Mobile4D: Crowdsourced Disaster Alerting and Reporting

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ABSTRACT
Small and large-scale disasters are a major factor for poverty. When information is sent out at an early stage and directly to people affected, impact on environment, people, livestock, crop, and belongings can be minimized. We present Mobile4D, an integrated mobile crowdsourcing-based disaster alerting and reporting system tested in Lao PDR. With Mobile4D it is possible to gather information from affected people, to establish direct communication channels between affected people and administrative units, and to rapidly distribute information to regions and people struck by disasters.

Categories and Subject Descriptors
C.4 [**Performance of Systems**]: *Reliability, availability, and serviceabilit.* H.1.2 [**User/Machine Systems**]: *Human factors.* H.3.4 [**Systems and Software**]: *Distributed systems.* J.1 [**Administrative Processing**]: *Government*

General Terms
Algorithms, Human Factors

Keywords
Disaster Alerting, Crowdsourcing, Mobile Systems

1. INTRODUCTION
It is widely recognized that natural disasters are a main reason for poverty, as they "reduce or eliminate equal access to opportunities, and therefore to development" [1]. Effective response to disasters requires taking quick actions by administrative units supported by disaster management systems (DMS). DMSs usually deal with large-scale disasters like earthquakes, hurricanes, or floods. Existing DMSs are designed to cope with the large complexity under difficult conditions in such cases. While these disasters are also relevant in emerging countries, people there are often faced with problems on a smaller scale, e.g., local outbreaks of human, plant or animal diseases. However, these smaller incidents can have severe consequences for affected individuals and can easily spread and affect others, and thus become a larger scale problem. Therefore it is reasonable to design DMSs to be able to cope with local situations to allow responding at early stages.

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However, in developing countries communication infrastructure and information flow within governmental administrative units (GAUs) and affected regions is not seamless in many cases: areas may be remote, information may get lost or delayed, responsibilities on local level may remain unclear. One solution to these problems is to establish direct communication channels between affected people and GAUs. These channels can be used to inform GAUs directly about situations at the local level. In return, GAUs can send out warnings, information material and support directly to the people and places affected.

In this work, we report on the design and first experiences with the Mobile4D disaster alerting and reporting system. Mobile4D was designed and tested in tight cooperation with the Ministry for Agriculture and Forestry (MAF) in Laos.

2. RELATED WORK
Several ICT frameworks and systems related to disasters have been implemented in the developed world. In developing countries, specific issues have to be faced. As [14] point out, effective warning systems require "not only the use of ICTs, but also the existence of institutions that allow for the effective mobilization of their potential", so the effective inclusion of administrative units plays a critical role.

Sahana [4] is a complex modular Open Source disaster management toolkit targeting at large-scale disasters, especially for organizing and coordinating disaster response. It has been successfully applied in developing countries. Mobile devices gain increasing importance in disaster cases, e.g., systems based on SMS show a good impact in developing countries [10]. An Android smartphone based disaster alerting system which focuses mostly on routing issues in the disaster response phase was presented in [5]. For a review on geo-hazard warning systems in general refer to [2].

Crowdsourcing is an increasingly popular way to collect data provided from people at the local level and build larger information bases. Ushahidi is one of the most popular examples of the impact of crowdsourcing crisis information [13]. In the context of natural disasters, crowdsourcing was used in the 2012 Haiti earthquake to organize help [15]. Especially crowdsourcing of geographical information can have a strong impact in developing countries, for example for monitoring development [7].

3. DESIGN CHALLENGES AND GOALS
We report on Mobile4D, a mobile crowdsourcing disaster alerting and reporting system for Laos. Mobile4D brings together the power of local knowledge about e.g., places, people, livestock, or crop with GAUs responsible for coordination and support. In contrast to other crowdsourcing based disaster alerting systems, Mobile4D enables affected people to directly report disasters to GAUs and enables GAUs to use direct personal communication channels to coordinate action and advice. In the following, we sum up the requirements for a successful integrated disaster

