附件 3-7、An Efficient Early Earthquake Alert Message Delivery Algorithm Using an In Time Control-Theoretic Approach

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An Efficient Early Earthquake Alert Message Delivery Algorithm Using an In Time Control-Theoretic Approach

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附件 3-7

An Efficient Early Earthquake Alert Message Delivery Algorithm Using an In Time Control-Theoretic Approach

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Abstract. Earthquake is one of the natural disasters in the world. As Japan the earthquake is expected to occur with high probability in Taiwan. The Central Weather Bureau of Taiwan develops the early earthquake warning system as other countries. In this paper, we introduce the development status for the early earthquake alert system. Also we replace the private commutation protocol with Instant Message (IM) base on Session Initiation Protocol (SIP) for delivering the emergency message. By improve the message delivery algorithm with location information and in time control-theoretic approach; we can reduce the burst message traffic for network but also send the message in time.

Keywords: earthquake, IM/SIP, emergency message, location information, control-theoretic

1 Introduction

There are a lot of disasters in the world; one of them is the earthquake. In the early of 2011 a major earthquake occurred in Japan, which the earthquake calculated to be at the Micron Log 9. According to official estimates, there are 10,000 people missed and 6,000 people killed by the tsunami in the same area. Haiti also had an earthquake in 2010, which the earthquake calculated to be at the Micron Log 7. According to official estimates, there are 222,570 people died, 300,000 injured, 1.3 million displaced, 97,294 houses destroyed and 188,383 damaged in the Port-au-Prince area and in much of southern Haiti. In Taiwan, the Chi-Chi Earthquake is in 1999 and made the serious damage.

By the recent developing of communication network, real-time earthquake information can be detected and calculate the predictive Micron Log for nation-wide locations. In today's technology, the early earthquake warning system announces that the warning message 10 seconds before the earthquake arrives. There are theree major research issues for early earthquake warning system – (1) Collect the information from the sensor nodes (2) Estimate earthquake to get the predictive result (3) Deliver the messages to users. In the paper, we will introduce the related research and then focus on the mechanism to deliver the warning messages.

To collect the information from the sensor nodes, most of the projects [1][2] use digital seismometers or customized sensors. One of the innovated ideas [3] tries to use the three-axis acceleration information in Hard disk or smart phones as a collaborative sensor system in the recent years. The other researches try to use wireless mesh network、wireless sensor network 、P2P technology [4][5][6] to collect the data rapidly.

The data from the sensor nodes is as the input for calculating the predictive Micron Log in nation-wide locations. There are a lot of studies [7][8][9][10] can finish the simulation in seconds. In Japan, several studies about earthquake early warning system are carried out. UrEDAS(Urgent Earthquake Detection and Alarm System) [11] was launched the service in 1992. The Japan Meteorological Agency (JMA) started providing the Earthquake Early Warning by several means such as TV and radio on Oct 2007. There are some works [12][13][14][15][16][17] try to provide the information to the mobile users、Home automated systems and vehicles.

Delivery the emergency message is the most important issue for early earthquake warning system. Due to the price and performance issue for SMS system, there are more and more works [18][19][20][21] use SIP or IMS based message delivery mechanism. In this paper we introduce the early earthquake warning system in the Introduction and analysis the status of current SIP/IMS based message delivery mechanism in Related Work. Then we will purpose our system architecture and message delivery algorithm to reduce the useless message traffic issue. Finally we will verify our algorithm by simulating with MATLAB and make a conclusion.

