

An Efficient Alarm Notification Algorithm for Earthquake Early Warning System

TingYun Chi ^{1*}, Te-Lung Liu ², Li-Chi Ku ², and Sy-Yen Kuo ¹

1 National Taiwan University/ No. 1, Sec. 4, Roosevelt Road, Taipei, 10617 Taiwan(R.O.C.)

2 National Center for High-Performance Computing / No. 28, Nan-Ke 3rd Rd., Hsin-Shi Dist., Tainan City, Taiwan, R.O.C. 74147

E-Mails: louk.chi@gmail.com; tliu@nchc.narl.org.tw; lku@nchc.narl.org.tw;
sykuo@cc.ee.ntu.edu.tw

* Tel.: +886-933-994-032; Fax: +886-2-2682-3971

<http://dx.doi.org/10.7125/APAN.32.16> ISSN 2227-3026

Abstract: Alarm Notification is a service that addresses devices and users with messages to be processed immediately or at a specific time. In this paper, we propose an efficient alarm notification algorithm for earthquake early warning system in Taiwan. Due to the lack of multicast support in the general IP network, we try to deliver notification messages to multiple receivers in time base on location information、network throughput with peering ISPs and priority with IoT devices. With the proposed algorithm, we can not only reduce the burst message traffic for network but also send the messages in time.

Keywords: Notification; Location; IoT; Early Earthquake Alert.

1. Introduction

Earthquake is one of the fatal disasters in the world. In early 2011, a major earthquake hit Japan, which calculated to be at the Micron Log 9. With today's technology, the earthquake early warning system is able to announce the alert message before the earthquake arrives. There are three major components for earthquake early warning system – (1) Real time earthquake information collection from the sensor nodes (2) Earthquake estimation with predictive result (3) Alarm messages delivery to users.

To collect the real time earthquake information from the sensor nodes, there are several projects [1, 2] use digital seismometers or customized sensors to collect the data. In [3], Heindl proposes an innovated idea tries to use the three-axis acceleration information in smart phones or hard disk as a collaborative sensor system. The other researches [4, 5, 6] focus on connection organization by using wireless mesh network 、 wireless sensor network P2P technology to collect the data rapidly. The Japan Meteorological Agency (JMA) started providing the Earthquake Early Warning by several means such as TV and radio on Oct 2007. Researches in [7, 8] tries to provide the alert notifications to the mobile users 、 home automated systems and vehicles.

Alarm emergency message delivery is the most important issue for earthquake early warning system. Compared to information collection from hundreds of nodes, delivery the alert to millions of clients is much difficult. Although the japan mobile handset alert system proves itself with successful results, the same architecture cannot work in Taiwan. The telecom service providers do not enable Multimedia Broadcast and Multicast Services (MBMS) [14] in their network. MBMS enables the possibility to broadcast information simultaneously to many cellular subscribers, which is suitable for earthquake early warning system. It is also a bad idea to use SMS to deliver warning messages. Even the SMS messaging may beat out other technologies in terms of popularity, it suffers two disadvantages. First, the cost is relatively high – if we would like to send the message to large number of users. Secondly, although SMS message delivery is usually rapid, the receipt time and reliability can't be guaranteed, which is the fatal issue of SMS system. In [13], approximately 5.1% messages were not delivered at all. It is a large amount compared to the end to end message loss for e-mail, which was only 1.6%. In general case, each SMS server only can handle two million messages per hour (around 500 messages per second).

In Taiwan, the earthquake will take 30sec to propagate from Taichung to Taipei. CWB (Central Weather Bureau) could collect the data from the sensors and finish the estimation in 10sec. Fig.1 shows the system architecture. Currently, CWB uses proprietary Client-Server TCP communication protocol to deliver the alert message. The CWB looks for a reliable and efficient solution to deliver the emergency message to general public. Due to the price and performance issue for SMS system, there are more and more works [9, 10, 11, 12] use SIP or IMS based message delivery mechanism in recent years. According to comparison from Table 1, SIP will be the most appropriate solution for NGN(All IP) emergency message delivery system. It is designed for general IP network – without multicast support with private IP issue. Our previous work [15, 16] shows how to deliver the unicast SIP alert message efficiently by location information.

