Emergency Broadcast System – A Reverse 911 Tsunami Information Dissemination System Prototype: The Case of Indonesia

Joe Yuan Yulian Mambu

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Abstract

This research introduces a communication system that disseminates tsunami warnings to the community at risk right after an earthquake hits. Its function also aids the existing warning dissemination channels which may be unavailable or be affected by the earthquake. Due to its capability to be powered autonomously and its portability, it has advantages when compared to the existing solutions based on the commercial cellular infrastructure, and it may act as an alternative channel that can stand independently. On top of that the universal use of GSM handsets may help the system reach a significant number of at risk civilians. We ran experiments and analysed the results and have also examined how the system would fit within the existing disaster management operating procedure in Indonesia through data gathering. The proposed system, technically, has adequately fulfilled the user requirements we investigated and has the potential to be incorporated in the existing procedures and synchronised with other existing early warning dissemination channels.

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List of Abbreviations

BMKG/BMG	Indonesian Agency for Meteorology, Climatology and Geophysics
BNPB	Indonesian National Board for Disaster Management
BPBD	Indonesian Regional Board for Disaster Management
BTS	Base Transceiver Station
DMB	Digital Multimedia Broadcasting
DMC	Disaster Management Cycle
DVB-T	Digital Video Broadcasting-Terrestrial
EW	Early Warning
FPGA	Field-Programmable Gate Array
GSM	Global System for Mobile Communications
ICT	Information and Communication Technology
IMSI	International Mobile Subscriber Identity
ISDB	Integrated Services Digital Broadcasting
MANET	Mobile Ad-hoc NETwork
MS	Mobile Station
PBX	Private Branch eXchange
REL	Remote Emergency Localisation
RF	Radio Frequency
SDR	Software-Defined Radio
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
SMS	Short Message Service
SOP	Standard Operating Procedure
UHD	USRP Hardware Driver
USRP	Universal Software Radio Peripheral
VSAT	Very Small Aperture Terminal
WMN	Wireless Mesh Networks

Attestation of authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

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Joe Yuan Yulian Mambu

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Ethics approvals

Ethical approval was obtained from AUT University Ethics Committee (15/355) on 25 September, 2015

1. Introduction

1.1 Research Overview

The notorious "Ring of Fire" is situated around the Pacific, which includes South and South-Eastern Asian nations and makes the towns and villages along the “ring” particularly vulnerable to tsunami attacks. In 2004, one of these deadly tsunamis occurred in South Asia leading to the deaths of about 166,000 people along the Indonesian coast. A study revealed that over 5 million people per annum residing in that area are predisposed to such disasters, the highest threat posed by tsunamis globally (United Nations Office for Disaster Risk Reduction, 2009 p. 47).

Unlike earthquakes, landslides or avalanches, tsunamis are one of those natural disasters that provide a certain amount of time for people to respond before they demolish infrastructure and cause harm to communities. One of the crucial live-saving responses is communication – that is, getting the right message to the right population at the right time. Therefore, it is very important to have a reliable and effective communication system since spreading of tsunami warnings and subsequent updates has to be well-timed as a tsunami may reach to the coastline within minutes. (UNESCO, 2005 p.64 & 71).

On numerous occasions warnings are sounded through various media or networks but there is a possibility of communication breakdown resulting from infrastructure collapse, overwhelming panic calls and loss of power including backup power. The major medium of disseminating information from the authorities in the Pacific is through sirens alarms, radio and television broadcast (UNESCO, 2005, p. 142). Due to its simplicity, there is usually not much information that can be disseminated via a siren. On the other hand, not everyone will have a radio close by or tuned in at that point in time and if the local power relay station was heavily hit the possibility of providing users with clear information is zero. In some instances, it is seen that the power supply will be interrupted, specifically in towns or remote villages, and also in adherence to their operating procedure, in order to circumvent the possibility of fire outbreaks, power firms may intentionally interrupt the power supply to affected areas.

The term reverse 911 is chosen to clarify its function not only to warn civilians but to make sure to get the warning message itself to their fingertips. Since the cellphone has becoming very common nowadays, thus getting the message to their cellphones may have substantiated the chosen term. Similar to a regular 911 emergency call which certainly reaches the police, fire fighters or ambulance, the reverse 911 method aims to make sure the warning message reaches targeted civilians.

Hence, in this research, we focus on a solution in the form of an IT device and system that acts as a communication medium to aid or act as a warning dissemination medium within a disaster management scheme.

The research will also examine how the system would fit within the existing disaster management operating procedure of an administered region (Alpha, 2016).

1.2 Research Motivation

We have a literature review that may be split into two general topics. Firstly, we discuss disaster management and the role of Information and Communication Technology (ICT) within it and secondly we cover the technology and the existing related solutions.

Initially, we will explore what a disaster is, and the different states of disasters from the perspective of disaster management and response. From that point we will then investigate the role of the ICT channels that support all the management and response effort. In addition to that we will also try to identify the scope, reach and limitations of the different channels. Furthermore, we will try to focus on the disaster response part that is related to tsunami response such as warning dissemination – a task that is crucial in minimising tsunami impact casualties. Then we will examine some case studies to find important facts and learned lessons that may be improved upon if better communication exists. In the second part of the literature review, we will explore the technology that will be used and also existing solutions and how this research may be different and bring a contribution to the field of ICT-enabled emergency response.

Through the discussion the above problems will be identified, a research question will be formulated and the research methodology will be outlined.

Once we have finished the literature review, we will then focus on the solution part – setting up the system that will help the warning dissemination process. In this phase we will also investigate the current Standard Operating Procedure (SOP) of certain regions in regards to tsunami response and specifically the warning dissemination process. From that point we will examine and analyse how the system would integrate within the existing procedure.

1.3 Thesis Outline

As outlined above, the thesis is divided into the following chapters:

Disaster management and the role of the ICT process are discussed in Chapter 2. In the first part, we discuss the definition and cycles of disaster management and then in the second part, we investigate how ICT can be used within disaster management and its cycle. In this part also we discuss several ICT tools functions, contributions and limitations as well as several case studies highlighting how important and life-saving a reliable warning system with a proper propagation can be.

In Chapter 3 we discuss the technology behind the proposed solution including the software, hardware, related work and research. Through the discussion, we will show how our proposed solution can fill some gaps, bring contribution and offer an alternative solution to our specified problem.

Research questions and methods are discussed in Chapter 4 while discussion of data collection, including the discussion of the current system and primary and secondary sources is presented in Chapter 5. In the same chapter we will also discuss how the proposed system can be incorporated into the existing one and also discuss the user requirements.

Chapter 6 will present the prototype development including the system design and experimental setup and lastly, in responding to the research questions, analysis and conclusions will be presented in Chapter 7.

2. Disaster Management and the Role of ICT

2.1 Disaster Management

2.1.1 Definition of Disaster

Over the years numerous natural disasters have occurred which have not only claimed the lives of countless numbers of individuals and ruined livelihoods of numerous communities but also have shed light on the world's outlook on the importance of the preparedness of authorities and populations at risk and how this impacts on the society at large. The fact is that natural disasters cannot be prevented despite advancements in science and technology and humankind will continue to be affected by their impacts. In the light of this fact, there is a need to have an emergency plan and a structure set aside to look into matters of this nature, so as to be able to withstand the impacts of earthquakes, tsunamis and other disasters. These arrangements are crucial to protect lives as well as safeguard community properties and the ecosystem, which will support their living and cultivate a resilient mentality within the society.

The word "disaster" originates from the Latin word "astro", which means "a star", and a negative prefix "dis", which implies "bad-star". The faith of ancients was that when stars are not properly aligned, bad things tend to occur. (ISDR, 2006) defined natural disaster as a social catastrophe which happens when a physical spontaneous phenomenon negatively affects prone populations resulting in vicious extensive damage and impacts negatively on the socio-economic activities of the society. In a case where a natural catastrophe occurs in an uninhabited region it is not viewed as a disaster (Quarantelli, 1998). The criteria for categorising a catastrophe as a disaster or otherwise involves the location, timing of the event and other factors.

2.1.2 Disaster Management Phases

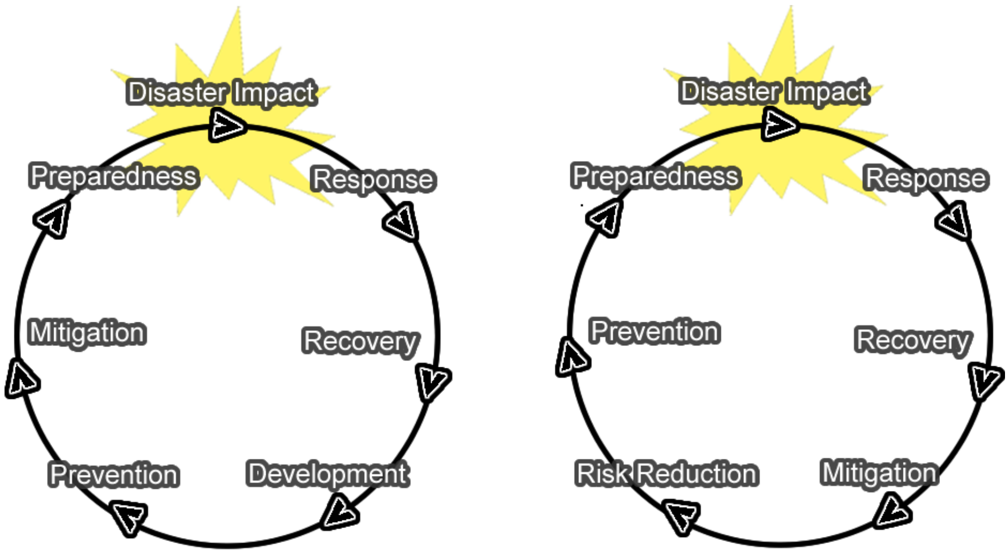
In order to curtail the harmful effect of disasters there are important steps or factors that are to be considered. Handling these occurrences involves managerial processes termed disaster management equipped to provide a functional structure with the sole aim of handling disasters and lessening the impacts of catastrophes (Waugh & Tierney, 2007).

Disaster management is usually viewed as a dynamic and vibrant field because it encompasses various expertise and integrates many experts and affiliates such as police force, civil defence, armed forces, healthcare providers, engineers, local and executive governmental authorities, fire and rescue services, utility firms and monitoring and observatory institutions. Therefore, disaster management requires a holistic approach to harness and incorporate all these groups with diverse knowledge in order to get the most out of the available information and be able to reduce overlapping or redundant work. This will produce better organised planning and an efficient and effective execution.

This shows that such cooperation will connect both the physical and intellectual resources in order to empower all levels of disaster management processes ranging from conceptualisation, development, utilisation and implementation. Approaches involve installing infrastructure, proposing a reaction plan, making policies, forming a risk management committee, preparing recovery and emergency strategies and evaluating the required ICT resources to be used.

It is obvious that clear cut strategies should be adopted to handle all the actions and measures in reacting to disasters. Every task involved in disaster management can be classified into diverse inter-related stages. These inter-related stages are grouped under a Disaster Management Cycle (DMC).

Diverse criteria are involved in classifying stages within a disaster management cycle and the method employed by diverse agencies and organisations is based on their objectives (Vasilescu, Khan, & Khan, 2008). On the other hand, according to Carter (2008) and Wattegama (2007) there are two preliminary stages preceding a disaster: response and recovery.



Disaster Management Cycle diagram

Figure 1. Mehrotra et al. (2003) (right) and Carter (2008) (left) shows their Disaster Management Cycle diagram. These diagrams can be split into to three phases "during a disaster", "post-disaster" and "pre-disaster" (Vasilescu et al., 2008)

Wattegama (2007) states that the mitigation stage is followed by a prevention stage while Carter (2008) reveals that prevention precedes the mitigation stage (Figure 1).

Based on the findings of Vasilescu et al. (2008) there are three major stages involved in disaster management: "during a disaster", "pre-disaster and "post-disaster". Vasilescu et al. (2008) and Carter (2008) highlighted in detail each stage as follows:

a. The preliminary stage is *during a disaster* which pays attention to the emergency response. The activities that occur at this stage are in response to emergency calls. The purpose of this is to ascertain that provisions are arranged to meet the needs of affected persons and reduce the suffering they undergo to a reasonable extent. Natural disasters occur in various dimensions; some can be predicted and they allow for warnings to be sent through emergency communications techniques and processes while other disasters may occur abruptly. The tasks under this stage all relate to emergency response activities.

b. The *post-disaster stage* focuses on recovery from impact. The activities and plan undertaken are concentrated on abrupt recovery and rehabilitation of the impacted community and individuals. Post-disaster can be further classified into response and recovery. Response refers to activities undertaken immediately after the disaster. These activities include establishing plans and strategies, surveying and making evaluations, carrying out search and rescue operations, furnishing inhabitants with shelter, medical care, foodstuffs and evacuation. Recovery refers to the reorientation of the affected community to their typical life prior to the occurrence. Activities involved are reinstating infrastructural facilities, renovation of houses or creating a camp for displaced individuals, repairing necessary services like electricity supply and furnishing physical and psychological support. All the measures carried out at this stage are termed response and recovery tasks.

c. The *pre-disaster* stage describes actions taken to lessen the associated risks. This can be classified into three sub-stages that include prevention, mitigation and preparedness. Prevention denotes all activities carried out to prevent the damaging impact of natural disasters on the population. This may include building a dam to curtail bushfires. The objective of mitigation is to reduce the impact of disaster on a society or region. In an earthquake-vulnerable region the authorities may decide to enforce a building standard that will aid in lessening the impact of such a disaster. Other examples of mitigation may involve providing a safety standard for sea transport, air transport and agricultural programs that are fashioned to prevent adverse impact on economic crops.

   Preparedness involves the framework put in place to enable the authorities or society to be proactive and respond effectively in the event of a catastrophe. This may involve arranging and giving frequent updates on strategies and educating the community through regular sensitisation.

2.2 Role of ICT

2.2.1 Integrating ICT within Disaster Management Cycle

The introduction of ICT over the years has proved to be a blessing to the diverse professions involved in disaster management because they are better equipped to undertake the implementation stage. Specifically, information dissemination through technology is now advanced, and such progress has been noticed also in interconnectivity and on prescribing communications between different nodes which can be integrated to form a multiple platform and have a wide implementation. Many are employed as tools in disaster management for declaring early warnings, warning broadcasts, data mining and advanced decision support mechanisms, data visualisation and incorporation of Web 2.0 (Asimakopoulou & Bessis, 2010 p. xvii).

According to Underwood (2010), research organisations and relief agencies have agreed that, in reacting to a disaster, technology has the capability to save lives. Sagun, Bouchlaghem, and Anumba (2009) reported that some activities determine how ICT may impact each DMC stage as presented in Table 1.

According to Carter (2008), though there are several ways where ICT can be applied to DMC stages in various areas, there are bottlenecks which hinder the utilisation of technology within disaster management. For example, there is no special institution that cooperates with manufacturers or vendors to track, identify and evaluate viable upcoming technologies that may be utilised for disaster management. On the other side of the coin, inventors also take a huge risk in developing and deploying technologies for disaster management due to a very limited market.

Pre-disaster	During disaster	Post-disaster
Research	Warning	Damage detection
Training	Data management	Data management
Raising public awareness	Assignments for rescue operations	Archiving/back-up
ICT integration	Rescue	Information dissemination
Collaboration with stakeholders	Collaboration with stakeholders	Collaboration with stakeholders

Table 1. Plan and activities in Disaster Management Cycle's phases (Sagun et al., 2009)

Comprehensive details on IT tools employed in each stage of response (during the disaster stage) will be discussed in the subsequent sections since the aspect of pre-disaster management is quite broad.

2.2.2 Effect of ICT on Disaster Response

ICT tools are of benefit in numerous tasks linked to the disaster response stage such as search and rescue operations, alert broadcasting and within stake holder cooperation. When the effect of a disaster has been measured or detected, warning broadcasts are sent out to alert the inhabitants on the threat posed. In case of tsunamis, cyclones and eruptions the warning broadcast is key to saving life and property but in the case of earthquakes this may not be possible because of the difficulty detecting or predicting occurrences. Based on a report by ISDR (2006) there are quite a few groups, such as communities, local and central government, religious establishments and firms, NGOs and internal organisations, the private sector (media) and the science community, which play a great role within disaster warning broadcasting. These aforementioned groups employ the use of ICT tools. The study discusses the tools and progress attained in the use of ICT tools.

a. Radio and Television.

Radio and television are viewed as archaic electronic media but the truth is they still remain an effective method of information dispersal. As soon as the local and central government are equipped with the right information on disasters they alert the public on the estimated time at which impact will occur and about the strategy for evacuation through local radio and television. Apart from regular television and radio broadcast, digital standards such as DVB-T, ISDB and DMB found on televisions also have message services that can be used. “Announcement Service” at DVB-T is one example (Azmi, Budiarto, & Widyanto, 2011).

b. Telephone & cell phone

The use of telephone cannot be overemphasised as a method of dispersing warnings. A strategy has been developed which, differing from making calls to alert someone, is a reverse 911 warning mechanism, where the potential victim gets a call rather than having to place a call. A similar system was successfully used in the wild fire of San Diego that occurred in 2007 (Strawderman, Salehi, Babski-Reeves, Thornton-Neaves, & Cosby, 2012).

On the other hand, a cell phones have unique characteristics which make them a great tool for dispersing warnings in diverse ways. As seen during the Haiti earthquake in 2010 (Meier & Munro, 2010) and also during the Katrina Hurricane in 2005 (Young, 2008). SMS services have proved vital in the aftermath of disasters.

A recent development related to GSM (Global System for Mobile Communications) technology would be the OpenBTS system which has led to the generation of a compact Base Transceiver Station (BTS) which serves as the access point for GSM-based phones (Rose, Meier, Zorn, Goetz, & Weigel, 2011). When a major earthquake occurs, even the foremost network and service providers become sedentary (Crane, 2012), and at this point of inactivity from the top network providers the BTS service can be utilised to temporarily provide connectivity within a particular area. Relevant authorities make use of this connection to send warning messages, present evaluation of threat levels and transmit plans for evacuation. As for developing nations, where access to Wi-Fi or other mobile facilities are not available because inhabitants do not have a smart phone, studies have shown that GSM devices are owned by over 90% of inhabitants in 219 countries and regions covered in the survey (4G Americas, 2012). The authorities can decide to utilise the cell broadcast system that is featured in the GSM technology if the BTS is not lost to the disaster (Udu-gama, 2010).

Smart phones can be employed in search and rescue operations. Utilising the WI-FI feature and 802.11-based wireless mesh networks (WMN) is effective in search and rescue operations during the aftermath of a disaster. This can be observed with the WIISARD system which was introduced to prompt medical responses (Lenert et al., 2006) and also with Project RESCUE which employs WMN features to serve as a back haul connection to local networks (Mehrotra et al., 2003)

In a scenario where an earthquake impacts a seaside and there is no smart phone available in that location, the location of trapped victims can be estimated with the use of GSM signals and Remote Emergency Localisation (REL) (Ma, Huang, Shu, & Yang, 2012)

c. Siren

This is a device that can cover a wide area. This tool will only be functional if the communities have already been sensitised on the aim and the significance because the amount of information passed across is limited. Developments have occurred regarding the siren so that rather than functioning like a church bell, a modernised siren can be connected to the government system and this new system can be triggered automatically to alert the population. An example of this is the All Hazard Alert Broadcasting (AHAB) Radio that was established by the Washington State Tsunami Work Group. The device features a 360 degree coverage speaker which is battery powered (solar and wind operated) and activated by a unique message passed across by the national weather service (Crawford, 2005).

d. Internet Network

The internet is a vast information organ which consists of features like email, web chat and social media apps which involve Twitter and Facebook, among many other options. The internet has progressed to become a reliable tool for disaster management. It furnishes a large platform to provide warning on a disaster which may occur in a region. Even though the reports are not from the authorities, many of them are actually first-hand sources. In 2008, when the Greek riots started, twitter was widely utilised and inhabitants of the region provided feedback through accurate pictures from the scene (Dandoulaki & Halkia, 2010). Some twitter messages received during the tsunami in 2011, were a misrepresentation of happenings and this resulted in misperceptions among the inhabitants of the region (Acar & Muraki, 2011).

The web 2.0 tool provides the disaster response team with crowdsourcing information which is very important in disaster management. This was observed in the Ushahidi project. This open software depends on users giving information regarding their location and allows for visual communication. This web tool has an edge over other approaches because it helps to address the needs and status of the victim instantaneously. Another cogent advantage is that it can harness data from diverse sources like email, twitter and other platforms and it furnishes the rescue team with the geographical information which is vital data required for an efficient rescue operation (Gao, Barbier, Goolsby, & Zeng, 2011).

2.2.3 Case Studies

The following are several different discussions on earthquake and tsunami incidents. Analysis shows several important learned lessons related to the importance of a warning system and its propagation, and how the usual communication infrastructure can be often unreliable.

Case 1: Bangladesh, Haiti and New Zealand – Unreliable Communication Infrastructure

We consider the effect of a natural disaster (a major earthquake) on an established communication facility. When an earthquake disaster strikes in an underdeveloped area, facilities related to communication may be lost or damaged. When Bangladesh was impacted by cyclones and earthquakes, telecommunication facilities were lost. Based on the report of Hazarika, Das, and Samarakoon (2010), three key problems arise when disaster strikes: there are blackouts, interrupted power supply and network traffic jams. Blackout occurs when infrastructures are highly impacted resulting in their collapse or damage. Interrupted power supply occurs when there is damage to the distribution channel from the source grid to the affected region. Traffic overload occurs over telecommunication lines due to high influx of fright calls and repetitious call attempts. The level of damage caused by the issue above can be evaluated in the cases of Digicel and Comcel, which are major providers of telecommunication services in Haiti, losing connections to an approximatly three million subscribers. The damages were traced to the destruction of properties, power loss and traffic overload (Corley, 2010)

It is not only less-developed areas that get affected; infrastructural damage also occurred recently in the well-developed region of Canterbury, New Zealand when 7.1 and 6.8 earthquakes hit the area in late 2010 and early 2011 respectively. In the case of the second big earthquake in 2011, which occurred in a busy day-time period, telecommunication was inaccessible in many areas causing many people to be unable to get in touch with family and relatives for a few hours (Corin, 2011).

Case 2: Mauritius (2004) and Chile (2010) – Poor Warning Propagation

Perry (2007) conducted a survey that described the effect of disseminating warnings in Mauritius. The survey utilised the use of call centre professionals adopting a random sampling approach to cover nine regions in the island. The time of the survey was seven weeks after the December 2004 tsunami. The survey was aimed at evaluating the effectiveness of warning signals in preparation against future incidents. The outcome of the survey shows that the warning propagation was quite slow and that only an estimated 42 per cent of the area's population had known about the tsunami. This research concluded that the probability of survival of the remaining population was zero due to their lack of receiving the warning propagation. The breakdown in the mode of propagation of the warning shows that the use of television accounted for 51% while 27.6% got the information from the radio, and personal contact amounted to about 4.7%. Although (Hazarika et al., 2010) text messaging (SMS) is an effective mode of communication in the area under review, none of the respondents mentioned it in their response. This communication medium should be more utilised in the future as it has a high possibility of reaching the population affected and it can do it faster than any other mode of propagation.

In the case of the Chile earthquake in 2010, a huge mistake was made by the Chilean Navy when they decided not to issue a tsunami warning sooner. An alarm was later sounded by port captains and some lives were saved (Associated Press, 2010; Bernard, Mofjeld, Titov, Synolakis, & González, 2006). The need for timely and reliable signal propagation cannot be over emphasised as this may save a lot of lives. The Chilean 1960 and the South Asian Tsunamis were just ten and thirty minutes apart respectively, thus the need for a fast and reliable warning propagation method (UNESCO, 2005 p.64 & 71).

Case 3: Papua New Guinea (1998) – Importance of a Warning System

Disaster response plans are made up of warning systems and other tools such as tsunami education and evacuation plans. These tools are important as they can help save lots of lives and also reduce the level of damage recorded during a tsunami by up to 25% (Singh, 2009 p.189). The 1998 Papua New Guinea tsunami had about 40% of the affected population at risk of death while just 15% in the 1993 Japan earthquake were at risk. The difference was accredited to the existence of a proper evacuation plan, educating the citizens about the tsunami incidence and a proper warning system that had been put in place (Bernard et al., 2006); thus emphasising the importance of a proper warning system.

