Last-Mile Hazard Warning System in Sri Lanka: Performance of the ICT First Responder Training Regime

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ABSTRACT

M=9+ earthquake in Sumatara, Indonesia, on December 26, 2004 00:59 GMT, triggered destructive tsunami waves, which greatly affected Indonesia, Sri Lanka, India, the Maldives, and Thailand. People were caught unawares as there was no warning system in place for tsunamis in the Indian Ocean. Overall it is estimated that more than 225,000 people, in the region, perished (Samarajiva, 2007 - [9]). Last-Mile Hazard Warning System (LM-HWS) is introducing Alerting and Notification to improve the "situational awareness" of all-hazards in 15,000 Sarvodaya embedded Communities in Sri Lanka. The Pilot phase established Last-Mile networking capability for 30 tsunami-affected communities with a heterogeneous deployment 5 ICTs: Addressable Satellite Radios for Emergency Alerting, GSM based Remote Alarm Devices, Mobile Phones, CDMA Nomadic Phones and Very Small Aperture Terminals. Lessons to-date suggests the basic internetworking arrangement at lower technical layers has proven to be reasonably robust and reliable but a key challenge remains in the upper layers of human capacity, application software, terminal devices and content provision (Waidyanatha et al, 2007 - [11], [12] and [13]). The Sri Lankan experience shows that the LM-HWS is neither efficient nor effective without competent human-capacity at the message-relays: Hazard-Information-Hub and Last-Mile Communities; a necessary condition to supplement the deficit of an end-to-end automated alerting system. Despite the training that was offered to the Hazard-Information-Hub Monitors and Community ICT Guardians; their performance was well bellow the 95% benchmark (see Fig 4). The project identifies that the Common Alerting Protocol intensive ICT based last-Mile alerting and notification system requires periodically repeated training and certification to improve the reliability and effectiveness of the human resources who are entrusted with mission critical LM-HWS processes.

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* The paper uses data from the live-exercises conducted in 30 villages belonging to the coastal districts: Colombo, Kalutara, Galle, Matara, Hambantota, Ampara, Batticaloa, and Trincomalee. The exercises were carried out over a 6 month period: November 2006 – May 2007. Author would like to acknowledge all partners: TVE Asia Pacific, Dialog Telekom, University of Moratuwa, WorldSpace, Solana Networks, Innovative Technologies, Vanguard Foundation, and Sarvodaya for their contributions through training programs, technology, Human Resources, and Institutional facilities. Author extends the gratitude to Peter Anderson (Simon Fraser University, Canada) and Gordon Gow (University of Alberta, Canada) for their contribution in expert knowledge of disaster communication and the Common Alerting Protocol.

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1.0 INTRODUCTION

In December 2005, LIRNE*asia*, an ICT policy and reform research organization, initiated a research project to evaluate the "last-of-the-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", was carried out with the aid of a grant from the International Development Research Center (IDRC), Ottawa, Canada. Its research design was based on recommendations of a "participatory concept paper" for a national early warning system (NEWS:SL) completed in the months following the 2004 tsunami (Samarajiva et al, 2005 - [10]). The paper noted that although the issuing of public hazard warnings was the responsibility of the government, it is unlikely that the Last-Mile of such a system can be provided solely by government. Rather, it requires a partnership of all concerned including government, private and non-government sectors.

For purposes of the HazInfo project, the research would focus on the non-government organization (NGO) contribution and be designed around a governance structure whereby a non-profit NGO, Sarvodaya[1], would provide oversight, training, and a hazard information hub for the monitoring of hazard threats and dissemination of alert messages to local communities within the Sarvodaya network of villages utilizing combinations of different ICTs. Designated first-responders selected from the local communities would be responsible for monitoring messages delivered by the ICTs, overseeing emergency preparedness, message dissemination, and emergency response at the local level. The project findings from the simulated "silent-tests" and "live-exercises" of the ICTs and integrated risk management processes are intended to provide a guide to implementing an early warning system for the 15,000 plus Sarvodaya embedded villages[2] in Sri Lanka.

The general objective was to evaluate the suitability of 5 ICTs deployed in varied conditions (a combination of 8 configurations, see table 1) in a last-mile of a national disaster warning system for Sri Lanka and possibly by extension to other developing countries. Specific objectives are to measure the system design and performance for: reliability of the ICTs; effectiveness of the ICTs; effectiveness of the training regime; contribution of organizational development; gender specific response, and integration of ICTs into everyday life. These factors have been assigned a set of corresponding indicators that will form the basis for observations and evaluations of the technology and training.

2.0 COMMUNITY-BASED LAST-MILE HAZARD WARNINIG SYSTEM

The LM-HWS 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.

