the ENSURE system for volunteer registration, activation, tasking and response. The system architecture was designed to ensure scalability, load balancing, performance, and availability. In order to realise the performance and scalability of the system, the following design decisions were consistently applied within the implementation:

- *Key-value caches* are used to quickly respond to queries. These are designed for the purpose of load distribution using multiple distributable instances. The number of instances can be dynamically adjusted depending on the expected or actual load. Additionally, key-value storage instances provide advantages over relational storage instances in terms of scalability.

- All data is persistently stored in databases. This means that all cache instances have persistent data storage. If an (unexpected) restart occurs, the information in the caches can be restored.
- Communication between the individual components in the system backend is asynchronous

It was implemented using server-side JavaScript technology included in the MEAN stack (MongoDB, Express.js, AngularJS, and Node.js) as well as Redis as a key value store.

Apps: The volunteer apps shown were implemented for iOS and Android devices. The apps provide the end user functionality for registration, activation, tasking and response. During registration the user can provide her/his skills that can be used for volunteer selection. For activation (Figure 3), the selected volunteers (by current location or skills) receive a message via push notification on their smartphones. The users can see all the information about the emergency operation in the app and can decide whether to accept or reject the request. After accepting the volunteer is guided through a certain task by text and/or graphics.

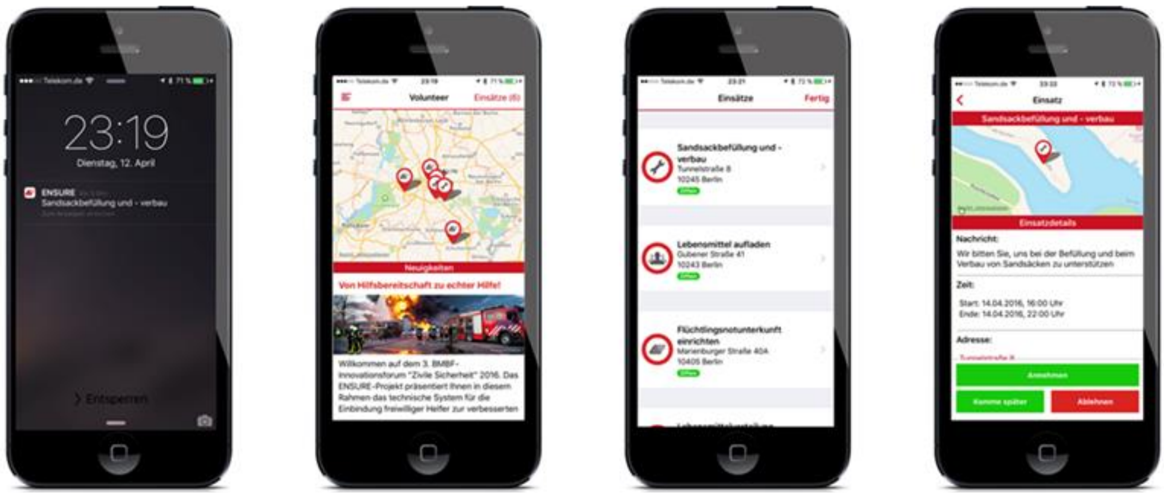

Figure 3: Volunteer activation via the mobile app

Coordination system: This web-based application is located at the emergency or disaster authorities that activate or coordinate volunteers. In this system filtering and alerting volunteers is a multistep process and proceeds as follows:

Alert type: It must first be established whether to send a regional alert or a topic-based alert.

Filtering: Volunteers are chosen based on the location and time of the emergency, the number of volunteers needed, and any special skills that may be required.

Alert details: Additional information such as specific tasks, estimated duration of the emergency operation, instructions, etc., can be added to the alert.