3. Technology Involved in the Proposed System

In this chapter we discuss the technology part of the proposed system including related and similar works. In section 3.1 we discuss several related works and proposed systems and categorise them into three categories: system with mobility, non-GSM system, and GSM-based system. In each discussion we show how our how our proposed system may fill in the gaps, bring forth contribution or add alternative solutions in reaching our objectives.

In section 3.2, we discuss the technology that is being used within our research as well as in our final product. First we will discuss the OpenBTS Architecture, the model architecture which the system is based on, as well as the hardware and software that will be utilised. Lastly we will discuss how the internal systems work.

3.1 Related Work

3.1.1 System with Mobility

The Network on Wheels (NOW) project is an attempt to constitute a communication system arrangement for car-to-infrastructure by using ad-hoc principles and WLAN technology. With its mobility capabilities NOW can be implemented and integrated within disaster management and response efforts to be utilised in providing communication needs such as, in our case, tsunami warning and information dissemination. A NOW-related project called 911-NOW (Abusch-Magder et al., 2007), shows advancement of a NOW concept that was designed for emergency response and disaster recovery operations.

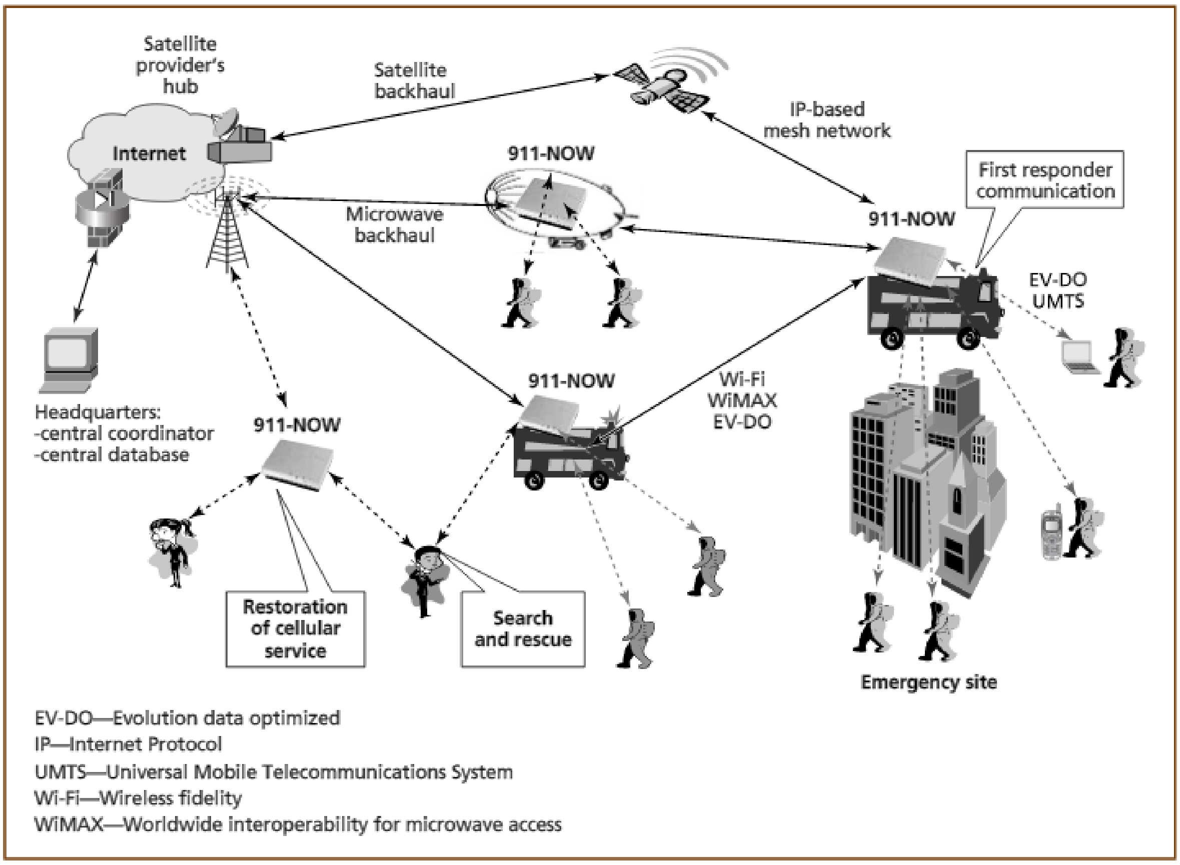


Figure 2. 911-NOW infrastructure which highly relied on back-haul connectivity (Abusch-Magder et al., 2007)

The 911-NOW system would work in several different cases as shown in Figure 2. The first scenario is it would serve as a communication channel between the first responder deployed and the headquarters. The second scenario is it would be serving as a communication path between various cell phone units around the emergency site. As the existing infrastructure may be damaged or overloaded, the 911-NOW network would allow local communication independently.

Another proposed solution is the AirGSM, an Unmanned Aerial Vehicle (UAV) version of the 911-NOW, or put simply, a flying GSM base station (Wypych, Angelo, & Kuester, 2012). Similar to AirGSM is the High Altitude Platform (HAP) which utilises aircraft in the form of an aeroplane or balloon (Lee & Choi, 2011). Both AirGSM and HAP aim to offer rapid deployment and a wide range of coverage (Figure 3).

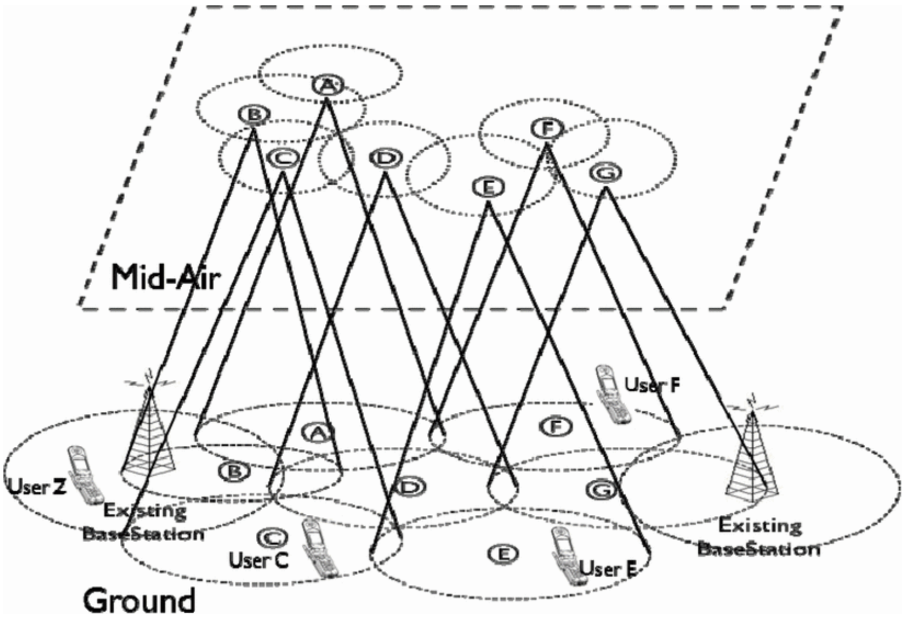


Figure 3. Network Deployment Scenario of HAP (Lee & Choi, 2011)

However, there are several drawbacks to the systems listed above if applied in the case of warning dissemination. All the schema heavily relies on back-haul connectivity which may be unavailable due to damage by the earthquake and/or loss of power, or congested due to sudden excessive usage. As for the 911-NOW, possible drawbacks would be limited access to the specific emergency site due to roadblocks caused by earthquake such as damaged roads or landslides. Nevertheless, there are possibilities where the system proposed in this research work may be combined with these methods and technologies.

3.1.2 System Using Non-GSM Channels

Another technology that has also been utilised for a similar purpose is based on Wi-Fi networks deployed as a MANET-based emergency information and communication system (Lien, Jang, & Tsai, 2009) as shown on Figure 4. The proposed solution allows a large number of nodes to be connected to the system. However, it has several drawbacks: it has a limited range of only up to 200 metres of coverage and it is only compatible with a Wi-Fi enabled device. Compared to Wi-Fi, in the case of warning dissemination, GSM has more advantages due to its wider range of coverage and being more commonly used by the public.

An enhanced implementation similar to MANET is the implementation Worldwide Interoperability for Microwave Access (WiMAX) as disaster communication backhaul that was implemented by the US Naval Postgraduate School (NPS) team in Thailand after the infamous 2004 Christmas earthquake damaged all the infrastructure (Donahoo & Steckler, 2005). WiMAX, with a 50km reach and up to 70Mbps transmission rates, does have a tremendous advantage over typical Wi-Fi configurations (Yarali, Ahsant, & Rahman, 2009).

However, WiMAX is still not widely implemented and it is starting to lose to its main competitor, the Long-Term Evolution (LTE) technology, in providing wireless broadband to mainstream consumers such as in the US (Pegoraro, 2014) and Taiwan (Chen, 2015). While WiMAX may be useful as a backhaul network in a disaster situation as implemented by the US NPS in Thailand, due to its lack of narrow adaptation to end-users, WiMAX-enabled devices such as WiMAX handsets aren’t widely used and available; thus may not be suitable for our case.

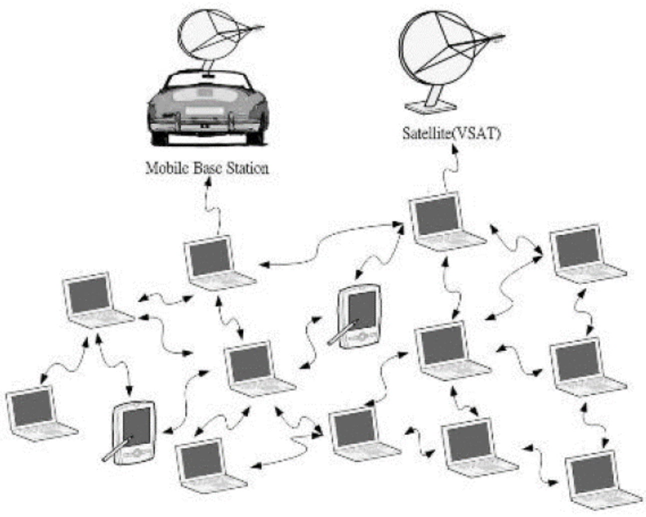


Figure 4. Schema of MANET based on peer-to-peer network running on Wi-Fi connectivity. (Lien et al., 2009)

Similar to Wi-Fi, satellite technologies were also commonly deployed as a means of communication in a disaster site (Berioli, Courville, & Werner, 2007). With its large area of coverage, satellite may provide boundless coverage. However, by nature, satellite peripherals and connections are quite expensive and rarely used by ordinary civilians.

3.1.3 GSM Based Emergency Network

There are several proposed solutions that also use GSM, the same technology as our system, as their means of communication, such as the concept offered by Rescue Base Station (RBS) (Ghaznavi et al., 2014) as shown on Figure 5, Beacon (Crane, 2012), Emergenet (Iland & Belding, 2014) and concepts offered by Sankhe, Pradhan, Kumar, and Murthy (2014). These concepts and systems are designed to be deployed instantly in the emergency area to provide communication channels while the conventional infrastructure is unavailable, which commonly happens in the case of an earthquake. Both systems also use GSM which is feasible as many people have their own GSM handset such as a standard cell phone.

These devices can aid rescue and recovery operations in several ways. The temporary communication channel may be very handy for first responders and rescuers to communicate with each other and also with disaster affected civilians. It also may be used for civilians to communicate with each other or to get new updates from the rescuers or civil defence organisations.

Though the systems above are not explicitly designed for warning dissemination purposes, they offer inspiration for our proposed solution by how they work as a substitute communication means in the absence of the standard networks.

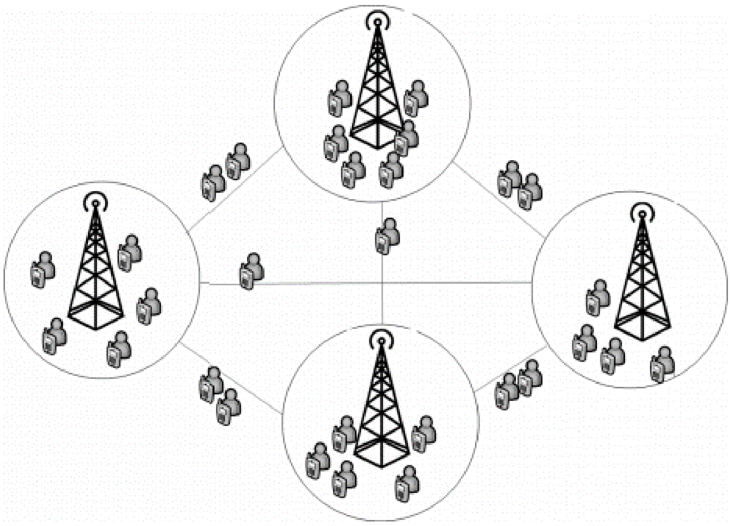


Figure 5. Schema showing GSM clients and their connected Rescue Base Station (RBS) as replacement of the conventional GSM network which may be unavailable after a disaster impact (Ghaznavi et al., 2014).

3.2 Review of the Technology Involved in the Proposed System

Based on the evolution of Cognitive Network (CN), Software Defined Radio (SDR) was able to transform all the analog components to digital. This advancement is able to produce easy-to-use, low-cost, better interoperable and customable solutions. One of the implementations facilitated by these advances is the setting up of a GSM Base Transceiver System (BTS) which utilises an RF (Radio Frequency) daughterboard, a Universal Software Radio Peripheral (USRP) motherboard, an antenna and a PC as the basic hardware, and GNU Radio, OpenBTS and a Linux operating system running on the PC for the software components (Natalizio, Loscri, Aloi, Paoli, & Barbaro, 2010).

Furthermore, the USRP is a range of SDRs produced by Ettus Research. The USRP itself is basically a Field-Programmable Gate Array (FPGA) board that has slots for different interchangeable RF daughterboards. Most USRP is designed to be connected to a host computer through an Ethernet or USB link where the host computer runs software to control the data traffic and USRP hardware. Other USRP models integrate the host computer into one with the SDR allowing the USRP to be operated in a stand-alone or embedded model (Natalizio et al., 2010). Ettus E110 is an example of the embedded model and is the one that is being used in this research.

In the next section we will discuss more details of the architecture, hardware and software, and how the system works.

3.2.1 OpenBTS Architecture

The OpenBTS architecture provides a system designed to imitate “logically”, in its operation, the components of GSM 04.03 (Burgess & Samra, 2008 p. 15). Based on GSM 04.01, the signalling on the GSM Mobile Station, also called the Base Station System (MS-BSS) interface, consists of three layers. This bears similarity to the OSI standard model (ETSI, 1996 p.11):

- Layer 1 consists of a physical layer which is the lowermost layer for the radio modem, time-division multiplexing and error-correcting coding (defined on GSM 04.04)

- Layer 2 has to do with addressing of the data link layer, segmentation and retransmission (defined on GSM 04.05 and .06)
- Layer 3 refers to the uppermost layer, with the objective of managing connections and signalling (defined on GSM 04.07, .08, .11 and .12)

From a BTS, an “uplink” refers to an upstream flow (low to high layers), while “downlink” refers to a downstream flow (high to low layers). Reserved labels are employed from the cell phone or mobile station (MS).

3.2.2 Hardware

The USRP, created by the Ettus LLC, is a tool that has features to assist users to program and set radio protocols and also to interface analogue and digital signals to an external computer through a USB connection or Ethernet or internally for the embedded model (GNURadio, 2013). Kish (2004) explains that expansion into several other frequencies through this tool is made possible by employing daughterboards. The use of an FM radio transmitter and digital television’s decoding function is a good example of its usage (Kasim, March, Zhang, & See, 2008). For this installation we acquired a USRP E110 and RFX1800 daughterboard that supports a frequency range of 1,5 to 2,1 GHz (GSM-1900 and GSM-1800) as well as a 750 to 1050 MHz range (GSM-900, GSM-850 and EGSM-900) if converted to RFX900 (Research, 2014). For better implementation, a duplexer is needed to prevent a transmit signal from interrupting the uplink receiver and saturating the Low-Noise Amplifier (LNA). There was also the need to acquire an affordable Power Amplifier (PA) in order to mitigate cost over a larger area (Azad, 2011).

The USRP E110 model is powered by an 800 MHz ARM Cortex A8 processor with 512 MB RAM and replaceable 4GB flash running Angstrom Linux. Other ports include USB (Console, Host and On-The-Go (OTG)), HDMI output and Ethernet port (Ettus Research, 2012a).

The USRP E110 motherboard houses a Field Programmable Gate Array (FPGA) and two Analog-to-Digital Converters (ADCs) and two Digital-to-Analog Converters (DACs). In the case of USRP1, links the FPGA to the PC and handles modulation and demodulation processes. With our USRP E110 it will be handled by the embedded system running Angstrom Linux.

By utilising the USB connector and HDMI output, the E110 can be configured without involving other computers. However, for the actual operation a PC will be used to control the device remotely via LAN. To run the test on a handset, a minimum of two unlocked phones GSM1800 band compatible and any two providers' SIM cards are needed. An in-depth discussion of the proposed system design hardware is presented on Section 6.1.2.

As for the client side, the client may use any GSM-based cell phone, including the newer generations such as 3G (WCDMA & HSPA) and 4G (LTE). The CDMA-based cell phone, which is mostly used in Japan only, is currently not supported.

3.2.3 Software

Several software are needed to manage the streams that are coming from the interface connection. First would be the host driver and API for the USRP which is called a USRP Hardware Driver or UHD. This piece of software is responsible to link all the USRP functions and all the software that interacts with the USRP hardware components. As soon as the interface comes online, a cell phone can be linked and it will be relayed to an IP-based PBX through the OpenBTS. There are two versions of OpenBTS: a commercially available release and a free public release. The free version is built for the purpose of education, evaluation, experimentation and proof of concept projects while the commercial one is targeted for commercial projects and companies.

Last but not least, all of these software packages will run on top of a Linux-based operating system that is embedded in the device. An in-depth discussion of the software used is presented on section 6.1.3

3.2.4 How it works

As soon as a radio burst arrives at the USRP, it is digitised and sent to the transceiver software. The transceiver then synchronises it with the master clock of the GSM, separates the radio burst and demodulates it as a vector of symbols. It then uses the GSM frame clock as a time-tag and sends it to the GSM stack through a datagram interface. The time-division multiplexing (TDM), a sub layer 1 within the GSM master clock, then demultiplexes each burst corresponding to their time-tags and sends them to their anticipated channels prior to being sent to a Forward Error Correction (FEC) processor to be decoded by it. At this point, the output will be in the appropriate sequence of L2 frames and they are transported to an L2 processor using the logical channel. The L2 Processor then executes the LAPDm (Link Access Procedure, Channel Dm), a data link layer protocol in GSM state machine that will acknowledge, segment and retransmit the output, a similar process as done by the TCP layer of the OSI. After it has gone through a verification and assembly process, the L3 then forwards it to layer 3. At this layer, the frame will be selected and sent with an appropriate message protocol and then request an operation to deserialise the information on the downlink, which leads to the generation of an L3 response. The direction of the upstream flow would be same as the downstream one in reverse order (Burgess & Samra, 2008 pp. 15-16).

The Asterisk software then regulates and manages the calls and messages as soon as the data arrives at the PC. The Asterisk functions are similar to the PBX, but based on IP and not on a circuit-switched system. The subscriber International Mobile Subscriber Identity (IMSI) is used by Asterisk as Session Initiation Protocol (SIP) user names. All mapping processes are carried out by layer 3 of the OpenBTS control layer (Ali, Khan, Arshad, & Younis, 2013).

4. Research Question & Methods

4.1 Research Questions

We have seen in previous discussion that there exists a communication issue during and shortly after natural disasters occur. This has been supported by several case studies. We have also seen how a communication line can be unstable or even unavailable both in developed and less-developed areas as in the case of Bangladesh, Haiti and New Zealand. We have also seen how warning dissemination can be crucial and vital, especially in the case of tsunamis as in Mauritius and Papua New Guinea. Some previous research has also shown how various ad-hoc networks can be used for such problems. We have also discussed several other projects that serve related purposes and use similar technologies.

Therefore, as described in Chapter 1, we aim to provide a solution in aiding tsunami warning and updates dissemination. Thus, the purpose of this research is to answer the following two questions:

> RQ1: How can first responders set up a communication system for tsunami warning dissemination purposes for the exposed population that fits within the disaster response's Standard Operating Procedure (SOP) of a certain area?
>
> RQ2: What would be a suitable user manual and documentation to accompany the proposed system?

As commercial infrastructure tends to be unavailable due to overload or to it being affected by an earthquake, this solution will also add another "channel" of information to the existing ones which may extend the reach and capabilities of the warning dissemination and increase effectiveness. The proposed solution also needs to be examined in order to integrate it into the existing tsunami disaster management SOP.

4.2 Research Methods

In this section we will go through the research methodologies, techniques used for data collection, data analysis process, and design to meet our research goals.

4.2.1 Methodology and Approach

The system development will follow the multi-methodological approach to information system research (Nunamaker Jr & Chen, 1990), where system development phases become the hub of three other research strategies: Theory building, Observation and Experimentation.

The main idea of this approach is creating and evaluating. This approach will enable each phase to complement and provide feedback to one another. Therefore, any significant findings or changes on one of the phases would be taken into the other phases and eventually will contribute to the system development and the adaptation of the approach as shown on Figure 6 below.

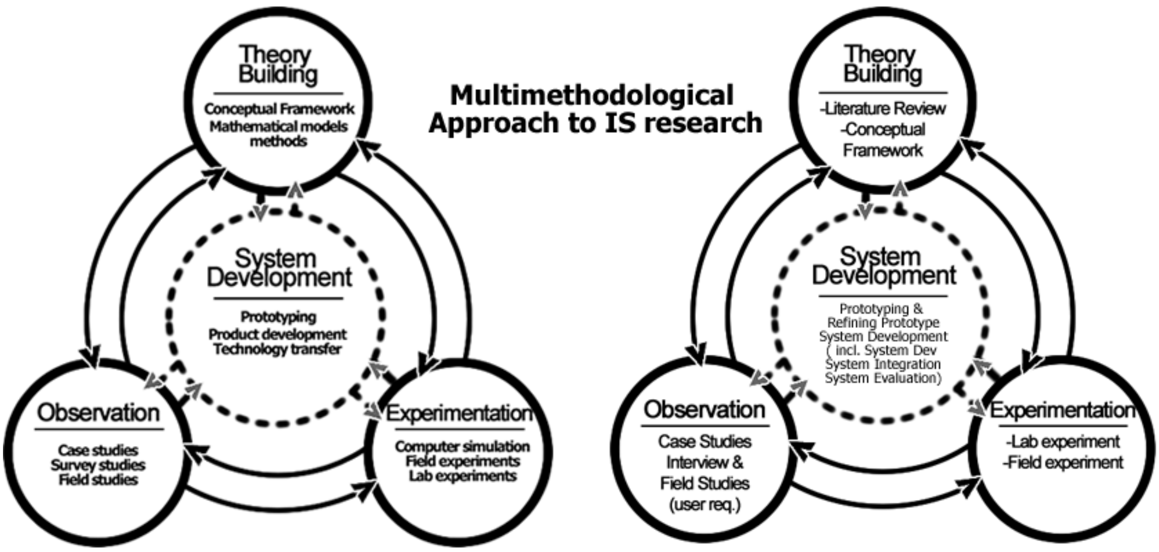


Figure 6. Left: a sample of multimethodological approach to IS research (Nunamaker Jr & Chen, 1990)
Right: the adaptation to the multimethodological approach in this study.

We will go through different tasks and actions revolving around the four strategies above. Under observation we will have interviews, case studies through document reviews and field observations. In experimentation we will need to have laboratory and field experiments. Changes or any significant findings during the observation and experimentation phase will contribute to prototyping and developing the system.

4.2.2 Theory Building

To answer the first question, we will need to gather and review the background information or theories related to disaster management as well as ICT's contribution in that field in literature reviews. To carry out the technical assembly of the system we then need to review several associated technologies that are associated with or may be involved with any existing similar or related solutions. These are part of our literature review and both were extensively covered in Chapter 3.