2 Related Work

2.1 SMS Messaging

Even the SMS messaging may beat out other technologies in terms of popular appeal, it suffers from several disadvantages. The first disadvantage is the cost – if we would like to send the message to large group. Another issue –although SMS message delivery is usually rapid, receipt time and reliability can't be guaranteed. Recent study [22] found approximately 5.1 percent of messages were not delivered at all. The end to end message loss for email was only 1.6 percent. In the general case, the SMS server only can handle two million messages per hour (around 500 messages per second)

2.2 SIP / IMS Messaging

SIP is the most popular communication protocol today. In the APP IP cellar network, the IMS is based on the SIP protocol. A lot of studies[23][24][25] try to deliver the emergency message on SIP/IMS.Compare with SMS, SIP/IMS clients provide much

more multimedia capacity[26]. 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. However the messages will delivery by unicast when the sender sends the message to the group or updates the presence information. The burst message traffic will influence the low bandwidth network and may be blocked by the firewall.

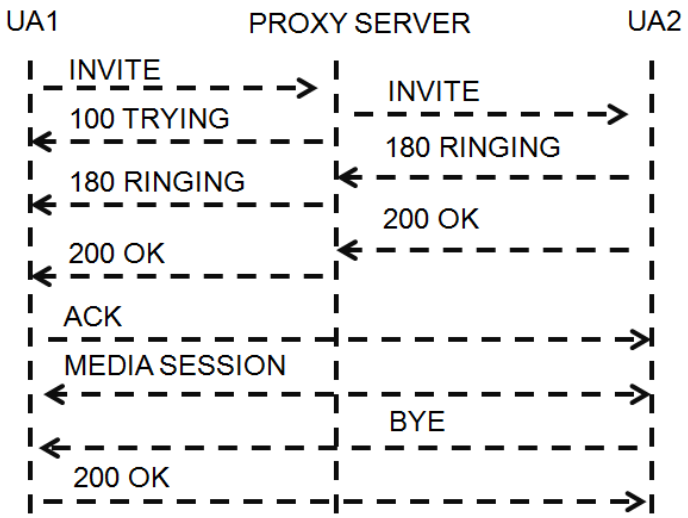

Fig. 1. IM Message Flow for RFC3261

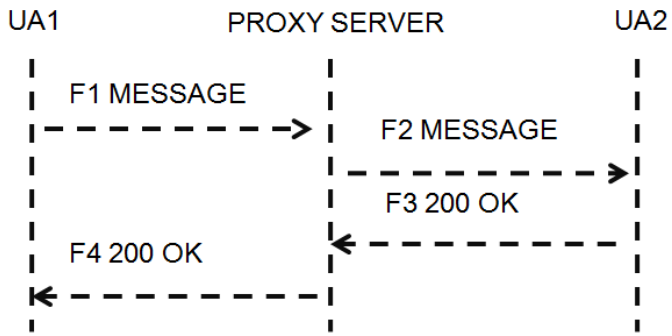

Fig. 2. IM Message Flow for RFC3428 (Page Mode)

2.3 Multimedia Broadcast Multicast Service (MBMS) Messaging

Multimedia Broadcast and Multicast Services (MBMS) [27] 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 unicast links for each end device. The broadcast capability enables to reach unlimited number of users with constant network load. It also enables the possibility to broadcast information simultaneously to many cellular subscribers for example emergency alerts. However, the multicast network only work in the particular network.

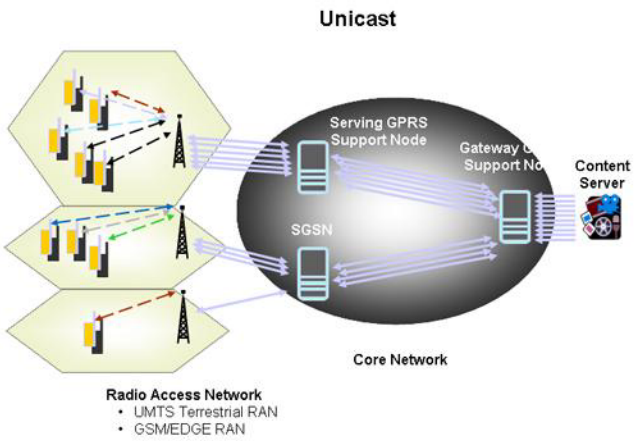

Fig. 3. Without MBMS, unicast transmissions consume more network resources as usage grows

