2005

Notifying Civilians in Time - Disaster Warning Systems Based on a Multilaterally Secure, Economic, and Mobile Infastructure

Tobias Scherner
University of Frankfurt, tobias.scherner@m-lehrstuhl.de

Lothar Frisch
University of Frankfurt, lothar.fritsch@m-lehrstuhl.de

Notifying Civilians in Time - Disaster Warning Systems Based on a Multilaterally Secure, Economic, and Mobile Infrastructure

Tobias Scherner
Chair of Mobile Commerce and Multilateral Security, University of Frankfurt
Tobias.Scherner@m-lehrstuhl.de

Lothar Fritsch
Chair of Mobile Commerce and Multilateral Security, University of Frankfurt
Lothar.Fritsch@m-lehrstuhl.de

ABSTRACT

The spread of mobile communication equipment offers new opportunities for disaster management referring to civilians. At the same time, location based services are regarded as privacy invading, and are regulated in many countries by specific legislation. We analyze the requirements of a LBS-based disaster management scenario that enables the timely notification of civilians. In addition, we propose a solution for building a privacy-friendly, multilaterally secure disaster management infrastructure based on robust mobile phone infrastructures with high reachability of citizens. We will also point out additional features based on mobile networks. Traditionally, disaster management is a government domain. We will propose another option to implement and run disaster management. We analyze in how far an early warning system could be profitable for the insurance sector. Our comments will sketch that it is possible to reach a large number of persons, avoid insurance damage, and save costs in disaster warning systems.

This work was supported by the IST PRIME project; however, it represents the view of the authors only.

Keywords

Disaster management, location based services, civil protection, e-government, mobile phone, GSM.

INTRODUCTION

Mobile communication infrastructures provide wireless telephony services around the globe. Data services for mobile commerce are thought to generate additional revenue for network operators and service providers. Among these new services, location-based services (LBS) promise revenues with context-based services. However, mostly mobile commerce scenarios with private actors involved are discussed, while the government usage of LBS is restricted to emergency call legislation (Burke and Yasinsac, 2004). In this article, we envision much more complex system architectures for government-use of LBS technology – disaster warning of civilians. However, this could only be one element for an effective mass warning.

Disaster scenario: Volcanic eruption

We assume a scenario where a large number of civilians have to be notified in short time due to an approaching volcanic eruption in a populated area. Mount Usu in Japan at 42.5°N, 140.8°E is our example territory for disaster notification. In (Vic staff, 2002), the situation around Mount Usu is described as follows: “Usu is a 2,416 foot stratovolcano located approximately 42 miles southeast of Sapporo City in Japan’s most northern prefecture, Hokkaido. Five small communities totaling approximately 55,000 people live in the vicinity. Eruptions have occurred in 1663, 1769, 1822, 1853, 1910, 1943-45 (Showa-Shinzan lava dome eruption), and 1977-78. The last eruption claimed 3 lives (from mudslides) and 196 houses. According to Akihiko Tomiya, Geological Survey of Japan, precursory phenomena of these eruptions, mainly volcanic earthquake events, have varied in length from 32 hours (1977-78) to 6 months (1943-45 eruption). Most of them began with the Plinian eruption phase, followed by pyroclastic flows and then dome growth“. Regularly, tens of thousands of civilians have to be evacuated during such events. In 2000, more than 11,000 civilians had to be evacuated, according to (HKN and CNN, 2000). Figure 1 shows Mount Usu disaster planning with the respect of wind and fallout distribution during an eruption.

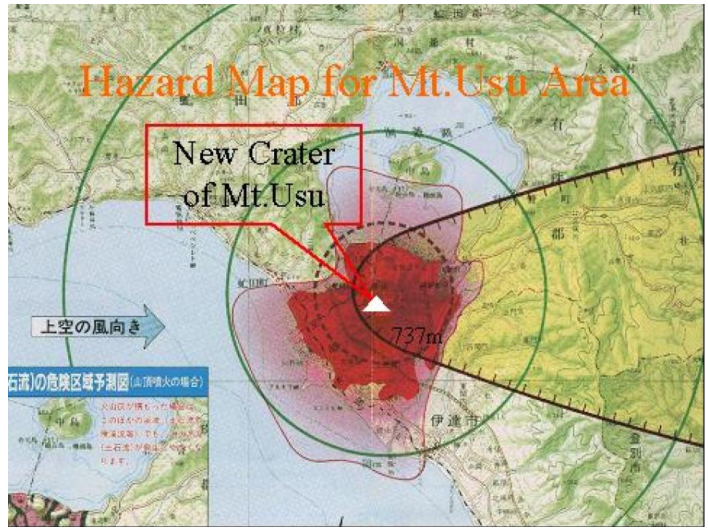

Figure 1. Mount Usu volcanic hazard map from (Yoshimura, 2002). Note the wind influence on ash fallout