In this section, we introduce current earthquake early warning system in Taiwan and analyze the status of current message delivery mechanisms. In next section, we modify existing system architecture and propose an innovative alarm notification algorithm to reduce system traffic. Our

algorithm is verified by both with MATLAB simulation and implementation on android platform in section 3. Finally, the conclusion and our contribution are given in section 4.

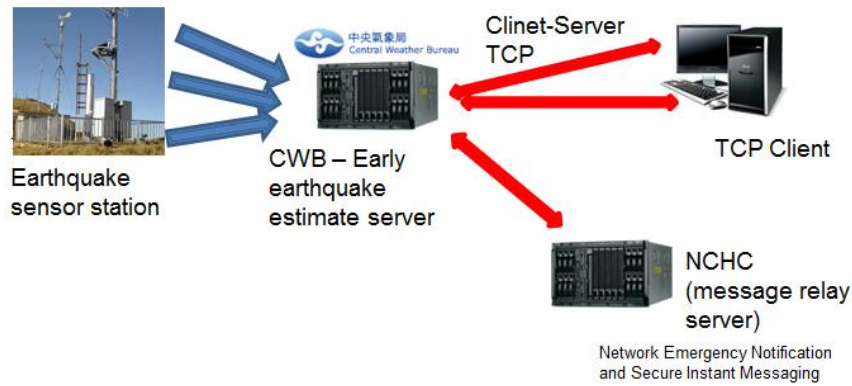


Figure 1. Architecture of earthquake early warning system in Taiwan.

Table 1. Comparison for the different delivered mechanisms

	SMS	Proprietary TCP(client-server)	SIP	MBMS
Reliability	Low(without Ack)	High(with Ack)	High(with Ack)	Low(without Ack)
Message deliver efficiency	Low	Middle	Middle	High(multicast)
Advantage	It can be used without IP network	The communication protocol can be optimized	The most popular protocol in the IP network	High message deliver efficiency
Disadvantage	Low message deliver efficiency and expensive	High maintenance cost	Works with unicast in the real world	Only work in particular cellular network

2. Modified System Architecture and Proposed Alarm Notification Algorithm

To integrate with various smart devices, we adopt SIP page-mode as the next generation earthquake warning alert protocol. However, separate unicast messages are still required to be sent to users because multicast cannot work in general IP network. It leads to two problems: First, it takes time to send these separate messages sequentially. Second, these messages may block the communication channel to peering ISPs. To deal with these issues, we design an efficient alarm notification algorithm considering with both location information and the capacity of communication channel to peer ISPs.

2.1. System Architecture

The modified system architecture is illustrated in Fig.2. When the earthquake occurs, the early earthquake estimation server will send the alert to message relay server in National Center for High-Performance Computing (NCHC) after t_{cal} (estimation time) . The message relay server will then forward the message to message delivery server through JSON interface. The message delivery server will deliver messages according to the proposed alarm notification algorithm considering with both location information and the capacity of communication channel to peer ISPs.

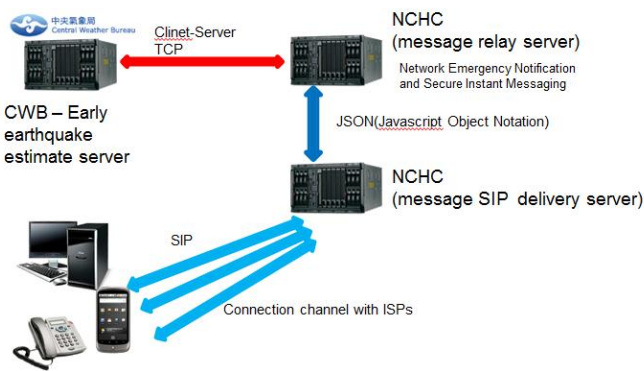


Figure 2. Proposed system architecture.

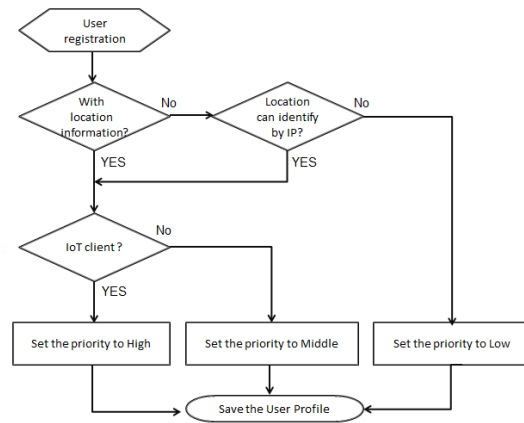


Figure 3. User registers Flow.

