Towards a general system design for community-centered crisis and emergency warning systems

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ABSTRACT

Early Warning Systems (EWS) provide an effective measure for better disaster preparedness, response, and mitigation. The effectiveness of EWS depends highly on the ability to distribute alert message to the persons that will be affected. In this context mobile devices play already a vital role in the ability to reach people in time and at the endangered location. Most existing approaches focus on mass dissemination methods via SMS and Cell-Broadcasting. As these approaches are effective to inform masses about a disaster with one message for all they have their weaknesses in telling the people how to respond according to their location and provide individual guidance (e.g. by maps) within specific communities. Research in disaster management gives strong evidence that the later is often crucial for better disaster response. Accordingly, we witness an increasing demand for more community-centered warnings systems solutions. This paper introduces the general foundations and architecture for alert services on mobile devices that adapt incoming alert information to the profile and situation of user groups and even individual users. The approach is scalable for different community-centered warning systems. Its first applicability and community engagement effects are shown in the example of the community-centered public disaster alert system in Germany and a target group specific weather hazard alert system, KATWARN and WIND with currently over 2.5 million subscribed users, which was developed by the authors.

Keywords

Community-centered system design, Early warning, Alerting, Reference architectures, Situation-awareness, Community engagement

I. INTRODUCTION

In current warning solution for the public the focus is mainly set on mass application and the use of state of the art technologies such as *SMS*, *Cell-Broadcasting* - or recently – *Push Notification Services* for smartphones. These are mainly used for mass distributions of one warning message for all recipients within affected areas. Interdisciplinary research has shown [1] that this “one message fits all”-approach is effective for indicating the disaster threat. However, this does not necessarily apply to the advices on how to respond to it. This can be highly target group dependent (e.g., elder people, children, impaired or non-native speakers, etc.) or even depending on the individual situation of the person (e.g., in a building, at the beach, in a car, in public transport, etc.). Additionally, further effective support such as risk maps and evacuation guidance cannot be provided with these text-message-oriented approaches. The more we look into communities and their individual information needs and response capabilities the more we see the importance of community-centered and individualized warning systems

Approaches to individualize SMS and push notifications within warning systems require the collection, storing, and processing of profile and context information on server infrastructures, which come to their limits in terms of mass capacity, necessary opt-in and privacy problems. However, some centralized pre-individualization such as location and target group addressing can decrease the amount of alerts to be sent over limited network capacities significantly, which is particular in interest in the case of disasters. Thus, a possible optimal solution would be a scalable approach between non- (or only partly) individualization of warning messages on alert servers and full individualization on receiving mobile alert services. This approach would even allow the individualization of the yet – in terms of dissemination capacity – most effective cell-broadcast messages through mobile alert services.

The approach presented in this paper sets the foundations for such a scalable mobile alert service infrastructure within a general reference architecture for warning systems presented in [2] and the Common Alerting Protocol (CAP) standard [3]. The paper is structured as follows: Section II describes relevant existing approaches in this field and points out the missing gap that is filled with the presented approach. Section III describes the foundations and the reference architecture of the envisioned approach. Section IV shows the application of the approach in two examples: First, KATWARN [4] a public alert service and WIND [5] a target group specific weather alert service by the insurance industry in Germany and Europe. Finally, in Section IV we draw the conclusions of the presented approach and describe further research directions.

II. EXISTING APPROACHES

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 now been laid for the development of new personalized mobile warning systems. The initial steps towards this type of targeted alerting were taken e.g., by [6,7]. What these share in common with other systems is that they are based on rather static profile- and subscription-based content filtering and full individualization on a central alert server. Some already use location as a dynamic parameter and are providing the first steps towards context-awareness. However, these solutions do not provide a general model for processing recipient profiles and context for alerting. The first steps in developing a universal model for user profiling for alerting was proposed by [8] who presents a first generic model for alert personalization based on user profiles. [9] introduces an ontology for alert notification with the aim of supporting the accessibility of alerts to impaired people. [10] present a logic-based language and a rule based approach to address alerts to different parts of the population based on their general context.