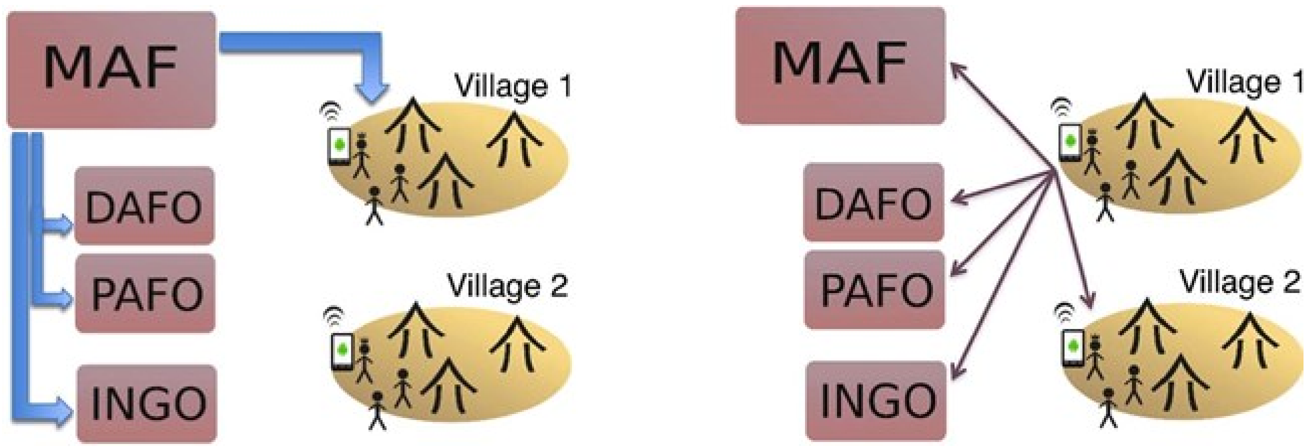

Figure 1: Top-down and bottom-up information flow in Mobile4D: information exchange and communication is flexible and can be established from GAUs as well from local individuals.

alerting and crowdsourcing system that were the starting points for the design of Mobile4D (jointly identified with the Ministry of Agriculture and Forestry of Lao PDR):

Reliable flow of data A reliable flow of information is essential, as all information has to go to the right people: all people affected, and all GAUs responsible. Data must not be lost, bad connectivity must be considered.

Fast distribution of alerts Alerts must be spread as soon as they are created, ideally in real-time.

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Ease of use The success of any crowdsourcing effort critically depends on how easily the system can be used. Any barrier can lower the success.

Data quality Quality of volunteered data is a critical issue [8]. Data entered by volunteers might not be exact, or partially wrong. Credibility of user provided inputs/alerts must be transparent.

Exploiting all sensory opportunities The sensors of smartphones are valuable information sources: location is known by GPS, users can take pictures, which can be a powerful means, e.g., in remote diagnosis [11] of diseases or documentation of impact.

Cost-effectiveness Cost of communication and infrastructure is always an issue in developing countries. Neither GAUs nor local stakeholder can afford to pay larger sums for setting up systems or covering running costs.

Exploiting local knowledge Detailed knowledge about situations is available at the local level, but not in GAUs. Also, local stakeholders can have solutions available that can be shared with other people affected by similar problems.

Providing tools for analysis and response Local administrators must be able to review and analyze incoming disaster warnings and to do administrative work such as combining different alerts, update information, or providing feedback and help.

Connecting people In many cases, direct contact between people is much more helpful than administrative response. The system must enable people to get in contact with each other, to distribute alerts, to share solutions, etc.. Many issues can be solved locally without administrative engagement. The system has to support conventional communication channels such as SMS and voice telephony as those are often preferred by users.

4. MOBILE4D: SYSTEM OVERVIEW

As Lao PDR has a near complete mobile Internet coverage, Mobile4D is designed as an Internet and smartphone based system. The costs for (Android) smartphones drop drastically, and even older devices offer the full range of sensors and interaction possibilities necessary. In the following we explain how these technologies allow the development of a system meeting the list of requirements.

4.1 System Description

Mobile4D basically consists of three components:

- an Android app which allows people in the villages to report disasters, to receive warnings and make contact with people in GAUs to get help,
- a web front end which allows the different GAUs to receive and manage reports, send out warnings and information material, and contact people affected,
- a disaster management server handling the commu¬nication traffic.