4.2.3 Observations

Data gathering methods would be in the form of observations, interviews and collecting existing tangible information from documents and records both digital and non-digital from the units and sub-units of analysis. Thus, we will interview the associated officials to get information and ideas related to field information and experience on the existing response plan and, in addition to that, we will try to bring together related documents and resources such as types of identified threats and their corresponding warning status, warning dissemination procedures and flow, the list of stakeholders and their structure of command, and also types of channels and devices currently used.

In the observation phase we will also apply case studies. According to Leedy and Ormrod (2010) a case study is suitable for learning more about a situation that is still new, little known or inadequate and therefore has room to be explored and analysed. A case study approach can also be used to examine progress and changes that may have occurred naturally or as a result of intervention. To start with, a case study method will need to have a case study research design.

As stated by Yin (2013), in a case study research design we need to identify the type of case study research (exploratory, descriptive or explanatory) and also define the following components within the case: study question, study propositions and unit(s) of analysis:

Type of Case Study

The nature of our case study is to examine potentials and possibilities to improve tsunami warning systems, covering the progress and changes that may have occurred within the field, and therefore it may be classified as an exploratory and in-depth case study.

Study Question and Propositions

In regards to the case study method, the study question would be in the part: “How will the proposed system fit within the disaster management SOP?” which constitutes our “how” question. We also have some study propositions that were developed through previous research: 1) within the existing warning dissemination system, there is room where the proposed system can contribute, and 2) there are situations where the proposed system may fill a gap when other warning dissemination channels have failed or become limited.

Unit of Analysis and Observation

In this case study we will explore the SOP and will try to integrate the system within the SOP, hence the case study unit of analysis would be that of the SOP. The sub-unit of study, also called the unit of observation, will be the staff, the geographical area covered by the SOP and their previous incident experience as recorded in their post-mortem reports. From these sub-units we can gather more insight into what usually happens, where and how the system can be placed and other details that may come up in this exploratory study.

According to Creswell (2009), data analysis in a case study will go through several steps: organising details of the case, categorising the data, interpretation of instances and then identification of patterns before concluding with a synthesis. Combined with information gathered from the first task; that is the features, capabilities and limitations of the system, all the information captured from the interview and documents will be categorised, interpreted and concluded with a synthesis of requirements or standards that would suggest how the new system could meet its purpose which may include additional modifications, prerequisites and/or limitations of the system.

4.2.4 System Design, Development, Integration and Evaluation

Once we have some extensive ideas and information gathered from our literature review and initial observation (interviews and case studies) we could go ahead with system design, development, integration and evaluation.

With the above approach in mind we will go through the next step which is divided into two main tasks: Design and Development, and Integration and Evaluation.

4.2.4.1 System Design & Development

Before configuring the prototype, we will first gather some early user requirements and on-field data to have some preliminary information and ideas on what the system needs to achieve. These user requirements will include information about the background, issues and problems and the possible improvements or solutions the proposed system could bring and which will be used in designing the conceptual framework and our work in the prototyping phase. To acquire the information, interviews with an open ended questionnaire will be carried out using direct face-to-face meetings and/or email communications or phone call conversations. This method would be part of the observation part of the multi-methodological approach that contributes to the early system development phase.

4.2.4.2 Concept Design & Prototyping

Once we have our preliminary user requirements, the system design process can proceed. According to (Nunamaker Jr & Chen, 1990), system development may consist of two parts before the actual product development: concept design and prototyping. Concept design is the adaptation and incorporation of the technological and theoretical aspects to our proposed system – that is adapting the system's software and hardware with the system's purpose and user requirements. On the other hand, prototyping is where the system will demonstrate its feasibility. Therefore, we will create first the concept design that incorporates the needs and the system, and start building the first prototype for the initial feasibility test in the next phase.

4.2.5 Experimentation

Once we have the initial prototype ready we can proceed to the laboratory and field experimentation part. This part needs to be carried out before integrating it in the field. To do this we will go with a quasi-experimental design approach by adopting a research method that is commonly used within the wireless sensor networks research domain: simulation-based study and test bed measurements. This study's research question is to analyse how the proposed system can integrate within an existing SOP and fulfil the user requirements.

4.2.5.1 Test structure

Before we go to the field test, we have the first testing in a controlled lab setting. The purposes of lab testing to be conducted beforehand is to have an actual initial full run of all the system functions and identify and fix issues that may arise before we go on the field test. On the other hand, to simulate a disaster situation where there is no phone signal, a field test is needed to meet some requirements or factors where a lab test may be insufficient such as interference caused by concrete and other structures or used frequencies that may interfere with the signals. Below are summaries of the test structure for both locations.

The lab test will be conducted in a small room and perform the following tasks:

1. Turn on and go to standby mode,
2. Establish a terminal (PC or laptop) to the device directly or through a router,
3. Run scripts from the terminal,
4. Manually set and confirm mobile phone connection and check signal strength,
5. Input and broadcast EW from the terminal,
6. Check mobile phones' EW reception.

The same test will be conducted on the field test with the following additional task

7. Let the mobile phone search and auto connect to the device,
8. To test the device coverage, tests 7, 5 and 6 will be tested while the mobile phone is 50 and 100 metres from the device and in four cardinal directions,

9. We will also measure the signal strength on each point of task 8.

In-depth details of the experiment setup are discussed in section 6.2 while the result is shown in section 6.3.

4.2.5.2 Test devices and environment

For the lab test, the device will be connected to a laptop through a LAN cable directly and through a router. The user then will run a terminal (PuTTy) from a PC and run scripts and instructions remotely. For the field test, a location where there are no 2G signals will be chosen, and the device and router will be powered from a car lighter plug through a 150W inverter. The laptop will connect through a LAN cable and wirelessly through the router. In addition to these, two mobile GSM-based mobile phones will be used to receive the test messages.

4.2.6 System Documentation

As for the second question we will create a user manual and documentation. The material then will be given to real users for usage validating purposes. On the documentation we will cover the operational manual where the operator should able to refer in operating the device as well as troubleshooting where a common known error can be resolved. The documentation will also provide essential device maintenance guidelines and documentation about the device specifications.

The manual should function as a quick reference, and thus should be simple and straightforward as this will be used by the end-user and in response to the disaster situation.

5. Data Collection

As part of the multi-methodological approach discussed earlier, observations are one of the data collection techniques planned for this work and in particular in the format of an in-depth case study. The data collection in this study will help the researcher achieve two main goals:

First, in section 5.1, to find out how the prototype fits within the disaster response unit's SOP. To investigate this, we will go through data and information gathered or findings related to:

a. The existing tsunami disaster response system in the country
b. The tsunami early warning (EW) dissemination including the content, timeline, involved stakeholders and media/channel the system uses.

In the second part, in section 5.2 and 5.3, we will discuss the work findings and how to utilise the proposed system. To accomplish this, we will discuss the following:

a. What are the current system's limitations and shortcomings and in what ways can our devices improve and be beneficial to the current system.
b. Discussion about local assessment and the locally controlled EW channels.
c. Build up user requirements and incorporate the system within the EW dissemination process.

The discussions on this chapter would help the researcher answer the study's research questions 1 and 2.

The interviews were conducted face-to-face with several staff at one of the organisations involved with disaster response activities; in particular, personnel working with the tsunami early warning system in Indonesia. However, a significant portion of data also came from several printed and digitally available sources, including articles, websites and other publications provided or shown to the researcher by the staff members interviewed. In this research the name of the individuals, organisation and other details that may lead to their identities would not be disclosed due to this research's anonymity commitment. In this research, the organisation will be called the “Alpha” organisation and the staff will be called Alpha’s staff. There is also an organisation working together with Alpha which was the source of information and data that were provided and shown by the Alpha staff to us. This organisation will be called Beta.

5.1 The Current Disaster Response System

On this section we will review existing disaster response systems and how they work. First, we will go through the findings. The following information was gathered through interviews as well as from documents related to the tsunami disaster response system in Indonesia and Indonesia’s tsunami early warning system.

5.1.1 The Indonesian Tsunami Early Warning System (InaTEWS)

In response to the 2004 Boxing Day earthquake that caused more than a quarter of a million deaths due to the lack of a tsunami early warning system, the Indonesian government, working with multiple institutions and organisations, setup a national-scale centralised tsunami early warning system to prevent the same devastating impact ever happening again in the country.

The InaTEWS was also based on the people-centered early warning system that had been developed by disaster management academics and practitioners. According to UNISDR (2006) there are four key elements for people-centred early warning systems: First is “Risk Knowledge”, that is conducting risk assessment and data gathering; second is “Monitoring and Warning Service” that is developing observation and warning technologies; Third is “Dissemination and Communication” which provides information warning and guidance, and lastly, “Response Capability” which builds people’s capacity and preparedness.

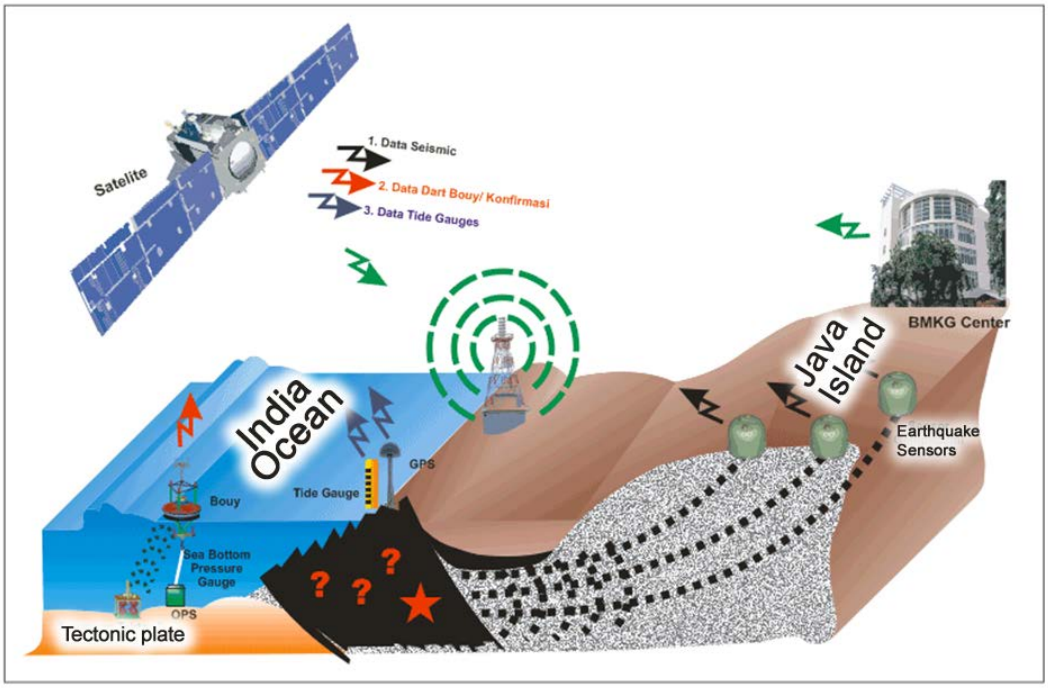


Figure 7. InaTEWS Observation Systems (Beta, 2015)

According to the Alpha (2016) and Beta (2015), InaTEWS mainly consists of three main system components: the first is an "Observation System" which includes land observatory devices such as seismometers, accelerometers and GPS, and marine observatory devices such as buoys, tide gauges and CCTV. The second main component is a set of "Analysis Systems" which are located at 10 Regional Centres and one National Centre. Their purpose is to analyse data from the seismic network, buoys and tide gauges as seen on Figure 7 through a dedicated seismic reader and Decision Support System that will produce a warning level for a tsunami. The third one is the communication and network lines which have the role of connecting all the Analysis Centres to the National Centres (gathering network) and the role of disseminating the warning to all the stakeholders in the system (the EW Dissemination network) as seen in Figure 8. More details about the Seismic network, GPS, tide gauges and buoys are included in Appendix A.

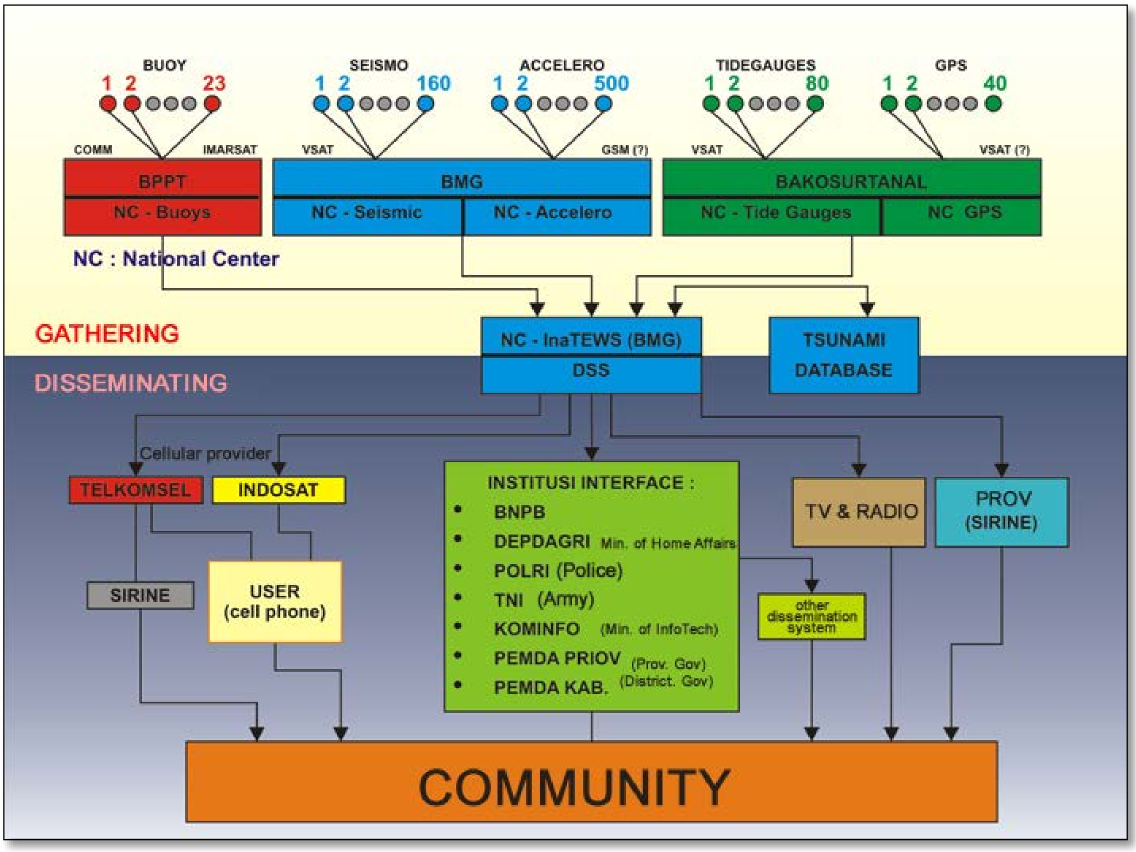


Figure 8. All Gathering Components and Dissemination Stakeholders (Beta, 2015)

All the information gathered will be assessed at the Decision Support System (DSS) at the InaTEWS National Centre of BMKG/BMG (Indonesian Agency for Meteorology, Climatology and Geophysics). The DSS will use the location, magnitude and depth of the earthquake to determine the tsunami effect on a tsunami simulator and using a geospatial analysis system. From the tsunami modelling the DSS can determine how high the tsunami could be and how far it will reach. The level of warning is categorised into three levels as shown on Table 2 (Beta, 2012).

Threat Level	Height of Wave	Action
Warning	> 3 meters	Mass evacuation to the designated meeting point
Advisory	0.5 – 3 meters	Evacuation of surrounding coastal community to the designated meeting point
Watch	0 – 0.5 meters	Stay away from the seashore/coastline

Table 2. Level of Warning, Height of Wave and Action (Beta, 2012)

There are other factors in determining a mass evacuation that will be included in a later discussion.

5.1.2 Early Warning Dissemination Process

As shown on Figure 8, we can see how the dissemination all started from the InaTEWS DSS which is located at the BMKG National Centre office. The DSS will produce an Early Warning (EW) to be disseminated. The EW is the main warning message that will inform the stakeholders and eventually the community about the severity level of a potential tsunami caused by an earthquake.

5.1.2.1 EW Message Content

Format	Content	Target Audience	Mode
Long Version	Earthquake parameter, warning segment, warning level, advise, map	Interface institution, local government, decision maker, media	Email
Long Version	Earthquake parameter, warning segment, warning level, map	Interface institution, local government	WRS
Long Version	Earthquake parameter, warning segment, warning level, advise, map	Interface institution, local government, media	Fax
Media Version	Earthquake parameter, map, “berpotensi tsunami”	Media	WRS
Short Version	Earthquake parameter, warning level at province level	Interface institution, local government, decision maker, media	SMS
Web Version	Earthquake parameter,	Public	Website

Table 3. EW Formats (Beta, 2012)

As shown in Table 3, in terms of content, there are four formats of the EW that depend on where it will be delivered: Long, Media, Web and Short versions. The Long version is for Email, WRS and Fax; the Media format is for WRS, and for TV and Radio broadcasts; the short version is for SMS and the web version is for websites. Depending on the format, the EW will show the earthquake parameter, warning segment, warning level, map and tsunami potential. Figure 9 shows the short- and long-text format (Beta, 2012). Additional examples of long, media, short and web versions are shown on Appendix A.

Peringatan Tsunami: Waspada di BANTEN, DIY, JABAR, JATENG, JATIM, LAMPUNG, NTB, NTT, Gempa Mag:7.2SR, 04-Apr-11 03:06:39 WIB, Lok:10.00LS/107.71BT,Kdlmn:10km::BMKG

Issued date : 11 April 2012, 15:43:05 WIB (UTC=WIB-7)
Bulletin-1
No.:103/warning/InaTEWS/IV/2012

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS:

Magnitude : 8.9 RS
Date : 11-Apr-2012
Origin Time: 08:38:29 UTC
Latitude : 2.31 N
Longitude : 92.67 E
Depth : 10 Km

Location : Off West Coast of Northern Sumatra
Remarks : 434 km SOUTHWEST of Meulaboh
463 km SOUTHWEST of Banda Aceh
493 km SOUTHWEST of Sabang
497 km SOUTHWEST of Sigli
550 km SOUTHWEST of Bireun

Evaluation:

THERE IS THE POSSIBILITY OF A TSUNAMI IN THE FOLLOWING AREAS:

Province	Location	Warning Level
BENGKULU	Bengkulu-Selatan	MAJOR WARNING
BENGKULU	Bengkulu-Utara Bagian Utara	MAJOR WARNING
BENGKULU	Bengkulu-Utara Pulau Enggano	MAJOR WARNING
BENGKULU	Kaur	MAJOR WARNING
BENGKULU	Kota-Bengkulu Pantai-Panjang	MAJOR WARNING
BENGKULU	Mukomuko	MAJOR WARNING
BENGKULU	Seluma	MAJOR WARNING
LAMPUNG	Lampung-Barat Pesisir-Selatan	MAJOR WARNING
LAMPUNG	Lampung-Barat Pesisir-Tengah	MAJOR WARNING

Advice:

Province/District/City governments that are at "Major Warning" level are expected to pay attention to this warning and immediately guide their communities for full evacuation.

Province/District/City governments that are at "Warning" level are expected to pay attention to this warning and immediately guide their communities for evacuation.

Province/District/City governments that are at "Advisory" level are expected to pay attention to this warning and immediately guide their communities to move away from the beach and river banks.

Figure 9. Short and Long-Text Format

5.1.2.2 EW Timeline

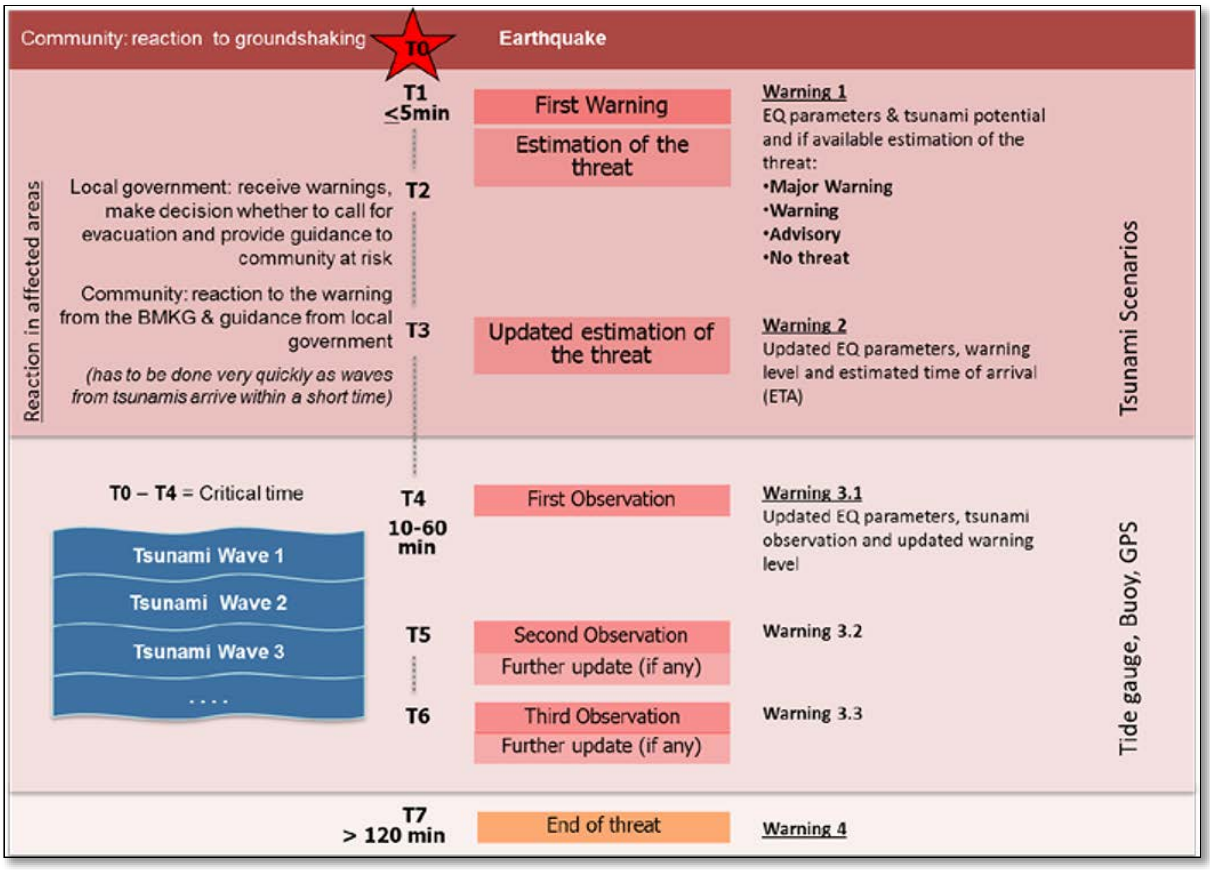


Figure 10. EW Timeline (Beta, 2012)

According to Beta (2012), the warning information consists of four consecutive stages (Figure 10):

i. EW1: this is information is broadcast with an initial valuation threat level which may include: Warning, Advisory, Watch or No Threat/Risk for different areas or regions. Actions taken should follow the Table 1 guidelines.

ii. EW2: warning is disseminated after 5-6 minutes of the disaster and it consists of modified earthquake values, an extra evaluation on EW1 and an estimate of when the tsunami will occur.

iii. EW3: this refers to the information dispersed between 10 and 60 minutes after the impact of the tsunami. The information disseminated will consist of a detailed observation on the tsunami and briefings on the degree of threat that will be posed. The Broadcast may be sounded repeatedly depending on the level of threat and the changes in tide measurements and station signals.

iv. EW4, EW5 and subsequent warnings will occur if there are changes to the EW3 message communicated to the community.

5.1.2.3 EW Stakeholders

First and foremost, warnings will be dispersed via the BMKG to diverse tools and entities involved in information broadcasting and then to the community in danger. The local authorities, Local Disaster Board (BPBD), Indonesian National Board for Disaster (BNPB), National Army and the Police and National Media (TV and Radio) are bodies that may send warning messages to the public through tools such as Sirens, Internet or Websites, TV and Radio. All stakeholders have their own responsibilities as shown in Figure 11 (Beta, 2012).

