附件 3-6、An Efficient Alarm Notification Algorithm for Earthquake Early Warning System

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An Efficient Alarm Notification Algorithm for Earthquake Early Warning System

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An Efficient Notification Service Algorithm for Earthquake Early Warning System

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***Abstract*—Earthquake Early Warning Alarm Notification is a service that addresses devices and users with messages to be processed at a specific time. In this paper, we propose an efficient 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. By the SIP protocol, we can integrate various devices into the same communication platform.**

***Keywords*—Notification; SIP; IoT; Early Earthquake Alert.**

I. INTRODUCTION

The effects of earthquakes include: shaking and ground rupture, landslides, avalanches, fires and Tsunami. In early 2011, a major earthquake hit Japan, which calculated to be at the Micron Log 9. According to official estimation, there are 6,000 people killed and 10,000 missed by the tsunami in the nearby area. In 1999, the Chi-Chi Earthquake hit Taiwan and made the serious damage. By the recent developing of communication technology, Earthquake can be estimated the predictive Micron Log for nation-wide locations by monitor the real-time earthquake information. With today's message delivery 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, [1] [2] use digital seismometers or customized sensors to collect the data from sensor nodes. In [3],the author proposes an innovated ideas 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 mechanisms by using wireless mesh network、wireless sensor network 、P2P technology to collect the data rapidly.

There are some studies in [7] [8] [9] [10] try to estimate earthquake to get the predictive result in seconds. In Japan, several studies about earthquake early alert system are carried out. UrEDAS(Urgent Earthquake Detection and Alarm System) service [11] was launched in 1992. The Japan Meteorological Agency (JMA) started providing the Earthquake Early Warning by several delivery channels such as TV and radio in 2007. Another researches in [12][13] tries to provide the alert notifications to the mobile handsets、home automated systems and vehicles.

In first section, we introduce and analyze the status of current earthquake early warning system. In next section, we will introduce the status of current earthquake early warning system in Taiwan and analyze the various alarm notification delivery mechanism. In third 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 4. Finally, the conclusion and our contribution are given in section 5.

II. RELATED WORK

A. Multimedia Broadcast Multicast Service (MBMS) Messaging

Compared to information collection from hundreds of nodes, delivery the alert to millions of clients is much difficult. Alarm emergency message delivery is the most important issue for earthquake early warning system. Although the japan mobile handset alert system proves itself with successful results in 2011, the same architecture cannot work in Taiwan. The telecom service providers in Taiwan do not enable Multimedia Broadcast and Multicast Services (MBMS) [14] in their network. MBMS is a broadcasting service offered via existing GSM and UMTS cellular networks. The main application is mobile TV. MBMS uses multicast distribution in the core network instead of dedicated unicasts for each end device. With the broadcast capability, unlimited number of users can be reached with constant network load. It also enables the possibility to broadcast information simultaneously to many cellular subscribers, which is suitable for earthquake early warning system.

B. SMS Messaging

Using SMS to deliver warning messages is a bad idea. Even the SMS messaging may beat out other technologies in terms of popularity, it suffers two major 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 [15], 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).

C. Early earthquake warning system in Taiwan

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. When the earthquake in Taichung, Taipei will receive the warning message before the earthquake arrives 20 seconds ahead. Fig. 1 shows the system architecture. Currently, CWB uses proprietary Client-Server TCP communication protocol to deliver the alert message.

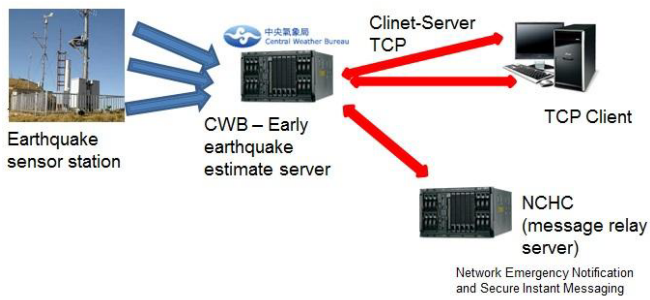

Figure 1. Earthquake Early Warning System in Taiwan.

D. SIP / IMS Messaging

The CWB are looking 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 [16][17][18][19] 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. Compare with SMS, SIP/IMS clients provide much more multimedia capacity [20]. They usually use Session Initiation Protocol for Instant Messaging and Presence Leveraging Extension (SIMPLE) as the message format. SIP has a number of benefits over SMS, such as explicit rendezvous, tighter integration with other media-types, direct client to client operation. By RFC3428 page-mode message is enabled in SIP as a much simple way via the SIP MESSAGE method. The message flow shows in Fig. 2.

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However, it is designed for general IP network – without multicast support with private IP issue. The burst message traffic will influence the low bandwidth network and may be blocked by the firewall. Our previous work [21][22] already shows how to deliver the unicast SIP alert message efficiently by location information.