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1 The Lanka Jatika Sarvodaya Shramadana Sangamaya (Sarvodaya) is Sri Lanka's largest and most broadly embedded people's organization, with a network covering: 15,000 villages, 345 divisional units, 34 Sarvodaya district offices; 10 specialist Development Education Institutes. http://www.sarvodaya.org/about. Selected Sarvodaya Communities were affected by the December 2004 Indian Ocean Tsunami and uniformly represent the 10 Tsunami affected Coastal Districts of Sri Lanka. These Communities also represent the different ethnic communities in the country.

2 Sri Lanka has more than 23,000 villages comprising, predominantly, Sinhala, Tamil, Muslim, and Burger ethnic groups.

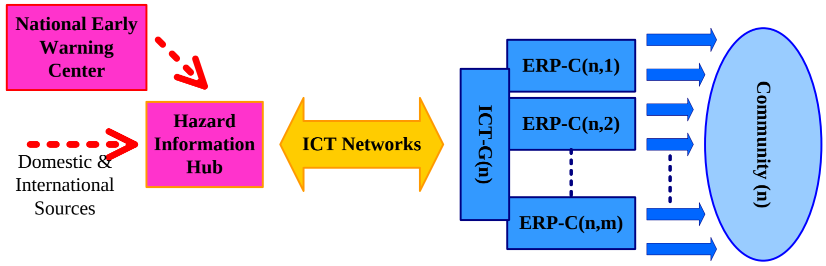

Figure 1 - end-to-end hazard information communication architecture of the LM-HWS; where messages received at the HIH are relayed to the villages

A simplified information flow for the LM-HWS is as follows: staff members (HIH-Monitors) at the HIH monitor hazard events around-the-clock using the Internet. When a potential threat is detected by an HIH-Monitor (HIH-M), the HIH activates its Emergency Response Plan (ERP) by issuing a message to the n-number of communities at risk using a combination of wireless ICTs to reach local first responders (denoted by the arrow 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 device and monitoring it 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. 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 as word-of-mouth, ringing local temple bells, loudspeaker, and so forth.

3.0 ALL MEDIA ALL HAZARDS CONTENT STANDARD TO TEST EFFECIVENESS

Message content is encoded using Common Alerting Protocol (CAP), an open source data interchange standard that includes numerous fields intended to provide consistent and complete messages across different technologies.[3] The implementation of CAP in the LM-HWS is an important aspect of the project because it is crucial in establishing an “all-media” warning capability. Reader is strongly recommended to read (Gow) - [5], (Waidyanatha et al) [11], and [12] to learn of the CAP Profile for Sri Lanka, Assessment of the terminal devices with CAP as a message content, and the need for a CAP based software to increase the performance of the HIH, respectively. This paper will refer to CAP in the context as it is discussed in (Gow, 2007 - [5]), and (Waidyanatha et al, 2007 - [11], [12]).

A major feature of the HazInfo Project employs the use of a standard data interchange known as the “Common Alert Protocol” (CAP) between the Hazard Information Hub (HIH) and the end-user technologies.[4] Project is specifically interested in researching the use of CAP in a Multi language environment such as in Sri Lanka, exemplified in (Gow, 2007 - [5]) and (Waidyanatha et al, 2007 - [11], [12], [15]). CAP was integrated into the project because it is an open source, XML-based protocol with clearly defined elements, is capable of supporting data interchange across multiple dissemination channels; with CAP, one input at the central information hub can be translated into multiple outputs for downstream alerting; CAP provides a standardized template for submitting observations to the central hub (upstream) and thereby supports situational awareness to improve overall management of a critical incident; A CAP-enabled system will more easily integrate with other national and international information

3 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.

4 CAP Cookbook (Wiki). (2006) Welcome to the CAP Cookbook. 2006. Available http://www.incident.com/cookbook/index.php/Welcome_to_the_CAP_Cookbook

systems.

Table 1 - Matrix to determine Message Priority with CAP elements

Priority	<urgency>	<severity>	<certainty>
Urgent	Immediate	Extreme	Observed
High	Expected	Severe	Observed
Medium	Expected	Moderate	Observed
Low	Expected	Unknown	Likely

4.0 FIRST RESPONDERS ARMED WITH ICT

HIH-M and ICT-G are the only first-responders in the LM-HWS equipped with ICTs and the activation procedures of the two first responders are defined in the "Guidelines for the HIH"[5]. This paper does not discuss the performance of the Emergency Response Plan Coordinators.