4.2 Information Flow and Sharing

Mobile4D is designed to be fully integrated in the organization of GAUs and supports direct top-down and bottom-up communication to exchange information. Information can be disaster alerts, information material, media, ongoing communication about situations between GAUs and people affected. Figure 1 shows how information can flow top-down from the ministry level (MAF) directly to specific affected villages and back. Additionally, information is distributed to the correct subordinate units on province (PAFO) and district (DAFO) level, and to international nongovernmental organizations (INGO). These direct channels enable to shortcut slow information distribution and make information available immediately where it is required.

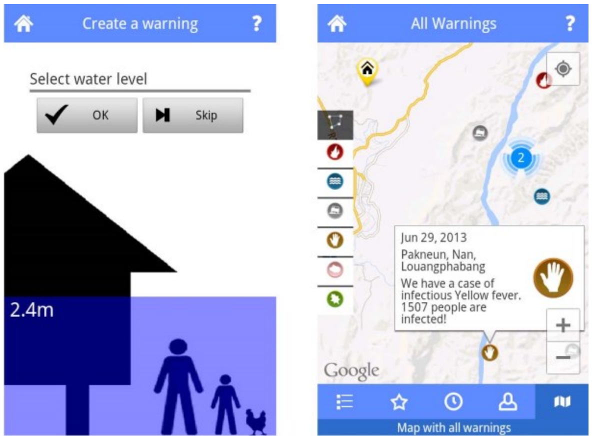

Figure 2: Screens of the Mobile4D Android app. Left: intuitive text-free interface for entering the water level in a flooding by sliding the water up and down. Right: Map overview of nearby alerts.

Most importantly, our crowdsourcing approach enables information to flow in the same way bottom-up: when people are affected by disasters, they can report on the situation to GAUs and INGOs. Mobile4D sends the reports to all GAUs in the hierarchy, but directs the information to the GAU responsible to take action (e.g., infrastructural problems can be resolved on district level, while severe disease outbreaks are handled on province level). Internal protocols ensure that information gets reviewed and questions get answered. Also, reporters will always be automatically notified when their report is processed by administrative staff. Whenever a disaster is reported at local level, the information is immediately sent out to all neighboring villages without administrative review. Potentially affected people get informed when situations are reported and can prevent potential threads to protect health and belongings at a very early stage.

All information can be shared with everybody by forwarding received information via SMS or voice calls. Phone numbers of local reporters and GAU staff are always prominently displayed and can be used for direct communication by everyone. In the smartphone app, this just invokes one touch action. Furthermore, Mobile4D supports interfacing with social network platforms such as Twitter, where detailed information about disasters and their states can be made available.

4.3 Information Generation and Processing

In contrast to social network based platforms, Mobile4D supports structured assembly of information to create specific disaster alerts (floods, bush fires, infrastructural problems, and diseases of humans, animals, and plants). Both mobile and web client users are guided step by step through an intuitive dialogue. Mobile4D tries to avoid textual interfaces wherever possible (see Fig. 3 for an example) as it is well known that text-free widgets can usually be fully understood [3].

Staff of GAUs has a role-based web browser interface (see Fig. 2) to process incoming information of local reporters or other GAUs. They can establish direct communication, send out information and support to places and people in their area of responsibility. Mobile4D provides tools to perform any kind of administrative work related to disasters: reviewing information, getting in touch with reporters, assigning issues to other administrative layers, sending out information material, updating, merging, resolving disasters, etc.

4.4 Further Features

The design of Mobile4D is completely devoted to low-cost technology, real-time communication, and reliability. Mobile4D