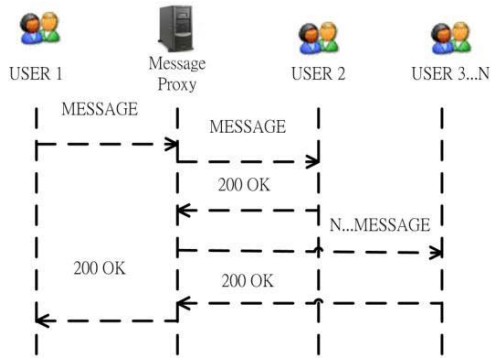

Figure 2. IM Message Flow for RFC3428 (Page Mode)

TABLE I. 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

III. AN EFFICIENT NOTIFICATION SERVICE ALGORITHM FOR EARTHQUAKE EARLY WARNING

To integrate with various smart devices in the same communication platform, 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 three problems: First, it takes time to send these separate messages sequentially. Second, these messages may block the communication channel to peering ISPs. Third, the IoT devices

should have the high priority because they usually work with brake system for elevator and train. To deal with these issues, we design an efficient alarm notification algorithm considering with both location information, priority for different users and the capacity of communication channel to peer ISPs.

A. System Architecture

The next generation earthquake warning alert system architecture is illustrated in Fig. 3. When the earthquake occurs, the early earthquake estimation server will send the estimated alert to message relay server in National Center for High-Performance Computing (NCHC) after t_{cal} (the time for collect the data from the sensor node and estimate the result). 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 location information, priority for different users and the capacity of communication channel to peer ISPs.

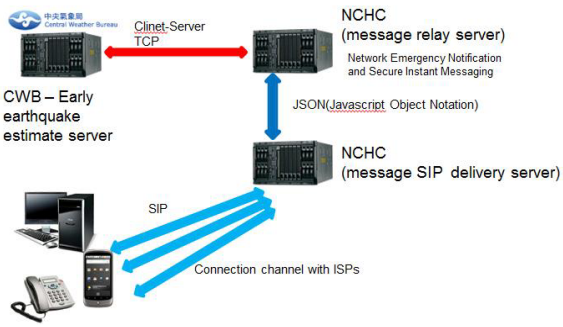

Figure 3. Proposed system architecture

B. 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. 4: (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.

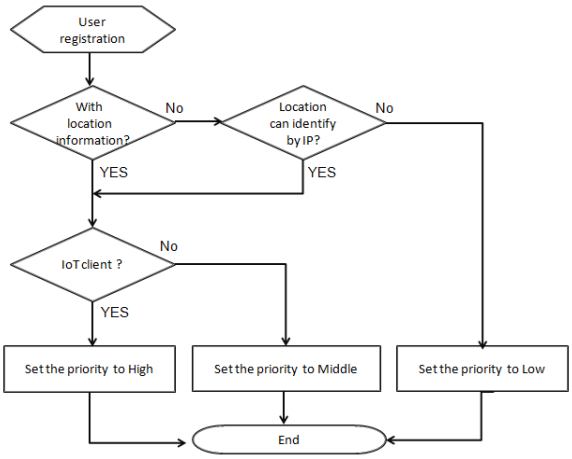

Figure 4. User Registration Flow

C. An Efficient Message Delivery Algorithm

The Fig.5 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.

The clients are distributed in each ISP and the capacity of communication channel to peer ISPs is limited.We deliver the alert messages to each ISP in each city according to the corresponding proportion. 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. Our algorithm makes more efficient use of bandwidth.

We set the time for earthquake estimation as "t_{cal}", the message delivery server can process "*capability*" messages per second. There are "i" cities in the system and the earthquake will arrive on "$t_1.....t_i$". In each city the IoT and human clients can be marked as "$ISPIoT_i$+ $ISPuser_i$". There are "j" ISPs in each city and the communication channel bandwidth for each ISP is "$ISPbw_j$ *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 equation 1. We will verify the

proposed algorithm by simulation. The result will show in the next session.

$$LOSSIoT_i + LOSSUSERS_i = LOSS_i \qquad (1)$$

Pseudo code of the delivey algorithm and calculate messages loss ratio:

For($i = 1$ to n)

{

IF($t_i <= t_{cal}$)

$Drop_i = \sum_{1}^{i} [Sum_i]$;

ELSE

{

For($j = 1$ to n)

{

IF($ISPbw_i >= capability * (ISP_j user_i + ISP_j IoT_i / Sum_i)$)

{

IF($capability * (ISP_j user_i + ISP_j IoT_i / Sum_i) * (t_i - t_{cal}) < \sum_{1}^{i} [(ISP_j user_i + ISP_j IoT_i) - LOSS_i]$

{

Giving priority to deliver messages to IoT devices than Human users;

$Drop_i = \sum_{1}^{i} [(ISP_j user_i + ISP_j IoT_i) - LOSS_i] - capability * (\frac{ISP_j user_i + ISP_j IoT_i}{Sum_i}) * (t_i - t_{cal})$;

}

}

ELSE // activate the algorithm

{

Set $Capability * (ISP_j user_i + ISP_j IoT_i / Sum_i) = ISPbw_i$;

The redundant messages assign to other ISP;

IF($ISP_j AdjustMessage_i * (t_i - t_{cal}) < \sum_{1}^{i} [(ISP_j user_i + ISP_j IoT_i) - LOSS_i]$)

$Drop_i = \sum_{1}^{i} [(ISP_j user_i + ISP_j IoT_i) - LOSS_i] - ISP_j AdjustMessage_i * (t_i - t_{cal})$;

}

}

}

}

Figure 5. Pseudo code for delivery algorithm

IV. SIMULATION

A. Simulation

We use the data obtained from Taiwan's Chi-Chi Earthquake in 1999. There are 23 major sensor stations in Taiwan (N=23) shown in Table II. The amount of users in each city is 10,000. More detail information can be found in Table III. The system takes 10 sec to finish the simulation (t_{cal}=10). CWB have one message server that can handle 6,000 messages per second (*capacity*=6,000).