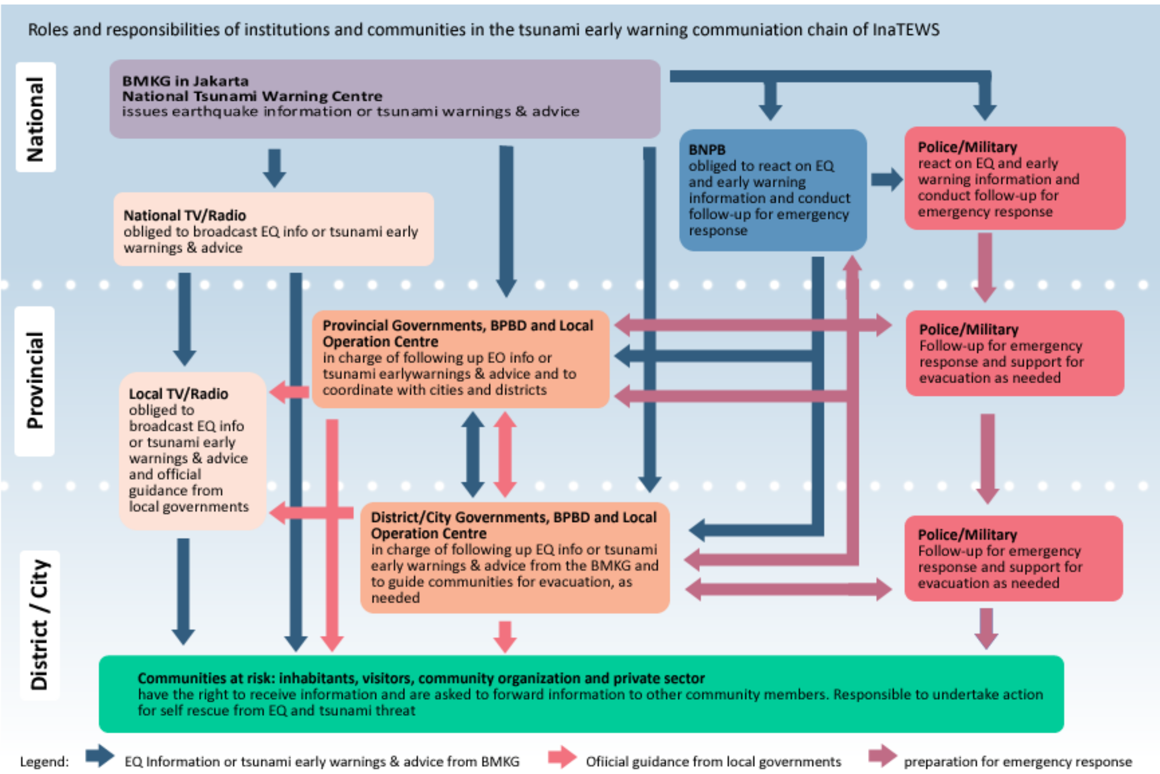


Figure 11. Stakeholders and their responsibilities (Beta, 2012)

5.1.2.4 EW Dissemination Media and Channels

To spread the EW to the stakeholders and communities at risk, the InaTEWS uses the following media and channels: Siren, Media (Radio and TV), SMS, Email, Fax and Warning Receiver System (WRS).

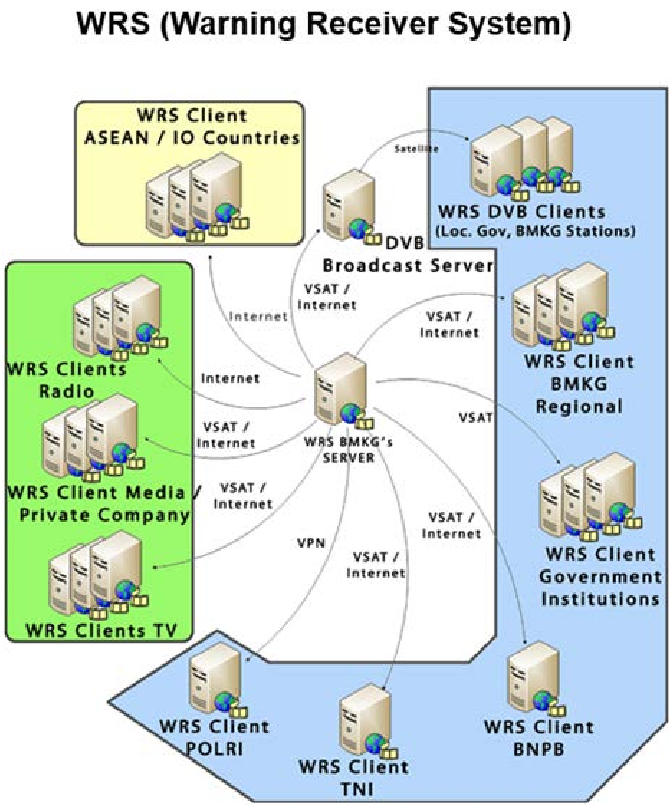


Figure 12. The Warning Receiver System (Beta, 2015)

The WRS is the backbone of all the media and channels. It is a standardised media that carries the warning using many different formats and through VSAT and the Internet. As shown on Figure 12 each stakeholder will have either a WRS Client or WRS Digital Video Broadcast (WVB). From there the EW will be converted into SMS, Fax, Email, TV and Radio Broadcast. Sirens will be used if evacuation is needed (Beta, 2015).

If we combine Figures 8 and 10 we will have Figure 11 in section 5.1.2.3 which shows both the media and stakeholders as well as the EW dissemination flow. However, as shown in Figure 14, there is a local assessment task, which specifically produces the instruction to evacuate or not. This will be decided by the local government and the BPBD (Alpha, 2016). More of this will be discussed in section 5.2.2.

5.2 Interviews and Data from Secondary Sources

The discussion below will first examine what are the current systems and the weaknesses of the channels used. Secondly, we will assess in what ways our proposed system may improve the current EW dissemination process. Lastly we will discuss the user requirements that were gathered from the staff of the Alpha organisation.

5.2.1 Other Media and Channels Shortcomings

The WRS systems are robust and may only have a small chance of failure but if the warning doesn't reach the target community or is somehow disrupted then it will be a worthless effort. Sirens, TV and Radio are the frontline media and channels to reach the community, yet according to Alpha (2016), those media have several limitations and drawbacks that may be crucial in disseminating the early warnings, and these delays can be a survival factor for the affected people as discussed below.

5.2.1.1 TV & Radio

As shown in Figure 11, the authorities adopt tools such as TV and radio to get across the message to the community at risk. While TV and radio may reach many people, they have some limitations.

Previous tsunami reports in Indonesia show that there were cases when certain affected areas had their electric power intentionally cut off to prevent fire that may cause damage to electrical facilities (GIZ IS PROTECTS, 2012 pp. 5, 13-14). This loss of power to certain villages or towns, resulted in no TV or radio broadcasts being received in those regions.

Although not everyone watches TV or listens to the radio to receive the crucial warning, the importance of these media should not be ignored. As shown by Perry (2007) in the case of Mauritius, out of all media used to send tsunami warnings to the affected community, TV accounted for 51% and radio for 27.6% of recipients. While Indonesia might be different socially and geographically from Mauritius, TV and radio are the main channels used by the local authorities in spreading early warnings especially to communities living by the coastal areas.

Looking back at the other section 2.2.3 case studies, there is a high tendency for individuals that do not get the information passed at the right time, to be in danger.

5.2.1.2 Sirens

Sirens may reach the community at risk up to a radius of 2.5 kilometres. They are simple to operate and have a straight forward function. Through previous training, the surrounding community would recognise that if the siren goes off it means there is a tsunami warning. However, it has several flaws and crucial limitations.

First of all sirens will only go off when the local authorities are 100% sure that the tsunami threat level is at least of an “advisory” nature. And since the sirens don’t have several different warning levels, they may not be able to warn the community when dealing with EW1 and EW2 which are warnings still at the “watch” threat level when the local authorities are still unsure whether to evacuate or not. In short, sirens can only tell the public to evacuate but not when they need to stay away from the shore, or when they need to be prepared of a possible tsunami nor to inform them about several messages or updated EWs. The decision to evacuate or not to evacuate itself is quite complicated and it will be discussed in section 5.2.2.

The other problem with sirens is that they are not available everywhere as they are very costly to build. With a height of around 15-16 metres, a siren tower will cost around US$60,000 to US$90,000. Ideally one siren tower should be built every 10 kilometres along the coastline. As Indonesia has around 50,000 kilometres of coastline (40% out of the total) that is considered prone to tsunami, at least 5,000 sirens are needed. Currently Indonesia only has 29 sirens spread over several provinces and in the province where the data was collected there are only two sirens available (Alpha, 2016).

5.2.1.3 SMS System

During the interviews the staff also talked about the SMS service. The SMS service is provided to people who want to receive tsunami information. Users need to send “GA (CITY NAME)” to 2303 to get the latest information about tsunamis in that specific city.

Unfortunately, the SMS service provided also has several drawbacks. First there is the possibility that as a result of overwhelming distress calls or breakdown, the commercial provider's BTS may be overloaded, therefore cell phone users will have difficulty connecting to their provider and they will be unable to send or receive SMS.

Secondly, the SMS service does not operate on a reverse-911 manner but messages will be sent only by request, thus people are not automatically informed. In a panic state people may not be able to remember to request the service or they may be occupied with other things; therefore they may miss out on the information available from the SMS service.

Thirdly the cost is a burden on users. While it may not cost a lot, this obstruction might be significant and crucial due to the situation's time-sensitive nature. For example, what if the users haven't topped up their credit or don't have enough credit? Such conditions will surely prevent them getting some crucial information. This might be another reason why only around 7000 users had used this service until 2012 (Beta, 2015).

Lastly, the service is only available for customers of two providers, Telkomsel and Indosat, out of six providers in the country. While those two providers dominate 68.7% of the total mobile users' market share or around 206 million users (Noor, 2015), there are still 31.3% or around 93.9 million users who are using other providers and won't able to use this SMS service.

The factors discussed above can be decisive in the case of emergencies, and they may put the community in danger.

5.2.2 The Needs of Local Assessment and the Importance of Locally Controlled EW Dissemination Channels

Due to certain conditions and factors, according to the Alpha (2016), there are some situations where the local authorities may take a different decision or they may provide earlier updates as to whether to evacuate or not. Therefore, it is suggested that the local authorities should have more local channels (i.e.

controlled locally) to disseminate EW in addition to the central EW. As shown on Figure 13, the TV, Radio, SMS, Email and Web are controlled by the central BMKG; that leaves sirens and local TV & Radio as the only channel the local authorities have. The conditions and factors are discussed below.

5.2.2.1 Local Assessment

Should an earthquake hit a certain area, the tsunami EW (early warning) will be sent by BMKG to both the Governor and BPBD (via WRS, SMS, FAX or email). The warning should have either one of three types of threat levels: *Major Warning*, *Warning* or *Advisory*. And it will follow the decision flowchart on Figure 13 below. Despite this, as shared by Alpha (2016) there are some cases where the local authorities need to take some further actions.

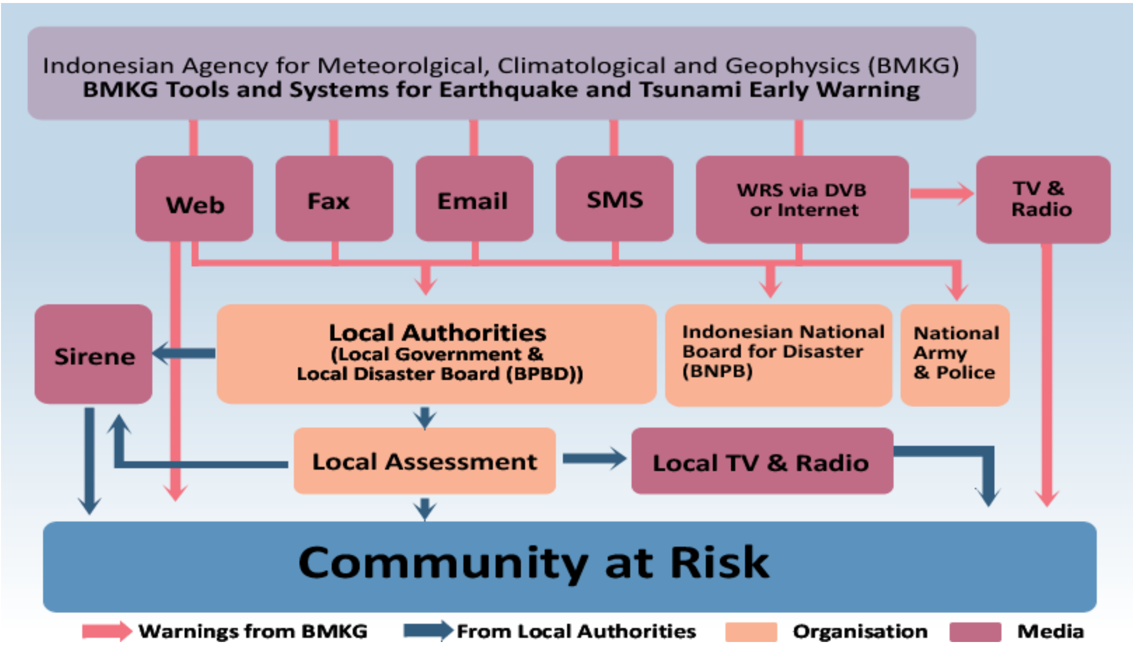


Figure 13. Warning Dissemination Media/Channel Flow & Stakeholders – A modified flowchart from Beta (2012)

First, Alpha staff members need to undergo a field inspection by checking the water levels on the coastline. This is important especially in the case of a “no need for evacuation” message to be sent by BMKG. Apart from that they also need to consult and crosscheck with other source data, such as from the USGS (United States Geological Survey), E-MSC (European-Mediterranean Seismological Centre), and PTWC (Pacific Tsunami Warning Centre). These other sources’ data should align with the BMKG’s to eliminate any doubts. There are also several situations where an urgent call to evacuate due to uncertainty may be needed. An example of these situations is when the tsunami detected may be too close to the coastal area thus it would be too costly to wait for the 2nd EW from BMKG. An urgent call also may be needed when there are earthquakes with multiple aftershocks that are less than 5 minutes apart; such conditions may affect the observation system's accuracy. Other situations may also be derived if information received from field checks and the BMKG reports have differences which may lead to a non-conclusive analysis. If faced with those situations described above, the government most likely will take precautionary action, such as immediate evacuation, instead of taking the risk.

Secondly, the staff members also need to keep in mind that negative and harmful rumours may spread rapidly among the community and may potentially create havoc and mass panic. Such a situation should be responded to promptly by taking extra measures such as a "No Earthquake" or "Stand by" EW updates to calm down the panic and chaos when it is starting to take place.

On top of the factors mentioned above, the local authorities' re-assessment has to be certain that everything is pointing to evacuation or standby/not. One single ambiguous statement can be taken as overly negative. And this is very important as an evacuation instruction cannot be withdrawn or changed as it may cause even more confusion.

This type of confusion actually happened when an earthquake struck near the West Sumatra Province on April 11, 2012. The situation back then was that the authorities of the capital city of the province instructed for evacuation while the province authorities said you may evacuate (PROTECTS, 2012).

5.2.2.2 Locally Controlled EW Dissemination System

If we look up Figure 13 the current locally controlled EW dissemination media and channels are sirens, local TV & radio. Sirens can only be used for evacuation instruction; therefore, any local assessment other than evacuation cannot be disseminated through sirens. While local TV stations can reach many people, they are not popular with the public and the local communities tend to watch the national TV stations. Local radio might be the only possible channel that may reach the community in significant numbers even though not everyone will receive the warnings.

As reported by the staff, the local authorities may also inform the national TV channels and radio stations, but it may take time as the information will need to go through BMKG again. National TV would usually pick up the information from the local TV stations through their media network. Therefore, as discussed above an additional locally controlled EW dissemination channel may improve the current system.

5.2.2.3 Timing of the Local Assessment

Officially there's no exact standard time of how long the local assessment should be finalised. While sometimes the community would already have been informed through national TV and radio broadcast or through websites (website & social media), there are cases where local assessment will a take different course. Therefore, it is recommended to have the local assessment, if different from the BMKG instruction, to be released according to its urgency. For example, in the case of the West Sumatra earthquake the BMKG might have sent a warning with a "Warning-Advisory" level. The province authorities did a local assessment within 5 minutes (almost the same time as when the EW2 arrived) and decided that the warning level on "advisory" which means no evacuation other than those in coastal areas (PROTECTS, 2012).

5.3 Assessment and User Requirements

As shown and discussed in 5.2.1 and 5.2.2 the current EW systems, while centralised and useful in the case of tsunamis, have some limitations in certain key aspects. On this section we will discuss how our proposed system may be incorporated and what are all the user requirements that it needs to be useful as an additional EW system; especially a locally controlled EW system.

5.3.1 System Incorporation

The proposed system incorporation is pretty straightforward. As shown on Figure 14, it can just simply plug in to the existing system. EW will be received from BMKG and/or from local authorities' (Local Government & BPBD) assessment.

Each EW update (EW2, EW3 and so on) can then be broadcast right away to the community as shown in Figure 15.

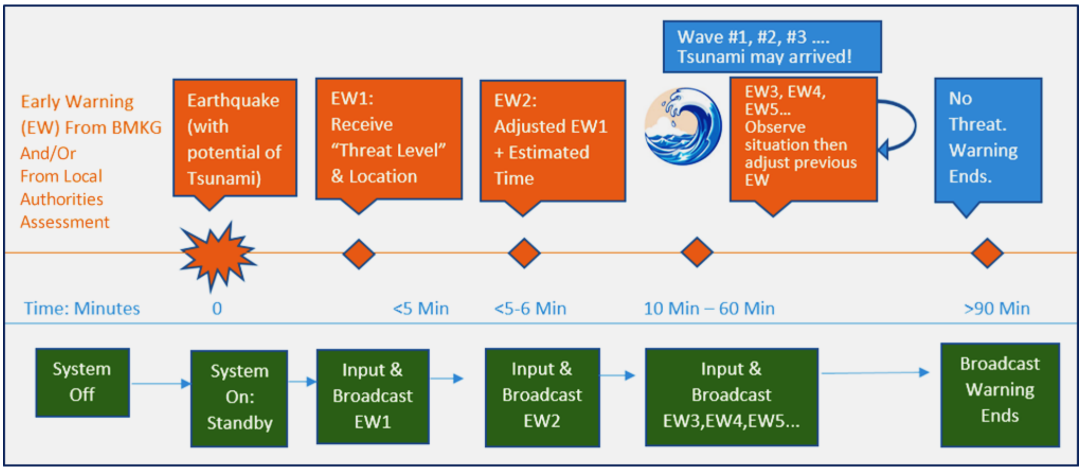


Figure 14. Proposed system integration in broadcasting Early Warnings (EW)

Figure 15 also reveals the stakeholders involved and shows the locally controlled EW (sirens, local TV and radio) alongside the proposed system. The BMKG will first produce the EW1 about 5 minutes after an earthquake strikes and send it to all stakeholders.

As for the Local Authorities the EW1 will be received via WRS (DVB or Internet) Client. It then may go through local assessment first before being forwarded to the locally controlled EW dissemination channels and media. At this point the proposed system will also stand as one of the EW dissemination media used to reach the at risk community.

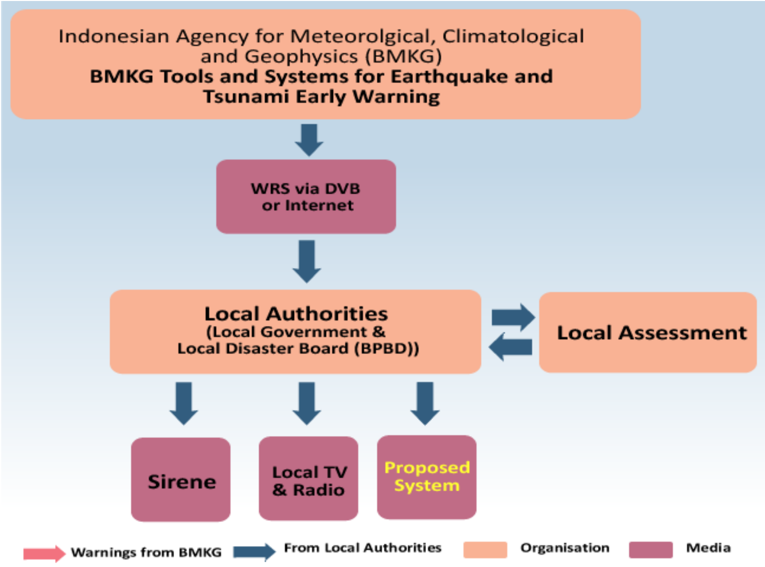


Figure 15. Proposed system getting EW from BMKG and Local Assessment modified from Figure 13 (Beta, 2012)

5.3.2 User Requirements

According to Baxter and Courage (2005) "User Requirements", from the user's perspective, are features or attributes that a product should have and from which it is expected to perform. To accomplish this, the user requirements are gathered from interviews and field studies. At this stage we will use the information gathered from the interviews that have been conducted and case study data that are available on the documents and reports provided by Alpha.

Operating Requirements

According to the staff, the system should have a simple and easy operating procedure. This means it has to be user-friendly. While the user will be given training, the system should include some plain guide such as clear and easy to understand text and guidelines the user can refer to. Similar to operating an ATM, while people understand the basics to operate it, a few text instructions would help the user confidence in using the machine. User-friendly also means it should be straightforward and simple without unnecessary menus or buttons that may cause confusion, especially if this will be used in emergency situations. In addition, a manual should also be available whenever users need specific information about operating the system.

Required Capabilities

The system should have several minimum features and capabilities to meet its purpose. First is its range to reach the communities and their cell phones. According to the staff, the ideal range would be as far as possible, however the farther the range, the costlier the system will be. Therefore, ideally 2.5 to 3 kilometres should be sufficient for a small town. While this may mean it would be the same as the range of a siren, the cost of the proposed system would be much more affordable; therefore, having this system on several points would be more achievable.

A second capability required is that the system should easily connect to GSM cell phones. The system should be able to do this instantly and once the connection is established, the system should be able to disseminate the EW’s SMS to the user immediately. It is understandable there may be some delay and that depends on how many users are getting the EW, but they should be getting the EW’s SMS no more than 3 minutes after the initial dissemination started. This is to ensure that the community gets the updates and is able to react the EW as soon as possible, especially in the case of evacuations.

Another capability required is related to the number of users it can send messages to. The best scenario would be to reach all inhabitants within the 2.5 to 3 kilometres coverage area.

Characteristics

Warning dissemination is a race against time, especially in the case of tsunamis. Since it is necessary for the messages to be disseminated quickly, the system should start up quickly or be in standby mode all the time.

Given its critical purpose, the system also needs to be reliable and robust. A system failure or malfunction, however small, should be avoided at all cost. System errors such as a blue screen should be anticipated through comprehensive system testing. It is also essential for the staff managing the system to maintain stocks of all the replaceable components such as monitors, keyboards, etc. The system should also have a backup battery or power generator in the case of power failure, as discussed in the section 5.2.1.1 case study.

Lastly, the system device should be durable, not fragile and able to endure a certain degree of physical impact in case of tremors or other minor damage that may be caused by an earthquake. To achieve this, the system should be protected by placing it in an impact resistant case.

5.4 Proposed System's Operation

With the previous discussion, the following diagram (Figure 16) shows the involved agents and information flow on the proposed system. First, the EW will be received from BMKG through the InaTEWS. The EW will come in long format as shown on Appendix A.2. The staff or the device user will need to assess the EW as well as conduct local assessment as discussed in section 5.2.2. The device user then needs to construct the message into SMS format for the device. They will start the device, run the program, input the message and broadcast it to the community.