2.2. User Registration Flow

When a new user tries to register with the service, the system will keep the following information by the steps depicted in Fig.3: (1) Network subnet prefix (2) Human or IoT Client. (3) Location information. When a user registers with the server, the system will check user's geographical location. If the user does not set the location information in his register information, the system will identify his possible location by IP address lookup. Then system will mark which peering ISP the user comes from. Finally, the system will check if the user is a real human holding smart device or an IoT device such as elevator braking system. It will set the higher priority to IoT device.

2.3. Alarm Notification Algorithm

The Fig.4 shows the pseudo code for proposed message delivery algorithm. Due to the earthquake estimation server need a period of time (t_{cal}) to collect the real time earthquake information from the sensors and estimates the predictive Micron Log for nation-wide locations. The clients in the cities cannot receive the earthquake early warning in time that earthquake hit in

less than t_{cal} . After t_{cal} , the Earthquake early warning system starts to deliver the messages to clients in each city. The basic purpose for our delivery algorithm tries to deliver messages to clients as many as possible and try to save life. If we can send all of the clients in time, the message delivery server works as normal one. When we cannot send the message due to the capacity for process or network connection, we set IoT devices have the high priority because they usually much important than the human users. The warning messages will be sent to the IoT devices first. When we transmit the burst alert message to client in each ISP, maybe the capacity of communication channels will be a bottleneck. We activate the message delivery algorithm when the above-mentioned situations happen. The message delivery algorithm can dynamic allocation message to each ISP based on the bandwidth usage status.

The message delivery server can process “capability” messages per second. There are “ i ” cities in the system and the earthquake will arrive on “ t_1, \dots, t_i ”. In each city the IoT and human clients can be marked as “ $ISP_{IoT_i} + ISP_{user_i}$ ”. There are “ j ” ISPs in each city and the communication channel bandwidth for each ISP is “ ISP_{bw_j} messages per second”. If the alert message in the queue can’t be sent in time, it will be dropped from the delivery queue. The number of messages for each city that cannot be sent in time marks in Eq 1. We will verify the proposed algorithm by simulation. The result will show in the next session.

$$LOSS_{IoT_i} + LOSS_{USER_i} = LOSS_i \quad (1)$$

```

-----
Pseudo code of the delivery algorithm and calculate messages loss ratio:
-----
For( $i = 1$  to  $n$ )
{
  IF( $t_i \leq t_{cal}$ )
     $Drop_i = \sum_1^i [Sum_i]$ ;
  ELSE
  {
    For( $j = 1$  to  $n$ )
    {
      IF( $ISP_{bw_j} \geq capability * (ISP_{user_i} + ISP_{IoT_i} / Sum_i)$ )
      {
        IF( $capability * (ISP_{user_i} + ISP_{IoT_i} / Sum_i) * (t_i - t_{cal}) < \sum_1^i [(ISP_{user_i} + ISP_{IoT_i}) - LOSS_i]$ )
        {
          Giving priority to deliver messages to IoT devices than Human users;
           $Drop_i = \sum_1^i [(ISP_{user_i} + ISP_{IoT_i}) - LOSS_i] - capability * (\frac{ISP_{user_i} + ISP_{IoT_i}}{Sum_i}) * (t_i - t_{cal})$ ;
        }
      }
    }
  }
  ELSE // activate the algorithm
  {
    Set  $Capability * (ISP_{user_i} + ISP_{IoT_i} / Sum_i) = ISP_{bw_j}$ ;

    The redundant messages assign to other ISP;
    IF( $ISP_{AdjustMessage_i} * (t_i - t_{cal}) < \sum_1^i [(ISP_{user_i} + ISP_{IoT_i}) - LOSS_i]$ )
     $Drop_i = \sum_1^i [(ISP_{user_i} + ISP_{IoT_i}) - LOSS_i] - ISP_{AdjustMessage_i} * (t_i - t_{cal})$ ;
  }
}
}
}