Volcanic eruptions, like other disasters including Tsunamis and flash flooding, can be forecast with considerable error margins. Some events happen unexpectedly or earlier than projected. Civil protection consists of observation, event detection, and finally the issuance of warnings. Our article presents the state of ongoing research concerning the warning phase of disaster management.

Survey of technologies and opportunities

To compare different technologies it is necessary to analyze build-up and operating costs of the options and their features. With regard to the costs we propose to distinguish between those that are operator sided and those that have to be covered by the civilians. For predictions of the possible acceptance of technologies among the citizens the availability of the technical equipment is taken into consideration. Disaster management communication technology needs to be reliable and robust against disaster specific risks. Following Held (Held, 2003), we introduce the technical requirements. First the establishment of a uniform emergency signal is needed. This enables every person to immediately recognize the emergency notification. This warning function can be divided into a wake-up function to direct the citizen’s attention to the emergency notification and into an information function to provide citizens with customized information about the emergency and further instruction for action. We present a survey of existing warning technologies, based on (Lane, 2000):

Warning sirens

Warning sirens are a popular medium. The build-up costs are 14000$ per siren (AGBF-NRW, 2003), which is a competitive disadvantage. An installation of a wide network of warning sirens is only efficient for areas with a high population density. Concerning the information function, we find another handicap: Natural language warnings as part of the information function through sirens are not possible. Caused by harmonic distortions and reflections of sound waves, warning messages are not expedient for the in-house area (AGBF-NRW, 2003). A message like ‘Close the doors and windows!’ could not be understood acoustically if issued outside.

Radio

Radio devices can be divided into two main groups: Those who have one radio receiver and those with a second system which can be activated automatically by signals. Today’s radios only fulfill the information function and require additional technology to implement the wake-up. The two receiver versions provide the whole band of the warning function but require new terminal equipment which has to be bought by the citizens. Due to the increasing mobility of the citizens, radios possess the disadvantage that radio interfaces are not integrated into the devices that people carry around.

Mobile phones

Mobile phones based on GSM[1] / UMTS[2] combine all required features of the warning function. Additionally, they are everyday objects, carried even by very mobile people. All functions are already implemented into current GSM-mobile phones. Government acceptance of such warning systems should not be problematic, because of the very low financial commitment needed. The existing infrastructure and the synergy of projects like E911 (Burke and Yasinsac, 2004) going to be implemented in the USA and E112 (Ludden et al., 2002) in the European Union support mobile phone based warning.

To secure reliable, robust warning, cell broadcast (CB) is very attractive. CB belongs to the point-to-multipoint technologies offering useful characteristics:

- CB has very low setup costs for operators, users and disaster managers.
- Activation of CB can be provided by the operator via SIM Application Toolkit.
- CB reduces the traffic as recipients in the disaster area receive the notification just in time.
- Concerns about privacy of CB don't exist.
- Mobile networks can be secured against power outages (Gerpott and Walter, 2004).
- Mobile phones offer the possibility of direct communication between rescue forces and victims.

The safeguard of mobile networks against power outages depends on the particular network. In our approach, we execute the warning before the wireless network is destroyed by a disaster. With uninterruptible power and battery support, mobile networks might even be available for a certain time after a disaster struck. Nevertheless, nearly every warning medium has to cope with that problem. Even modern church bells, a traditional warning medium in Europe, are based upon electrical power.

Mobile networks offer valuable functionalities such as positioning, guidance of gatherings and identification of specialists like firemen, police officers and medical service personnel. Further discussions can be found in the section "system design".

Overview of usability of technologies in the context of modern crisis response systems

Following the methodology of (Yuan and Detlor, 2005), we introduce the six main tasks of an intelligent mobile crisis response system (CRS). These tasks do not necessarily take place in the sequence quoted below. The original presentation has been extended by the fulfillment of these tasks by different technologies.

