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Last-Mile Hazard Warnings System: Evaluation of a Pilot for a National Implementation Plan

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***Abstract* - The plan of the Community-based Last-Mile Hazard Warning System (LM-HWS) is to complement the efforts at the National and Global levels by preparing the last-mile communication segment of an end-to-end hazard detection and notification chain of systems. While the main focus in the world is on detection and monitoring systems very little or no emphasis is given to 'last-mile' segment of a National Early Warning System (NEWS). The LM-HWS pilot phase completed in May 2007 deployed and assessed various alert and notification Information Communication Technologies (ICT) and the relevant processes intended to reduce the vulnerability of local communities to natural and manmade hazards in the last-mile of Sri Lanka. The project adopts an "all-hazards, all-media" approach designed around a set of five wireless communication technologies. The pilot project involved deployment, training, and field-testing of the technologies, in various combinations, across 32 tsunami-affected villages, using Common Alerting Protocol (CAP) for data interchange with content provided in three languages (English, Sinhalese and Tamil). This paper reports on findings from a series of field tests conducted in Sri Lanka to compare the performance of the centralized message five 'last-mile' devices with their relative effectiveness in terms of alert and notification capabilities. One finding indicate that overall performance of the alert and notification system is enhanced when a village is equipped with a technology combination that enhances "complimentary redundancy" in reliability and effectiveness. Second finding indicates that the reliability can be enhanced by introducing a Multilanguage single input multiple output software application (i.e. CAP Broker) at the central message relay. Further implications of these findings for planning and future research are discussed. Third aspects of the findings imply that the first responders require rigorous training and certification in emergency communication to avoid ambiguity and misinformation. The Last-Mile Hazard Warning System takes an all-hazards all-media approach in reacting to global and local hazard warnings The LM-HWS project is pioneering this work providing policy makers in the region with assessment methods and analytics to justify the best practices in deploying a communication system for multi-hazard alerting and notification.**

I. INTRODUCTION

In December 2005, LIRNE*asia*, an ICT policy and reform research organization, initiated a research project to evaluate the "last-mile" communication component of an all-hazards warning system for Sri Lanka. The project entitled, "Evaluating Last-Mile Hazard Information Dissemination", or the "HazInfo Project"[1], was carried out with the aid of a grant from the International Development Research Center (IDRC), Ottawa, Canada. Research design was based on recommendations contained in a concept paper developed following the 2004 tsunami.[2]

The primary objective of the research project was to evaluate five wireless ICTs deployed in varied conditions for their suitability in the 'last-mile' of a national disaster warning system for Sri Lanka and possibly extending to other developing countries. This paper evaluates three systems of the communication chain for alert and notification and provides recommendations to planners based on the findings from the pilot project. It is anticipated that an improved understanding of these factors can lead to better investment decisions in NEWS.

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1 Research Project: Evaluating Last-Mile Hazard Information Dissemination (HazInfo). 2006. Available http://www.lirneasia.net/projects/current-projects/evaluating-last-mile-hazard-information-dissemination-hazinfo/

2 Samarajiva, Rohan, Knight-John, Malathy, Anderson, Peter, Zainudeen, Ayesha et al. (2005, March 17). National Early Warning System Sri Lanka: A *Participatory Concept Paper for the Design of an Effective All Hazard Public Warning System* Version 2.1, LIRNEasia and Vanguard Foundation, 2006. Available http://www.lirneasia.net/projects/completed-projects/national-early-warning-system/

The HazInfo project involves a non-government organization (NGO) Sarvodaya[3] and is established on a governance structure whereby this organization provides project oversight, training, and operates a Hazard Information Hub (HIH) for the monitoring of hazard threats and dissemination of warning messages to local communities within the Sarvodaya network of villages. Each of the 32 participating communities varies in size from 150 – 1000 households.

II. COMMUNICATION ARCHITECTURE OF THE COMMUNITY-BASED SYSTEM

The system architecture depicted in Fig. 1 complements the traditional public alerting system design usually established by local and/or national governments. A traditional public alerting system issues warnings directly to communities via broadcast media such as television and radio, or through designated public address (PA) systems. By contrast, the LM-HWS project architecture establishes a closed user group of first responders, who are equipped with addressable wireless devices for receiving bulletins issued from Sarvodaya's Hazard Information Hub.

