An Appropriate Flood Warning System in the Context of Developing Countries

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***Abstract*—Flooding due to natural disasters such as heavy rains and tropical cyclones, results in huge losses of life and property. In many countries flood warning systems (FWS) have been introduced to minimize this loss by warning people in flood prone areas to evacuate and protect their property, albeit some damage still occurs. This paper explores flood warning systems and associated issues in developing countries which potentially can reduce the loss of lives and property during a flooding occurrence. The paper then proposes an appropriate FWS in the context of developing countries.**

***Index Terms*—Flood warning system (FWS), developing countries, SMS**

I. Introduction

Natural disasters such as floods are a worldwide phenomenon, they are occurring more frequently and lead to devastating loses. In developing countries, the effects of flood are more harmful than in developed countries. During 2010 China suffered a flood along the Yangtze River caused by heavy rain. In this flood 1100 people were killed, 120 million people were affected and direct economic losses were nearly U$25 billion [1]. European countries have also had large floods, but with less property and life loss. The large Asian losses were caused in part by the lack of a flood warning system and poor information dissemination at the community level [2]. However, flood impact can be reduced by effective flood risk management and timely dissemination of flood warnings to citizens. This paper explores the existing flood warning systems in developing countries, describes issues associated with disaster warnings, and proposes an appropriate flood warning system for developing countries.

II. Flood Occurrence and its Impact

A. Floods and Affect

A flood is a natural phenomenon which affects people around the world; it leads to financial, environmental and human loss. Many types of flood occur yearly namely river floods, flash floods and coastal floods [16].

1) River flood

A river flood is generally the result of water from heavy rains caused by monsoons, hurricanes, tropical storms or snow melts upstream exceeding the capacity of the rivers and their tributaries. A flood can also occur if the free flow of a river is temporarily blocked by obstructions such as mud from landslides and other natural overgrowth. Human activities such as excessive clearance of vegetation upstream can also cause river floods.

2) Flash flood

Flash floods are brought about by the convective precipitation of large volumes of water from intense thunderstorms or water suddenly released from an upstream storage and the drainage system is insufficient to cope with the flow. Flash floods may occur after the collapse of a human structure such as a dam or reservoir.

3) Coastal flood

Storms or other extreme weather conditions such as low atmospheric pressure combined with high tides can cause sea levels to rise above normal, forcing sea water inland and causing a coastal flood. These floods also result from tsunamis which are caused by earthquakes, hurricanes or tropical cyclones. High tides can also cause water in a river to back up resulting in a flood.

B. Flood Impact

Flooding is one of the major disasters occurring in various parts of the world. Every year, they cause loss of lives and damage to infrastructure, agriculture and severely affect economic development.

The 2010 Pakistan floods began in late July 2010, as a result of heavy monsoon rains. The floods directly affected about 20 million people, mostly via destruction of property, livelihood and infrastructure. About 2,000 people died and the total economic impact was $US40 billion [17].

A number of floods hit Australia during the years 2011 and 2012, the floods swept across Queensland, New South Wales and Victoria. In 2011, the floods forced the evacuation of thousands of people from towns and cities, over 200,000 people were affected and the damage was in excess of $A1 billion [14].

Every year, floods in the Lower Mekong River Basin (LMRB) and along the Mekong River and its tributaries result in a massive loss of life and property damage. For instance, in 2010 floods affected the LMRB countries (Cambodia, Laos, Thailand and Vietnam). The floods destroyed more than 64 million hectares of rice paddy, affected 1.1 million households, about 5 million people, and it was estimated that the total damage to property was $US1.2 billion [13].

III. Related Work

Previous studies cover a wide variety of topics including flood detection, flood warning systems and flood forecasting. The systems used are based on sensor networks, websites, geographic information systems (GIS), radio, TVs, SMS

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A. Sensor Networks for Flood Detection

Wireless sensor networks have been used for flood detection in Honduras, which is affected by heavy rain and hurricanes [2]. The network was designed as a two-tier architecture, a short-range communication link within an 8-km range as a single-hop network in the 900 MHz band and an inter-cluster communication network with a radio-range of up to 25 km in the 144 MHz band. The authors of the paper did not address data transmission or the warning approach used. However, they mentioned as main issues: the protection of the system from environmental and human damage, appropriate coverage of the area at risk and effective prediction.

Krzhizhanovskaya, V et al. presented a prototype of an early flood warning system [8]. The system used sensor networks installed in flood defences (dams and embankments) to calculate dam and embankment failure probability and simulate possible scenarios of flood propagation. All the relevant information and simulation results are fed into a decision support system that helps flood managers to make informed decisions in the case of an emergency.