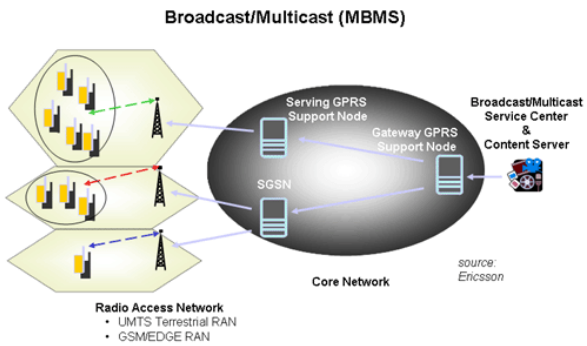

Fig. 4. With MBMS, broadcast transmissions efficiently use network resources at all usage levels

2.4 Mitigating SIP Overload Using a Control-Theoretic Approach

SIP (Session Initiation Protocol) is becoming the dominant signaling protocol for Internet-based communication services and it maintains its reliability by retransmission mechanism. The redundant retransmissions increase the CPU loads of both the overloaded server and its upstream servers. In [30] demonstrates that without overload control algorithm applied, the overload at the downstream server may propagate or migrate to its upstream servers eventually without protocol modification. The author proposes an overload control algorithm that can mitigate the overload effectively and prevent the overload propagation.

2.5 Early earthquake warning system in Taiwan

In Taiwan, the earthquake will take 30sec from Taichung to Taipei. CWB can receive the data form the sensors and finish the simulation in 10sec. currently they use Client-Server TCP software to deliver the message.

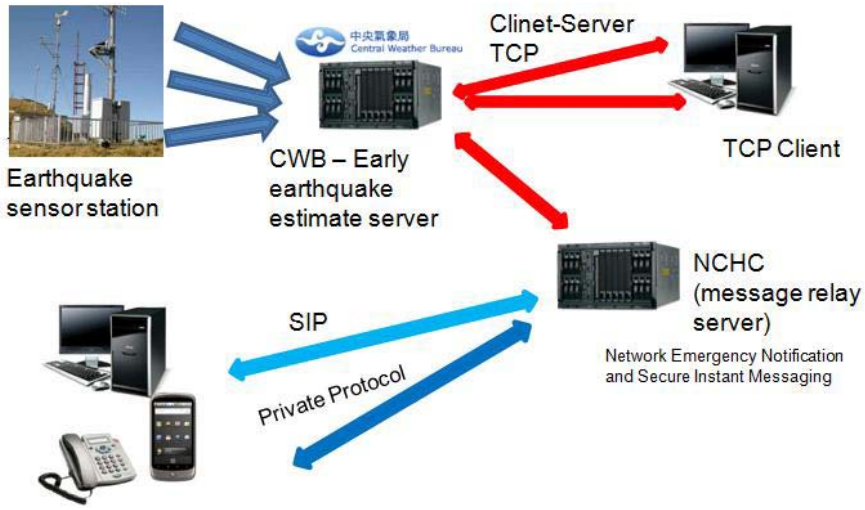

Fig. 5. Early earthquake warning system in Taiwan

Table 1. Comparison for the different delivered mechanisms.

	SMS	Private 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 design is simple	The most simple protocol in the IP network	High message deliver efficiency
Disadvantage	Low message deliver efficiency but expensive	It's hard to extend the protocol	Work with unicast in the real world	Only work in particular cellular network

The CWB looks for a reliable and efficient solution to deliver the emergency message. By the comparison in Table 1, we can understand SIP will be the most appropriate solution for NGN(All IP) emergency message delivery system. The system is designed for general network – without multicast funcation. How to deliver the unicast SIP message efficiency is the most important issue[28][29].