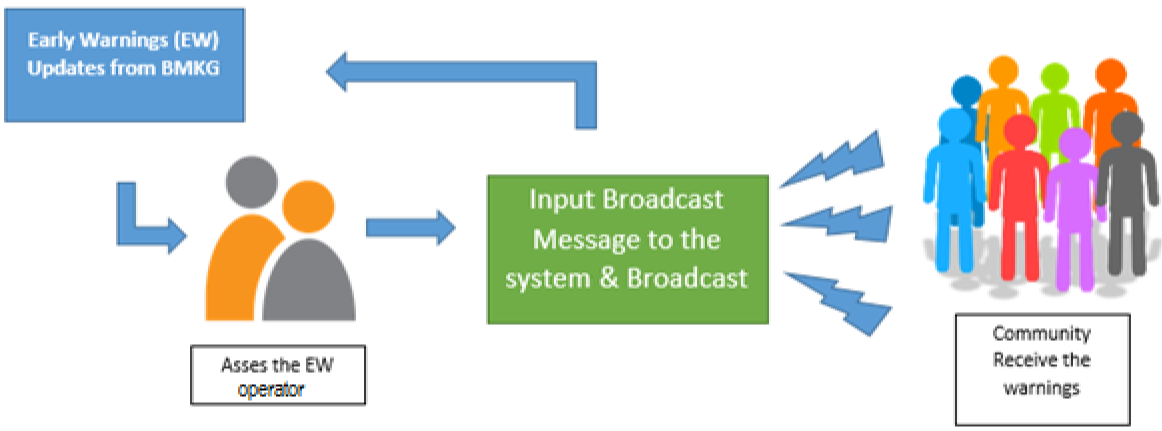


Figure 16. Proposed system operation

6. Developing a Prototype

In this chapter we will go through the prototype design as well as identify other factors that are involved in setting up a Proof of Concept (POC) plan where we can have an idea of its implementation and integration within the disaster response. The prototype technical design is based on the preceding discussion, specifically of Chapters 3 and 5.

6.1 System Design

In Chapter 3 we went over the technologies related to or involved with the proposed system and in Section 5.3, we discussed the user requirements and explained our aim to set up a system to be another channel for tsunami warning dissemination.

In this section we go through the proposed system design. First we discuss the system infrastructure, features, hardware and software components that are being utilised and then the experimental setup and lastly the conceptual framework.

6.1.1 System Infrastructure

The proposed system follows the OpenBTS architecture (Azad, 2011) which emulates the GSM 04.03 standard as shown in Figure 17. It has the OpenBTS and supporting software, drivers, a USRP board, a daughterboard (RFX900) and the antenna and amplifier. At the client end is a MS in the form of a GSM cell phone.

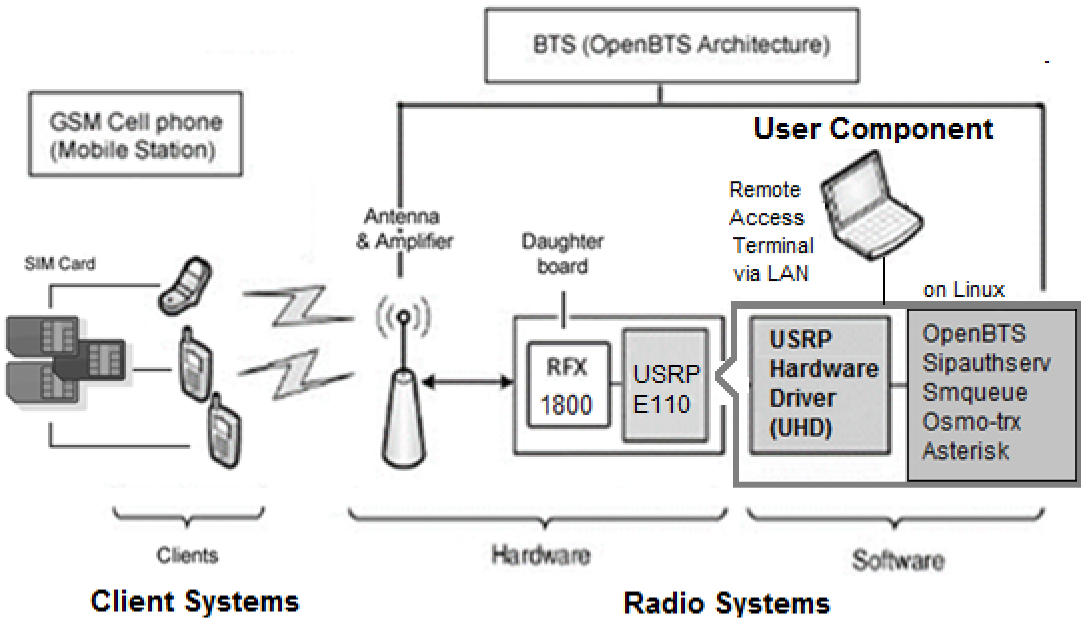


Figure 17. Proposed system architecture based on OpenBTS architecture based on NYU ITP (2013) schema.

6.1.2 Hardware

The system hardware is divided into three main components: the radio system component, the user interface component and the client component. The radio system acts as the brain that connects the client and the user and allows the user to disseminate messages. The radio system has two main sub-components: USRP and a RF daughterboard. The user interface component is the device that gives a user-friendly interface and allows the user to control and utilise the radio system. In this case the user interface component is in the form of a standard PC. Lastly is the component which is the device held by the client. The client, in this case, is the targeted or at risk community who receive the warning messages sent by the operator. The client component is in the form of a GSM-based handset. Detailed explanations of each component are as follows:

USRP: The proposed system uses a Universal Software Radio Peripheral (USRP) model E110. The USRP E110 allows the user to program and modify radio protocols for development and has its own embedded OS running within.

RF Daughterboard: The USRP E110 is paired with a RFX1800 daughter board. The RFX1800 is a highly rated transceiver that can be converted to RFX900 and able to operate at the 900, 850, 1800 and 1900 MHz band, which is the frequency used in New Zealand, Indonesia and many other countries. On the proposed system we will let it stay as RFX1800.

Antenna & Amplifier: The proposed system is equipped with two omni-directional vertical antennae with 3dBi gain.

PC for Remote Access: We use a standard PC to access the device via LAN (may be also from Router/Wi-Fi if required). For the test we used a Windows based laptop.

Mobile Phones: Two GSM-based mobile phones are used with a standard commercial SIM. The mobile phone should support the GSM band to match with the daughterboard RFX1800.

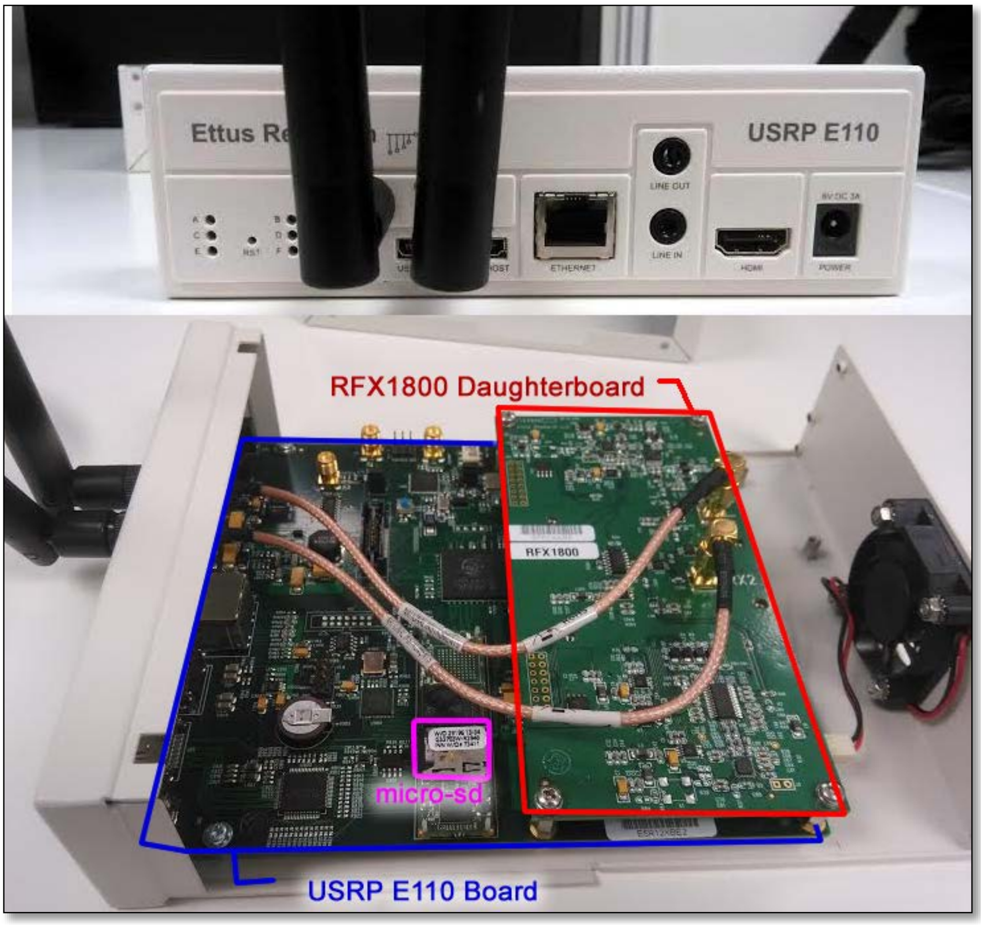


Figure 18. USRP E110 with RFX1800 daughterboard in our proposed system

6.1.3 Software configuration and components

6.1.3.1 List of Software

The following software are required to be obtained, set up properly and run on the device remotely via a PC. As a note, the USRP device, OpenBTS and UHD can be treated as one inter-related system. To illustrate their functions, we can think of the USRP as a printer and of the OpenBTS as the printer software; while UHD is the printer driver and a mobile phone would be the paper. Details of each software and their functionality are as follows:

OpenBTS: is a Unix-based application that utilises a software radio able to reproduce the GSM frequency to a standard 2G-capable GSM handset. OpenBTS allows the BTS to transmit and receive at the same time. Transmission to the handset (MS) is called "downlink" while from the handset to the network is called "uplink". The code is available at: http://openbts.org/w/index.php/BuildInstallRun

USRP Hardware Driver (UHD): Provided by Ettus Research, UHD is the device hardware driver to be used as host driver and software interface/API for various Ettus USRPs (Ettus Research, 2012b).

SIP Message Queue (SMQueue): Smqueue, comes with OpenBTS and is responsible to process the SIP MESSAGE requests that are generated by OpenBTS. It stores the messages and it also reschedules them if the target phone is not available (Iedema, 2014 p.13).

SIP Authorization Server (SIPAuthServ): SIPAuthServ is the application that manages the SIP REGISTER requests that are generated by OpenBTS when a new user attempts to join the network (Iedema, 2014).

OsmoTRX: OsmoTRX, based on the OpenBTS's transceiver code, is a software-defined radio transceiver that operates at the BTS physical layer (Tsou, 2015). OsmoTRX is used instead of the OpenBTS native transceiver since it has better support and it uses the ARM processor that is used in embedded USRP devices such as the series E3xx and E1xx (Ettus Research, 2012a)

Other Software: All the above software will run on top of Linux Angstrom OS that is pre-installed on the USRP E110. On the other hand, we have two custom scripts called launch.bat, to run the OpenBTS, SIPAuthServ, SMQueue and OsmoTRX, and sendmsg.exe to broadcast messages. These two scripts need to be run from a Windows based PC remotely. Section 6.2 shows a sample scenario on executing them and Appendix B.3 shows the code of both scripts.

6.1.3.2 Configurations and Operating the Device

For the lab test, we configured our network to not interfere with existing commercial provider signals and only allow our own SIM to be connected. To achieve this we used an unoccupied frequency (ARFCN 761 which is: uplink 1760 MHz and 1855 MHz downlink) with low power when carrying out our tests in the lab environment (Crane, 2012). The same configuration may be used for field test thus doesn't need to be changed. However, to test the signal strength and how far it can reach we used full base station power on the configuration.

The actual configurations can be seen in Appendix B.2. The custom scripts that were created to launch the system easily from a remote PC are shown in Appendix B.3 while the instructions on how to use the device are shown in Appendix B.4. On the other hand, Appendix B.1 shows the installation and setup.

To emulate real conditions, we used two actual commercial SIM, 2Degrees and Vodafone that are used by regular cell phone users in New Zealand.

6.1.4 Features

In this part we will discuss the system features. We will divide this part into: server user interface, system capacity, supporting hardware and client-side functionality.

6.1.4.1 Server User interface

The system is aimed to be used by the related organisation once they have assessed the situation and decided to disseminate the message to the public along with other media and channels (siren, radio and TVs) as seen in Figure 16. Firstly, the early warning message will be received from the BMKG and be analysed by staff. After the analysis discussed on section 5.2.2.1, the staff then will take certain parameters and will transform that message into a shorter one that will fit into a single SMS (maximum 160 characters including spaces).

The server user interface is pretty straight-forward. To send the message using the system, both radio and PC components need to be turned on and once the start-up script on the Linux OS has finished, the user may input the warning message by using the OpenBTS command line through a script that has been created for user friendliness.

Once it is executed, any GSM-based mobile phones that are connected to the system will be processed by the radio components; both USRP E110 and the daughterboard, and send the warning message in real-time. The same process will need to be repeated for the next updated warning messages as shown earlier in Figures 14 and 16. Users who got connected after the message was broadcasted will receive the latest message sent.

We will also be able to see how many mobile phones have connected and received the SMS through the OpenBTS software.

6.1.4.2 System Capabilities and Capacity

At this proposed setup, it is estimated that we will able to register around 1000 users and be able to broadcast SMS simultaneously to all these registered users. To allow any IMSI (International Mobile Subscriber Identity) that is factory installed on each phone SIM card, to be able to connect to the system we will setup the Open Registration feature of the OpenBTS software. This allows any SIM card with a different IMSI that may vary between countries and cellular providers, to be connected and get the message.

As for the reach we will need to add an amplifier to reach 2 to 3 kilometres, as in this setup with a 3db antenna the reach is just about 100 metres. This setup is considered a minimalistic setup due to the limited budget; however, we can estimate an upgraded system's capacity and capabilities during the post-experimental analysis.

Any GSM handset with any SIM should able to join the network since it is an open network. However, the user may not able to send a message or make a phone call as the system is designed as one-way broadcasting only. As for the system performance, we tested it with the experiments.

6.1.4.3 Supporting Hardware

Since an earthquake may cause loss of power, and either the nearest power station may be damaged or the emergency power cut off, the system needs to be equipped with backup power such as an uninterrupted power supply (UPS) to keep the system uninterrupted, and diesel or fuel generators to prolong the power supply. A generator is chosen as it is quite economic to run. As for the server we may use a laptop and the battery that comes with it to conserve power.

6.1.4.4 Client-side Functionality

Once the primary cellular provider becomes unavailable due to congestion, or due to damage or power loss, the client, equipped with a GSM cell-phone, will be automatically connected to the system and should able to receive the emergency SMS just like receiving a standard SMS. However, they may not able to reply or send SMS to other users.

6.2 Experimental Setup

To conduct a test, we need to setup the experimental environment and set the task and goals that need to be carried out. As described on section 4.2.5 the system is intended to be operated in disaster situations therefore an experiment in the form of a simulation would be the best route open to us to prove our concept.

The following are the system main functions that need to be tested during the experimental simulations: starting up the system, connection and connectivity test, message broadcasting test, message receiving test and coverage test. A detailed description of each function or phase along with guidelines that need to be followed and their expected results are discussed below

6.2.1 Starting up the system

As an emergency tool the system is expected to stand by and be ready to be used at all times. Once the device is in standby mode, it should able to be controlled remotely through terminal access from a laptop or PC through a direct Ethernet cable or wirelessly via a router. The system OS should not be running other unnecessary applications or services to minimise any intrusion while booting up and running.

The operator needs to run the following services on the device: “smqueue”, “sipauthserv”, “osmo-trx” and “openbts”. A script to be run from the PC called “launch.bat” has been created to run a terminal, connect to the device and execute all these services at once.

The expected outcome of this test is that the PC can connect to the device and the OpenBTS and to the other services running on the device in less than two minutes. An OpenBTS standby prompt will show up at the end of the script.

Another note on the actual setup, the system should be equipped with an Uninterruptible Power System (UPS) since the device needs continuous power. However, to cover a longer period of time, a backup power generator is recommended on top of the UPS.

6.2.2 Connection and Connectivity Test

The purpose of the next test is to check two main functions: first is to make sure that the system is able to broadcast and is visible to the mobile phones and second to have the mobile phones connected to the system.

Once the OpenBTS is up and running, we will turn on the mobile phones with any SIM card and make sure the “automatically choose network” setting is on default (enabled) as this will allow the phone to be connected to the system automatically. To simulate the emergency situation, the test will only work if the SIM card cellular provider is not in reach or has a weak signal; therefore, it is best to run the test in an area without any or only weak cellular signals.

The expected result of this test is that the phone is connected to the system BTS, and this will be shown on the phone display and on the OpenBTS status.

6.2.3 Message Broadcasting & Receiving Test

After being able to connect the phone we can test broadcasting a message. This is where we are going to broadcast the warning messages. The messages in the form of EW may be broadcasted several times as EW1, EW2 and so on. The mobile phone should be able to receive the message immediately (in less than 10 seconds) and receive the whole text. Another mobile phone is tested to be turned on after the broadcast. It should, in this case, be able to receive the latest message.

To broadcast the message, we will run a script from our laptop called “sendmsg.exe” where the user will be required to input the current EW stage message. The script will also set that message as the “welcome message” when new users join the network. This will allow users who get connected following a broadcast, to receive the latest EW. The “welcome message” is a message sent to any new user when they first connect to the device.

The expected result of this test is that all the clients receive the message and the user who connected after the broadcast time will receive the latest EW.

6.2.4 Coverage test

While the other features such as the connectivity and message dissemination can be fully tested, on the other hand, the coverage test can only be offered as a proof of concept due to limitation of our budget. However, given that our proof of concept system may cover only a radius of 50 to 100 metres, our coverage test will consist of checking recipients in different cardinal points in the limits of a 50 to 100 meters’ radius. In addition to this we will also have a record of the signal power for each distance and point.

The expected result of the test would be that all clients are able to connect and receive the message from up to 100 metres radius from the system location.

6.2.5 Test environment and other devices

As discussed in 6.3.2, a location with no mobile signal would be ideal for the field test. We will be using a New Zealand 2 Degrees SIM card and conducting the test at an area around Bethell’s Beach, West Auckland. Through their website and actual visit, we discovered that the area doesn't have a carrier signal at all. To power the device, we will use an inverter plugged into a car lighter socket. We also have two sets of GSM-enabled phones; one is set to 4G-preferred and 3G-preferred, which is a default setting of the network selection. Both phones are less than 2 years old.

6.2.6 Limitations of the System's Design

There are two aspects that are not covered by the system: an uninterrupted power supply and the message conversion procedure.

As discussed on 5.3.2, the system should able to run without interruption and stay awake even when there is no conventional electricity for a few hours. However, these conditions would not be covered on these tests as these devices, such as a UPS, are quite straightforward and have been standardly used in many situations.

Also, as discussed in section 5.1.2, the warning messages will be received from the BMKG. The conversion of the message to the SMS format will be done manually by the officials thus this step would not be covered and discussed in our experimental setup as it is part of BMKG's procedures.

6.3 Experiment Process and Results

The following are the process and results of the lab and field experiments. We will follow the 5 experimental tests as listed in section 6.2.

6.3.1 Lab Experiment

As we are simulating an emergency situation, the device was powered immediately and a connection was established while the device was in standby mode. The script was executed nicely with no problems and all services seemed to be running right away. All this was done in less than 1.5 minutes. If this is considered too long, we can also turn on the device 24/7 to save about a minute of start-up loading time. We then ran the sendmsg.exe script which will also set the EW1 as the welcome message.

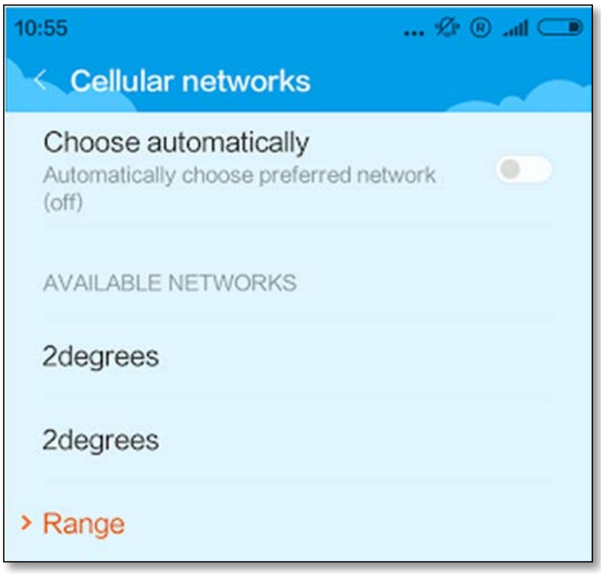


Figure 19. Choosing BTS manually. Our system is called Range. This is unnecessary on the field experiment where our cell phones automatically connected to Range.

The next step was to switch the phones to “manually choose provider” and have it connect to the device (Figure 21). It took a while for the device to list all the available BTSes. However, this was not the case when we tested in the field where the mobile phone connected to the device right away since there were no other BTSes around. After about 2 minutes since the device was turned on, the phones were connected to our network and immediately received the EW1 as the welcome message. We waited for about 2 minutes and then we broadcast the EW2. The message was received with about 1 second difference between the two phones. The sendmsg.exe prompt and the test EW are shown in Figure 20.

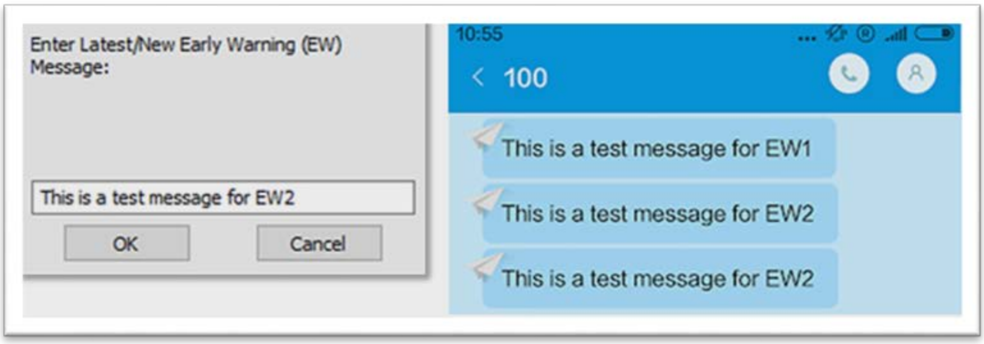


Figure 20. Prompt of the Sendmsg.exe and when it was received on the mobile phones

We also checked the signal strength on both occasions. Figure 21 shows the signal strength while inside the lab room and about 100 meters outside the building. Signal strengths on the field experiment, for 50 and 100 metres, are shown in Figure 22.

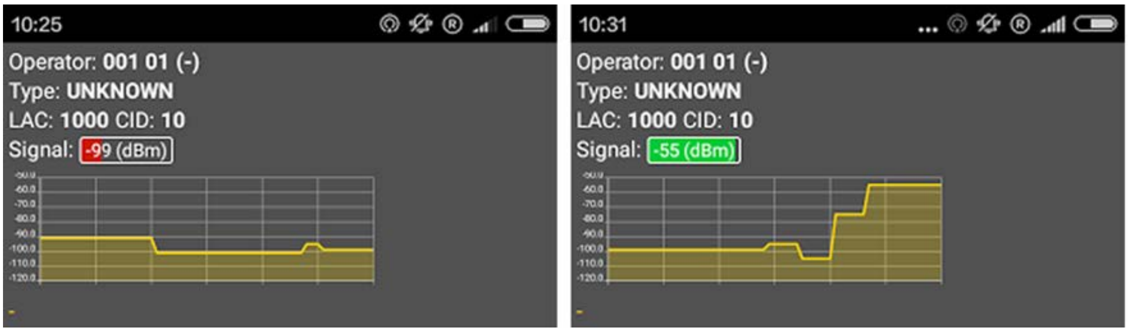


Figure 21. Signal strength for the lab test. Around 100 metres away the device outside the building (left) and around 1 metre away inside the room (right)

6.3.2 Field Experiment

We drove to Bethell's Beach in West Auckland and past a point where cellular phone signals were not detected and started up the device and ran the system. To avoid other users' mobile phones from connecting to our device, we chose quite a large empty field. The device started up pretty much with the same speed as when in the lab test only this time our phones connected to it right away while they were on default settings and without us changing anything. This shows the auto connect is working.