A simplified information flow for the LM-HWS is as follows: staff members at the HIH monitor hazard events around-the-clock using the Internet. When a potential threat is detected, the HIH activates its Emergency Response Plan (ERP) by issuing a message to the n-number of communities (Villages) at risk using a combination of wireless ICTs to reach local first responders (denoted by the arrow and block between the HIH and ICT-G blocks in Fig. 1). Each community has assigned a person or persons to be responsible for managing the wireless terminal device(s) and monitoring it (or them) for incoming warning messages. This person has received training from Sarvodaya and is designated as a community ICT-Guardian (ICT-G). When the ICT-G receives a warning message at the HIH, they are responsible for activating the community-level ERP. The community response will vary depending on the content of the message, including its priority level.

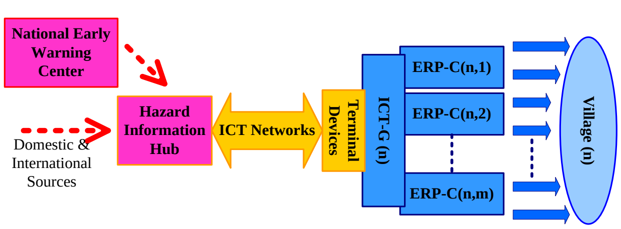

Figure 1 - end-to-end hazard information communication architecture of the LM-HWS; where messages received at the HIH are relayed to the villages.

During activation, the ICT-G informs the m-number of ERP Coordinators (ERP-C), consisting of a First-Aid team, Evacuation team, Security team, and Message Dissemination team. The Message Dissemination team then relays the message village-wide through various methods, including word-of-mouth, ringing local temple bells, loudspeaker, and so forth.

Message content is encoded using CAP, an open source data interchange standard that includes numerous fields intended to provide consistent and complete messages across different technologies.[4] The implementation of CAP in the LM-HWS is an important aspect of the project because it is key in establishing an "all-media" warning capability.

III. RESEARCH DESIGN FOR EVALUATING THE COMMUITY-BASED SYSTEM

The research proposal of this project defined six specific research parameters for assessment: reliability of different wireless devices for transmitting messages, effectiveness of devices for alert and notification, impact of the technology on community organizational structure, effectiveness of the training regime, gender specific concerns, and integration of the wireless technology into the daily activities of the villages. This paper will focus on the first four parameters concerning the reliability and effectiveness of wireless technologies for providing hazard warnings to villages as well as the behavioral implications of organized versus less organized villages and the importance of the training at all levels of the communication chain.

LM-HWS assessed five wireless technologies, selected for their diverse communication paths and different features: Addressable Satellite Radios for Emergency Alerts (AREA), a specialized Remote Alarm Device (RAD), Mobile Handheld Phones (MOP), Wireless Fixed Phones (FXP), and Very Small Aperture Terminal (VSAT) coupled with a Personal Computer. The technologies were deployed in communities in a heterogeneous configuration. The research team also acknowledged the importance of incorporating "bi-directional" capabilities at the village level so that devices could provide communities with means to inquire of situations and inform local hazards to the Sarvodaya HIH (upstream communication). The AREA unit was the only device that was limited to downstream communication. Therefore, this particular equipment was married with one of the other 4 equipments to form

[4] Botterell, Art and Addams-Moring, Ronja. (2007). Public warning in the networked age: open standards to the rescue. *Communications of the ACM*, 30 (7), 59-60.

an ICT where the coupled configuration: AREA+MOP, AREA+FXP, AREA+RAD, and AREA+VSAT would have bi-directional capabilities.

IV. METHODOLOGY FOR ANALYZING THE PERFROMANCE

Evaluation of the processes and technologies was done through a series of "silent-tests" and "live-exercises". The silent-tests would involve the HIH issuing a message to the terminal devices where the ICT-G would pickup the message and acknowledge receipt but would terminate the message at that point and not relay to the ERP-C. Similarly in the community the ICT-G would mimic the receipt of a message and propagate it to the relevant ERP-C. The ERP-C would take the message as an input to run through their plans without disseminating the message to the community (i.e. conduct "table top exercises"). After the silent-tests have been completed and the first responders were comfortable with there activities the community would engage in live-exercises; where a message related to a hypothetical hazardous situation is initiated at HIH and transmitted to selected communities. The ICT-G would accept the message, if applicable, would communicate it to the ERP-C who intern would disseminate to the community. The community would exercise their evacuation drills according established plans and training received. The paper does not discuss the methodology of evaluating the performance but makes a reference to other papers involving the same project, which have defined quantitative and qualitative analytical techniques used to assess the system and components.