TABLE II. HISTORY DATA FOR 1999 CHI-CHI EARTHQUAKE

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

TABLE III. THE NUMBER OF USERS IN EACH CITY

Station ID	$ISP_{USER1/2/3}$	Station ID	$ISP_{USER1/2/3}$
City01	4000/3000/3000	City07	4000/3000/3000
City02	5000/3000/2000	City08	3000/5000/2000
City03	7000/1000/1000	City09	3000/3000/4000
City04	1000/3000/6000	City10	3000/2000/5000
City05	3000/4000/3000	City11	3000/5000/2000
City06	5000/3000/2000	City12	7000/2000/1000
City13	3000/3000/4000	City19	4000/3000/3000
City14	4000/3000/3000	City20	4000/2000/4000
City15	2000/5000/3000	City21	2000/5000/3000
City16	4000/3000/3000	City22	2000/6000/2000
City17	4000/2000/4000	City23	3000/1000/6000
City18	3000/2000/5000		

The results of the simulation show in Fig. 6 and Fig. 7. Fig. 6 show the number of dropped messages without considering the capacity of communication channel to peer ISPs. For the first simulation, the server delivered the messages without using the algorithm when the earthquake hit. Fig. 6(a) shows the number of loss messages for each ISP. According to simulation result, the early earthquake estimation server sends the estimated alert to message relay server on 10 second. It means that we can't send the alert to city1, city2, city3, city4 and even city5. When the earthquake arrives in the fifth city, we can see that a considerable number of users and IoT devices cannot receive the earthquake alert message in time. Fig. 6(b) shows the sum of the number of dropped messages without proposed algorithm for IoT devices and Human users.

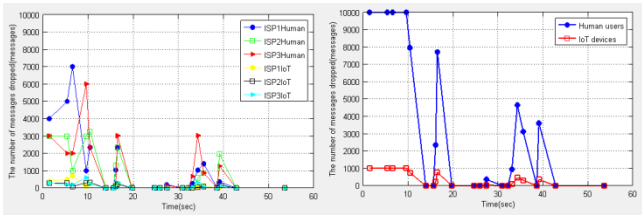

Figure 6. The number of dropped messages without proposed algorithm
(a)for each ISP. (b)sum for IoT devices and Human users

For the second simulation, we considering the capacity of communication channel to peer ISPs. Fig. 7(a)(b) show the result. By the result , we can find that the number of loss message is reduced with our algorithm that considering the capacity of communication channel to peer ISPs. It shows that our algorithm uses the connection capacity resource more efficient.

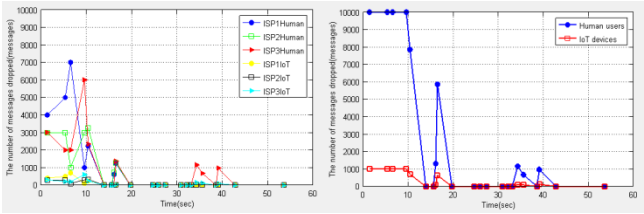

Figure 7. The number of dropped messages with considering the capacity of communication channel to peer ISPs
(a)for each ISP. (b)sum for IoT devices and Human users

For the final simulation, we try to set the higher priority for IoT devices. It make sense that bake system for high speed rail carry 989 people is much important than a handset. Fig. 8(a) shows the result when the server sets higher priority to the IoT devices, we can see the significant improvement on the uumber of dropped messages to IoT devices. Fig. 8(b) shows the improvement in number of dropped messages by campare proposed algorithm(location, connection capacity, priority to IoT) with baseline algorithm (only considering with locaiotn).

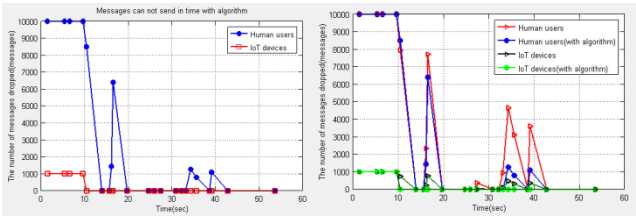

Figure 8. The number of dropped messages
(a)IoT devices and human users(considering the higher priority to IoT)
(b)Comparing with the baseline result(only considering with locaiotn)

B. *Implementation*

We also implement a prototype client on Android platform. Fig. 9(a)(b) show the user interface for earthquake early warning system.

Figure 9. (a) UA setting interface. (b) UA interface

V. 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. It also can be implemented in real world with low cost.

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