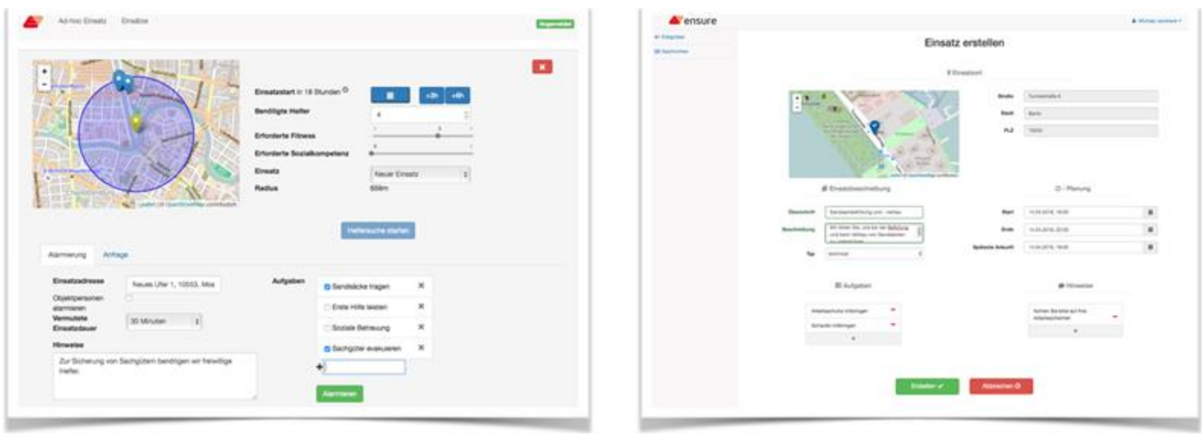

Figure 4: Volunteer activation via the coordination system

Further it provides additional functionalities such as sending updates to all users, sending additional information about an emergency operation to all users taking part in that operation, and a detailed view of ongoing emergency operations (including volunteer feedback). It was implemented as a single-page web application using the client-side JavaScript framework AngularJS.

6 TESTS AND EVALUATION

The general test and evaluation approach for ENSURE consisted of two detailed scenario-focused field exercises and one large field test in the city of Berlin. The major focus of the field exercise were to test and evaluate the system in specific response scenarios in terms of volunteer behavior and system functionality in different contexts. The exercises were preformed in October 2015 and 2016 on a special training city for police and fire brigades involving each over 140 persons (organizational staff, actors, response forces, observers, and volunteers).

The field exercise setting in an emergency training area of the city was as follows: The scenarios implicated an extreme Thunderstorm in a city with major destructions and a longer isolation phase. The 50 volunteer test persons were selected by an agency for consumer research providing of a randomly selected panel of the population by age, gender, and education. Half of them went through a special designed training for unbound volunteers. The emergency services were represented by 40 members of the fire brigades including all necessary rescue equipment. The members of the emergency services did not have a special training for on-side volunteer coordination besides a technical training on the ENSURE coordination tool. The other staff consisted of observers for monitoring the behavior and actors for the specific scenarios (persons to evacuate, injured persons, etc.). Volunteers registered for the volunteer app starting three months before the exercise. At the registration process in the app the volunteers were asked several questions in order to derive directly implicitly information about their abilities (first aid, psychological background, engineering background, languages, etc.), physical or psychological profiles. Due to privacy reasons these profiles were kept within the app and were only selected anonymously for volunteer selection. The scenarios on the field exercises consisted of the simulation of an extreme Thunderstorm in a city with major destructions and a longer isolation phase. The fire brigades selected and activated actions of volunteers by vicinity and profile through the ENSURE coordination tool both during the isolation and relief phase. Performed actions by the volunteers were beside others: evacuation of persons in buildings, securing buildings, fire distinguishing, first aid, person transport, observation for emergency services, organization of collecting places, salvation of cultural goods, helping disabled persons, or sand sack filling.

Besides the observed problems of volunteer coordination such as volunteer identification, misunderstandings between emergency services/volunteers, antagonism between integration versus collaboration, lack of specific training for collaboration on both sides, the volunteer behavior in these exercises showed a surprisingly positive result on the capabilities and effectiveness of even of untrained volunteers for certain tasks. Between both exercises a long-term field test was performed Berlin-wide open to the public in the context of supporting the fire brigades and the Red Cross for refugee aid. For the purpose the coordination system provided a selection mechanism based on time availability instead of vicinity. The profiling was reduced to a minimum since it was needed in this context. The detailed organisational, legal, sociological and psychological findings of the two field exercises and the large-scale field test are published in (Meissen and Peperhove, 2017).

In the following we focus solely on the technical aspects of the ENSURE system. This technical evaluation was performed with respect to established requirements for IT applications in disaster management in the literature (Mauthner et al., 2015) as mentioned under the non-functional requirements:

- Efficiency and safety
- Clarity and usability
- Reliability and availability

For the exercise the evaluation results were, without exception, positive in all three evaluation areas. In particular, the app was found to be very usable (SUS score: 90 points), highly stable, and had short response time as well a good success rate when storing a personal profile. First aid tasks were especially well performed (observation) and the volunteers followed instructions very accurately (clearing vehicle access routes, etc.) (see (Jendreck et al., 2016) for details).