B. Web Based and GIS-Based Flood Warning

A case study of a flood forecasting system for the Demer basin (UK) has been presented by Tate, E.et al [12]. This system uses a web-based approach. Data is collected in real time from hydrological observation stations and processed with a cluster of server computers, and then the results are made available on client computers in the control room and via remote access. This gives operational managers fast, accurate, real-time flood forecasting and facilitates the decision to issue an alert. However, this study did not discuss the dissemination of flood information to people.

Sharif, H et al have reported the use of a remote sensing and geographical information system(GIS) to detect flooding in the Indus river basin and its tributaries in Pakistan[11].The project used digital maps of the river basin to show output from flood routing models so that early flood warnings could be issued to threatened flood prone areas.

A flash flood guidance system (FFGS) has been implemented by the Mekong River Commission Secretariat (MRCS) in Vietnam to warn of flash floods [13]. The FFGS evaluates the possibility of a flash flood within a certain basin from the collected data, which includes rainfall, water level, and the velocity of the river and the system creates maps indicating a risk flood area for hydrological authorities.

C. Flood Warning based on Radio, SMS, TVs and Phones

Oprea, M. et al introduced a prototype intelligent system for flood forecasting and real time alerts [9]. The system used a microcontroller from the ARM family, a Marvell 88F6281 and the Unix FreeBSD interface and integrated database. This study proposes sending the real-time hydrological data for decision making via radio communication.

An SMS-based disaster warning system was proposed by Cioca, M. et al. to warn citizens of a flood in the Sibiu area of Romania [3]. In this system an SMS message was sent by the hydrology institute to authorities such as the mayor and prefecture's office to ask for permission to issue a flood warning, and then the flood information alert is sent to citizens. It is interesting to note that before a flood alert can reach citizens, it must get through several steps of bureaucracy.

Each of the LMRB countries has its own flood warning systems, which are similar to each other and use a traditional approach for warning citizens. Parameter data such as water level, water flows, precipitation and temperature are collected from hydrological stations, and then the data is analyzed to predict and issue daily flood forecasting bulletins. National television, radio broadcasting, telephone, facsimile, e-mail, websites and the newspaper network are used to deliver flood information and weather messages to the public. However, many people cannot receive real time alerts as they do not have access to email and websites [5].

IV. Issues Related to Flood Warnings

From the related work it can be seen that there are many flood warning systems worldwide, but there are a number of issues relating to ineffective flood warnings, including bureaucratic inefficiency, water management issues and the digital divide.

1) Bureaucratic inefficiency

Bureaucracy is one of the main reasons for delays in flood warnings because the warnings go through several steps before reaching the people in a flood area. In many cases of flood warning systems, the Bureau of Meteorology and Hydrology must ask for permission from management before issuing a flood alert. For instance, in Romania, the hydrology institute must ask for approval from the prefecture's office and civil defence before issuing the flood alert [3]. This method of issuing a flood warning may not be useful in the case of a flash flood.

2) Water management strategies

Water management is a critical issue in saving people's lives and their property before and during flooding. An appropriate safe place and enough time to evacuate need to be considered. In case of a flood, management needs to know when to alert people to move to a safe place (such as a high point) to give them enough time to evacuate. Blocking water drainage systems and releasing water from a dam at the wrong time might increase the flood risk or the height of the flood. For example, in 2011 the Brisbane floods were made larger when too much water was stored then released from the Wivenhoe dam when there was further heavy rain [15].

3) Digital divide

A flood might occur at any time of the day or night. For people in a remote area, particularly in developing countries, technology availability and accessibility such internet access or TV sets might be an issue, if flood information is issued via these channels. Moreover, if a flood occurs during the night time, warning people in these areas might be difficult because delivery devices such as TVs or radios might be switched off. Mobile phones are an available alternative option to deliver an alert because most people have a mobile phone and they can be left on at night [2].

The above factors are critical issues for many existing flood warning systems. In developing countries a flood

warning system based on sensor networks, websites and GIS would be challenging to manage and maintain due to a lack of human resources, budget and existing infrastructure. However, mobile phone networks have been widely developed and their penetration is high compared to that of the internet [7]. SMS messages can be sent to a large number of people in near "real" time. Therefore, using a mobile phone infrastructure as a flood warning network to alert people of the risk of flood is a good means of real time information dissemination and an effective approach to help people evacuate from a flood area.

V. The Proposed System: An Appropriate Flood Warning System (AFWS)

This proposed system aims to use appropriate and available mobile communication infrastructure for a flood warning system in developing countries, particularly in remote areas. The AFWS will use mobile phone network technology, GPRS for transmitting collected data and SMS for alerting citizens in possible flood areas for the following reasons.

1) Why use GPRS?