4.1 Hazard Information Hub Monitors

The Hazard Information Hub is fully equipped with redundant internet access; where one link is via a VSAT that directly connects the hub with a ISP in Hong Kong: Speedcast[6], via the AsiaSat II Satellite relay and the second is a microwave link that connects the hub to a local ISP: Dialog Internet[7], via a point-to-point terrestrial relay. The VSAT link is used as the primary source. The microwave link is used as a secondary source.

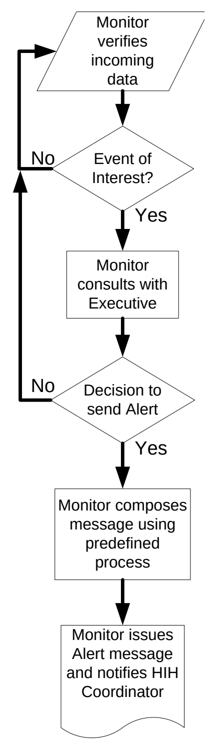

Figure 2 - HIH Activation Flows

The HIH-M use the internet to watch for RSS or CAP feeds from the United States Geological Survey or National Meteorological Department, mainly for, for tsunami and cyclone threats as well as tune to the web based media broadcasts such as BBC News. The internet connection is also the gateway to receiving email bulletins from the United Nations Intergovernmental Oceanographic Commission (UN-IOC) tsunami warnings and the Global Disaster Alert Coordination System (GDACS). Further, the HIH staff mobile phones are registered with GDACS to receive SMS alerts.

HIH-M first validate that the alert messages received from International and domestic source, as illustrated in Fig. 1 are of threat to the Sarvodaya communities. If such a treat is certain to affect any of the Sarvodaya communities, then it is signaled as an EOI. At this point the protocol requires that the HIH-Monitor document the EOI on a readily available paper form. The purpose of the form is to maintain a "paper trail" of the events that activated the HIH ERPs.

The event is reported to the Sarvodaya executive to obtain authorization to issue the alert to the communities at risk. There are approximately 6 Sarvodaya Executives who work according to a roster. The Executive on the roster for the particular month is accessible via redundant phone lines as and when needed. In most situations the Executives are on the premises of the Sarvodaya Campus.

5 Gow, Gordon A. (2006, July 12). Last-Mile Hazard Warning System: Guidelines for HIH *Procedures, System Activation, and Testing*, LIRNEasia HazInfo Project [Available from the author]

6 Speedcast is a leading satellite communications service provider in Asia. See http://www.speedcast.com/ for more details.

7 Dialog Internet is an Internet Service Provider in Sri Lanka, which is a subsidiary of Dialog Telekom -- http://www.dialog.lk/en/internet/

The Sarvodaya Executive may request additional information from the HIH-M as well as personally verify the event through their own networks such as calling a known official in the Government. Once the executive is content that the event is real he or she will authorize the HIH-M to issue the alert.

Each ICT has an independent interface to construct and issue the messages to the five wireless terminal devices. The HIH monitor will compose the CAP message where the information is directly extracted from the EOI paper based form. The messages will be issued directly to the ICT-Gs in the vulnerable areas.
In August 2006, HIH staff were given training for certification as Hazard Information Hub Monitors and "authorized users". The basis of the course is the *Common Alerting Protocol* (CAP) for risk information communication. By the end of the course the Monitors were able to: 1) *identify* an Event of Interest (EOI), 2) *confirm* the EOIs with a Sarvodaya Executive, 3) *construct* a CAP Message, and 4) *relay* the CAP message to HazInfo ICT devices in designated communities.

The training also emphasized, in the event the government of Sri Lanka issued a public warning, how the Monitor should relay this message directly through the HazInfo network. If the government does not issue CAP-compliant messages, the Monitor would develop a system for translating or reformatting these messages quickly and accurately into a HazInfo CAP-compliant message.

4.2 Last-Mile Community ICT Guardians

The last-mile communities are equipped with one or two ICT terminal devices. Refer to Table 2 - research matrix to identify communities with one and communities with two terminal devices. The ICT devices are owned by the Sarvodaya Shramadana Society (i.e. Sarvodaya Voluntary Society) of that community. The community selects an appropriate person, belonging to the society, to house the ICT and maintain it in good operational state. In two societies where they were given two devices, because of the geographic disposition of the community, the society decided to distribute the two terminals between two ICT-Gs. This was mainly to cover the community residents who were located farther apart.

The terminal devices would be strategically placed based on mobile, nomadic, and fixed nature of the terminal device. For example, the AREA, RAD and FXP that are nomadic would be guarded by the Society Chair who would take the device to the society office during day time and bring it home at night. The VSAT, a permanent fixed solution, would be placed in the nearby Sarvodaya District or Divisional office; where there is an IT Administrator present around-the-clock and would act as the ICT-G for the community. ICT-Gs with MOPs had none of the intricacies that apply to nomadic and fixed terminal devices.

