

Community-based Hazard Warning in Sri Lanka: Miniaturization Assessment of Terminal Devices in the Last-Mile Link

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ABSTRACT: The M=9+ earthquake in Sumatra, Indonesia, on December 26, 2004 at 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 250,000 in the region perished. The aim of the Last-Mile Hazard Warning System (LM-HWS) was to deploy various alert and notification wireless technologies intended to reduce the vulnerability of local communities to natural and manmade hazards in Sri Lanka. The project adopted an “all-hazards, all-media” approach designed around a set of five wireless communication technologies: Addressable Satellite Radios for Emergency Alerting, Remote Alarm Devices, Mobile Phones, Fixed Phones and Very Small Aperture Terminals. The pilot project entitled, “Evaluating Last-Mile Hazard Information Dissemination”, or the “HazInfo Project”, involved deployment, training, and field-testing of the technologies, in various combinations, across 32 tsunami-affected villages, using the “Common Alerting Protocol¹” (CAP) for data interchange with content provided in three languages (English, Sinhalese and Tamil). The ultimate LM-HWS intentions are to introduce Alerting and Notification to improve the “situational awareness” of all-hazards in 15,000 Sarvodaya² embedded Communities in the Island of Sri Lanka. While this paper discusses the overall performance of the LM-HWS its main purpose is to report on one aspect of the effectiveness measure - identifying the need for miniaturized terminal devices that not only can be used during hazard alert and notification but also during the response and recovery stages of the disaster management cycle. The measure introduced gives a set of guidelines for equipment manufacturers as well as a mechanism for planners to set a strategy when introducing terminal devices in to a Last-Mile warning system.

1. INTRODUCTION

In December 2005, LIRNEasia, an Information Communication Technology (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”³, 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 contained in a concept paper developed following the 2004 tsunami.⁴

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- 1 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.
 - 2 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.
 - 3 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/>
 - 4 Samarajiva, Rohan, Knight-John, Malathy, Anderson, Peter, Zainudeen, Ayesha et al. (2005, March 17). National Early

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 provides recommendations to researchers and planners based on findings from the pilot project. It is anticipated that an improved understanding of these factors can lead to better investment decisions in a National Early Warning System (NEWS).

The HazInfo project involves a non-government organization (NGO) Sarvodaya and is established on a governance structure whereby Sarvodaya 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.

2. COMMUNICATION ARCHITECTURE OF THE COMMUNITY-BASED SYSTEM

The system architecture depicted in Figure 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. Waidyanatha (2007) provides an overall assessment of the entire Community-based alert and notification system in [8] aimed at providing planners with recommendations when designing a National system.

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 Figure 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-Gs receives a warning message from the HIH, they are responsible for activating their community-level Emergency Response Plans (ERPs).

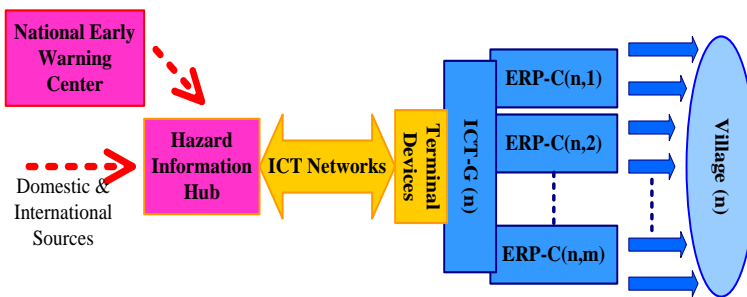


Figure 1 Community-based alert and notification architecture

The community response will vary depending on the content of the message, including its priority level. During activation, the ICT-G informs the 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, etc.

3. RESEARCH DESIGN FOR EVALUATING THE COMMUNITY-BASED SYSTEM

LM-HWS assessed five wireless technologies, selected for their diverse communication paths and different features: Addressable Satellite Radios for Emergency Alerts (AREA), a specialized SMS transport based Remote Alarm Device (RAD), GSM Mobile Handheld Phones (MOP), CDMA Wireless Fixed Phones (FXP), and C-Band 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 3 equipments to form an ICT where the coupled configuration: AREA+MOP, AREA+FXP, and AREA+RAD would have bi-directional capabilities. Gow et al (2007) provide an overview of the alerting capabilities of the 5 ICTs in [2]; while Waidyanatha et al (2007) provide the system architecture and technical know how of the SMS based technologies: MOP and RAD in [5] and AREA satellite technology in [6]. Moreover, the HazInfo project adopted the Common Alerting Protocol (CAP) as a standard to alert the local communities in the national languages: Sinhala, Tamil, and English. Gow (2007) and Waidyanatha et al (2007) have documented the challenges of implementing CAP as a standard for emergency communication in Sri Lank [1], [3], and [4].