The General Packet Radio Service (GPRS) network uses the existing GSM network to transmit and receive TCP/IP based data to and from GPRS mobile devices such as mobile phones, GPRS modems and GPRS Radio cards. GPRS is related to the Multimedia Message Service (MMS) and the Internet Communication Service (ICS) and there is no limit to the amount of data that can be sent [10]. The availability of GSM networks and GPRS technology, and the low cost of the services in developing countries, means GPRS is an appropriate tool in these regions for transmitting data from remote hydrological stations to the data centre.

2) Why use SMS?

A short message service (SMS) is a text messaging service that allows a mobile phone user to exchange short text messages between mobile devices over the GSM networks. The SMS message consists of words or numbers or/and alphanumeric combinations, it can carry up to 160 characters of information and an SMS gateway can send a message to multiple mobile clients, the SMS message can be in the local language[4]. The SMS message could give details such as the predicted height and time of the flood and where to relocate to. If a mobile phone is turned off an SMS message is not lost, it is forwarded when the phone is turned on.

GMS networks are available in developing countries. In 2011, there were 78.8 mobile phone users per 100 inhabitants compared to 26.3 per cent of internet users [6]. As a result, sending SMS to mobile phones for alerting people at risk in remote flood areas could be an effective flood warning mechanism.

B. The AFWS Framework

The proposed AFWS framework consists of four main parts, data collection, data processing, information dissemination and data management as shown in Fig.1.

C. Data Collection

Data collection is the process of measuring and transmitting hydrological parameter data such as water level, water flows, precipitation and temperature from hydrological monitoring stations which are located in flood-prone areas to a data centre for flood prediction. The data is collected by parameter data sensors and data loggers and sent to the data centre via GPRS.

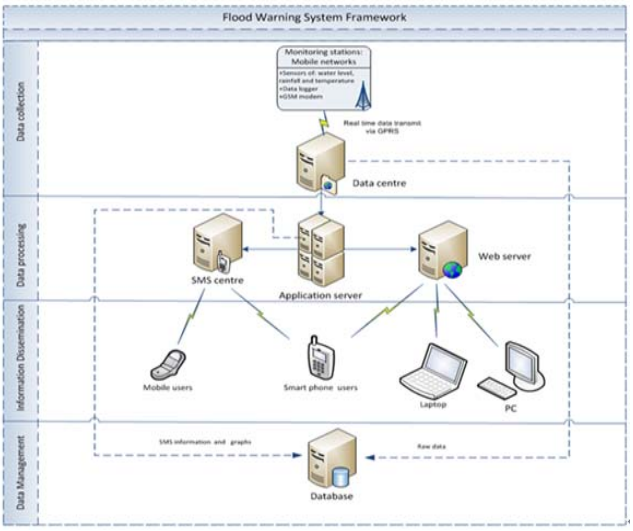

Fig. 1. The proposed AFWS framework

D. Data Processing

The data processing is comprised of two parts. The first part analyses the data in an application server to produce graphs of water level, water flows and precipitation as real time graphs, and to predict a flood. The second part sends the graphs to a web server and sends warning messages to an SMS server if flooding is predicted. Specifically, the parameter data is checked for a flood status, if the water level exceeds the threshold of the flood warning stage at monitoring stations, a "warning message" SMS text message is created and sent to the SMS centre for distribution to mobile phone users.

E. Data Management

Data at the data centre is divided into two categories, real time data and historical data. Real time data is data which just has reached in data centre in the past few minutes, the historical data is data which was collected in the past. Both categories of data are important for current and future use. The real time data is for current flood warning process and for future flood forecasting, the historical data can be used for an environment analysis such as climate change, drought management and to improve the flood warning model. All data is stored in a database server and backed up routinely.

F. Flood Information Dissemination

If the water level prediction exceeds the flood stage at each monitoring station of the flood areas, an SMS notification will send to alert mobile users (including smart phone users) located in the area of the predicted flood via the SMS gateway of a mobile provider. A computer, laptop or smart phone can be used to view a disaster warning via a website.

A mobile phone user can send an SMS to request flood

information for any hydrological station from the data centre using a specific station code or name. Alternatively, smart phones and computer users can browse near real-time graphs of flood forecasting information on the web servers.

VI. Conclusion and Future Work

Floods are natural hazards, affecting people around the globe; Floods are occurring more often more property damage and loss of life. Many countries have introduced alert systems to minimize this impact. However, it seems the systems are not always effective due to poor flood warning strategies and procedures. This paper has proposed an appropriate automatic flood warning system using SMS to directly warn people in remote flood areas in developing countries, where mobile phone networks are available and there is a high level of mobile phone penetration.

Future work aims to develop a prototype of AFWS using SMS to alert people in a risk flood area, the prototype will include an application to analyse data in near real time and an application to automatically send SMS messages to mobile phones in an effected area. The proposed research will also cover data management by developing a web-based system for historical data using Google maps, and a data download link to be made available for research studies or for commercial purposes.

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