We then broadcast the first EW1 and set it as the "welcome message" to make sure the subsequently connected user will receive the EW1 that we have already broadcast, which is the latest EW. The "welcome message" is an SMS that is automatically sent to any new user when they are first connected to the system.

Both cell phones were able to receive the message in less than a minute. EW2 was sent a few minutes later and was received by both cell phones in no time. We then tried to send a message from a 50-metre distance and another one from a 100-metre distance. Though messages were still received at the 100-metre distance the signal, however, was quite low, around -99 to -105 dBm in all four cardinal directions. A few steps beyond 100 metres and we lost signal completely in a few seconds. On 50 metres we did get -71 to -73 dBm which was considered good.

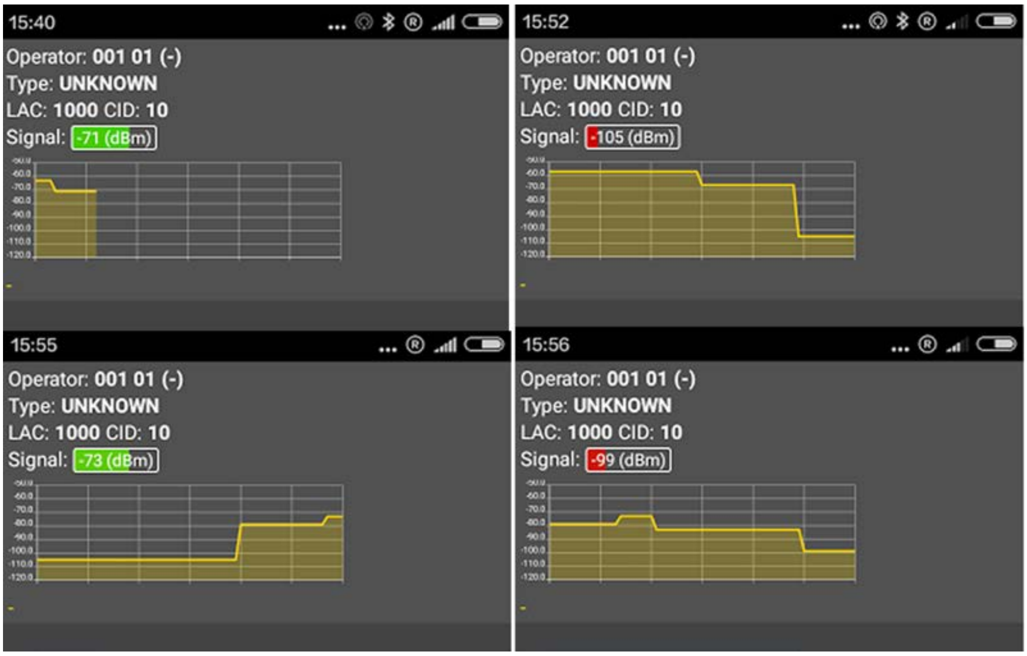


Figure 22. Signal strength for the field test. Around 50 metres radius away from the device in different direction (top and bottom left) and 100 metres away (top and bottom right)

7. Analysis & Conclusions

In this chapter we will present our analysis and show how this will answer our research questions. The analysis will discuss the systems' overall performance and usability including relations to its incorporation, user requirements performance as well as drawbacks. And in the last part will be the conclusion including also unique contributions and future work. First, we review our research questions.

> RQ1: "How can first responders set up a communication system for tsunami warning dissemination purposes for the exposed population that fits within the disaster response's Standard Operating Procedure (SOP) of a certain area?"
>
> RQ2: "What would be a suitable user manual and documentation to accompany the proposed system?"

Both questions' responses are discussed below.

7.1 Responding to the Research Question

In answering RQ1, we divided the question into two parts. The first part is responding to the device's usability, functionality and performance to be used by first responders for tsunami dissemination purposes. Our analysis on this is discussed in section 7.1.1. The second part will be related to the device incorporation with the existing disaster response system. This is discussed in section 7.1.2. As for RQ2, the system operation manual is provided in Appendix C while the conclusion is in section 7.1.3.

7.1.1 Proposed Device as Early Warning Disseminator

In Chapter 2 we discussed how a disaster may impact populations and how disaster management covers the warning disseminations part. While a combination of earthquake and tsunami is not something that happens every few years, the impact of it can be staggering and devastating. Because there is a chance of a tsunami after an earthquake hits, factors such as time, communication, base knowledge and recent information can become very crucial and extremely important as they can save a single life or even large populations. Early warning is considered one of the dynamics that can make a huge difference.

Lessons learned through previous recorded earthquake and tsunami incidents show how communications can become so important and quite fragile at the same time just as in the case of Bangladesh, Haiti and New Zealand where the commercial network was quite affected and even went offline for a significant period of time (Corin, 2011; Corley, 2010; Hazarika et al., 2010). While network and infrastructure may not be affected, however, a poor tsunami warning propagation coordination may also bring serious problems as shown in the Mauritius and Chile cases (Associated Press, 2010; Perry, 2007). Lastly, a proper evacuation plan, education and warning system has also shown significant difference in reducing causalities as shown in the cases of Papua New Guinea and Japan (Bernard et al., 2006).

7.1.1.1 Experimental Outcome

By utilising an unused frequency, we were able to test the device both in a closed building in the city and also at a location where no cellular network being available simulated a conventional network breakdown which possibly happens after an earthquake incident. Through these controlled experiments we were able to connect different kinds of handsets with various SIM attached to the network and were able to disseminate the EW message. The system is designed to send the users the latest EW messages once they are connected to the system, and this will ensure civilians’ safety in case there are significant changes between EW messages.

With its quick startup and simple interface, the system is believed to be user friendly and have straightforward operation. While the radio system runs an embedded version Linux, it will be remotely operated from a Windows based laptop or PC which may give much familiarity for the end-user who will be operating it.

While we didn't test its performance close to a real disaster situation (i.e. disseminating messages to 100+ users within 2 to 2.5 kilometres) which may be costly and require another large experiment, we believe it is capable of this.

7.1.1.2 Functional and Performance Analysis

The proposed system has several user requirements that need to be met as listed and discussed in section 5.3.2. The following are the responses to those user requirements:

- Operating requirements
  The system should be user-friendly and simple to use. As shown in 6.2 and 6.3 the system operation is considered user-friendly and straightforward. Starting up the system is quite fast and the prompts are accompanied by the text descriptions (see Figure 20). The system is also accompanied by a manual which will help the operator for training and familiarity purposes.

- Capabilities
  The system should able to connect to the community and disseminate the early warnings without any significant issues. Through our lab and field tests, the system was able to connect with any commercial network SIM (we have tested on several different local providers' SIM cards and even overseas providers' SIM cards) in just a few seconds after startup. This is very important as the community may have various kinds of phones and be using different providers. We also tested sending EWs through the system and they were received in just a few seconds.

- Characteristics

  Due to the time constraint during or after a disaster has just occurred, the system should be robust and quick in performing its task. As an embedded system, the device also only runs the OpenBTS and its supporting software, making it a dedicated system which means it doesn't have multiple purposes and will not be mixed with other software or applications which may affect its stability and performance. This characteristic has been maintained in the lab and field test. The system started and was up and running in less than 90 seconds.

7.1.1.3 Advantages of the proposed system

The system also utilises GSM technology on the cellphone which is used by over 90% of inhabitants in 219 countries (4G Americas, 2012). And the fact that the cellphone has its own battery means it can be really reliable when other early warning channels' infrastructure such as sirens, TV or radio stations become unavailable due to power loss or damaged. Furthermore, unlike radio or TV, people nowadays always carry their cellphone with them, making it even handier.

Even though many handsets nowadays are built for the 3G and 4G networks, they, however, are backward compatible with GSM technology (2G) and would be still working with the proposed system.

7.1.2 Device Incorporation

The second part of RQ1 is regarding the device incorporation. The existing disaster response system involves various stakeholders and utilises a variety of channels. A well-structured response system is crucial and even extremely important in the case of an earthquake with a tsunami due to time pressure and the possibility of the conventional communication channel being unavailable. Therefore, efficiently incorporating the proposed solution within the existing disaster response system is essential.

Referring to sections 5.1 and 5.2, we can see how EWs are being produced and distributed to different channels and stakeholders before being inputted or converted to different channels and media for dissemination before they reach the community. Through our discussions in previous chapters we can see how the proposed system is fairly similar in terms of its operation to the other media and channels such as TV, radio, sirens and SMS as shown in Figure 15.

In terms of physical and operational aspects, as discussed in Chapter 6, the proposed system is rather simple and straightforward in its implementation and operation. It doesn't have a complicated user interface and is physically quite portable. While it requires a backup power supply, this is the norm for a device or system that runs and gives support during or after a disaster. In short, the proposed system would likely be able to be incorporated without much problem in to an existing disaster response system.

7.1.3 Conclusions

The proposed system, technically, has sufficiently fulfilled the required operating capabilities and requirements and due to the popularity of the GSM-based handset, the system is also socially capable of being integrated as one of the components of an early warning system. On top of that, the proposed system also has the potential to be incorporated in the existing procedures and synchronised with other existing early warning dissemination channels.

Throughout our data gathering and experiments we believe that first responders may able to set up and use our proposed device to disseminate tsunami early warnings to an exposed community. We also believe that the proposed system can be integrated within the current SOP or disaster response system along with other existing channels and media.

7.2 Drawbacks

From the experiment we have learned several drawbacks of the current system setup and experiment method as discussed below:

- Potential flaws and possible solutions

  While the system is very useful in extending or adding another channel of early warning dissemination, the GSM mechanism on a typical cellphone, however, is not flexible in terms of switching from one base station to another. After a commercial network becomes unavailable, a cellphone would automatically be connected to the proposed system if it is in range. However, when the commercial network becomes available again, the cellphone would not be connected back to it unless the user set it up manually. The procedure to switch networks is not common, especially for typical phone users. Unless they are out of range, the phone would still be connected to our network. One solution to this potential issue would be the operator has to shut down the system once the commercial network is up and running. This means there should be a communication with the cellular provider to get the latest status of their network through communication that was not affected.

- Untested

  There are two aspects of the device that can't be tested on the current setup. First, would be its performance and capacity. While we have successfully tested the connectivity and EW dissemination, we were only able to disseminate the message at 100 metres at most. Theoretically we could reach the ideal range of 2 to 2.5 kilometres with an antenna amplifier. However, due to budget constraints this was not possible. Secondly would be its capacity. During a real earthquake there might be hundreds or even thousands of users within the 2 to 2.5 kilometres that should get the EWs. However, to simulate this is quite impossible and might need another long and costly experiment since it would need hundreds or even thousands of active cellphones.

7.3 Unique Contribution & Future Work

As discussed in section 3.3 there are several projects that aim to provide communication channels within a disaster scenario. The solutions offered by Wypych et al. (2012) and Lee and Choi (2011) heavily rely on back-haul connectivity which may itself be unavailable due to the earthquake. The systems presented by Lien et al. (2009), or, on the other hand, Yarali et al. (2009) and Berioli et al. (2007) provide alternative communications using Wi-Fi, WiMAX and Satellite. Unfortunately, these technologies are still not available in every home or commonly used yet. Projects such as Rescue Base Station (RBS) (Ghaznavi et al., 2014), Beacon (Crane, 2012), Emergenet (Iland & Belding, 2014) and concepts offered by Sankhe et al. (2014) also utilise GSM technology similar to our proposed system. However, warning dissemination is not what these systems were designed for.

We not only offer a new technology for warning dissemination, but our research also covers how it could be implemented into a current disaster response system in Indonesia, including gathering data for meeting its user requirements and integrating it within the existing response system.

To further improve the system several things can be explored further. The first is to extend and improve the signal reach to more people in a radius of 2 to 2.5 kilometres and have it tested in an open field with no existing commercial network. This would require an additional external omnidirectional antenna amplifier.

We would like to know also its capabilities and capacity in handling a lot more users to improve the disaster simulation experiment. Letting the device connect and interact with 50 GSM handsets simultaneously would be sufficient. From the test we would be able to identify its performance and improve any issues arising from that particular experimental setting.

Once the two above improvements have been made, it would be a great idea to test the system and compare it with other proposed or existing solutions and related works.

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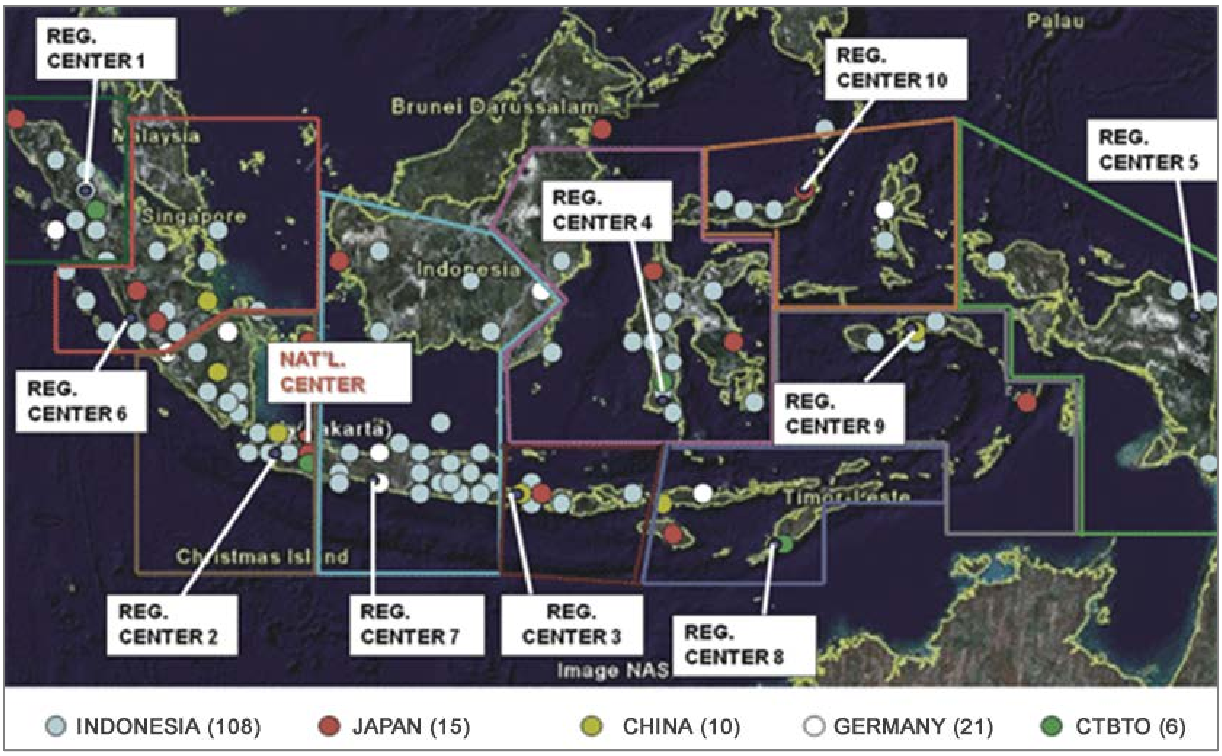
Appendix A:

A.1 InaTEWS Observation Systems

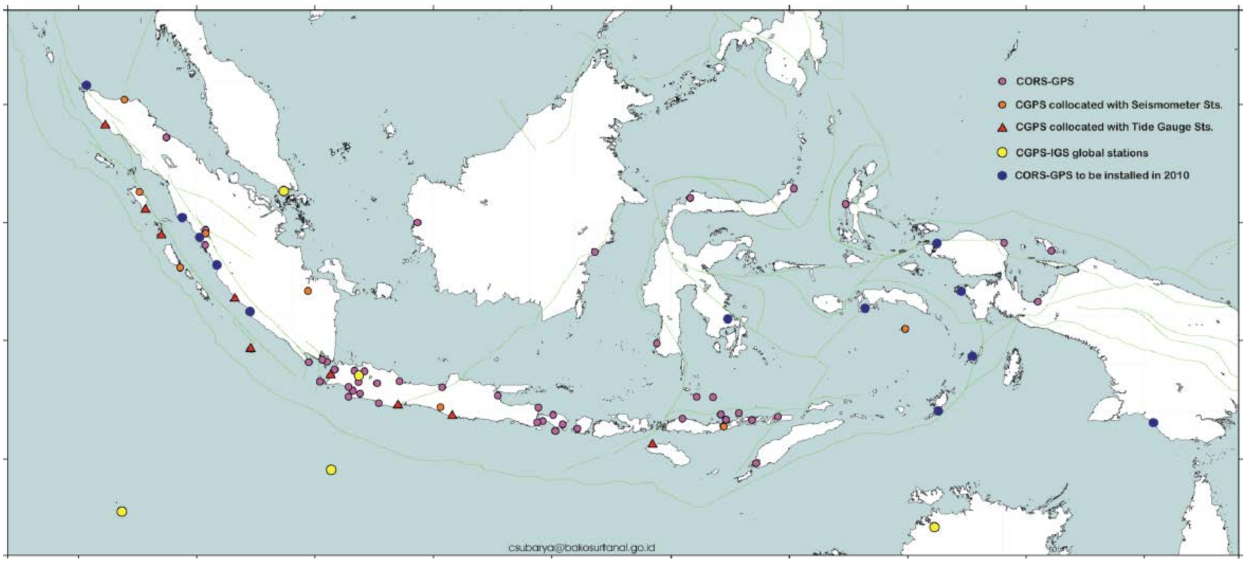
Seismic and Accelerometer



Map of National Centre & Regional Centres and borders location. Also broadband seismic and accelerometer and their owner (Beta, 2015).

GPS Network

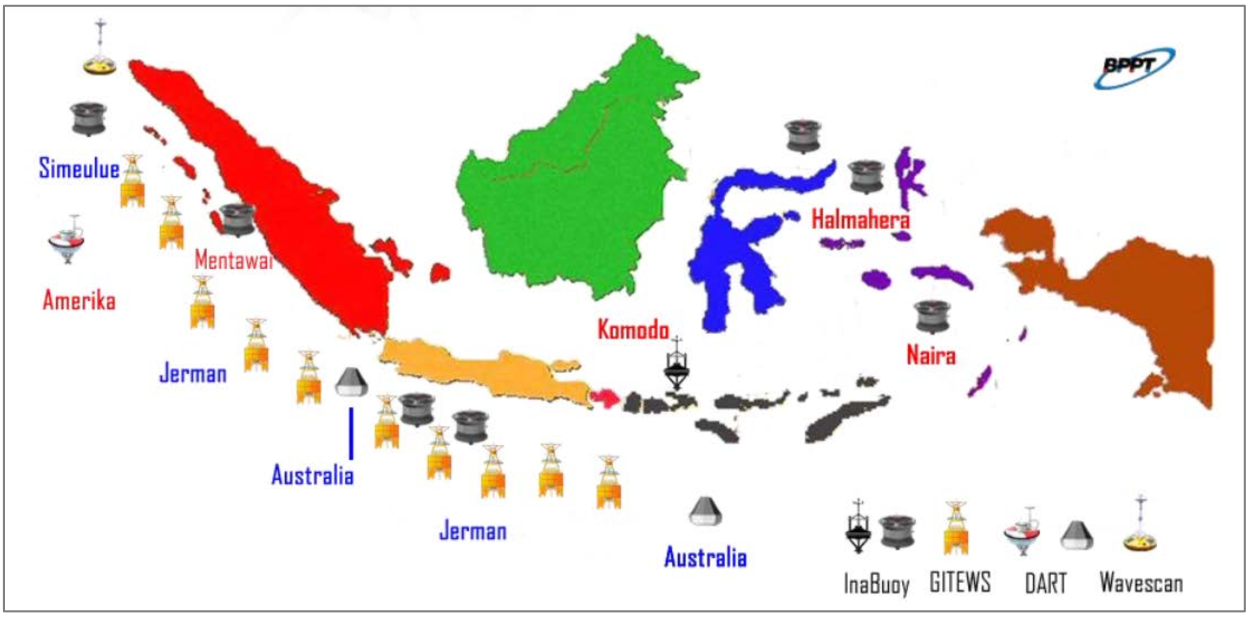
Map of GPS Network Location. Some GPS system is installed along the Seismometer and Tide Gauge Stations (Beta, 2015).



Buoys Network

Map of 23 buoys was organised by the Agency for the Assessment and Application of Technology (BPPT). Currently there are 10 buoys owned by Indonesia, 10 donated by Germany, another 2 from by DART USA and 1 owned by Malaysia (Beta, 2015).

Tide Gauge



There are of 113 Tide Gauge spread along Indonesian coastal area. 93 Stations owned by Indonesia, 10 is operated with cooperation by University of Hawaii

Sea Level Centre and Intergovernmental Oceanographic Commission (UHSLC-IOC) and another 10 owned by German Research Center for GeoScience (GFZ) (Beta, 2015)

A.2 Early Warning SMS Formats

Example of **EW1** in long-text format for e-mail, fax and GTS. It contains earthquake parameter, warning segment, warning level and advice

::::BMKG::::::::::::BMKG:::::::::::::::BMKG::::::::::::::BMKG:::::::::::::::BMKG::::

Indonesian Tsunami Early Warning System (InaTEWS)

METEOROLOGICAL CLIMATOLOGICAL AND GEOPHYSICAL AGENCY

Address:Jl. Angkasa I no.2 Kemayoran, Jakarta, Indonesia, 10720

Telp.: (+62-21) 4246321/6546316 , Fax: (+62-21) 6546316/4246703

P.O. Box 3540 Jkt, Website : http://www.bmkg.go.id

Issued date : 11 April 2012, 15:43:05 WIB (UTC=WIB-7)

Bulletin-1

No.:103/warning/InaTEWS/IV/2012

AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS:

Magnitude : 8.9 RS
Date : 11-Apr-2012
Origin Time: 08:38:29 UTC
Latitude : 2.31 N
Longitude : 92.67 E
Depth : 10 Km

Location : Off West Coast of Northern Sumatra
Remarks : 434 km SOUTHWEST of Meulaboh
463 km SOUTHWEST of Banda Aceh
493 km SOUTHWEST of Sabang
497 km SOUTHWEST of Sigli
550 km SOUTHWEST of Bireun

Evaluation:

THERE IS THE POSSIBILITY OF A TSUNAMI IN THE FOLLOWING AREAS:

Province	Location	Warning Level
BENGKULU	Bengkulu-Selatan	MAJOR WARNING
BENGKULU	Bengkulu-Utara Bagian Utara	MAJOR WARNING
BENGKULU	Bengkulu-Utara Pulau Enggano	MAJOR WARNING
BENGKULU	Kaur	MAJOR WARNING
BENGKULU	Kota-Bengkulu Pantai-Panjang	MAJOR WARNING
BENGKULU	Mukomuko	MAJOR WARNING
BENGKULU	Seluma	MAJOR WARNING
LAMPUNG	Lampung-Barat Pesisir-Selatan	MAJOR WARNING
LAMPUNG	Lampung-Barat Pesisir-Tengah	MAJOR WARNING
LAMPUNG	Lampung-Barat Pesisir-Utara	MAJOR WARNING
NAD	Aceh-Barat	MAJOR WARNING
NAD	Aceh-Barat-Daya	MAJOR WARNING
...	...	...
...	...	...
...	...	...
LAMPUNG	Lampung-Selatan Bagian Barat	WARNING
LAMPUNG	Tanggamus Bagian Barat	WARNING
LAMPUNG	Tanggamus Bagian Timur	WARNING
LAMPUNG	Tanggamus Pulau Tabuan	WARNING
SUMBAR	Agam	WARNING
SUMBAR	Kota-Padang	WARNING
SUMBAR	Kota-Padang Bagian Selatan	WARNING
SUMBAR	Kota-Padang Bagian Utara	WARNING
SUMBAR	Padang-Pariaman Bagian Selatan	WARNING
SUMBAR	Padang-Pariaman Bagian Utara	WARNING
SUMBAR	Pasaman-Barat	WARNING
SUMBAR	Pesisir-Selatan Bagian Selatan	WARNING
SUMBAR	Pesisir-Selatan Bagian Utara	WARNING
BANTEN	Lebak	ADVISORY
JABAR	Cianjur Sindangbarang	ADVISORY
LAMPUNG	Lampung-Selatan Kep. Krakatau	ADVISORY
LAMPUNG	Lampung-Selatan Kep. Sebuku	ADVISORY

Advice:

Province/District/City governments that are at "Major Warning" level are expected to pay attention to this warning and immediately guide their communities for full evacuation.