A. *Common Alerting Protocol*

A major feature of the HazInfo Project employed the use of a standard data interchange known as the "Common Alert Protocol" (CAP) between the message-relay and the end-user technology. The reasons for integrating open source XML-based CAP into the project, mentioned in [1] and [2], is because it is an open source and a standard independent of the ICT platform being used. The implementation strategy and construction of the 'CAP Profile for Sri Lanka' is discussed in [2]. "*CAP Message Interoperability*" was subjectively studied by assessing the "action taken" by the message recipient. For this assessment, the CAP message relayed from the HIH and actions taken were recorded by each First-Responder for the respective ICTs. The effectiveness was measured as to how well the First-Responders could record the message received over the particular terminal device and interpret it accurately. The input of CAP messages to the system and the respective output of the CAP message being displayed on the terminal device are discussed in [4].

B. *Reliability of the processes and technologies*

The basic question governing the reliability measure is "did the ICT based system work on the day of the live-exercise?" Reliability of all the processes are measured in terms of *efficiency* (i.e., will the message be received with enough advance warning to take action?) [6]; except for the reliability of the terminal devices, which in addition to efficiency use a measure defined as *certainty* [7]. Certainty is a measure that is a function of the signal strength that indicates the probability of receiving the alert message (i.e. operational state of a device on the day of the exercise). The signal strength required to receive an alert message may vary from the signal strength required for the terminal device for normal operations.

In order to give the community ample time to execute their ERP the author suggests that the benchmark efficiency for the processes at the HIH, ICT, and Community should be 90%, 90%, and 60%, which translates to the HIH-M taking nor more than 10% of the time to issue the message, ICT-G taking nor more than 10% of the time to decipher and communicate the message to the ERP-C, and the ERP-C taking nor more than 40% of the time to disseminate message to the households and evacuate the community to safety; leaving a 20% buffer time prior to disaster striking.

C. *Effectiveness of the technologies and actors*

Effectiveness of the ICT terminal devises were measured as a function of a set of discrete parameters. The project has defined 11 such discrete parameters: language diversity, full CAP capability, audio and text medium availability, bi-directionality, total cost of ownership, DC power consumption, daily utilization, acknowledgement of message receipt, active alerting functionality, weight of wireless ICT, and volume of terminal device. A "Liken" type rating was used to obtain a real valued score between 0 and 1 for each of the parameters. The 11 parameters are further grouped in to 5 cliques: CAP Completeness, Two-way, Adoptability, Miniaturization, and Alerting. A subset of the mentioned parameters (language diversity, full CAP capability, and audio/text medium availability), which defines the aspect of being *CAP Complete*, is already discussed in [4]. Equally important feature: *Alerting* capability of wireless ICT terminal devices, on the basis of the parameters: acknowledgement of message receipt and active alerting function is discussed in [6]. The remaining cliques: Two-way, Adoptability, and Miniaturization are discussed in [7].

Effectiveness of the HIH and Community is a measure of the HIH-M and ICT-G capability to encode and decode a CAP message. In the case of the HIH-M they are expected to transform any bulletin received from an external source to fit the form of a CAP message. This task is done with the aid of a form called the “EOI” (Event of Interest). The EOI form contains all the attributes of a CAP message and is concarcted in a way to assist the HIH-M with the task of encoding a CAP message. The ICT-G must be capable of interpreting the CAP message received from the HIH and most importantly be able to determine the priority of the message. ERP-C are expected to activate all their ERPs with respect to the Hazadous event invloving the activation of the local dissemination teams, first-aid teams, security teams, and evacuation teams. They are further expected to clearly and accurately deliver the information related to the incident as well as cover all the households in their juresdiction. Effectiveness of the community-based system’s components related to the HIH and Community are elaborated in [9].