Once an Alert message is received by an ICT-G, the first task is to determine the priority of the message. Only the AREA device had the capability of displaying the CAP elements <urgency>, <severity>, and <certainty>. Table 3 expresses the method for determining the priority of a message using the three CAP elements: <urgency>, <severity>, and <certainty>. All others devices could mainly carry the qualifier CAP elements in the <alert> segment of the message or the content provided in the <description> element of the devices.

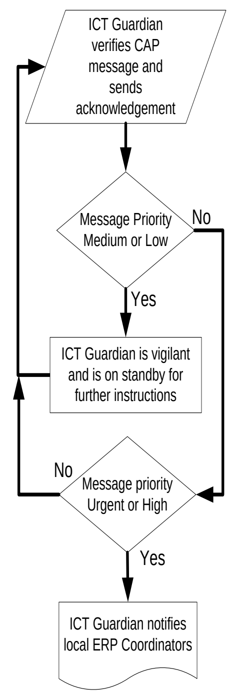

Figure 3 - ICT-G activation flow of Emergency Response Plans

When an alert message is received the ICT-G will document the message on paper (a standard form was given to them). The paper form is for two purposes 1) to be used as a paper trail for community records and 2) to be used as a communication document to be produced to the ERP-Cs. Immediately following the documentation the ICT-G is expected to send an acknowledgement to the HIH confirming receipt of message and clear comprehension of the message content. In the event the message is 'Medium' or 'Low' priority the ICT-G will stay vigilant to receive follow up messages as well as tune in to other sources such as the media (tv and radio) or contact neighboring communities to gather additional information. "Urgent" and "High" priority messages are immediately relayed to the community ERP-Cs to take further action (i.e. execute community ERPs).

5.0 RESEARCH DESIGN OF THE LM-HWS

Table 2 - The distribution of ICTs in the 32 Sarvodaya Communities (District defined in parenthesis) that participated in the Last-Mile HazInfo Project. Table is subdivided in to 4 quadrants with 8 villages in each. VSAT – very small aperture terminal, MOP – mobile phone, FXP – fixed phone, AREA – Addressable radio for emergency alerts, RAD – remote alarm device, and Control Village – community without an ICT.

VSAT Urawatha (Galle)	MOP Nidavur (Batticalo)	FXP Thirukadalar (Trincomalee)	AREA Moratuwella (Colombo)	MOP Meddhawatha (Matara)	MOP Thamiluvil (Kalmunai)	FXP Oluville (Kalmunai)	AREA Maggona (Kalutara)
AREA + RAD Modara-pallassa (Hambantota)	AREA + FXP Wathegama North (Matara)	AREA + MOP Palmunnai (Batticalo)	Control Village Abeyasinghe Pura (Ampara)	AREA + RAD Thondamanar (Jaffna)	AREA + FXP Shithani-kudipuram (Kalmunai)	AREA + MOP Munnai (Jaffna)	Control Village Modara (Colombo)
VSAT Modaragama (Hambantota)	MOP Diyalagoda (Kalutara)	FXP Periyakallar (Batticalo)	AREA Panama North (Ampara)	MOP Satur-kondagnya (Batticallo)	MOP Samodhagama (Hambantota)	FXP Indivinna (Galle)	AREA Brahamana-wattha (Galle)
AREA + RAD Kalmunai II (Kalmunai)	AREA + FXP Samudragama (Trincomalee	AREA + MP Valhengoda (Galle)	Control Village Mirissa South (Matara)	AREA + RAD Venamulla (Galle)	AREA + FXP Kottegoda (Matara)	AREA + MOP Thallala South (Matara)	Control Village Thalpitiya (Kalutara)

The other literals that are different from the acronyms: VSAT, MOP, FXP, AREA, and RAD along with the Control Villages in Table 1 are the names of the community; where the literal in the "( )" is the name of the District the community belongs to. A combination of the ICTs were tested among 28 ICT-G (32 communities minus 4 control villages). This allows the project to scrutinize the most user friendly combination of ICT for the ICT-G in Sri Lanka; where the performance of the HIH-M and ICT-G is not restricted to 1 ICT.

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.[8] This paper will focus on the parameter concerning the reliability and effectiveness of the training regimes of the human resources associated with owning and operating the ICTs used for providing hazard warnings to villages participating in the LM-HWS project.