Province/District/City governments that are at "Warning" level are expected to pay attention to this warning and immediately guide their communities for evacuation.

Province/District/City governments that are at "Advisory" level are expected to pay attention to this warning and immediately guide their communities to move away from the beach and river banks.

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Example of **EW2** in long-text format for e-mail, fax and GTS. It contains earthquake parameter, warning segment, warning level and advice

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Indonesian Tsunami Early Warning System (InaTEWS)
METEOROLOGICAL CLIMATOLOGICAL AND GEOPHYSICAL AGENCY
Address:Jl. Angkasa I no.2 Kemayoran, Jakarta, Indonesia, 10720
Telp.: (+62-21) 4246321/6546316 , Fax: (+62-21) 6546316/4246703
P.O. Box 3540 Jkt, Website : http://www.bmkg.go.id

==

Issued date : 11 April 2012, 15:47:45 WIB (UTC=WIB-7)
Bulletin-2
No.:104/warning/InaTEWS/IV/2012

UPDATING OF EARTHQUAKE PARAMETERS:

Magnitude : 8.5 RS
Date : 11-Apr-2012
Origin Time: 08:38:33 UTC
Latitude : 2.40 N
Longitude : 92.99 E
Depth : 10 Km

Location : Off West Coast of Northern Sumatra
Remarks : 398 km SOUTHWEST of Meulaboh
433 km SOUTHWEST of Banda Aceh
464 km SOUTHWEST of Sabang
465 km SOUTHWEST of Sigli
515 km SOUTHWEST of Bireun

Evaluation:

THERE IS THE POSSIBILITY OF A TSUNAMI IN THE FOLLOWING AREAS:

Province	Warning Segment	Warning Level	ETA [UTC]	Date [YYYY-MM-DD]
NAD	Simeulue Pulau Simeulue	MAJOR WARNING	09:00:13	2012-04-11
SUMUT	Nias Bagian Barat	MAJOR WARNING	09:16:58	2012-04-11
SUMUT	Nias-Selatan Pulau Nias	MAJOR WARNING	09:22:03	2012-04-11
SUMUT	Nias-Selatan Pulau Tanahmasa	WARNING	09:22:48	2012-04-11
NAD	Aceh-Jaya	MAJOR WARNING	09:25:13	2012-04-11
NAD	Aceh-Besar Bagian Barat	MAJOR WARNING	09:27:03	2012-04-11
...	...	...	...	...
...	...	...	...	
...	...	...	...	...
BENGKULU	Kota-Bengkulu Pantai-Panjang	ADVISORY	10:58:18	2012-04-11
BANTEN	Pandeglang Pulau Panaitan	WARNING	11:01:43	2012-04-11
BENGKULU	Bengkulu-Utara Bagian Selatan	ADVISORY	11:03:13	2012-04-11
BANTEN	Pandeglang Bagian Selatan	NO THREAT	11:03:52	2012-04-11
JABAR	Sukabumi Pelabuhan-Ratu	NO THREAT	11:05:18	2012-04-11
JABAR	Sukabumi Ujung-Genteng	NO THREAT	11:05:18	2012-04-11
LAMPUNG	Lampung-Selatan Kep. Krakatau	NO THREAT	11:05:22	2012-04-11
LAMPUNG	Lampung-Selatan Kep. Sebuku	NO THREAT	11:05:22	2012-04-11
LAMPUNG	Tanggamus Bagian Barat	ADVISORY	11:05:48	2012-04-11
LAMPUNG	Tanggamus Pulau Tabuan	ADVISORY	11:05:48	2012-04-11
LAMPUNG	Lampung-Selatan Bagian Barat	NO THREAT	11:06:22	2012-04-11
LAMPUNG	Tanggamus Bagian Timur	NO THREAT	11:06:22	2012-04-11
JABAR	Cianjur Sindangbarang	NO THREAT	11:06:33	2012-04-11
BANTEN	Lebak	NO THREAT	11:06:52	2012-04-11

(ETA: estimated time of arrival)

ACTUAL ARRIVAL TIMES MAY DIFFER AND THE INITIAL WAVE MAY NOT BE THE LARGEST.

Advice:

Province/District/City governments that are at "Major Warning" level are expected to pay attention to this warning and immediately guide their communities for full evacuation.

Province/District/City governments that are at "Warning" level are expected to pay attention to this warning and immediately guide their communities for evacuation.

Province/District/City governments that are at "Advisory" level are expected to pay attention to this warning and immediately guide their communities to move away from the beach and river banks.

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Example of **EW3** in long-text format for e-mail, fax and GTS. It contains earthquake parameter, warning segment, warning level and advice

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Indonesian Tsunami Early Warning System (InaTEWS)
METEOROLOGICAL CLIMATOLOGICAL AND GEOPHYSICAL AGENCY
Address:Jl. Angkasa I no.2 Kemayoran, Jakarta, Indonesia, 10720
Telp.: (+62-21) 4246321/6546316 , Fax: (+62-21) 6546316/4246703
P.O. Box 3540 Jkt, Website : http://www.bmkg.go.id

Issued date : 11 April 2012, 18:15:03 WIB (UTC=WIB-7)
Bulletin-3
No.:113/warning/InaTEWS/IV/2012

UPDATING OF EARTHQUAKE PARAMETERS:

Magnitude : 8.3 RS
Date : 11-Apr-2012
Origin Time: 08:38:35 UTC
Latitude : 2.33 N
Longitude : 93.05 E
Depth : 10 Km

Location : Off West Coast of Northern Sumatra
Remarks : 396 km SOUTHWEST of Meulaboh
435 km SOUTHWEST of Banda Aceh
465 km SOUTHWEST of Sigli
467 km SOUTHWEST of Sabang
514 km SOUTHWEST of Bireun

Evaluation:

Based on sea level observations, tsunami has detected in the following areas:

Location	Latitude	Longitude	Time[UTC] [HH:NN]	Date [YYYY-MM-DD]	Height
SABANG	05.80	95.00	10:00	2012-04-11	0.06 meter
MEULABOH	04.32	96.22	10:04	2012-04-11	0.8 meter

THERE IS THE POSSIBILITY OF A TSUNAMI IN THE FOLLOWING AREAS:

Province	Warning Segment	Warning Level	ETA [UTC]	Date [YYYY-MM-DD]
NAD	Simeulue Pulau Simeulue	MAJOR WARNING	09:00:20	2012-04-11
SUMUT	Nias Bagian Barat	MAJOR WARNING	09:16:50	2012-04-11
SUMUT	Nias-Selatan Pulau Nias	MAJOR WARNING	09:21:54	2012-04-11
...	...	...	...	...
...	...	...	...	...
...	...	...	...	...
LAMPUNG	Lampung-Barat Pesisir-Selatan	WARNING	10:54:20	2012-04-11
LAMPUNG	Lampung-Barat Pesisir-Tengah	WARNING	10:54:20	2012-04-11
LAMPUNG	Lampung-Barat Pesisir-Utara	WARNING	10:55:30	2012-04-11
BENGKULU	Kota-Bengkulu Pantai-Panjang	ADVISORY	10:58:15	2012-04-11
BANTEN	Pandeglang Pulau Panaitan	WARNING	11:01:35	2012-04-11
BENGKULU	Bengkulu-Utara Bagian Selatan	ADVISORY	11:03:09	2012-04-11
LAMPUNG	Tanggamus Bagian Barat	ADVISORY	11:05:39	2012-04-11
LAMPUNG	Tanggamus Pulau Tabuan	ADVISORY	11:05:39	2012-04-11

(ETA: estimated time of arrival)

ACTUAL ARRIVAL TIMES MAY DIFFER AND THE INITIAL WAVE MAY NOT BE THE LARGEST.

Advice:

Province/District/City governments that are at "Major Warning" level are expected to pay attention to this warning and immediately guide their communities for full evacuation.

Province/District/City governments that are at "Warning" level are expected to pay attention to this warning and immediately guide their communities for evacuation.

Province/District/City governments that are at "Advisory" level are expected to pay attention to this warning and immediately guide their communities to move away from the beach and river banks.

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Example of **EW4** in long-text format for e-mail, fax and GTS. It contains earthquake parameter, warning segment, warning level and advice

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Indonesian Tsunami Early Warning System (InaTEWS)
METEOROLOGICAL CLIMATOLOGICAL AND GEOPHYSICAL AGENCY
Address:Jl. Angkasa I no.2 Kemayoran, Jakarta, Indonesia, 10720
Telp.: (+62-21) 4246321/6546316 , Fax: (+62-21) 6546316/4246703
P.O. Box 3540 Jkt, Website : http://www.bmg.go.id
==
Issued date : 04-Apr-2011, 05:10:45 WIB (UTC=WIB-7)
Bulletin-4
No.:4/warning/InaTEWS/IV/2011

The Tsunami threat caused by the earthquake :
Magnitude : 7.1 RS
Date : 03-April-2011 20:06:39 UTC
is over.

This is the final message issued by the Indonesia Tsunami Early Warning System, unless new information becomes available.

Do not reply to this email, please address any inquiry to : info_inatews@bmg.go.id

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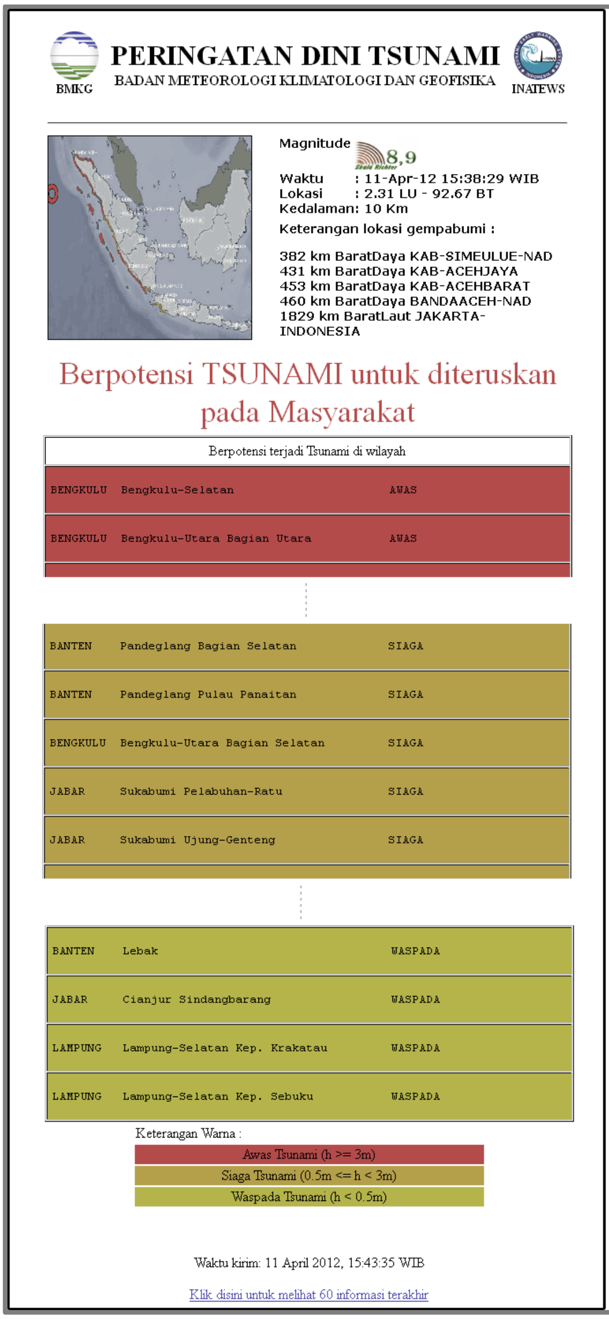
Example of **EW1 & EW2** Long-Version Format that sent to WRS-Client for institutions and local government. It contains earthquake parameter, warning segment, warning level, advice and map.



PERINGATAN DINI TSUNAMI

BMKG BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA INATEWS

Magnitude 8,9

Waktu : 11-Apr-12 15:38:29 WIB
Lokasi : 2.31 LU - 92.67 BT
Kedalaman: 10 Km

Keterangan lokasi gempabumi :

382 km BaratDaya KAB-SIMEULUE-NAD
431 km BaratDaya KAB-ACEHJAYA
453 km BaratDaya KAB-ACEHBARAT
460 km BaratDaya BANDAACEH-NAD
1829 km BaratLaut JAKARTA-INDONESIA

Berpotensi TSUNAMI untuk diteruskan pada Masyarakat

Berpotensi terjadi Tsunami di wilayah		
BENGKULU	Bengkulu-Selatan	AWAS
BENGKULU	Bengkulu-Utara Bagian Utara	AWAS
BANTEN	Pandeglang Bagian Selatan	SIAGA
BANTEN	Pandeglang Pulau Panaitan	SIAGA
BENGKULU	Bengkulu-Utara Bagian Selatan	SIAGA
JABAR	Sukabumi Pelabuhan-Ratu	SIAGA
JABAR	Sukabumi Ujung-Genteng	SIAGA
BANTEN	Lebak	WASPADA
JABAR	Cianjur Sindangbarang	WASPADA
LAMPUNG	Lampung-Selatan Kep. Krakatau	WASPADA
LAMPUNG	Lampung-Selatan Kep. Sebuku	WASPADA

Keterangan Warna :

Awas Tsunami (h >= 3m)
Siaga Tsunami (0.5m <= h < 3m)
Waspada Tsunami (h < 0.5m)

Waktu kirim: 11 April 2012, 15:43:35 WIB

Klik disini untuk melihat 60 informasi terakhir

PERINGATAN DINI TSUNAMI

BMKG BADAN METEOROLOGI KLIMATOLOGI DAN GEOFISIKA INATEWS

Magnitude 8,5

Waktu : 11-Apr-12 15:38:33 WIB
Lokasi : 2.40 LU - 92.99 BT
Kedalaman: 10 Km

Keterangan lokasi gempabumi :

346 km BaratDaya KAB-SIMEULUE-NAD
398 km BaratDaya KAB-ACEHJAYA
417 km BaratDaya KAB-ACEHBARAT
431 km BaratDaya BANDAACEH-NAD
1804 km BaratLaut JAKARTA-INDONESIA
(Pemutakhiran)

Berpotensi TSUNAMI untuk diteruskan pada Masyarakat

Berpotensi terjadi Tsunami di wilayah				
NAD	Simeulue Pulau Simeulue	AWAS	16:00:13	2012-04-11
SUMUT	Nias Bagian Barat	AWAS	16:16:58	2012-04-11
NAD	Aceh-Besar Bagian Utara	SIAGA	16:41:13	2012-04-11
SUMUT	Nias-Selatan Pulau Tanabala	SIAGA	16:41:52	2012-04-11
NAD	Pidie	SIAGA	16:43:28	2012-04-11
NAD	Aceh-Barat-Daya	AWAS	16:49:13	2012-04-11
SUMBAR	Kepulauan-Mentawai Pulau Sipora	SIAGA	16:53:28	2012-04-11
NAD	Aceh-Selatan Bagian Selatan	SIAGA	16:56:37	2012-04-11
LAMPUNG	Tanggamus Bagian Barat	WASPADA	18:05:48	2012-04-11
LAMPUNG	Tanggamus Pulau Tabuan	WASPADA	18:05:48	2012-04-11
LAMPUNG	Lampung-Selatan Bagian Barat	TAK ADA ANCAMAN	18:06:22	2012-04-11
LAMPUNG	Tanggamus Bagian Timur	TAK ADA ANCAMAN	18:06:22	2012-04-11
JABAR	Cianjur Sindangbarang	TAK ADA ANCAMAN	18:06:33	2012-04-11
BANTEN	Lebak	TAK ADA ANCAMAN	18:06:52	2012-04-11

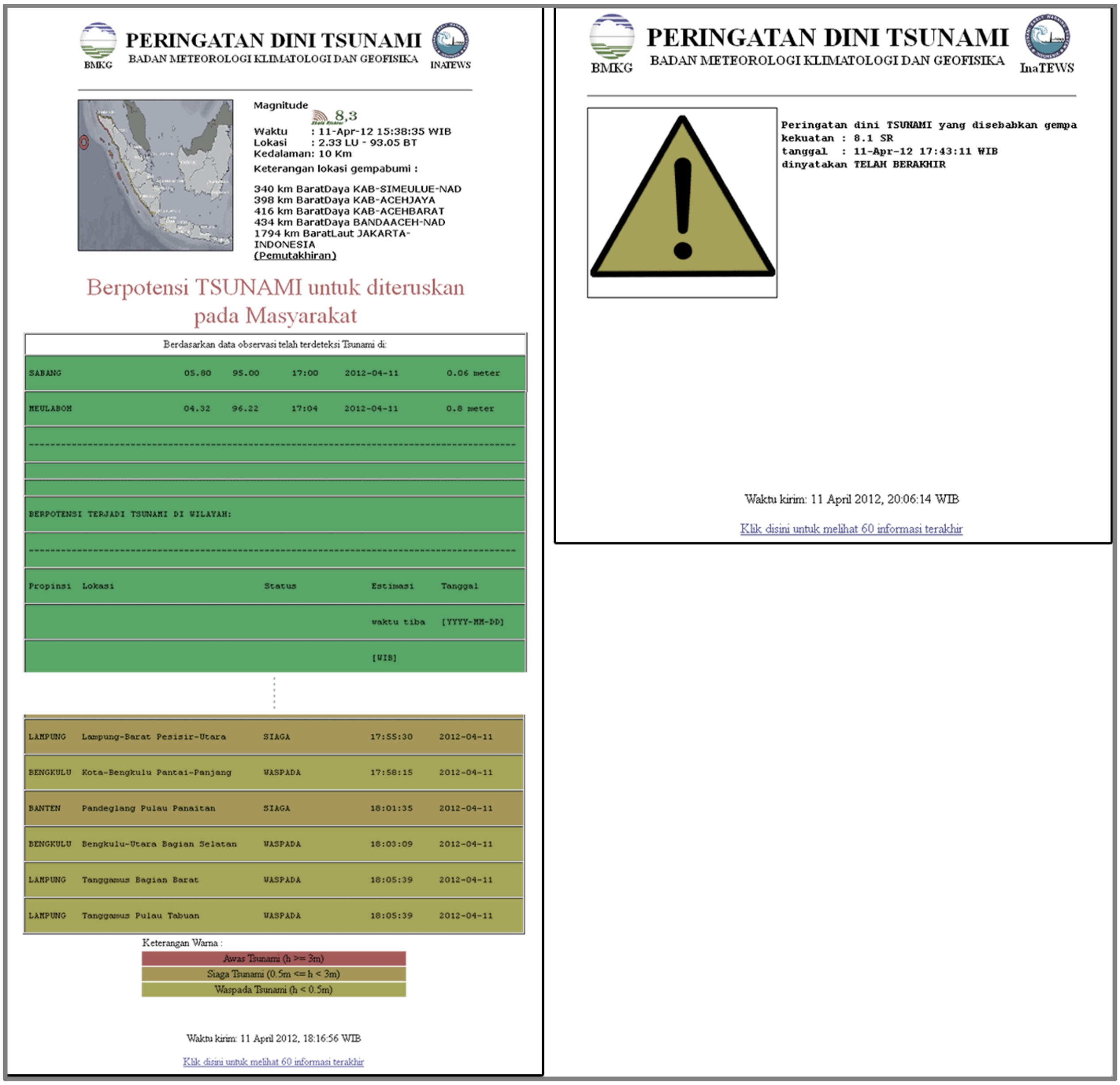
Keterangan Warna :

Awas Tsunami (h >= 3m)
Siaga Tsunami (0.5m <= h < 3m)
Waspada Tsunami (h < 0.5m)

Waktu kirim: 11 April 2012, 15:48:08 WIB

Klik disini untuk melihat 60 informasi terakhir

Example of **EW3 & EW4** Long-Version Format that sent to WRS-Client for institutions and local government. It contains earthquake parameter, warning segment, warning level, advice and map except for EW4.



Example of **EW1**, **EW2**, **EW3** and **EW4** in Media format for Media (specifically for TV). It contains Earthquake Parameter, map, and indicator whether it has tsunami potential or not.

Example of **EW1**, **EW2**, **EW3** and **EW4** in short-text format for SMS. It contains Earthquake Parameter, warning level in province and district level.

Example of Warning 1

> Peringatan Tsunami: Waspada di BANTEN, DIY, JABAR, JATENG, JATIM, LAMPUNG, NTB, NTT, Gempa Mag:7.2SR, 04-Apr-11 03:06:39 WIB, Lok:10.00LS/107.71BT,Kdlmn:10km::BMKG

Example of Warning 2

> Peringatan Tsunami: Waspada di BANTEN, DIY, JABAR, JATENG, JATIM, LAMPUNG, NTB, NTT, Gempa Mag:7.1SR, 04-Apr-11 03:06:39 WIB, Lok:10.00LS/107.71BT,Kdlmn:10km::BMKG

Example of Warning 3

> Pemutahiran: Tsunami akibat gempa Mag:7.1SR tlh terdeteksi di Cilacap 0.5m,Tasikmalaya 0.4m::BMKG

Example of Warning 4

> Peringatan dini TSUNAMI yang disebabkan oleh gempa mag:7.1 SR, tanggal: 04-Apr-11 03:06:39 WIB, dinyatakan telah berakhir::BMKG

Appendix B:

This appendix shows guides to install and setup the device as well as the configuration files.

B.1 Software Installation and Setup

This guide was taken from OpenBTS official guide for the E3xx and E1xx device at http://openbts.org/w/index.php?title=E3x0 . For installing process, the device need to be connected to the internet to download all of the files. However, for Git command we will need to run it from other system and copy to the device.

Information on how to access the E110 is discussed on Appendix B.2.1

B.1.1 Dependencies

There are several dependencies package that no preinstalled on the USRP E110 that need to be build: oRTP, libosip2 and OsmoTRX.

Libosip2 3.6.0

```
$ wget http://ftp.gnu.org/gnu/osip/libosip2-3.6.0.tar.gz
$ tar xvf libosip2-3.6.0.tar.gz
$ cd libosip2-3.6.0
$ ./configure CFLAGS="-mcpu=cortex-a9 -mfpu=neon"
$ make
$ make install
```

oRTP 0.22.0

```
$ wget
http://download.savannah.gnu.org/releases/linphone/ortp/sourc
es/ortp-0.22.0.tar.gz
$ tar xvf ortp-0.22.0.tar.gz
$ cd ortp-0.22.0
$ ./configure CFLAGS="-mcpu=cortex-a9 -mfpu=neon"
$ make
$ make install
```

OsmoTRX

```
$ git clone git://git.osmocom.org/osmo-trx
$ cd osmo-trx
$ autoreconf -i
$ ./configure --with-neon
$ make
$ make install
```

B.1.2 Installing OpenBTS

To install the OpenBTS, we will need first install other supporting components individually: liba53 and sipauthserve

liba53

```
$ git clone https://github.com/RangeNetworks/liba53.git
$ cd liba53
$ make
$ make install
```

Sipauthserve

```
$ git clone
https://github.com/RangeNetworks/subscriberRegistry.git
$ cd subscriberRegistry
$ git submodule init
$ git submodule update
$ cd CommonLibs
```

Since we wouldn't be needing the libcoredumper dependency, before make install, remove (minus sign) and add (plus sign) the following on Makefile.am:

```
-InterthreadTest_LDFLAGS = -lpthread -lcoredumper
+InterthreadTest_LDFLAGS = -lpthread
-SocketsTest_LDFLAGS = -lpthread -lcoredumper
+SocketsTest_LDFLAGS = -lpthread
-SelfDetectTest_LDADD = libcommon.la $(SQLITE_LA) -
lcoredumper
+SelfDetectTest_LDADD = libcommon.la $(SQLITE_LA)
-UnixSignalTest_LDADD = libcommon.la $(SQLITE_LA) -
lcoredumper
+UnixSignalTest_LDADD = libcommon.la $(SQLITE_LA)
```

On UnixSignal.cpp:

```
#include <unistd.h>
-#include <google/coredumper.h>

snprintf(buf, sizeof(buf)-1, "%s", mCoreFile.c_str());
-            WriteCoreDump(buf);
```

And then build sipauthserv

```
$ cd ..
$ ./autogen.sh
$ ./configure CXXFLAGS="-mcpu=cortex-a9 -mfpu=neon"
```

```
$ make
$ make install
```

OpenBTS

Once we have install those supporting components we can proceed to install OpenBTS. For our system we use OpenBTS 4.0

```
$ git clone https://github.com/RangeNetworks/openbts.git
```

Similar to sipauthserv, we need to remove the libcoredumper to avoid error on Makefile.am:

```
OpenBTS_SOURCES = OpenBTS.cpp GetConfigurationKeys.cpp
-OpenBTS_LDADD = $(ourlibs) -lcrypto -lssl -ldl -lortp -la53
-lcoredumper
+OpenBTS_LDADD = $(ourlibs) -lcrypto -lssl -ldl -lortp -la53
 OpenBTS_LDFLAGS = $(GPROF_OPTIONS) -rdynamic
```

And since we will use OsmoTRX instead of the native OpenBTS transceiver, we have to disable it before building it. Modify OpenBTS.cpp as follow:

```
//LOG(ALERT) << "starting the transceiver";
-                transceiverThread.start((void*(*)(void*))
startTransceiver, NULL);
                // sleep to let the FPGA code load
```

Now we can build the OpenBTS

```
$ cd ../
$ ./autogen.sh
$ ./configure CXXFLAGS="-mcpu=cortex-a9 -mfpu=neon"
$ make
$ make install
```

B.2 Software Configuration

B.2.1 USRP E110

Access

To allow us login to the E110 device it is recommended to access it directly first using USB mouse and keyboard and HDMI output for the monitor. The default login is username is *root* and password is *usrpe*. We then need to set the IP address to static. In this case our device IP address is 192.168.137.103. On the other side, we set our PC/Laptop IP address is set to 192.168.137.1 so we can access it remotely through terminal.