V. PERFORMANCE OF THE SYSTEM COMPONENTS

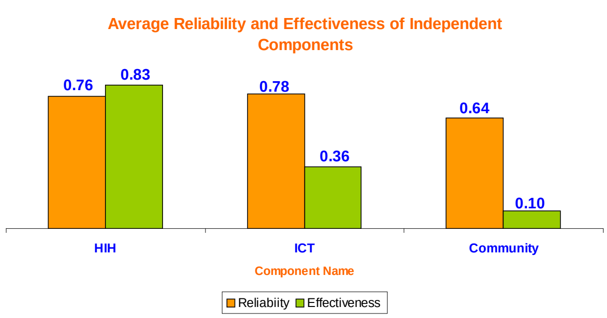

Figure 2 - Reliability and effectiveness of the HIH, ICT, and Community subsystems

A. *Hazard Information Hub*

The set of HIH-M functions are -- downloading bulletines from gloabal/local feeds. Acknowledging reciept, generating and EOI, getting pre-dissemination approvals, and issuing CAP message, which are illaborated in [9]. With some procedural improvement and training the HIH functions, up to the point of relaying (issuing) the CAP Message, can be made to perform over 90% efficiency. Howevere, the bottleneck is in the final step of issuing the message via the ICT interfaces. Some of the delays were caused by login failures as a result of the HIH-M not remembering the multiple passwords or the interface access password had expired and needed administrative assistance to reset it. Having to operate a multiple of Single Input Single Output (SISO) message relay software interfaces is intuitively a cumbersome task. Data shows that the efficiency drops exponentially when the number of independent applications the HIH-M has to use increase as a result of repetition of entries. Interfaces that require recording voice messages are a main bottleneck that brings down the efficiencies. Due to the time consuming recording and editing processes.

Emergency communication text messaging, in the live exercises, was mainly in English, except for the java enabled Multilanguage mobile phone, which carried Sinhala, Tamil, and English. Therefore, the complexity of translating the English CAP messages to Sinhala and Tamil is not reflected in the data too well. However, it is intuitive that without any intelligent real-time natural language translator it would be very difficult for the HIH Monitors to achieve the 90% Reliability benchmark; especially for all-media all-hazards communications.

Assuming the duration of a hazard such as a tsunami initiated in the Indian Ocean is 90 minutes, from the time of detection to the time of impact, by applying the methodology for calculating efficiencies described in [6], an efficiency of 0.76 (Fig. 2) translates to 21.6 minutes, which is too long and takes away valuable time from the community to activate their evacuation plans. An efficiency of 0.90 would translate to 9.0 minutes, which is what is expected from the HIH. In temrs of effectiveness the scoring had dropped below the 0.9 benchmark because the HIH-M did not populate essential attributes of the EOI form properly. There were also inconstancies among different HIH-M scheduled to participate in the respective live-exercise. Detailed analysis of the HIH performance is discussed in [5] and [9].

B. *Information Communication Technology*

Despite the high speed transmission of the ICTs, which took less than 7 seconds to carry a message from the HIH to the Community, there were delays caused mainly by human errors such as the message recipients: ICT-G not correctly aligning the antennas of the satellite system, accidentally deleting the Java applet on the mobile phone, wrongly configuring the application that restricted receipt of certain levels of hazardous events, ICT-G not being close to the nomadic/fixed wireless terminal devices to receive the message on time, or simply the ICT Provider terminating the services for not having received a payment for the monthly bill. An unusual occasion was the MOP and FXP failing on the day of the exercise as a result of the conflict situation in the North and East of the Island; where the Military had instructed all commercial wireless operators, GSM and CDMA, to shut off cells in the particular battle zones. However, the unidirectional AREA satellite based sets functioned in the war-zones when the terrestrial technologies were shut off. As mentioned previously communications in English in the rural communities were difficult for the locals to comprehend. The Active Alert function was not up to par to grab the attention of the ICT-G. Restrictions of the terminal capabilities of carrying a full message caused false information propagation in the communities. The qualitative and quantitative outcome of the effectiveness of the individual ICTs is illustrated in [5], [7], [8] and [9].

C. Community

ICT-Gs were forced to decode partial CAP messages displayed by ICT terminals that could not carry a full CAP message. Shortcomings of the ICT terminals with respect to displaying full CAP messages were a major challenge of Internetworking with CAP for relaying of complete messages [4]. As a result of the partial messages in many of the live-exercise mutation of information was witnessed. When the HIH had issued a “Category 4 Cyclone” alert the communities executed tsunami evacuation plans; i.e. running to a higher grounds when they were actually supposed to seek shelter at lower ground. According to the information in the alert message and the time the ICT-G received the message, the communities had approximately 4-6 hours to prepare for the arrival of the Cyclone. It is incorrect to put the blame on the Communities because the CAP structure is constructed to lodge all-hazards all-media unambiguous messages. The CAP message should aid ICT-G in giving clear and accurate information to the ERP Coordinators in order to decide on and execute precise ERPs and prevented panic and chaotic behavior in the community.