However, to our knowledge there is no general system design in existence that can make full and efficient use of evolving infrastructures in the field of mobile, pervasive and ubiquitous end user devices – and sensors. What is missing is a general reference architecture that provides the blueprint for a scalable implementation of mobile alert services fulfilling the following non-/functional requirements (further explained in Section III): Scalability, interoperability and full exploitation of current and future mobile device capabilities.

III. GENERAL SYSTEM DESIGN

Based on the foundations of a general warnings system architecture and a general representation model for the profile and the context of individuals and groups we derive in the following both a centralized and a distributed warning system architecture for community centered warnings on mobile devices. The presented architecture is an extension of the reference architecture for EWS presented in [2]. Recipient-specific warning processing requires profile and context information about recipient groups or – to its furthest extend – single recipients. In the following considerations we use a situation model for representing the context/profile (location, environment, abilities., age, etc.) of single recipients and recipient groups to adapt warnings to recipients as presented in [2] in centralized and de-centralized warning system approaches depicted in Figure 1.

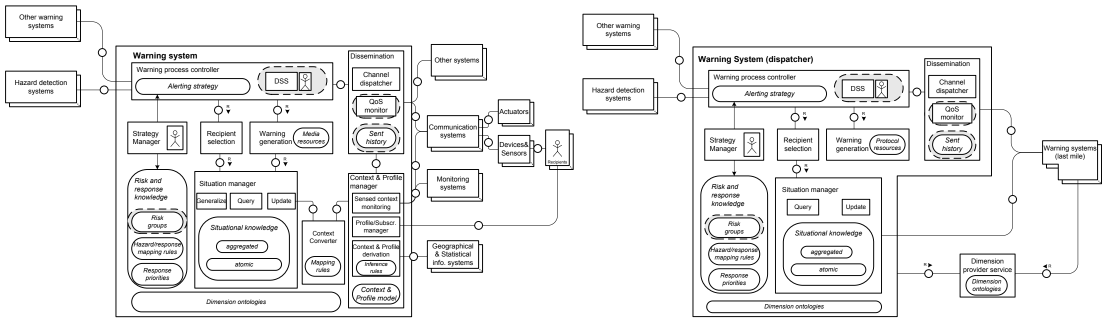


Figure 1. Centralized and de-centralized warning system architecture with the ability to adapt warnings to the situation of target groups or individuals

Based on the distributed approach we look at a possible distribution of the architecture to the mobile devices for a community centered warning system. Principally, it could be thinkable to move the last-mile warning systems to the alert devices. The major advantage of this approach is – besides the distribution of processing load – a better privacy warranty for the recipient. In contrast to any privacy protection approach on a server side, the recipient keeps full control of privacy sensitive data on his device. This can encourage him or her to let the system make use of context data to a much larger extent. Furthermore, it reduces the load for processing and providing more complex media such as individual risk maps by the ability to perform this generation on the devices. In general, simple mobile devices do not provide a necessary platform to implement and update a situation-aware warning system. Thus our considerations are focussing on smartphones – and possibly, some domotic or telematic platforms in the future. However, the relevance of smartphones for alerting has increased considerably in recent years and will most likely continue to do so in the future. Smartphones provide sufficient resources to implement tailored versions of targeted alerting services as depicted in Figure 2.

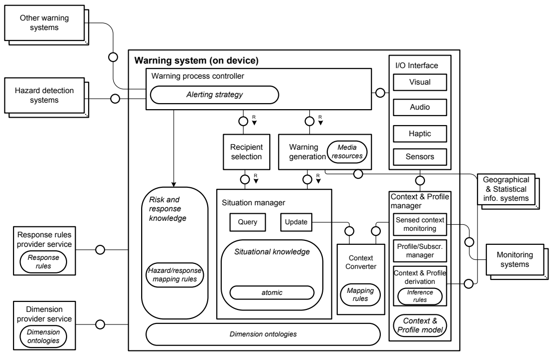


Figure 2. Alert service on a mobile device

The architecture for the on-device warning systems keeps the main components and logics of the overall architecture, namely the warning process controller, selection and generation, the situation and the context/profile manager and the necessary knowledge sources. The tailoring applies to all group aspects (i.e., risk groups, priorities, generalization and aggregated situations), all operator control features (i.e., strategy manager and DSS) and to the dissemination component, which is replaced by an I/O-Interface for presenting the warnings on the device. This approach also requires a common provision of the dimension ontologies and – additionally – a provision of common hazard/response mapping rules. Within this architecture we take a closer look at the following requirements as lined out in Section II:

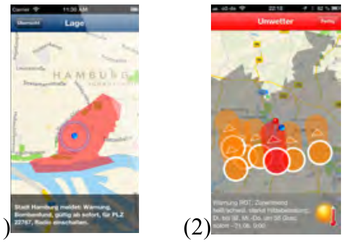
Scalability - As stated above, the reference architecture shows the full extension of an alert service capable to process profile and context information. In practice – in particular in the case of community centered warning – the profile and context information can be reduced to device address, location and – possibly – relevant profile information such as first aid abilities, disabilities or language. However, the architecture can host more extended context information that is relevant in cases of specific alert services (e.g., for workers on large industry plants or advanced weather hazard alert services for vehicle drivers). Further, we expect that context awareness will play a more prominent role on future smart phone devices thus it can be expected that this information can be used to enhance even public alert services.

Interoperability - The proposed architecture can work in general with all kinds of messaging technologies. However, – due to the content restrictions that comes with the commonly used alert messaging technologies such as SMS, Cell-Broadcast or Push Notifications – a combined push-/pull-method is required to exchange more complex information such as CAP-messages. In our implementation we process short messages as a trigger and first emergency information (in case the following pull procedure fails due to capacity restrictions) to trigger a request to a server to receive the full CAP information. Besides using the CAP-Standard and the integration in a common reference architecture for EWS the successful establishment as a general valid approach relies on the existence of common ontologies that enable the matching of risk, hazard, profile and context information relevant for disaster management. First approaches do only partly exist (e.g., SEMA4A[9]). In our implementations we had to use proprietary ontologies. We consider the establishment of common ontologies in the field of disaster management and mobile services as one of the major standardization challenges in the next decade.

Exploitation of device capabilities - The architecture requires and supports the full use of device capabilities in terms of connectivity, processing capabilities, sensing and UI. The approach is not relying on a specific device connectivity. It can work even with one-way broadcast-based technologies such as Cell-Broadcast. However, for more advanced processing that require the full CAP content a bi-directional data-connection is required. Due to the reduced content, processing capabilities of a smart phone device are more then sufficient to manage the situational knowledge and process the warning information fast enough. All sensing units, in particular the location sensing, can be used for deriving context information for the situational knowledge. In terms of individualized warning message presentation the implementer of a mobile alert service can make full use of the device UI capabilities for alert sounds/vibration, risk maps, evacuation plans, voice guidance, etc.

IV. IMPLEMENTATION AND COMMUNITY ENGAGEMENT EFFECTS

In the following, we present two instantiation of the main principles of the presented architecture for community centered warnings: KATWARN and WIND. Figure 3 shows screenshots of the mobile apps for both alert services.



(1) (2)

Figure 2. Screenshots from (1) KATWARN app: a risk map for a local bomb alert in Hamburg (2) WIND app: a dynamic risk map for heat and thunderstorms in Berlin

WIND is a commercial weather hazard system that is provided by insurance companies in several countries in Europe (Germany, Austria, Poland, Hungary, Romania, etc.) to their target groups in their customers in order to reduce damage costs. Currently the system supplies over 2,5 million subscribed users with weather alerts on their mobile devices (currently mainly via SMS but with an increasing part of using the mobile alert app). The system is built on the same architecture and code basis as KATWARN (in fact KATWARN was built out of WIND) but provides different functions, which focus more on profile and context information in order to enhance the effectiveness of warning advices: First, the insurances use profile information from their customers (e.g., house/car owners, specific professions and companies) to adapt warning advices. This information is processed on the central warning system and thus can support also SMS alerts. Second, the system offers within the alert app on a smartphone the possibility to further adapt alerts to the context of the recipients. In this case, it is the environment context (city, outside, street, forest, beach, lake, sea etc.), which is derived from the location of the user.