The additional public large scale test was performed with approximately 1200 volunteers throughout Berlin from Mai until October 2016. Based on this test we have performed an additional evaluation with a major focus on response effectiveness and system performance.

Response effectiveness: Figure 5a (left) shows the overall numbers of the volunteers increasing from appr. 600 to 1200 during 2 months in Berlin without major advertisement and clear communication that this is just a test system. The lines below show the activation rate over the 8 test during this two months. It shows a relatively high acceptance at the beginning of the test (over 50%) which decreased under 40% towards the and of the test period (most likely due to the frequency of the alerts). However it shows an astoundingly high acceptance which underlines the usability of the system and the willing of the population to take part in such systems.

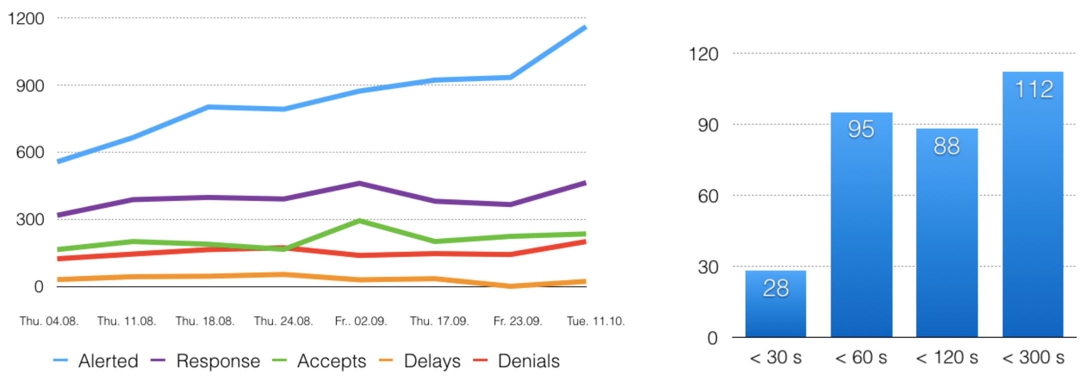

Figure 5a/b: Volunteer activation during the large scale field test

Figure 5b (right) shows the response time for the last test in October 2016 where 95% of the response was given within 5 Minutes.

System performance: Based on the fully operational system we simulated on the last test in October 2016 several performance tests by artificially increasing the number of registered volunteers to 95.000. In one test we initiated silent activations to the apps (activations received but not shown by the app) for all volunteers. Figure 6 shows that these 95.000 activations were sent out within 1 minute and 42 seconds. The testing environment consisted of 2 servers (CX40, 2VCores, 8GB Ram).

Figure 6: Activation performance for 95.000 volunteer devices

All further test results showed a high robustness of the system (no failure or downtime during 6 months of tests).

CONCLUSION AND FURTHER RESEARCH

Interactive, collaborative, and mobile technologies have the potential to overcome the challenges involved in the integration of volunteers into crisis and disaster control. The goal of the ENSURE system presented in this paper is to support the aid forces in recruiting, managing, activating, and coordinating volunteers in an urban area in the event of a large-scale emergency. To achieve this, ENSURE provides necessary functions such as volunteer registration, volunteer profiles, sending alerts (from the control system), and volunteer activation (via the mobile app). The system uses a subscription-based approach in which the volunteers agree to take part in an emergency operation by responding to an alert. The reference architecture provides technical insights into how to implement the combination of alert and crowdtasking systems. The implementation of the reference architecture proved its feasibility during two field exercises and a public large-scale field test, and showed the general applicability of the approach in terms of end user behavior, functionality and non-functional aspects. Given all open issues in the organizational, legal and sociological aspects in the practical use of such volunteer systems that differ from application scenarios, countries, organisations and target groups the system should be highly flexible, which is guaranteed by the highly modularized architecture of the presented system. This is also necessary in order to provide a support a variety of application scenarios over all categories presented in Section

3 as shown in the scenarios of the field exercises/tests in order to provide the psychologically necessary activation frequency for volunteer motivation in one system.

With the expected application of such systems it will be of high interest how volunteers behave in real crisis scenarios but also in standard emergency scenarios. The system architecture offers a variety of measure points that in sum provide a promising anonymous data collection basis for future research in that direction.

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