LM-HWS assessed five wireless technologies, selected for their diverse communication paths and

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

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 project 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, described in section 4.1 of this paper 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 an ICT where the coupled configuration: AREA+MOP, AREA+FXP, AREA+RAD, and AREA+VSAT would have bi-directional capabilities. Table 1 describes the research matrix with the distribution of the terminal devices in the communities to study their reliability and effectiveness in a LM-HWS.

Note that the four quadrants with 8 communities per quadrant have an identical pattern in the distribution of ICTs except for the cells row-1 column-5 and row-3 column-5 in the upper right and lower right quadrants. The adjustment was made because the project had under estimated the cost of the VSATs. Initial costs were estimated for relatively inexpensive Ku-band VSATs and during implementation the two VSATs were replaced by C-band VSATs to overcome the unreliability of Ku-band VSATs in tropical climates as is the case in Sri Lanka. As a precautionary measure to ensure that the project did not overrun the allowable budget, the respective communities had to be equipped with MOPs instead.

6.0 CALCULATING RELIABILITY OF FIRST-RESPONDERS

Reliability of the two first-reposnders: HIH-M and ICT-G who are associated with the operation of ICTs are measured in one aspect, which is efficiency of performinig their tasks related to activation of their ERPs. Efficieny measures the time taken to complete the transmission of a message in relation to the anticipated hazard risk (i.e. will the message be issued with enough advance warninig for subsequent first-responders to take action?). In conventional analysis, probability of reliability requires a large amount of data gathered from multiple trials, a luxury the LM-HWS does not have. Therefore, the project used the methodology proposed in [6], which provides means to quantify reliability using Mean-Time-To-Failure (MTTF) with a single set of data from one trial. MTTF is a measure of expected time where the process will fail. Hence, reliability, in terms of efficiency, is defined as 1-MTTF (i.e. subtract MTTF value from 1). The reliability measure would consider the aggregate of the time it took the HIH to transmit an alert message to the ICT-G to determine the reliability of the HIH-M and the time taken by the ICT-G to transmit an alert message to the ERP-C (see Fig. 1). Let T_0 and T_1 be the time period the HIH-M and ICT-G actually take to complete their processes. An assumption is made that the HIH-M and ICT-G processes must be completed by a benchmark time; i.e. expected time, $E(T_0)$ and $E(T_1)$, respectively. Define the "hazard-duration" to be the difference between the hazard initiating time and the hazard impacting time, denoted by the variable T. Usually the content of the hazard event bulletine will carry the hazard travel time or parameter such as the speed and direction to calculate the travel time of the hazard as well as the initiating time and location of the hazard event. For $i = 0,1$, the reliabilities: R_0 and R_1 of the HIH-M and ICT-G of an LM-HWS exercise is caluclated using the formula (1):

$$R_i = 1 - \left(\frac{T_i - E(T_i)}{T} \right) \qquad (1)$$

when $T_i > E(T_i)$. When $T_i \le E(T_i)$, then $R_i = 1$ because the process was completed prior to the benchmark time. The HIH-M and ICT-G processes are not the only processes of the LM-HWS (see Fig. 1). Therefore, the reliability measure must take in to consideration a maximum allowable time in order to prevent the subsequent processes from being deprived of being completed on time. Therefore, we denote $\overline{T}_0$ and $\overline{T}_1$ as the maximum allowable time for the HIH-M and ICT-G to complete their processes.

If $T_i > \overline{T_i}$, then $R_i = 0$ for $i = 0,1$. Since this project is first of its kind and the live-exercises conducted in Sri Lanka was the initial set of tests, an assumption was made to set the benchmark value to the best case scenario $E(T_i) = 0$, for $i = 0,1$. In the future $E(T_i)$ can estimated using the previous set of data; i.e. the data collected during the live-exercise conducted between November 2006 and May 2007. When the exercise is repeated the value of $E(T_i)$ will be updated with the lowest value of all previous trials.

7.0 EFFECTIVENESS OF FIRST-RESPONDER ACTIVITIES

Effectiveness is measure of the HIH-M and ICT-G capability to encode and decode a CAP message. In the case of the HIH-M they should be capable of transforming 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 concarted in a way to assist the HIH-M with the task of encoding a CAP message. The form has a set of check boxes for each of the CAP “qualifier” elements (i.e. header of the <alert> segment, see Fig. 2). By simply ticking the correct check boxes that correspond to the set of predefined values, the HIH-M can determine the appropriate values to pupulate the qualifier elements. The difficulty is in populating the <info> segment for each of the languages in the CAP Profile (see Fig. 2). The <info> segment cannot be neglected because it carries the important elements that describe the priority of the alert message. Although the CAP ontology allows the <info> section to be optional the CAP Profile for Sri Lanka makes it a mandetory element. HIH-M will extract this information from the bulletines to the best of their ability. Never the less, in all cases the entire payload of the bulletin received at the HIH will be implanted in the <description> element.