Tasks	**Key Roles**	**Fulfillments by**		
		warning sirens	**radio**	**mobile phones**
Monitoring and Reporting	• Provide automatic monitoring • Offer structured conversations for emergency call handling • Facilitate quick filing of reports via templates	No	No	Possible
Identification	• Support automatic searching for background information • Identify experts to contact • Support crisis classification with reasoning capability	No	No	Possible
Notification	• Identify parties for notification • Tailor messages to parties • Facilitate information dispatching	Partial	Partial	Possible
Organization	• Define required teams and tasks • Match individuals and groups to corresponding roles • Update and notify team assignments dynamically	No	Partial	Possible

[1] GSM – Global System for Mobile Communication, www.gsm.org, Feb.19.2004.

[2] UMTS – Universal Mobile Telecommunications System, www.3gpp.org, Feb.19.2004.

Operation	• Facilitate information exchange between teams and individuals • Optimize the use of communication channels • Facilitate knowledge sharing • Provide onsite consulting • Offer resource allocation and logistic support	No	Partial	Possible
Assessments and Investigation	• Facilitate information gathering • Classify and cleanse information • Support case-based reasoning and data mining for investigations • Generate assessment reports	No	No	Partial

Table 1: Tasks and roles in mobile CRS combined with fulfillment by technologies (Yuan and Detlor, 2005).

Table 1 reflects the great potential of using mobile networks for disaster management. Nevertheless the resulting prospects will depend on the specifications and implementations such as standards, interfaces and acceptance by the population.

Chronological development of (natural)disasters and density of population as a determinant

The statistics of the Munich Re Group (MünchnerRück-Gruppe, 2004) show a dramatic increase in the number of natural disaster events and the level of economic damage increased dramatically in the last 50 years (shown in Table 2).

Decades	1950 – 1959	1960 – 1969	1970 – 1979	1980 – 1989	1990 – 1999	Last 10 : 50
Number of events	20	27	47	63	91	**4.55**
Economic losses	42.7	76.7	140.6	217.3	670.4	**15.70**

Table 2. Worldwide losses in billion US$ (2003 values) (MünchnerRück-Gruppe, 2004)

This shows that early warning systems will become more important in the future. We state the opinion that increasing economic damages are positively correlated with population growth. This thesis can also be found in the "review of the Yokohama Strategy and Plan of Action for a safer world" (United Nations, 2004). Particularly, rapid urbanization and high density of population influences the impact of injured and killed people as well as economic losses (Sanker et al., 2003). This supports the establishment of effective warning systems based on mobile networks. The infrastructure is particularly available in metropolitan areas, as described in the next section.

GSM-Coverage

Mass warning with CB is effective in areas with a high population density. The advantages of a dense mobile network are the low investments required to build up an emergency alert system. Even in undeveloped countries mobile networks constitute an opportunity to establish a civilian communication network instead of constructing a cable bound one. We illustrate the point with figures of GSM-Coverage (GSMworld, 2005). Figure 2 shows the coverage of Rwanda. Compared with the population density there is a high level of radio signal accommodation. In countries with a low standard of living there is a high rate of theft of installed equipment. In the case of sirens this applies to solar power stations as well as batteries. In contrast, mobile networks are subject to everyday supervision resulting in a faster detection and repair of irregularities.

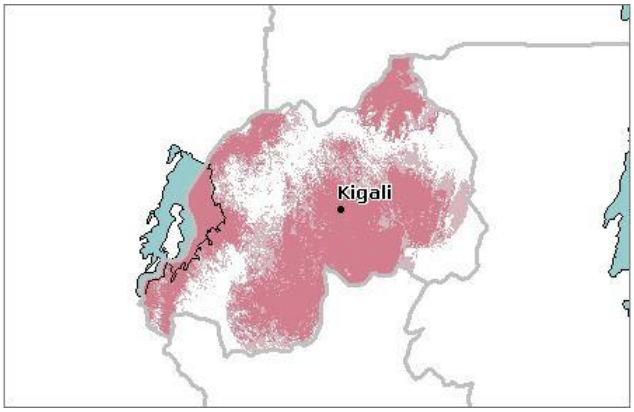

Figure 2. GSM-Coverage of Rwanda (GSMworld, 2005)

Figure 3. GSM-Coverage of Turkey (GSMworld, 2005)

Figure 3 shows the GSM coverage of Turkey. Even the sparsely populated region of Anatolia in the East possesses a coverage degree that can not (under financial aspects) be matched by warning sirens.