The HazInfo research project proposal 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 structures, effectiveness of the training regime, gender specific concerns, and integration of the wireless technology into the daily activities of the villages. This paper focuses on the first specific research parameter for assessment; the *Miniaturization* element contributing to the effectiveness of the terminal devices in a Community-based emergency communication system. Waidyanatha et al (2007) explained the Reliability measured in terms of *efficiency* and *certainty* of all the Terminal Devices in [5]. Effectiveness of the ICT terminal devices were measured as a function of eleven 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. The 11 parameters are further grouped in to 5 cliques: CAP Completeness, Two-way, Adoptability, Miniaturization, and Alerting. Waidyanatha et al (2007) evaluated the 5 ICTs with respect to the parameters: language diversity, full CAP capability, and audio/text medium availability, which defines the aspect of being *CAP Complete*, in [3]. Another important feature, *Alerting* capability of wireless ICT terminal devices and acknowledgement of message receipt and active alerting function, is discussed by Gow et al (2007) in [2]. Gow et al (2007) also discusses the overall effectiveness of the heterogeneous configurations of the ICTs in [2]. This paper chooses to discuss an equally important feature: Miniaturization of wireless ICT terminal devices in a LM-HWS.

4. MINIATURIZATION MEASURE OF TERMINAL DEVICES

The Community-based early warning equipment is not restricted to alert and notification but is expected to be a valuable communications source throughout the entire disaster management cycle of

mitigation, relief, and recovery. Relief workers are often called upon to perform their duties in remote areas which are not served by telecommunications or where networks have been destroyed. Coordinating aid efforts and keeping in touch with fellow workers and informing central authorities about the state of affairs of the community are vital to the rapid delivery of assistance where it is most needed. Hence, the project's belief is that the terminal devices must be easily portable to strategic locations and be rapidly deployable. The trend in the world is to build electronics as small and practical as possible. The same notion is envisaged in terminal devices designed for emergency communication. On this basis, the HazInfo project has identified weight, volume, and longevity as parameters that measure what is termed as Miniaturization. These key factors rate the transportability of the communications device since rapid deployment free of main infrastructure and uninterrupted service becomes essential in emergency communication..

4.1. Weight of the functional terminal device

To be truly portable, the weight of a terminal device must be below what an average adult human being is capable of carrying. The project sets a standard for the load a human, without special capabilities, can carry to be 20 kilograms. If the terminal device is over 20Kg, then the effectiveness of the device in terms of weight is penalized and given a score between 1 and 0. If the device weighs less than or equal to 20Kg then it will receive a full score of 1. A weight of 30Kg is bearable and a single person can carry. However, when the weight is beyond 40Kg it becomes intolerable for a single person to carry. The variable W defines the total weight of the equipment including battery, antenna, speakers, power adapters, processor, display etc; where $0 \leq G(W) \leq 1$ is a real valued penalty function, defined by equation (1), allocates an effectiveness score to the terminal device(s) with respect to the weight.

$$G(W) = \begin{cases} 1 & W \leq 20 \\ e^{\frac{1}{20}(-W+20)} & W > 20 \end{cases} \quad (1)$$

The penalty function is devised in a way to reduce the effectiveness exponentially because the intention is to minimize the number of resources allocated to the tasks of transporting and operationalizing the communications during a crisis situation. When the weight is beyond 35Kg the effectiveness score depreciates below 0.5 and approaches 0 rapidly there on. The reciprocal of the effectiveness score can be interpret as the number of people (resources) required to transport the equipment; i.e. when the weight is over 35Kg, $\frac{1}{G(35)} = 2.12 \approx 2$, implies that a minimum of two adults are need to carry the equipment.