VI. RECOMMENDATION FOR PLANNERS

A. HIH Monitors and CAP Broker

An early challenge faced by the project was whether or not the project would need to build a CAP user interface (GUI) from scratch, or whether there was an application available that could be borrowed. The CAP GUI provides a method (a template) for authorized users to enter data into a computer at the HIH and for the transformation of that data into the appropriate CAP XML elements to enable standardized content creation and passage to the various ICTs. The results show the need for a CAP broker. A CAP broker would remember the security access information to all of the teleports. Hence, the HIH Monitor will need only the CAP broker access information. Low reliability of the HIH-M during the live-exercises was a consequence of many factors that were due to time consuming tasks such as filling out the paper-work for generating an EOI and having to use multiple applications to disseminate the messages to each of the ICTs. The deficiency of a single-input-multiple-output “CAP Broker” application is evident in this process [5]. It is recommended that a free and open source software program (CAP Broker) be developed to integrate the project’s individual CAP message generators and processors to serve as a single non-repetitive data input and import/export function. Supplementing the deficiency in a LM-HWS with additional with human capacity is very costly. Therefore, most of the deficiencies must be remedied with Software such as a CAP broker.

B. Complementary Redundancy in Choice of ICTs

Test initial results show all devices to take less than one minute to push the alert messages to the end user devices but overall scores for reliability varied considerably. Effectiveness also varied widely across devices highlighting several user training concerns as well as some unforeseen difficulties implementing and maintaining the devices. Looking at the overall picture, the AREA performed very reliably in part because the footprint of the WorldSpace satellite’s strength over Sri Lanka. However, the AREA was somewhat less effective than initially anticipated because of limitations of text display and user friendliness issues. On the other hand, the MOP proved to be a very effective means of conveying messages to the ICT-G, despite the fact that its reliability score proved to be lower than anticipated. This is in part because terrestrial wireless networks have not fully penetrated the rural areas of Sri Lanka and cover only about 60 per cent of the Island. However, when considering combined performance of the devices, the high reliability of the AREA device with the high effectiveness score of the MOP provided what we might term “complimentary redundancy” with the two devices working well together in balancing reliability with effectiveness.

C. Strengthening Communication strategy in the Community

Researchers realize that there is a rather significant liability of false information diffusing rapidly in a community if the problem of information mutation at the

HIH-M, ICT-G, and ERP-C stages is not corrected. Further acknowledge that a comprehensive study of the problem related to information mutation and chaotic behavior due to false information diffusion in a LM-HWS must be studied. Such irregular social phenomena can be studied using techniques such as "patterned chaos forecasting" techniques (Fu et al, 2007 - [10]). As part of the community preparedness the ERP-C had to devise a scheme to disseminate the message to the households. Most of them used traditional methods such as sounding temple/church bells, voicing via mosque speakers or public announcing system attached to a vehicle. However, these methods were proven to be highly ineffective during the live-exercises. The villages themselves insisted that an audible siren be installed to communicate hazards such as tsunamis that have relatively little time opposed to cyclones that can be forecasted 48 hours ahead.

VII. CONCLUSION

We have seen the cases where inadequate training and improper prior notification has resulted in unstable behavior; i.e. create a havoc situation. With the LM-HWS taking the approach of all-hazards all-media alerting and notification, it is vital that unambiguous full CAP messages are issued by the HIH and are received by the Communities. As a result it is recommended that policies are implemented to provide formal training and certification of the HIH-M and ICT-G to be absolutely competent of communicating with the use of CAP standard. The author acknowledges that further exercises must be conducted to realize the true potential of utilizing a Community-based system; especially for the Last-Mile. Since the data reported is from the first trial of its kind it is impossible to adapt methodologies such "Markov Decision Processes" to improve the policies because of the insufficiency of probabilistic data to develop transition probability tables to determine the effectiveness of the policies in practice. However, through conventional trial and error methodologies the pilot project is able to suggest intuitive policies that can strengthen the performance of a Nation's Public Warning System.

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