SYSTEM DESIGN

This section describes our approach to implement a disaster management system (DMS) based on mobile networks. The system design was targeted to satisfy the principles of the multilateral security (Rannenberg, 2000) and warrants the requirements of each party for privacy and security. We designed additional features to deal with disasters. Summarizing, the LBS disaster management system is responsible for these functions (Figure 4):

- Geographical administration of disaster areas including weather and traffic data.
- Localization of mobile phones within the disaster area.
- Reporting of statistics of phones, phone movements, and population density based on LBS to disaster manager.
- Identification of registered disaster specialists (e.g. firemen and police officers) among the citizens with mobile phones.
- Delivery of messages to mobile phones (either for evacuation, or to give instructions for disaster specialists).
- Notification about citizens threatened by disasters to registered next-of-kin.
- Notification about area threatened by disaster to property owners or persons in charge for areas of interest.

Locating victims provokes the question which technologies should be included into this process. Grimm found out that the signaling channel of the GSM-Network could be bottle neck to provide this data for the disaster manager (Grimm, 2004). The E911 project suggests the Global Positioning System (GPS) for emergency calls to localize the victim. The difficulties within disaster management may bring this (at the moment not widely spread) technology to the limitation of the network. For example, an SMS from the victim to the disaster manager occupies the signaling channel 4.5 seconds. With the typical configuration of the German T-Mobile network[3] 6163 position transmissions per cell would be possible to the person in charge within one hour and per mobile network (Grimm, 2004). To cope with that problem, we suggest working with the cell ID. This technique just needs a request to a database of the mobile operator in which cell the mobile phone was logged in the last time. The position sensing will be less accurate, but it does not stress the mobile network "air gap". The diameters of cells differ between one hundred meters and 30 kilometers. This depends on the Settlement and the landscape. The accuracy can be raised up by using additional techniques like the time advance method (Ludden et al., 2002).

Summarizing the last paragraph we want to point out that the solutions may differ in each country depending on the network constellations, legal requirements and the financial resources that are funded for the disaster development.

[3] The typical configuration of the German T-Mobile network bases on sixteen Stand-alone dedicated Control Channels and thirteen Traffic Channels per Cell.