3 An Efficient Early Earthquake Alert Message Delivery Algorithm Using an In Time Control-Theoretic Approach

Our purpose is to use the SIP page-mode as the next generation earthquake warning system protocol. But it still needs to send message to the users individually because multicast cannot work in the general network.When a new user register with the service, the system will save the following information as Fig6:(1) network subnet prefix (with C class) (2) Human or IoT Client. (3)location information.

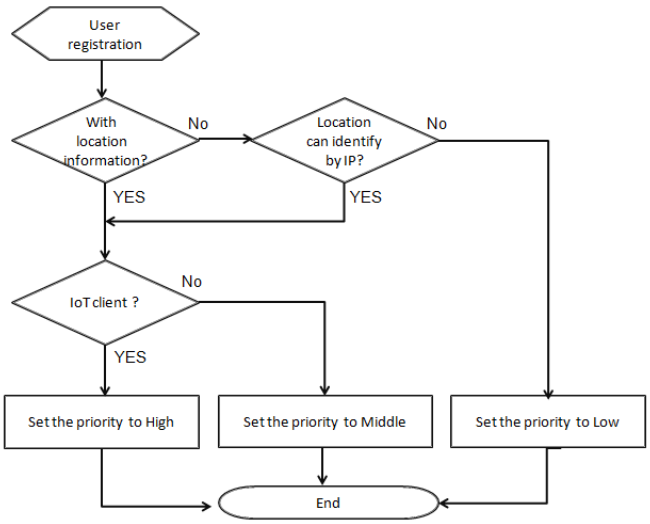

Fig. 6. User registration flow

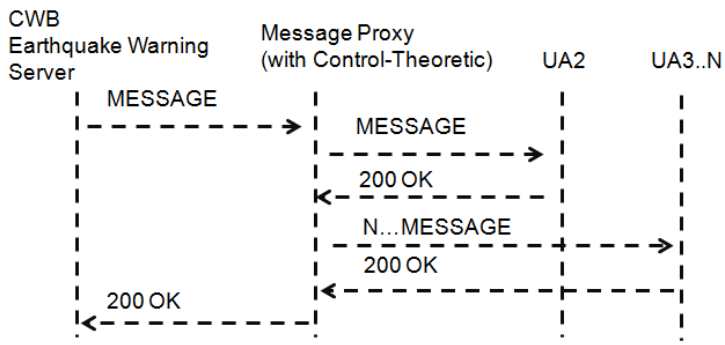

Fig. 7. Message delivery flow

We set the time for earthquake simulation as t_{cal} ,CWB has α message servers and each server can handle β messages per second. There are N cities in the system and the earthquake will arrive on t_1…..t_N. In the cities with the IoT and human clients that mark as IoT_i+ $USER_i$. If the message in the queue can't be sent on time, it will be dropped from the delivery queue. The message delivery failure will mark as equation 1 for each city.

$$LOSSIoT_i + LOSSUSER_i = LOSS_i \quad \textbf{(1)}$$

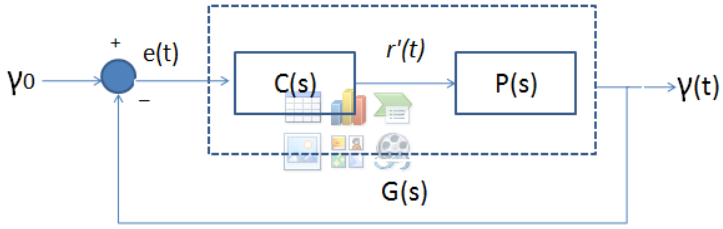

Fig. 8. Feedback control for SIP overload control system

The message delivery model reference from [30] and use the feedback control for SIP retransmission overload . Fig 8 and the equation (2) to (4) show how the feedback control work.