KATWARN is a community centered warning system for disaster that is currently available in major cities and districts of Germany (e.g., Berlin, Hamburg, Nurnberg and districts of the north-west coast of Germany). Currently, the system has appr. 200.000 subscribed users. The core of the system consists of a central warning server that provides warning for subscribed postal codes via SMS and email (or any other alert channel). The system has been extended by a smartphone app for iOS and Android, using push notification services. As push notification cannot yet be processed hidden on both operating systems, the on-device filtering described in the previous section cannot yet be applied. Thus, context and device profile information (in this case location and an encrypted device id) is managed on the central alert server. The disadvantage of this approach is the necessity of constant location updates in the background and possible privacy concerns of the users. This is solved by reducing it to significant location updates within larger boundaries (e.g., 2km) that are specific enough for alerting purposes. The system is also designed for processing Cell-Broadcasts, where this location pre-selection is already performed by addressing the cells in the mobile infrastructure within the endangered area. In a further extension within the ENSURE project [11] that is based on the presented architecture, the system will process profile information such as the abilities or roles of the recipient (e.g., first-aid-abilities, groundskeepers, operators of public transport, etc.) in order to enhance response by individualized messages for these specific groups, integrating feedback channels and social media.

In terms of community engagement effects, a first analysis of usage statistics, user feedbacks and user interviews show the following findings after one year: The total percentage of the population using such an alert service that requires an opt-in currently ranges between 1% - 3% in large cities without strong advertising und up to 7% in smaller towns with strong advertising measures on buses and household mailings. In special target such as deaf persons the usage percentage is up to three times higher. These are the numbers after the first year, yet constantly rising, especially after real or test alerts. The multiplicator effects (the fact that alerts are passed on to others) can only be guessed yet. However, user feedback and functionalities like the seamless integration in Twitter, gives evidence that it can be estimated as a highly effective factor. In terms of context awareness, even with a strong affinity to privacy concerns in Germany, we have no evidence yet that the system is not used due to privacy concerns. Location updates can be switched off, are anonymous and reduced to location boundaries of roughly 2km. Any other context or profile information is kept on the device.

V. CONCLUSION

The paper has presented the foundations and a reference architecture for the effective and flexible implementation of mobile alert services within a distributed architecture of warning systems. We are not aware of any existing and applied approaches that are comparable in terms of location-based and context/profile-aware adaptation of warnings to target groups and individuals. Known existing public alert systems are either build for mass dissemination using a broadcast based approach with a "one message fits all"-principle (e.g., Cell Broadcast or SMS-based solutions in the US, Netherlands, Norway etc.) or small scale alert solutions with a pre-selection of alerts (e.g., Campus alert systems as used in the US). Since we are lacking comparative approaches in this new functional class of warnings systems we are looking forward to alternative architectural proposals that can be compared on performance indicators and possibly lead to an improvement of the proposed reference architecture.

Beside the technical aspects, further research should focus also on interdisciplinary and practical studies about the functional design, the use and the effectiveness of such advanced community-centered warning systems. For example sociological and psychological guidelines are missing how to select, adapt and represent such target group specific warning and advice information in different communities. This requires a stronger participation of communities in the design phase e.g., through panel and focus interviews. One step towards this direction is currently performed by the interdisciplinary research project OPTI-ALERT [1] for which part of the presented work provides the technical basis. Further, in particular in terms of community engagement effects, our first findings have to be proven by more thorough combined technical, sociological and psychological studies on warning service functionalities, end user expectations and behavior. In user feedbacks we find strong evidence in the most active KATWARN-group for the support of more functionalities such as human sensor observation and helper activation (persons with special roles or medical background). Additionally current research stresses the importance of integrating the public in emergency planning [12], which would change the "one way"- to a "two-way"- communication paradigm to the public. In this field we are currently extending the presented architecture to a warning, coordination and support system within the ENSURE project.

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