4.2. Volume of terminal device and peripherals

The Volume parameter will be associated in the mathematical context of a “packing⁵”; where the object with a specific volume must meet certain criteria and as a result would score a high or low probabilistic value. Volume dimensions of the entire device, including all parts necessary for it to be fully functional, must be such that the device can be placed in a space without extra long pieces protruding making it difficult to transport or to placed in an indoor/outdoor environment. For example, there is a standard set of dimensions that go to make up a total volume of 114cm³ where length, width, and height, approximately, is 56 x 35 x 23 cm, respectively, for airline “carryon

⁵ Mathematical definition of *packing*: “The placement of objects so that they touch in some specified manner, often inside a container with specified properties”, <http://mathworld.wolfram.com/Packing.html>.

luggage". A similar constraint is set that the fundamental dimensions of the terminal device with shapes like a prism, a cuboid, a sphere, or ellipse, must be less than or equal to 0.5 meters (50cm). The value 0.5 is chosen such that the object (terminal device) can easily fit in a suitcase or backpack that can be easily carried by hand or on the shoulder in a backpack. Since it is inappropriate to compare two objects, the diameter of a sphere against the diagonal length of a cuboid, for example, to judge a winner, the project has chosen to compare the volume; given that that any fundamental dimension contributing to the volume must be less than or equal to 0.5 meters. Thus the maximum volume of a spherical object will be approximately 0.06m^3 or the maximum volume of a cuboid will be 0.125m^3 . From packing theory it is known that amongst three dimensional objects the cube with length l has the largest volume in comparison to the geometries such as a prism, sphere, or ellipse with same dimension of maximum length l . Equation (2) calculates the volume based ICT effectiveness score:

$$G(V) = \begin{cases} 1 & V \leq 0.125 \\ e^{2(-V+0.125)} & V > 0.125 \end{cases} \quad (2)$$

The variable V defines the combined volume of terminal device(s) with all the peripherals and $0 \leq G(V) \leq 1$ is the real valued effectiveness score. Any terminal device with a volume less than 0.125 m^3 will receive a score of 1; any volume greater than and 0.125m^3 will get a score between 0 and 1; effectiveness score approaches 0 when the volume is beyond 1 m^3 . The same argument as in section 4.1 applies; where $\frac{1}{G(V)}$ implies the number of individual maximum volume containers: suitcase or backpack, required to pack the equipment. For example, when the volume of the terminal device is 0.5m^3 , then $\frac{1}{G(0.5)} = 2.12 \approx 2$; implying that 2 containers are required to transport the terminal device, which may also amount to two individuals, provided the weight is below the standard constraint established in section 4.1.

4.3. Longevity of the operational state

Longevity is included as part of the set of parameters measuring miniaturization because the operational life span is dependent upon the rate of power consumption and capacity of the power source; usually determined by the physical characteristics and chemical compounds of the battery. All the electronics of the communications devices work on Direct Current (DC) power. The duration of the DC power source is relative to the capacity of the battery powering the device and the rate at which the power is consumed by the circuitry. The input voltage, acceptable range of the current, and the power consumed by the apparatus is usually provided by the manufacturers per IEEE requirement standards. All ICTs except the VSAT, tested in the project, were equipped with rechargeable batteries, which could be charged via Alternate Current (AC) from the main power grid or via solar power.

The project set the standard that each wireless device must function for a minimum of 16 hours on battery. The argument is based on that the device can operate for a maximum of 8 hours (maximum exposure time to the sun) powered by solar energy and operate with the charged battery during the rest of the time, for one day. Let L be the battery life and $G(L)$ be the effectiveness measure for operational longevity of the ICT; where $G(L) = 0$ if the battery has 0 capacity and $G(L) = 1$ if the battery life is over 16 hours. The linear penalty function is given by equation (3):

$$G(L) = \begin{cases} 1 & L \geq 16 \\ \left(\frac{L}{16}\right) & L < 16 \end{cases} \quad (3)$$

Equation (3) is linear because the battery power is assumed to drain uniformly. The reciprocal of the

effectiveness $\frac{1}{G(L)}$ can be interpreted as the number of batteries required to sustain the ICT for 16 hours. A battery with a 4 hour life span: $\frac{1}{G(4)}=4$ implies that 4 batteries are required to keep the ICT operational for 16 hours.

5. PHYSICAL DESCRIPTION OF THE TERMINAL DEVICES

5.1. Addressable Radio for Emergency Alerts

AREA is a class of WorldSpace⁶ 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 limitless reach is further augmented by alternative power-supply solutions that address the lack of connectivity to public electrical power grids as well. The receiver, called DAMB-R2, is a low-memory radio with a small display and a limited processing power. DAMB-R2 has the capability to monitor the alert, validate the message and perform the specified action. The combination of the DAMB-R2, battery, antenna and siren weigh 0.1680Kg and has a combined volume of 0.0003m³. The fully charged battery will last for 8 hours under normal operations. The action could range from activating a relay for a siren, turning on/switch to a WorldSpace channel for audio messages and displaying text regarding the alert. An optional USB connectible device is available to provide expanded message display capability. Waidynatha et al (2007) describe the WorldSpace system capabilities and the overall performance in [6].