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, which is determined by reading the <urgency>, <sevierity>, and <certainity> elements embeded in the CAP <info> segment. In the absence of the <urgency>, <sevierity>, and <certainty> elements, the ICT-G must be capable of identifying the information for these elements from the <description> element of the CAP message. ICT-G were provided with a paper form, which contained the essential elements needed for documenting the CAP message. The same form would provide them with the tools to extract the priority and description of the alert message.

A CAP message is defined to have a high effectiveness value of 1 if the message contains populated information for the mandatory CAP elements as described in the section 5.0. The lower end value 0 is when the message is an empty CAP message; i.e. dead air or elements with null text values. The compulsory Elements of the CAP Profile include elements in the <alert> qualifier elements: <incident>, <identifier>, <sender>, <sent>, <status>, <msgType>, <scope>, and the “sub” elements: <info>, <resource>, and <area>.

Table 3 –“Liken” type scaling function for CAP Compliance

Value	***Fuzzy Rules***
1.00	All sub elements that are contained in the <alert> element, which includes all the qualifiers and sub elements; i.e. all elements of the <info> segment
0.95	Mandatory defined in the Profile for Sri Lanka, which are the sub elements of the <Info> element <urgency>, <severity>, <certainty>, and <description>
0.85	Mandatory sub elements of the <alert> element and the sub element <description>
0.70	<description> only
0.50	Mandatory sub elements of the <alert> element only
0	Otherwise

8.0 EXPECTED PERFORMANCE OF ICT TERMINAL DEVICES

A broad description on the archetecture and the capabilities of the five ICTs and Terminal Devices can be found in [13]. The papers (Waidyanatha et al, 2007 – [14] and [15] discusses the WordSpace Satellite Radio technology and the Dialog GSM devices: mobile phone and Remote Alarm Device, respectively. The reader is expected to refer to the papers [13], [14], and [15] for technical details and technical perfromance of the ICTs. This section illustrates the activities associated with the HIH-M and ICT-G and the tasks they have to perfrom. The tasks discussed below are the tasks that follow after the EOI is completed and the HIH Monitor receives autherization from the Executive and the “decision to issue message” has been confirmed (see Fig 2).

8.1 WorldSpace Addressable Radios

AREA is a class of WorldSpace[9] Systems that is designed to be used in Disaster Warning, Recovery, and Response. Global Positioning System (GPS) technology incorporated into the radio set, along with the unique code assigned to every satellite radio receiver, allows for hazard warnings to be issued to sets that are within a vulnerable area or just to radio sets with specific assigned codes. WorldSpace has the capacity to easily reach widely dispersed geographic locations and even in areas where there is no telephone connectivity. The expansive reach is further augmented by alternative power-supply solutions that address the lack of connectivity to public electrical power grids as well. A description and analysis of the AREA system is discussed in (Rangarajan 2007 - [7], [8]), and (Waidyanatha et al - [15]).

The uplink segment includes a special, secure, web interface named as ANNY, hosted at one or more of the designated centers from where the Emergency Warning message is generated. The HIH-M access ANNY through one of the two internet links established at the HIH. Additionally, the interface incorporates procedures for authentication and logging of the alerts, generation, uploading and scheduling of transmission of content for the supplementary audio channel that WS supports once an alert is announced, updating an announced alert, canceling the alert, periodic end-to-end testing of the entire system. Unlike the audio message, which is a pure broadcast, the text message can be addressed to selected radios. Therefore, after the text message is constructed the HIH-M select the set of radios by their unique identifier or defines a polygon in the <Area> element of the ANNY CAP form to select the targeted audience. The HIH-M would also type “950” in the BCSID (Broadcast channel ID) field to indicate automatic switching of the all the receiving radio sets to the “Sarvodaya Talk” emergency audio channel.

The downlink is received by a digital satellite radio. The terminal device has a USB that can be extended to add-on peripherals such as a siren, GPS receiver, External Alert Box (i.e. additional display). Within 7 seconds of hitting the submit button on the ANNY internet application the text message is received by the radio set and the channel is automatically changed to channel 950. The ICT-G is actively alerted by the beeping siren of the radio set. The digital radio set has a limited 160 character display. Therefore, the ICT-G must use one of the controls (buttons) on the radio set to jump through the subset of CAP elements that carry the “qualifier” and “mandatory” information (see Table 3). However, the External Alert Box is capable of displaying the entire message (i.e. all the CAP elements).