```

Fig.4. Pseudo code of alarm notification algorithm

3. Simulation Results and Prototype Implementation

For simulation, we assume there are 3 major ISPs ($j=3$) in each city. The capacity of connection channel is 2,200 messages/sec ($ISPbw_1$), 2,000 messages/sec ($ISPbw_2$) and 1,800 messages/sec ($ISPbw_3$). We use the data obtained from Taiwan's Chi-Chi Earthquake in 1999. There are 23 major sensor stations in Taiwan ($i=23$) shown in Table 2. The amount of users in each city is 10,000. More detail information can be found in Table 3. The system takes 10 sec to finish the simulation ($t_{cal}=10$). CWB have one message server that can handle 6,000 message/sec ($capacity=6,000$). From the simulation results illustrated in Fig.5, we can not only reduce the burst message traffic for network but also send the message in time with fewer servers by the alarm notification algorithm considering with location information, network throughputs with peering ISPs and differentiated priority between human and IoT devices;

Table 2. History data for 1999 Chi-Chi Earthquake

Station	Distance/ time	Station	Distance/ time	Station	Distance/ time	Station	Distance/ time
City01	5.53KM/1.38s	City07	55.97KM/13.9s	City13	99.10KM/24.7s	City19	129.1KM/32.2s
City02	21.42KM/5.35s	City08	62.64KM/15.6s	City14	103.8KM/25.9s	City20	132.3KM/33.1s
City03	26.13KM/6.53s	City09	64.52KM/16.1s	City15	109.6KM/27.4s	City21	137.3KM/34.3s
City04	38.32KM/9.58s	City10	66.02KM/16.5s	City16	109.9KM/27.4s	City22	142.5KM/35.6s
City05	41.61KM/10.4s	City11	78.89KM/19.7s	City17	123.7KM/30.9s	City23	154.6KM/38.6s
City06	156.7KM/39.1s	City12	171.2KM/42.8s	City18	214.5KM/53.6s		

Table 3. The users in each city

Station ID	ISPUSER1/2/3	Station ID	ISPUSER1/2/3	Station ID	ISPUSER1/2/3	Station ID	ISPUSER1/2/3
City01	4000/3000/3000	City07	4000/3000/3000	City13	3000/3000/4000	City19	4000/3000/3000
City02	5000/3000/2000	City08	3000/5000/2000	City14	4000/3000/3000	City20	4000/2000/4000
City03	7000/1000/1000	City09	3000/3000/4000	City15	2000/5000/3000	City21	2000/5000/3000
City04	1000/3000/6000	City10	3000/2000/5000	City16	4000/3000/3000	City22	2000/6000/2000
City05	3000/4000/3000	City11	3000/5000/2000	City17	4000/2000/4000	City23	3000/1000/6000
City06	5000/3000/2000	City12	7000/2000/1000	City18	3000/2000/5000		

4. Conclusions

In this paper, we propose an innovative alarm notification algorithm with Instant Message (IM) base on Session Initiation Protocol (SIP) replacing current proprietary Client-Server protocol. By improving the alarm notification algorithm considering with location information,

network throughputs with peering ISPs and higher priority for IoT devices, we can both reduce the burst message traffic for network and send the message in time with fewer servers.

We also implement a prototype client on Android platform. Fig.6(a)(b) show the user interface for earthquake early warning system.

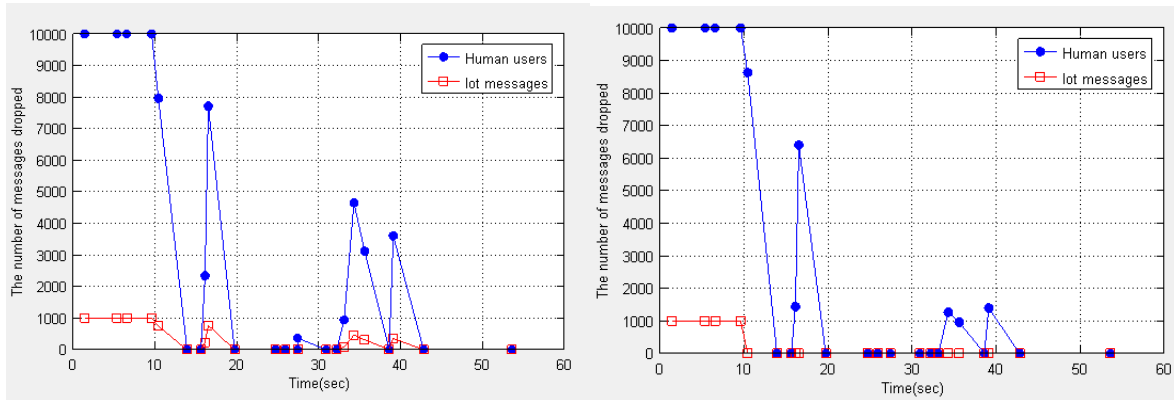


Figure 5. Total number of dropped messages
(a) without proposed algorithm. (b) with proposed algorithm