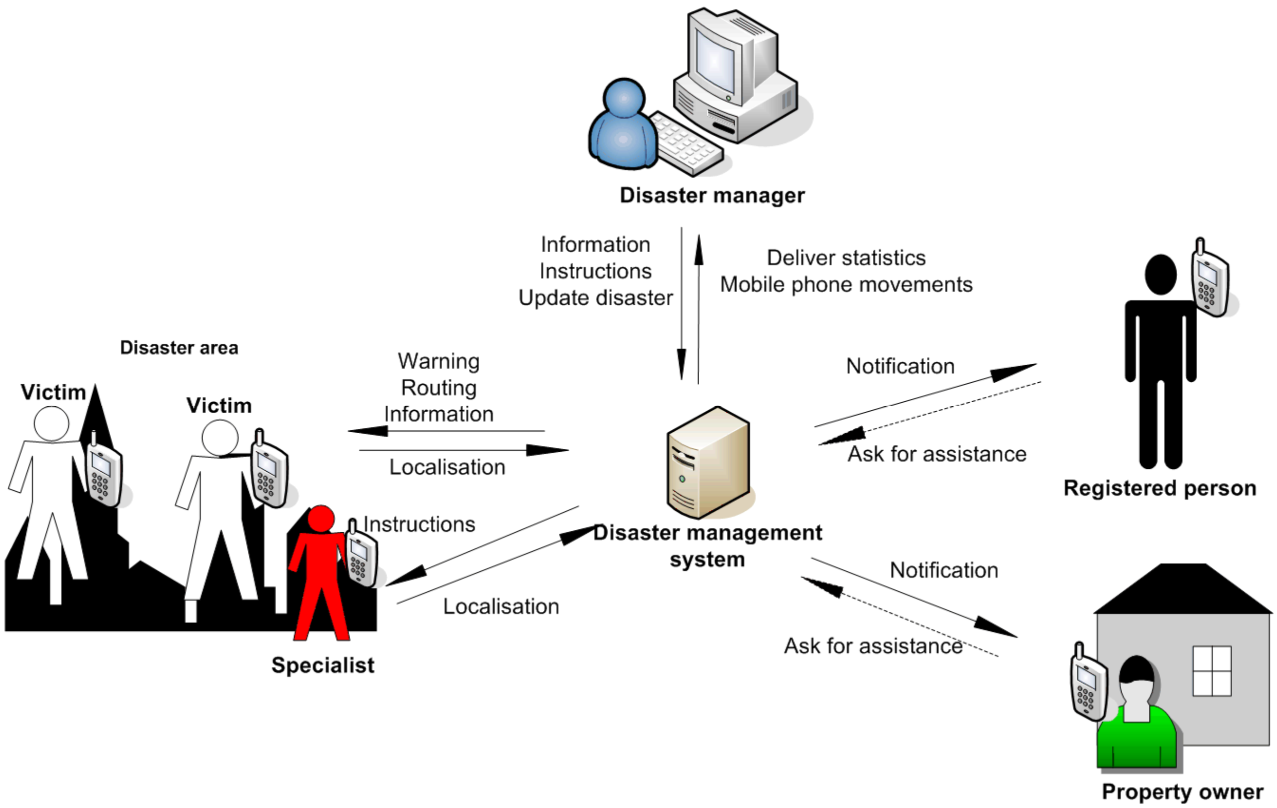

Figure 4. Disaster management scenario

We propose a middleware system with front-end support to control the flow of information and to protect the interests of every party. The system design was made in UML and follows the formalized catalog of Common Criteria to structure the results (ISO, 1999). It consists of three components shown in Figure 5:

- Matcher: locates civilians in the disaster area. Matches disaster area with observation rules of the users. Protects persistent store of individual observation rules. Matches profiles of threatened person with their registered contact person.
- Identity management system: Controls information exchange between the disaster management, the mobile operator and the civilians. Described by Borking (Borking, 1996).
- Process control: Controls the disaster management system, represents an interface to the disaster manager and is responsible for temporary storage of disaster data (observation rules and localization information).

The warning messages for victims and instructions for specialists are transmitted via cell broadcast. To simplify CB, as part of the point-to-multipoint technologies, can be understood like terrestrial television signals. It does not matter how much receiver are actually receiving the signals. This bypasses the performance limitations of point-to-point technologies like short message services (Baker and Carpenter, 2005). Notifications for specialists are encrypted. First of all this should prevent ordinary people from confusion if they are the addressees of the message. On the other side this secures the content of the message for the registered and therefore authorized specialists. To simplify the planning and to control the deployment of staff, the contacted specialists have to send back a status report (e.g. “I am coming” or “I am hindered”). Unlike the warning mass broadcast, these notifications will be sent point-to-point. To make that point clear, we suggest utilizing cell broadcast to warn victims and notify specialists. Point-to-point technologies are used to advise observers and transmit status updates from the specialists to the disaster manager. The previously mentioned disadvantages of point-to-point technologies should be future research targets to abolish the missing prioritization functions. Unfortunately there is no bypass until now.

To be able to use the whole bandwidth of the suggested system, it is necessary to register as a user and to deposit observation rules and specialist status including verification of status and claims. Unregistered users are only able to receive warnings and can be localized. After a disaster occurs, user-specific information will be deleted or anonymously stored. Only the user himself will be able to find out when and how often he was located.

The build up and operating costs of this specific system are, compared to radios and warning sirens, very low. This is caused by the major investment in the development of software. Once created, software can be employed with little adaptations in many countries.