8.2 Dialog Disaster and Emergency Warning Network System

The Dialog Telekom funded GSM based solutions were developed by Universoty of Moratuwa and Microimage. MOP/RAD is based entirely on widely available mobile communications technologies Short Messages (SMS) and Cell Broadcast Messages (CBM). SMS Based alerting is used to activate selected or individual MOP/RADs, while the CBM is used to activate all MOP/RADs. The RAD is a stand-alone

9 WorldSpace Addressable Satellite Radio url – http://www.worldspace.com

units that incorporate remotely activated alarms, flashing lights, a broadcast FM radio receiver to be turned off or on as directed by the message, the displaying of the SMS messages on LCD panel, a self-test button, message acknowledgement and a dynamic hotline GSM call-back feature for user to acquire additional information. Five push button switches labeled as Call, Ack, LCD, Test, and Radio control the operational states of the device. The GSM Alarm Device is a product of the University of Moratuwa Dialog Mobile Communication Research Laboratory. The project used Nokia 6600 MOP that are powered by a 104MHz ARM processor, and is based around Symbian's Series 60 platform. Microimage[10] developed a J2ME applet that sits on Symbian Operating System. The MOPs are activated by a SMS sent from an Internet Application that can be configured to send alerts to all or a group of MOP handsets. The GSM Java enabled SMS mobile phones receive text alerts in Sinhala, Tamil and English, sounds an alarm, and has a hotline GSM call-back feature. Disaster Warning and Emergency Network (DEWN), a web based internet application controls the terminal devices. A detailed analysis of the system performance of DEWN and terminal devices are discussed in (Dileeka et al) - [4] and (Waidyanatha et al) - [14].

DEWN application is accessible through the Internet and is hosted by Dialog at one of their sites. The DEWN application inputs conform to the CAP 1.1 standard and the CAP Profile for Sri Lanka (see section 3.0) because the input is capable of receiving a message with any combination of the three languages: Sinhala, Tamil, and English accept the null string. However, does not offer the entire set of CAP elements a well thought out strategy because the GSM devices which receive the message pay load through SMS packets are restricted by the packet size. The dilemmas of using SMS packets are discussed in Waidyanatha et al – [14]. ICT-G equipped with MOP receive the alert message in all three languages where as the ICT-G with RAD will only get an English message. Both devices display the message carried information of the <Description> sub element embedded in the <Info> element. The "call back" function is an option in both terminal devices. However, the dilemma is the many-to-one scenarios of many ICT-G wanting to connect to the few central helpdesk personnel (i.e. congestion).

8.3 CDMA Fixed Wireless Phones

CDMA FXP was used in the project, a Sri Lanka Telecom[11] solution called City Link for telephony mainly for Rural Sri Lanka. The phone sets also provide capabilities with Voice, SMS, Fax, and Internet connectivity. CDMA Fixed Wireless Phones with built-in speakerphones to provide voice communication via the public switched FXPs. The alerting for was a simple voice call, which would allow for an alert message to be voiced in any language. However, the language diversity of the staff at the HIH would limit the multilingual capabilities. Loud ring tone is a definite attention getter. However, the nomadic terminal device requires that the ICT-G be in close proximity. If the call is received by the ICT-G, then acknowledgment is instantaneous.

The ICT-G listens to the HIH-M read out the content in the <Description> element of the EOI form. ICT-G has the opportunity to ask questions instantly. Also the acknowledgment is instant in all cases the ICT-G answered the phone. However, the process is highly inefficient and holds the same congestion problems associated with GSM call back feature explained in section 8.2.

8.4 Very Small Aperture Terminals

The VSATs installed by Innovative Technologies[12] the project operate on the C-Band and used IP for communications. The Hazard Information Hub, serving as the central gateway, interconnected with earth stations in remote locations: Hambantota and Balapitiya. Alerts were issued and received with the use of

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10 Microimage website – http://www.microimage.com

11 Sri Lanka Telecom website – http://www.slt.lk

12 Innovative Technologies is a Sri Lankan company run by Warnakulasuriya et al (warnasl@yahoo.com), an Engineer who specializes in manufacturing antennas and installs satellite communication solutions in the Asia region.