Fig.6. (a) UA setting interface. (b) UA interface

Acknowledgements

The work is funded by MOTC under contract number MOTC-DPT-100-03 and supported from National Center for High-Performance Computing.

References

1. Jren-Chit Chin; Rautenberg, J.M.; Ma, C.Y.T.; Pujol, S.; Yau, D.K.Y. An Experimental Low-Cost, Low-Data-Rate Rapid Structural Assessment Network. *Sensors Journal, IEEE*, 2009; vol.9, no.11, pp.1361-1369

2. Basha, E.; Rus, D. Design of early warning flood detection systems for developing countries. *ICTD 2007*. 15-16 Dec. 2007; pp.1-10
3. Heindl, E. Peer-to-peer (P2P) earthquake warning system based on collaborative sensing. *DEST '09*. 1-3 June 2009; pp.174-176
4. Nachtigall, J.; Zubow, A.; Sombrutzki, R.; Picozzi, M. The Challenges of Using Wireless Mesh Networks for Earthquake Early Warning Systems. *MESH 2009*, 2009; pp.155-162.
5. Wang Wenjun; Yang Shun. Study of the TDM of the GPS Timing in Earthquake Early-Warning Information Transfer. *ICICTA 2010*, vol.3, 11-12 May 2010; pp.455-457.
6. Rajarapollu, P.; Sharma, V.K. Design and analysis of satellite based disaster warning system – II. *TENCON 2007*. 30 Oct. 2007; pp.1-4.
7. Nagaosa, T.; Moriya, S. An emergency Earthquake warning system for land mobile vehicles using the earthquake early warning. *ICVES 2008*. 22-24 Sept. 2008, pp.309-311.
8. Koike, N. Catching the wave: real-time tsunami warning systems. *IEEE Potentials*, October 2009; vol.28, no.5, pp.14-17.
9. Sun Ok Park; Mi-Young Huh; Jae Cheon Han; Shin Gak Kang. Enhanced 911 Mechanism for Internet Telephony Service. *Portland International Center for Management of Engineering and Technology*, 5-9 Aug. 2007; pp.899-902.
10. Costa-Requena, J.; Haitao Tang. Enhancing SIP with spatial location for emergency call services. *Tenth International Conference on Computer Communications and Networks Proceedings*, 2001; pp.326-333.
11. Maes, S.H. SDP-based IP and Multimedia real time communications integration with vehicle remote monitoring, monitoring and emergency systems. *ITST 2008*. 24-24 Oct. 2008; pp.328-333.
12. Waraporn, N.; Triyason, T.; Angsuchotmetee, C.; Tilkanont, P. Emergency service warning system using SIP for integrated media. *NCM 2010*, 16-18 Aug. 2010; pp.312-317.
13. DEWITT LATIMER. Text Messaging as Emergency Communication Superstar? Nt so gr8. *EDUCAUSE Review*, June 2008; vol. 43, no. 3, p84–85.
14. Gomez-Barquero, D.; Fernandez-Aguilella, A.; Cardona, N. Multicast Delivery of File Download Services in Evolved 3G Mobile Networks With HSDPA and MBMS. *IEEE Transactions on Broadcasting*, vol.55, no.4, Dec 2009; pp.742-751.
15. Ting-Yun Chi, Han-Chieh Chao, Sy-Yen Kuo: An efficient emergency message delivery algorithm for early earthquake warning system. *ICET-2011*, Phuket, 2011
16. Ting-Yun Chi, Chun-Hao Che, Han-Chieh Chao: An efficient early earthquake alert message delivery algorithm with multi-ISP channels. *ITAOI-2011*, Taiwan, 2011.

© 2011 by the authors; licensee Asia Pacific Advanced Network. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/3.0/>).