5.2. Remote Alarm Device

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 RADs. These terminal devices are stand-alone 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. The RAD unit has a handle that makes it easy to transport. The stand alone unit weighs 3.6Kg, is a single unit with a volume of 0.0017m³. The disadvantage is that the Matrix rechargeable battery has only a life time of 4 hours. Waidyanatha et al (2007) describe the engineering details of the RAD, provide a quantitative performance assessment, and discuss the shortcomings of the GSM Alarm Device in [5], a product of the University of Moratuwa Dialog⁷ Communication Research Lab.

5.3. Mobile Phone

The research used a Nokia 6600 MOP that is powered by a 104MHz ARM processor, and is based around Symbian's Series 60 platform. Microimage⁸ developed a J2ME applet that sits on Symbian

⁶ WorldSpace Addressable Satellite Radio url – <http://www.worldspace.com>

⁷ Dialog Telekom url on the Disaster and Emergency Warning Network –

<http://www.dialog.lk/en/corporate/cr/ourapproach/innovationinclusion/dewn.html>

⁸ Information on the Disaster and Emergency Warning System's mobile phone solution by Microimage can be found here – <http://www.microimage.com>

Operating System embedded in the java enabled mobile hand held. The MOPs are activated by a SMS. 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. The project measured the stand alone MOP to have a weight of 0.125Kg, volume less than 0.0001m³, and operational life span of 36 hours.

5.4. Wireless Fixed Phones

CDMA nomadic phones were used in the research, a Sri Lanka Telecom⁹ solution called City Link for telephony mainly for Rural Sri Lanka. The phone sets also provide 1xRTT capabilities with Voice, SMS, Fax, and Internet connectivity (54Kbps). However, the 1xRTT facilities, besides voice and SMS, require additional peripherals such as a PC or Fax machine. CDMA nomadic Wireless Phones come with built-in speakerphones to provide voice communication via the public switch. This is a single unit weighing 0.75Kg, with a volume of 0.0024m³, and a fully charged battery life of 8 hours.

5.5. Very Small Aperture Terminals

The VSATs installed by Innovative Technologies¹⁰ operate in the C-Band and use IP for communications. The Antenna used at the HIH was a Channel Master¹¹ 2.4 M C-Band linear antenna. The other ground stations used 1.8M C-Band linear antennas. Each antenna was aligned with the AsiaSat II satellite. All antennas were fitted with an Agilis¹² C-Band BUC (Block Up-Converter) and LNB (Low Noise Block, also known as Low Noise Converter). Two co-axial cables running from the BUCs and LNBS are connected to iDirect 3000 series modems/routers and local network switches. A Personal Computer linked to the VSAT system allowed TCP/IP communications. The overall weight of the ICT including dish antenna, modem, and other peripherals is 44.6Kg, with a combined volume of 1.275m³, and can be operated using a 0.6Kva uninterrupted Power Service (UPS) unit for 0.5 hours.

6. RATING OF ICT DEPLOYED IN LM-HWS

Table 1 illustrates the scores for each of the ICT configurations deployed in the last-mile communities. Gow et al (2007) conclude in [2] that deploying a combination of ICTs is far more reliable and effective opposed to deploying individual ICTs; where the combination of ICTs complement the weaknesses of one through the strengths of the other, which is termed as “complementary redundancy”. Results in Table 1 shows that the combination of ICTs used in the HazInfo project does not affect the overall effectiveness rating of the coupled deployment; i.e. the combined weight and volume does not disparage the effectiveness score. More so the combination of ICTs contribute the operational longevity because the two ICTs can be used alternately giving the community more communication time; where as the individual terminal devices alone, as in the case of the RAD, has very little power to sustain communication but the combination of the AREA and RAD provide adequate communication time. In the case of the AREA and RAD they share the same type of rechargeable battery: Matrix 7, which can be interchanged between the devices based on the communication requirement. Waidyanatha et al (2007) describe the deficits of the RAD in terms of

⁹ The “City Link” CDMA solution provided by Sri Lanka Telecom can be found here – <http://www.slt.lk>

¹⁰ 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.