Daughterboard

The RFX1800 daughterboard has the capability to be converted to RFX900 in case we want to run the device on 900MHz frequencies. To convert it to 900MHz :

execute *updatedb* and *locate* the application called *usrp_burn_db_eeprom* and do the following:

```
./usrp_burn_db_eeprom --id=0x0025 --unit=RX
./usrp_burn_db_eeprom --id=0x0029 --unit=TX
```

To revert it back to 1800 MHz

```
./usrp_burn_db_eeprom --id=0x0034 --unit=RX
./usrp_burn_db_eeprom --id=0x0035 --unit=TX
```

B.2.2. OpenBTS Configuration

To configure the OpenBTS we need to be inside the CLI and type in *config <key> <value>*. The list of keys can be viewed by typing *config*. We can see the list of all the keys and their purpose on OpenBTS manual at http://openbts.org/documentation.html

Below is the configuration on our system. Line denotes with default means it hasn’t been changed from the default configuration.

```
Control.GSMTAP.GPRS 0     [default]
Control.GSMTAP.GSM 0     [default]
Control.GSMTAP.TargetIP 127.0.0.1     [default]
Control.LUR.404RejectCause 0x04     [default]
Control.LUR.AttachDetach 1     [default]
Control.LUR.FailMode ACCEPT     [default]
Control.LUR.FailedRegistration.Message Your handset is not
provisioned for this network.     [default]
Control.LUR.FailedRegistration.ShortCode 1000     [default]
Control.LUR.NormalRegistration.Message (disabled)
[default]
Control.LUR.NormalRegistration.ShortCode 0000     [default]
Control.LUR.OpenRegistration 530240106007413
Control.LUR.OpenRegistration.Message This is a test message
for EW2
Control.LUR.OpenRegistration.Reject (disabled)     [default]
Control.LUR.OpenRegistration.ShortCode 101     [default]
Control.LUR.QueryClassmark 0     [default]
```

```
Control.LUR.QueryIMEI 0     [default]
Control.LUR.RegistrationMessageFrequency FIRST     [default]
Control.LUR.SendTMSIs 0     [default]
Control.LUR.UnprovisionedRejectCause 0x04     [default]
Control.Reporting.PhysStatusTable /var/run/ChannelTable.db
[default]
Control.Reporting.StatsTable /var/log/OpenBTSStats.db
[default]
Control.Reporting.TMSITable /var/run/TMSITable.db
[default]
Control.Reporting.TransactionTable
/var/run/TransactionTable.db     [default]
Control.SMSCB.Table (disabled)     [default]
Control.TMSITable.MaxAge 576     [default]
Control.VEA 0     [default]
GGSN.DNS (disabled)     [default]
GGSN.Firewall.Enable 1     [default]
GGSN.IP.TossDuplicatePackets 0     [default]
GGSN.MS.IP.Base 192.168.99.1     [default]
GGSN.MS.IP.MaxCount 254     [default]
GGSN.MS.IP.Route (disabled)     [default]
GGSN.ShellScript (disabled)     [default]
GPRS.CellOptions.T3168Code 5     [default]
GPRS.CellOptions.T3192Code 0     [default]
GPRS.ChannelCodingControl.RSSI -40     [default]
GPRS.Channels.Min.C0 2     [default]
GPRS.Channels.Min.CN 0     [default]
GPRS.Enable 0     [default]
GPRS.LocalTLLI.Enable 1     [default]
GPRS.Multislot.Max.Downlink 3     [default]
GPRS.Multislot.Max.Uplink 2     [default]
GPRS.NMO 2     [default]
GPRS.RAC 0     [default]
GPRS.RA_COLOUR 0     [default]
GPRS.Reassign.Enable 1     [default]
GPRS.TBF.EST 1     [default]
GPRS.TBF.Retry 1     [default]
GSM.BTS.RADIO_LINK_TIMEOUT 15     [default]
GSM.CallerID.Source auto     [default]
GSM.CellOptions.RADIO-LINK-TIMEOUT 15     [default]
GSM.CellSelection.CELL-RESELECT-HYSTERESIS 3     [default]
GSM.CellSelection.NCCsPermitted 1
GSM.CellSelection.NECI 1     [default]
GSM.Channels.C1sFirst 0     [default]
GSM.Channels.NumC1s auto     [default]
GSM.Channels.NumC7s auto     [default]
GSM.Channels.SDCCHReserve 0     [default]
GSM.Cipher.CCHBER 0     [default]
GSM.Cipher.Encrypt 0     [default]
GSM.Cipher.RandomNeighbor 0     [default]
GSM.Cipher.ScrambleFiller 0     [default]
GSM.Handover.FailureHoldoff 20     [default]
GSM.Handover.Margin 15     [default]
GSM.Handover.Ny1 50     [default]
GSM.Identity.BSIC.BCC 2     [default]
GSM.Identity.BSIC.NCC 0     [default]
GSM.Identity.CI 10     [default]
GSM.Identity.LAC 1000     [default]
GSM.Identity.MCC 001     [default]
```

```
GSM.Identity.MNC 01     [default]
GSM.Identity.ShortName OpenBTSTest
GSM.MS.Power.Damping 75     [default]
GSM.MS.Power.Max 33     [default]
GSM.MS.Power.Min 5     [default]
GSM.MS.TA.Damping 50     [default]
GSM.MS.TA.Max 62     [default]
GSM.MaxSpeechLatency 2     [default]
GSM.Neighbors (disabled)     [default]
GSM.Neighbors.NumToSend 31     [default]
GSM.RACH.AC 0x0400     [default]
GSM.RACH.MaxRetrans 1     [default]
GSM.RACH.TxInteger 14     [default]
GSM.Radio.ARFCNs 1     [default]
GSM.Radio.Band 1900
GSM.Radio.C0 761
GSM.Radio.MaxExpectedDelaySpread 4     [default]
GSM.Radio.PowerManager.MaxAttenDB 30
GSM.Radio.PowerManager.MinAttenDB 30
GSM.Radio.RSSITarget -50     [default]
GSM.Radio.SNRTarget 10     [default]
GSM.ShowCountry 0     [default]
GSM.SpeechBuffer 1     [default]
GSM.Timer.Handover.Holdoff 10     [default]
GSM.Timer.T3109 30000     [default]
GSM.Timer.T3212 0     [default]
Log.Alarms.Max 20     [default]
Log.Level NOTICE     [default]
Peering.Neighbor.RefreshAge 60     [default]
Peering.NeighborTable.Path /var/run/NeighborTable.db
[default]
Peering.Port 16001     [default]
RTP.Range 98     [default]
RTP.Start 16484     [default]
SIP.DTMF.RFC2833 1     [default]
SIP.DTMF.RFC2833.PayloadType 101     [default]
SIP.DTMF.RFC2976 0     [default]
SIP.Local.IP 127.0.0.1     [default]
SIP.Local.Port 5062     [default]
SIP.Proxy.Registration 127.0.0.1:5064     [default]
SIP.Proxy.SMS 127.0.0.1:5063     [default]
SIP.Proxy.Speech 127.0.0.1:5060     [default]
SIP.Proxy.USSD (disabled)     [default]
SIP.RFC3428.NoTrying 0     [default]
SIP.SMSC smsc     [default]
SMS.FakeSrcSMSC 0000     [default]
SMS.MIMEType application/vnd.3gpp.sms     [default]
TRX.IP 127.0.0.1     [default]
```

B.3 Scripts and PC Configuration

To have the system running there are several services and application that need to be run at the same time. *Launch.bat* make it easy for end-user to have the remote PC connect and automatically launch all the required services and the OpenBTS application itself. Once the services and application is running user will execute the sendmsg.exe. The executable, was made with Auto-IT script, will prompt for the EW input, set it as welcome message and broadcast it to all connected users. Both script requires and utilise PuTTy, as the computer SSH client.

On PC side (all in one folder)

Launch.bat:

```
REM This will connect and run the openbts batch
(Smqueue,Sipauthserve,Osmo-TRX and lastly OpenBTS)
putty -ssh root@192.168.137.103 -pw usrpe -m launch.txt –t
```

Shutdown.bat:

```
REM This shutdown the device
putty -ssh root@192.168.137.103 -pw usrpe -m shutdown.txt –t
```

Launch.txt:

```
/home/root/launch.sh
```

Shutdown.txt:

```
/sbin/shutdown now
```

Sendmsg.exe:

```
#include <Array.au3>
#include <File.au3>
#include <MsgBoxConstants.au3>

Example()

Func Example()
      Local $aRetArray

      $user = "root"
      $password ="usrpe"
      $host ="192.168.137.103"
      $callscript = "/home/root/getimsi.sh" ; script on
device to get the imsi list
      $savedlog = "imsilist.log" ;list of imsi log
    $plink_exe = @ScriptDir & "\plink.exe"; plink.exe to
connect and pull data accross the network
    $command = Run(@comspec & " /C "&$plink_exe&" -ssh -l
"&$user&" "&$host&" -pw "&$password&" "&$callscript&" >
"&$savedlog,@ScriptDir, @SW_HIDE, 1)
    Sleep(2000)
      WinActivate("[CLASS:PuTTY]")
```

```
      $sms = "Early Warning 1"

      ;set config welcome to be same as $SMS
      _FileReadToArray(".\imsilist.log", $aRetArray)

      ;disseminate to TMSIS list
      For $i = 1 To UBound($aRetArray)-1 Step 1
            Send("sendsms " & $aRetArray[$i] & " 100" & $sms)
            Send (";Enter;")
            Sleep(500)
      Next
EndFunc
```

We also utilise putty.exe and plink.exe – SSH clients and tools from http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html. So in one folder on the PC we will have: launch.bat, launch.txt, shutdown.bat, shutdown.txt, plink.exe, putty.exe and sendmsg.exe. Aside of those, we need also set a static IP address for the PC to 192.168.137.1 and the device to 192.168.137.103 connected with a standard Ethernet cable.

On Device Side (located at /home/root)

Getimsi.sh

```
cp /var/run/TMSITable.db ProcessIMSI.db
sqlite3 ProcessIMSI.db "select IMSI from TMSI_TABLE" | awk
';;printf "%s\r\n",$0;; '
```

Appendix C: System Manual

C.1 Preparation and Requirements

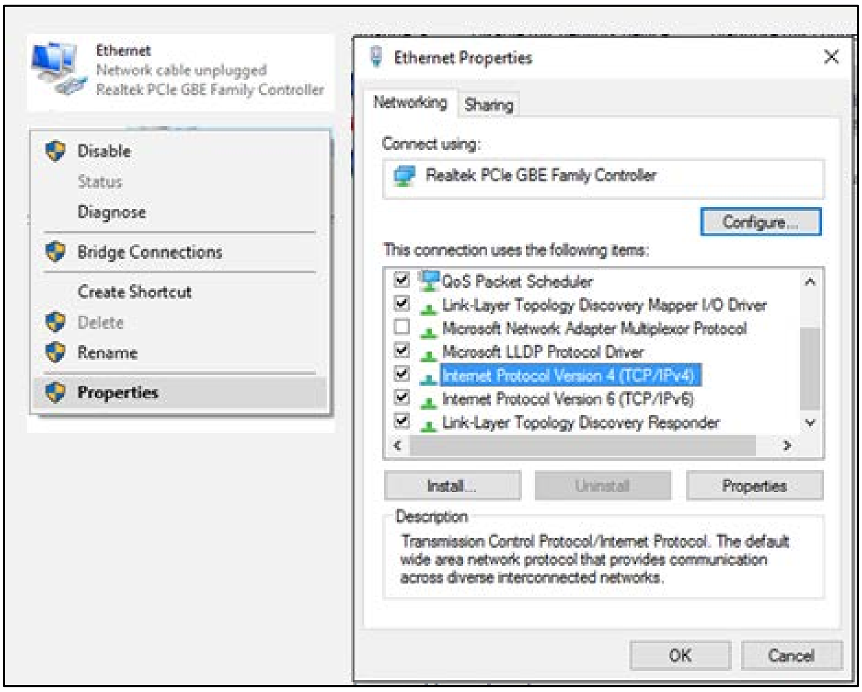
To operate below requirements are needed:

1. A Laptop/PC running Windows XP or better.
2. An Ethernet 10/100 LAN cable.
3. USRP E110 Device

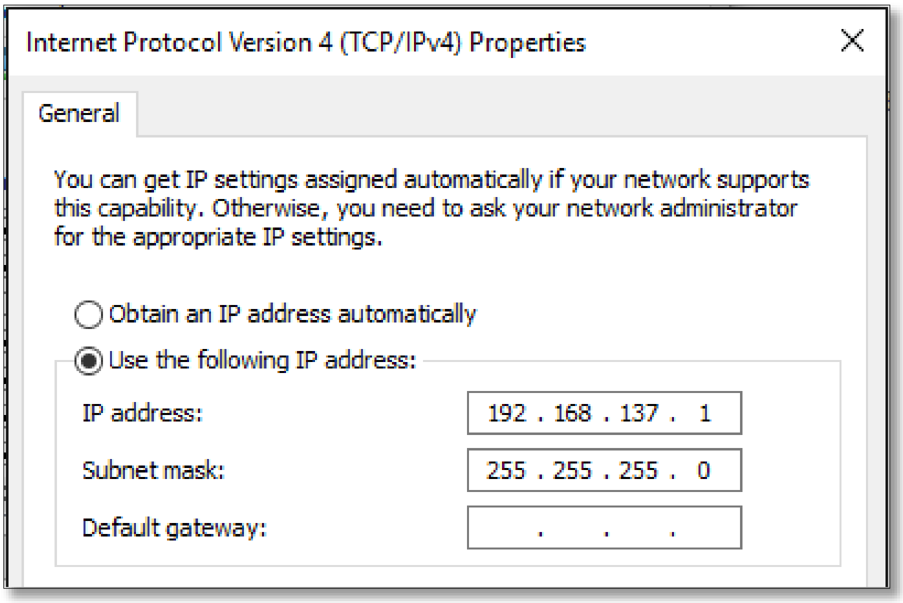
Software and scripts required: launch.bat, launch.txt, shutdown.bat, shutdown.txt, plink.exe, putty.exe and sendmsg.exe if not provided please download all from https://www.dropbox.com/s/wwcil58okvdp2tc/e110.zip

C.2 Connecting & Operating the Device

1. Set the laptop or PC network IP address to static 192.168.137.1 and subnet mask to 255.255.255.0. To do this click **START** > **RUN** > type "**ncpa.cpl**" and click **OK**. Right click on the active Ethernet and click **Properties**. Choose Internet Protocol Version 4 and choose **Properties.**

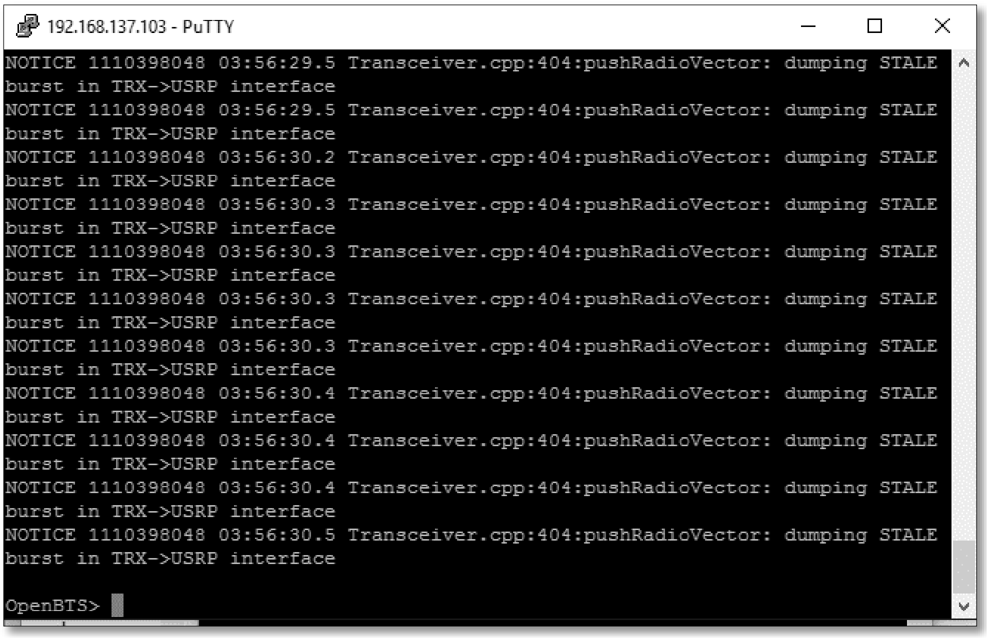


2. Set the IP to 192.168.137.1 as shown below



3. Connect a laptop or PC to the device via Ethernet cable and turn on the device by plugging in the adaptor to the wall plugs.

4. After 90 seconds run the launch.bat from the PC and a window will appear. User may press enter and a "**OpenBTS>**" prompt will appear. If doesn't work please make sure the Ethernet cable is properly connected and wait few more seconds and try again.

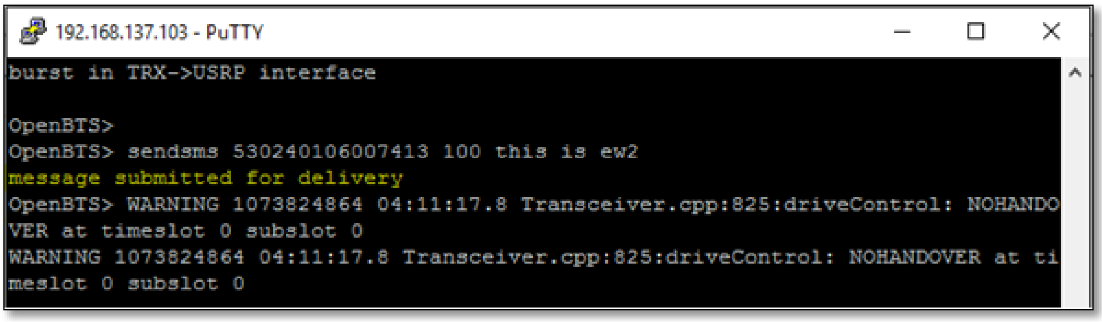


5. Once this was up and running user will automatically connected. To set and send Early Warnings (EW) we need to run the **sendmsg.exe**

6. When executed a window will appear for the EW prompt. Input the EW message and press OK.

7. The EW will be set as welcome message as well as disseminated to all connected users.

8. A successful delivery will be shown as below

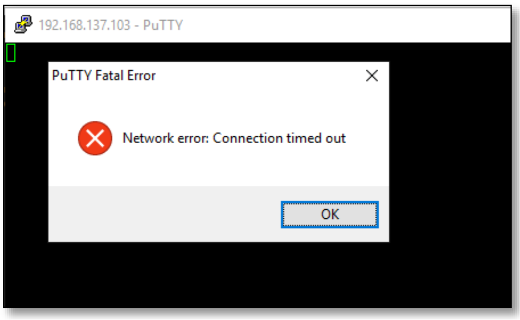


9. To send the next EWs operator simply run the **sendmsg.exe** again
10. To shut down the device user can run the **shutdown.bat** and wait for 1 minute then unplug the power.

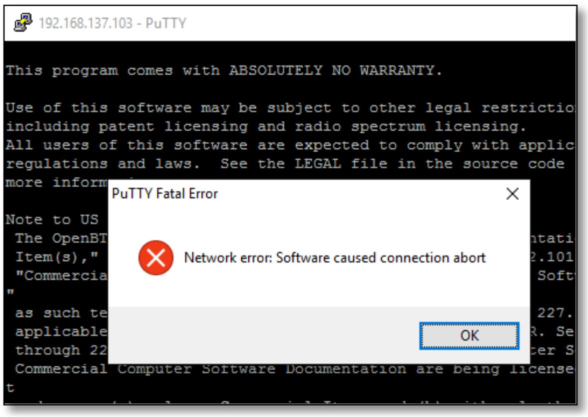
C.3 Troubleshooting

Below are the known error and its workaround

- "Network error: Connection timed out" appears after running **launch.bat**.
  Solution: Make sure the Ethernet cable is plugged in properly. This will be indicated by the flashing led on the Ethernet port and make sure the IP address is correct (see A.2 above). Try to run **launch.bat** again after that.



- "Network error: Software caused connection abort" appears during operating the device.
  Solution: Closed the windows, check and plug all the cables properly and run **launch.bat** again.



C.4 Maintenance

- While it has a strong steel case it should be treated and handle it with precautious due to its delicate internal components.
- It should not be placed in sealed compartment to allow air flows inside it.
- The case may be opened every few months to clean dust inside.
- The device may be plug in 24/7 and have it a rest for few hours once a while.

C.5 Features & Specifications

- Modular Architecture: DC-6 GHz
- Dual 64 MS/s, 12-bit ADC
- Dual 128 MS/s, 14-bit DAC
- DDC/DUC with 15 mHz Resolution
- Auxiliary Analog and Digital I/O
- 2.5 ppm TCXO Frequency Reference
- 0.01 ppm with Optional GPDSO Module
- Embedded OMAP Overo Module
- 800 MHz ARM Cortex A8 + C64 DSP
- Angstrom Linux w/ GNU Radio Built-In
- 512 MB RAM/4 GB Flash
- USB Console, OTG, and Host
- 10/100 Base T Supports SSH Access
- Stereo In/Out
- DVI Output for Monitor

Spec	Typ.	Unit
POWER		
DC Input	6	V
Current Consumption	1.5	A
w/ WBX Daughterboard	2.5	A
CONVERSION PERFORMANCE AND CLOCKS		
ADC Sample Rate	64	MS/s
ADC Resolution	12	bits
ADC Wideband SFDR	85	dBc
DAC Sample Rate	128	MS/s
DAC Resolution	14	bits
DAC Wideband SFDR	83	dBc
Host Sample Rate	4	MS/s
Frequency Accuracy	2.5	ppm
w/ GPSDO Reference	0.01	ppm

Spec	Typ.	Unit
RF PERFORMANCE (W/ WBX)		
SSB/LO Suppression	35/50	dBc
Phase Noise (1.8 Ghz)		
10 kHz	-80	dBc/Hz
100 kHz	-100	dBc/Hz
1 MHz	-137	dBc/Hz
Power Output	15	dBm
IIP3	0	dBm
Receive Noise Figure	5	dB
PHYSICAL		
Operating Temperature	0 to 55°	C
Dimensions (l x w x h)	22x16x5	cm
Weight	1.1	kg