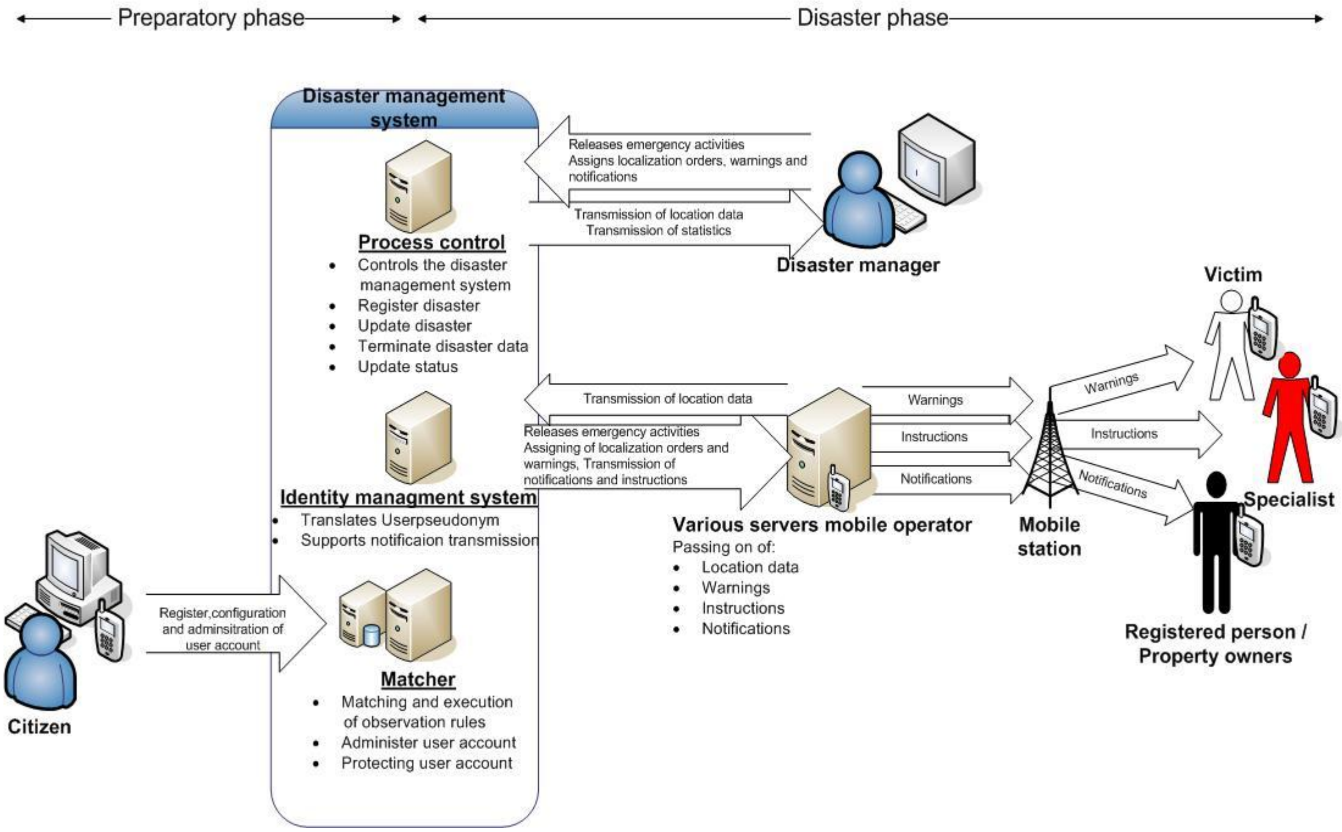

Figure 5. Solution overview

Summarizing the main security features of the disaster management system:

- Accountability of disaster management activities to the disaster manager. This tempers the danger of abuse of false alarms.
- Signed Cell Broadcast makes notifications revisable to the user and reduces the danger to fall for faked alarm messages.
- Victims can not be identified by the disaster manager. They appear only as a pseudonym in the disaster management system, so this allows for privacy of the individual.
- Mobile operators can be called to account in the case of not performing the job tickets of the disaster management system.
- The registration of relationship to next-of-kin and observing of properties are subject to compliance. The relationship of the observer and the observed is not traceable neither for the mobile operator nor the disaster manager.
- The process of enrolling as a fully-fledged user should be used to train the user. This secures user-sided knowledge of how to react to an alarm notification.

For further information about the security and privacy properties compare (Fritsch and Scherner, 2005).

An approach for a development plan of the mobile phone based disaster management system

Not every country has the financial power to build-up such a sophisticated system or the person in charge will come to the conclusion that not all of the presented functionalities are useful for the required applications. Therefore we present a possible development plan which can be upgraded with components. The basic version must contain the mass warning functionality. This includes the activation of the cell broadcast service on the SIM. A second expansion stage is to provide a locating service of the activated mobile phones for the disaster manager. Based on this, in stage three implementation of observing rules and the notification of the observers could be conducted. The resulting costs are directly correlated to the implemented stage. For example, the Netherlands are planning to realize a pure cell broadcast warning system with no further application than the warning function. This will require investments of 2 ½ Million Euros by the government to have access to the CB Systems for about 2 years (LogicaCMG, 2004). The final costs will depend, beside the expansion stage, on the question how much investments must be taken into the establishing of standards. In the case of the European Union, the E112 project will give a fundament of standards to stay within a limit of additional costs (Ludden et al., 2002). Regarding the USA and the E911 project, the research of Ellington (Ellington, 2004) and also Daley (Daley, 2003) shows a lack of standardization of interfaces, interoperability and how to localize a victim in time.