¹¹ Channel Master website – <http://www.channelmaster.com> and specs of antenna can be obtained here -- <http://www.esa-com.com/shop/type243-C-INTELSATapproved.pdf>

¹² Agilis website -- <http://www.agilis.com> and specs of the ALB 180 series BUC can be found here -- http://www.mwsatcom.ru/agilis/BUC_s.pdf

the limitation of two-way communication, which is not the case in terms of the MOP, indicating that the combination of the AREA and MOP is a good combination for deployment. Unlike the other 4 pervasive technologies, the VSATs cannot be rapidly transported and deployed to be operational. It requires skilled professionals to align the dish antenna to receive a signal from the satellite. There are commercially available self aligning VSATs that can be mounted on the hood of a vehicle. However, the budget limitations restricted the LM-HWS project to implementing a basic ground mounted. The dimensions of the equipment and the weight of the heavy dish as well as the requirement for main grid power to operate eliminate the VSAT from being an effective terminal device in terms of miniaturization.

Table 1 – Rating of ICTs for effectiveness in terms of Miniaturization

Measure	AREA	RAD	MOP	FXP	VSAT	AREA +MOP	AREA +FXP	AREA +RAD
Weight	1.00	1.00	1.00	1.00	0.29	1.00	1.00	1.00
Volume	1.00	1.00	1.00	1.00	0.10	1.00	1.00	1.00
longevity	0.50	0.25	1.00	0.50	0.03	1.00	0.75	1.00
Rating	0.50	0.25	1.00	0.50	0.00	1.00	0.75	1.00

REFERENCES

- [1] G. Gow (2007 March/April) Implementing Common Alerting Protocol for Hazard Warning in Sri Lanka, *Journal of Emergency Management*, Volume 5, Number 1, pages 50-56
- [2] G. Gow, N. Waidyanatha, P. Anderson (2007 October). Community-based Hazard Warnings in Rural Sri Lanka: Performance of Alerting and Notification in a Last-Mile Message Relay, *Proceedings IEEE 1st International WRECOM2007 Conference and Exhibition, Rome, Italy*. (Published)
- [3] N. Waidyanatha, G. Gow, P. Anderson (May 2007). Hazard Warnings in Sri Lanka: Challenges of Internetworking with Common Alerting Protocol, *Proceedings ISCRAM2007 (B. Van de Walle, P. Burghardt, and C. Nieuwenhuis, eds.)*, Pages 281-293. Paper can be found here -- http://www.iscram.org/dmdocuments/ISCRAM2007/Proceedings/Pages_281_293_40DSM_07_A_Hazard.pdf
- [4] N. Waidyanatha, G. Gow, P. Anderson (2007 August). "Common Alerting Protocol Message Broker for Last-Mile Hazard Warnings in Sri Lanka: An Essential Component". *Proceedings of the 2nd International ISCRAM Workshop, Harbin, China (B. Van de Walle, X. Li, and S. Zhang, eds.)*, Pages 59 - 65
- [5] N. Waidyanatha, D. Dias, H. Purasighe (2007 December). Challenges of Optimizing Common Alerting Protocol for SMS based GSM devices in a Last-Mile Hazard Warning System in Sri Lanka, *Proceedings 19th Meeting Wireless World Research Forum, Chennai, India*, <http://www.lirneasia.net/wp-content/uploads/2007/11/challenges-of-optimizing-cap-on-sms-over-gsm-in-sri-lanka.pdf>
- [6] N. Waidyanatha, S. Ranagarajan, G. Gow, P. Anderson (2007 December). Last-Mile Hazard Warning System in Sri Lanka: Performance of the WorldSpace Addressable Radios for Emergency Alerts, *Proceedings 10th International Wireless Personal Multimedia Communications, Jaipur, India*, Pages 233-237
- [7] N. Waidyanatha, (2007 December). Last-Mile Hazard Warning System in Sri Lanka: Performance of the ICT First Responder Training Regime, *Proceedings CPRsouth2 Conference, Chennai, India (Myeong-Cheol Park and Hameet Singh)*, <http://www.cprsouth.org/dspace/handle/123456789/237>
- [8] N. Waidyanatha, (2007 December). Last-Mile Hazard Warning System: Evaluation of a Pilot for a National Implementation Plan, *Proceedings of APSITT 7th Pacific Symposium on Information and Telecommunication Technologies, Bandos Island, Maldives (In Press)*