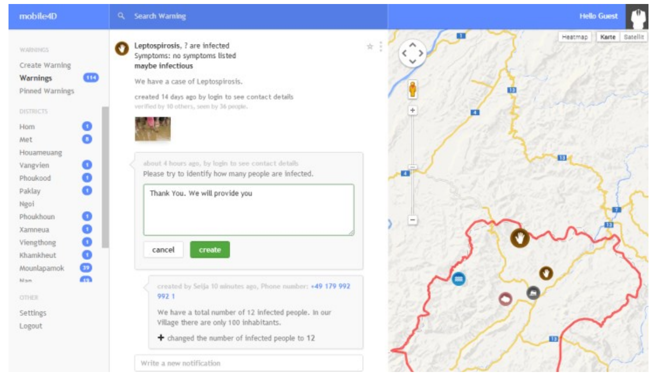

Figure 3: Screenshot of the administrative web interface

supports the widespread free Android platform from version 2.1 on to ensure large availability of compliant new or used low-cost devices. The web client runs on several years old PCs with up-to-date web browsers. It renders functionality with JavaScript, i.e., all code is loaded from the Internet when the page is first accessed. This results in some waiting time at initial startup, but after that, no other network communication is needed than transmitting the efficiently encoded disaster data. As a result, full functionality can be granted also under weak network conditions—an important issue since especially district offices often rely on mobile Internet connections with low bandwidths.

To minimize bandwidth requirements for the mobile app, all alerts and notifications are sent out as Push messages to ensure reliable real-time communication. Mobile4D always focuses on the flow of information: all data is buffered and, in case of connectivity loss, (re-)sent as soon as network service is available again. Photo transmission is adaptive to the actual bandwidth, the pictures are automatically transmitted in different resolutions (from low to high) and sent according to the current bandwidth with low resolution images first.

To assure the quality of data, Mobile4D provides a multi-leveled verification system: Each administrative layer has the opportunity to verify any report, e.g., after checking back via a phone call or personal visit, thus giving the report an "official" stamp. However, single users can also verify the report. That is, the crowd is used for quality assurance itself, as a large number of user verification is a good estimate of its reliability [6]. Furthermore, Mobile4D is fully compliant with the Common Alerting Protocol (CAP) [9]; it offers both import and export functionality.

5. FIRST RESULTS

In April 2013 we performed a three day field test of Mobile4D in the province of Luang Prabang, Lao PDR (see Figure 4). The test involved two staff members of MAF, two staff members of the province office of Luang Prabang (PAFO), and three district officers of the districts of Chompet and Pak-Ou (DAFO). We set up the system with locally available technical infrastructure, that is, laptops people used at work, two privately owned and three provided low-cost smartphones. In addition, we used mobile Internet from three different phone companies. This resulted in a highly heterogeneous technical ecosystem.

On the first day all staff members received introduction into functionality of the system and training on how to use the components. The participants were trained according to their role and responsibilities in their GAU. After initial problems like understanding workflows or handling smartphones the participants learned quickly how Mobile4D works and could use the features without larger problems. During that phase we closely analyzed noticeable usability issues and provided on-site fixing wherever it was possible. On the second day, we performed a system test according to a predefined protocol of events to ensure the technical reliability of Mobile4D under realistic conditions. During this test three teams went to the remote districts of Chompet and Pak Ou, and provided defined data and communication. Mobile4D performed highly reliable even under most difficult network conditions. On the third day of the field test the participants went again into the field to record actual data of current or recent small scale disasters by using a large variety of documentation and communication options. We collected data of so far unrecognized impacts of flooding, an early-stage outbreak of an unknown plant disease, several cases of bird flu, and a recent Malaria outbreak with more than 70 people affected. During the data collection phase the DAFO and PAFO staff in the offices in Luang Prabang administered incoming reports and established direct phone communication with affected people in the villages. For both sides this was a noticeably good experience: the affected people could directly report their problems, and GAU staff was able to gather yet unknown information from districts they are responsible for.

Figure 4: Mobile4D: training and data acquisition in Luang Prabang, Chompet und Pak-Ou

During extensive feedback sessions with all participants we identified points for improvement (mostly in the area of information visualization and usability) and ideas for future features (integrating more reasoning and forecasting capabilities). All participants pointed out the efficiency of direct communication channels between affected people and GAUs, which allows to take quick actions and provides important information directly where it is needed.

6. CONCLUSIONS

Mobile4D is a comprehensive disaster alerting and reporting system. On the one hand, it is fully integrated into administrative institutions and their workflows, and, on the other hand, it supports crowdsourcing information gathering. Mobile4D provides two-way communication from top to bottom level and vice versa, i.e., Mobile4D tackles two important challenges (missing institutionalization and missing two-way communication) that are found missing in current crowdsourcing disaster systems [12]. As a result of the successful field test, Mobile4D is planned to be used in a large-scale pilot test covering all districts of Luang Prabang province.

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