OPERATOR OPTIONS

While developing our infrastructure, we compared different operator schemes. Traditionally, disaster management is a sovereign function of the affected states. Unfortunately, in many countries warning systems are in bad conditions. For example, the coverage of German warning siren systems decreased from 80% coverage in 1992 to 16% in 2000 (Franke, 2000). In view of supra-regional disasters like the Tsunami of Dec. 26 2004, operator schemes across national borders must be discussed. The detection and analysis of disasters can result in international cooperation. We identified three possibilities:

1. Intergovernmental cooperation.
2. Insurers or underwriting associations pose as operators.
3. A re-insurer subsidizes the operator.

For further discussion, we want to concentrate on points two and three.

Insurer acts as warning system operator

Starting from the second scheme, we analyze the existing warning system “weather information on demand – WIND” of the Versicherungskammer Bayern, an insurer (Schulze-Neuhoff et al., 2003). This system offers the clients of the insurance company to define areas-of-interest. In the case of an event, predefined in the observation rules, the user will be notified via Short Message Service (SMS). The benefits for the insurer are:

- Direct contact to the customer / customer loyalty.
- Improve the image of the insurer / unique selling proposition.
- Reduction of damages, resulting in reduced damage events.

WIND neither takes advantage of LBS technology yet, nor explicitly cares for the users’ privacy, the authenticity of warnings or the security of the system as a whole. Additionally, the risk of concentrating on financially attractive segments of population can be seen. Therefore this business model has weaknesses in covering the whole population and not only insured parts.

Re-insurer subsidizes the operator

This operating scheme is based on the fact that disasters of enormous proportions concern mainly the small group of re-insurers. The dimension of economic strain of the insurance industry is described in Table 3 (MünchnerRück-Gruppe, 2004).

Decades	**1950 – 1959**	**1960 – 1969**	**1970 – 1979**	**1980 – 1989**	**1990 – 1999**	**Last 10 : 50**
Insured losses	-	6.2	13.1	27.4	126.0	13,5

Table 3. Insured worldwide losses in billion US$ (2003 values) (MünchnerRück-Gruppe, 2004)

The fact that warning systems “pay for themselves” (EWCII, 2003) affects reinsurance companies in a particular way. The main benefit for re-insurers are, as opposed to the benefits for primary insurers, neither customer loyalty nor specific information about a certain customer. The only economic surplus is provided by the potential reduction of damages.

A multilaterally secure system design based on mobile networks provides advantages for each concerned party:

Disaster forces are able to reduce the investments in the warning infrastructure by getting sponsored. Registered off duty specialists could be identified and directly briefed. Overall, the forces get a high-quality survey of the disaster area.

Mobile operators could use the network as another source of income.

Civilians benefit from effective and reliable early warnings through a commonly used infrastructure. Our approach provides the possibility of notifications about registered next-of-kin and areas of interest.

Re-insurers capitalize from the minimization of damage events.

CONCLUSION

In this paper, we showed that disaster warnings using mobile communications networks are technologically possible. Furthermore, with our analysis of multilateral security requirements, we designed a privacy-friendly architecture providing information security for the involved parties. By using a widely deployed infrastructure, we argued that the cost of warning provisioning in mobile networks is lower, and the warning more efficient than in established warning systems. Additionally to a government-driven setup, a public-private partnership with the insurance industry was found to be an option for funding setup and operation costs of the disaster warning system.

Further research on the topic should answer some remaining questions. First, a field test with a prototype implementation will provide further usability results. Second, field testing should take care of the question on how short a disaster notice can be deployed with mobile phones. Regarding the disastrous Tsunami of Dec. 2004 in Indonesia, very short notice could have saved many lives. Accommodations of mobile networks to include user-sided positioning systems, such as GPS and the future Galileo-system should be a further research topic.