the Internet Public Alerting System (IPAS) another internet web based application. IPAS "Message Clients" were installed on the ICT-G personal computers. The IPAS Client prompts the user to login. After logging in, the IPAS Client runs as a service in the background and is on standby listening to a dedicated Communication port for any incoming alerts messages. The ICT-G can configure a set of rules in the client application to setup the category, type, ad event of weather hazard notifications. The web application for "Public Emergency Officers" is where the message is entered. The interface first gives the HIH-M the access to select pre defined values describing the area, level, and type of message followed by a text box to enter the information in the <Description> element of the EOI form. Alerts are sent through a Web Services based text messaging technique by a central Server in Ottawa. When an IPAS Alert is received, if configured to Siren On, immediately sends a siren sound to the PC speakers and a Text Display window pops up on the screen with an Alert Message. After 10 seconds the sound is turned off. The end-user can cancel the Text Display and set the IPAS Client back on standby mode. If the user does not wish to receive alerts then the user can log out. Also if the PC is being powered down the operating system will force IPAS to log out before turning the PC Power off. IPAS software was developed by Solana Networks[13]. The alerting solution was limited to English text messaging; where ICT-G had difficulty in interpreting purely English messages.

9.0 PERFROMANCE OF LM-HWS ICT FIRST-RESPONDERS

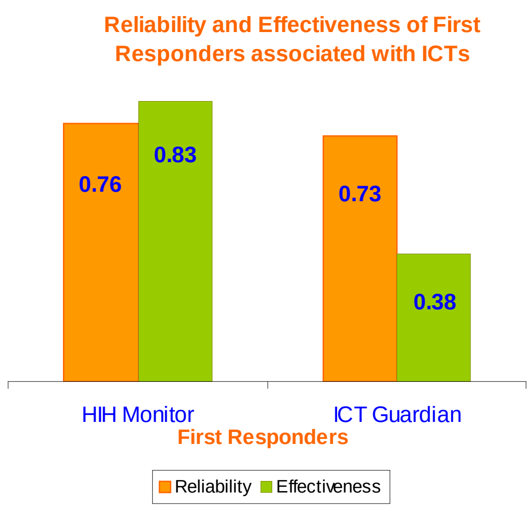

Figure 4 - Measure of HIH-M and ICT-G performance in LM-HWS live-exercises

ERP training was given to 16 of the 32 communities (i.e. the left two quadrants of Table 1) to investigate if there would be any difference in social behavior between the Trained and Untrained Communities and whether ERP training to develop hazard maps and evacuation plans were necessary in the last-mile communities in Sri Lanka. This paper does not address the ERP of the Community's other than the role of the ICT-G. Hence, this section discusses the performance with respect to the training given and the level of expectation of the HIH-M and ICT-G.

Main objective is to give the communities at risk adequate time to execute their ERPs. Relatively, the rest of the processes must take very little time. Hence, the expected performance level in regards to reliability and effectiveness of the HIH-M and ICT-G are benchmarked at 0.90. Bar chart in Fig. 5 shows that the HIH-M and ICT-G performed well bellow the required benchmark. With respect to a 90 minute for the duration of the hazard from the time of detection to the time of impact, efficiency of 0.76, applying equation (1) in section 6.0, translates to 21.6 minutes. An efficiency of 0.90 would translate to 9.0 minutes, which is what is expected from the HIH. The reader can see for themselves that the ICT-G should also increase their efficiency to at least 9.0. Same benchmark of 0.90 applies to the effectiveness measure, which implies at least 90% of the mandatory CAP elements are communicated.

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 (Waidyanatha et al, 2007 - [10]). A CAP Broker would improve the efficiency (reliability) of the HIH-M. The effectiveness, computed using Table 3, had

13 Solana Networks Internet Public Alerting System – http://www.solananetworks.com

dropped because the HIH-M did not populate the EOI form properly with the all of the required attributes. There were also inconstancies among different HIH-M scheduled to participate in the respective live-exercise.

ICT-Gs were forced to decode partial CAP messages received 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 (Waidyanatha et al, 2007 – [9]). 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. However, the communities thought the hazard was a short fuse type hazard (i.e. tsunami) and ordered immediate evacuation of the community.

The weakness can be blamed on the quality of the training the community had received in developing their ERPs. It is incorrect to put the blame on the Communities because the CAP structure is constructed to lodge all-hazards all-media unambiguous messages; where the ICT-G is supposed to provide accurate instruction to the ERP Coordinators in order to execute precise ERPs and prevented the community from executing the wrong ERPs. Except for ICT-Gs who were equipped exclusively with an AREA, all other ICT-G had bi-directional means to communicate with the HIH (upstream communication). Hence, when the ICT-Gs were doubtful of the meaning of the message they had the option of contacting the HIH or an alternate source to verify the alert communication. In all of the live-exercises none of the ICT-G took the responsibility to either acknowledge receipt of message or attempt to obtain full or further instructions from the HIH.

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 - [14]).

10.0 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 HIH-M and ICTG- based messaging component with the use of CAP in a LM-HWS. 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 the LM-HWS.

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