REFERENCES

1. AGBF-NRW(2003) Planungsgrundlage zur Warnung der Bevölkerung bei Gefahrenlage, Arbeitskreis Zivil- und Katastrophenschutz, Arbeitsgemeinschaft der Leiter der Berufsfeuerwehren in Nordrhein-Westfalen.
2. Baker, F. and Carpenter, B. (2005) Structure of an International Emergency Alert System, Network Working Group, Internet Draft, Internet Engineering Task Force (IETF).
3. Borking, J. (1996) Der Identity Protector, in Datenschutz und Datensicherheit (DuD), 20, 654-658.
4. Burke, K. and Yasinsac, A. (2004) The ramifications of E911, Research Report, Tallahassee, Florida, USA, College of Arts and Science, Florida State University.
5. Daley, E. (2003) Wireless Interoperability, Public Management, 85**,** 6 - 10.
6. Ellington, B. (2004) Enhancing E911 Systems a usability plan, Proceedings of the Tenth Americas Conference on Information Systems (AMCIS 2004),. ACM, New York, 3419 – 3425.
7. EWCII (2003) Integrating Early Warning into Relevant Policies, October 16-18 2003, Bonn.
8. Franke, D. (2000) Die Alarmsirene am Handgelenk, in Bevolkerungsschutz, 4. Quartal 2000, 27 - 29
9. Fritsch, L. and Scherner, T. (2005) A Multilaterally Secure, Privacy-Friendly Location-based Service for Disaster Management and Civil Protection, Proceedings of the AICED/ICN 2005, (Springer Lecture Notes on Computer Science LNCS 3421), Berlin, Heidelberg, New York, Springer,1130-1137
10. Gerpott, T.J. and Walter, A. (2004) Operative und Finanzielle Bewertung von TETRA-, Tetrapol und GSM - BOS Plattformen für das digitale BOS-Mobilfunknetz, Kurzfassung, Duisburg, Essen, Schwerpunk Telekommunikationswirtschaft, Universität Duisburg-Essen.
11. Grimm, M. **(**2004) Sichere transaktionsbasierte Behördenalarmierungssysteme auf GSM-Basis, Johann Wolfgang Goethe-Universität, Chair of mobile commerce, Frankfurt am Main.
12. GSMworld (2005), Overview of GSM availability, http://www.gsmworld.com/roaming/index.shtml (2005), as of 1-Mar-2005.
13. HKN and CNN (2000) Usu volcano erupts, http://www.cnn.com/2000/ASIANOW/east/03/30/japan.volcano.04, as of 31-Mar-2000.

14. Held, V. (2003) Technological Options for an Early Alert of the Population, short version, Bonn, Bundesregierung von Deutschland.
15. ISO (1999) ISO 15408 The Common Criteria for Information Security Evaluation.
16. Lane, N. (2000) Effective Disaster Warnings, Washington.
17. LogicaCMG **(**2004) LogicaCMG to create world's first nationwide information cell broadcast solution, www.logicacmg.com/pressroom, as of 11-August-2004.
18. Ludden, B., Pickford, A., Medland, J. and Johnson, H. (2002) Cgalies final report V1.0, Report on implementation issues related to access to location information by emergency services (E112) in the European Union, 99.
19. MünchnerRück-Gruppe (2004) TOPICSgeo **-** Natural Catastrophes 2003 **-** Annual review: natural catastrophes 2003, Munich.
20. Rannenberg, K. (2000) Multilateral Security **-** A concept and examples for balanced security, Proceedings of the 9th ACM New Security Paradims Workshop, Cork, Ireland, ACM Press,151-162.
21. Sanker, S., Yoshimura, F. and Yoshida, M.(2003) Natural Disasters in 2002: An analytical overview, Kobe, Japan, Asian Disaster Reduction Center.
22. Schulze-Neuhoff, K., Kachelmann, J. and Meissen, U. (2003) WIND (Weather information on demand) Experiences in Insurance Companies, in DKKV (Ed.), 4. Forum Katastrophenvorsorge, Munich, 79 – 81.
23. United Nations (2004) United Nations Review of the Yokohama Strategy and Plan of Action for a Safer World.
24. Yoshimura, F. (2002) Disaster Risk Management Through Hazards Analysis, in Proceedings of International Seminar on Disaster Preparedness and Mitigation, New Dehli.
25. Yuan, Y., and Detlor B. **(**2005) Intelligent Mobile Crisis Response Systems, Communications of the ACM, Volume 48, Issue 2 (February 2005). ACM Press, New York95- 98.
26. Vic staff (2002) Usu Volcano Primer, http://www.vic-info.org/RegionsTop.nsf/0/1c231c12c6cd47478a2568b30060bb7e?OpenDocument, as of 11-May-2002.