The overload control plant $P(s)$ represents the interaction between a receiving server and a sending server, the transfer function is given by

$$P(s) = \gamma(t) / r'(t) \tag{2}$$

And adaptive PI controller $C(s)$ is designed for mitigating the overload and achieving a desirable target redundant message ratio γ_0, when the overload is anticipated at the downstream server .The transfer function $C(s)$ is

$$C(s) = K_P + K_I / s \tag{3}$$

By the following PI control algorithm expressed via, we can obtain the equation 4

$$r'(t) = K_P e(t) + K_I \int_0^t e(x)dx = K_P(\gamma_0 - \gamma(t)) + K_I \int_0^t (\gamma_0 - \gamma(x))dx \tag{4}$$

We use the PI control to mitigate the overload and achieve a satisfactory target redundant message ratio by controlling retransmission rate.

Table 2. Control-Theoretic Parameters.

Parameters :	
γ (t): Redundant message ratio	γ 0(t) :Target redundant message ratio
r' (t): Message Retransmission rate	e(t): redundant message ratio deviation
Kp: Proportional gain	KI: Integral gain

As the pseudo code in Fig.9, we use the greedy algorithm try to process the most urgent event. Also we apply the in time limitation for the algorithm. If the message can't be sent in time, it will be skipped. The messages for IoT devices will get higher priority than human users in the same city. Based on our algorithm, we reduce the message traffic as equation 5.

$$\frac{\sum_{1}^{N}[(IoT_x + USER_x) - LOSS_x]}{\sum_{1}^{N}(IoT_x + USER_x)} = MessageTraffic \quad \textbf{(5)}$$

```
For(i=1;i<=N;i++) //deliver the message from City to CityN
{
 if(ti<=tcal)
  {
        //before the simulation finish, we can't send the alert nessages
         LOSSi = IoTi + USERi
      }
  else
      {
      /*If the message can't be sent in time ,
        the messages for IoT devices will get higher priority than human users,
        and we calculate the number of  loss users*/
       if(α * β * (ti-tcal) < ∑_1^i[(IoTx + USERx) − LOSSx])
          LOSSi=∑_1^i[(IoTx + USERx) − LOSSx] − α * β * (ti-tcal);
        if(LOSSi <= USERi)
           {LOSSUSERi = LOSSi}
       else
           {LOSSUSERi = USERi;
            LOSSIoTi=LOSSi − LOSSUSERi }
      }
}
```

Fig. 9. Pseudo code for the number of loss users by message delivery algorithm

4 Simulation

We use the data comes from 1999 Chi-Chi Earthquake in Taiwan, table3 show there are 23 mojor sensor stations in Taiwan(N=23). We assume there are 1000 IoT clients and 10000 human users in each city(IoT_i=1000, $USER_i$=10000). The system will take 10 sec to finish the simulation(Tcal=10). CWB have one message server that can handle 5000 message/sec (α=1, β=5000)

Table 3. Earthquake Historical data comes from 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		

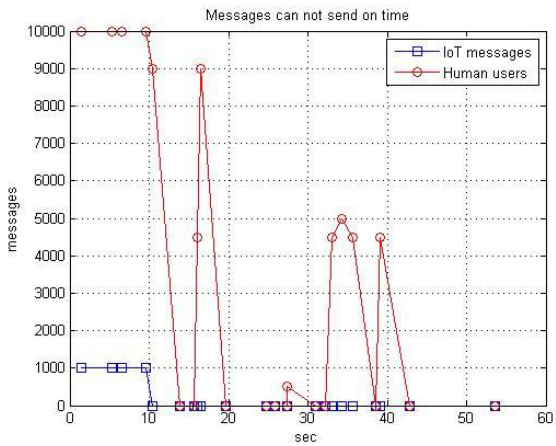

Fig. 10. The number of useless messages with one server

From the result in Fig10, it shows the messages that should be sent before t_{cal} is identified as useless message. When the system can't delivery all of the messages, it will drop the messages for human user first. The delivery algorithm tries to send the emergency messages to IoT devices as many as possible. The system delivers 167500 useful messages with only one message server.

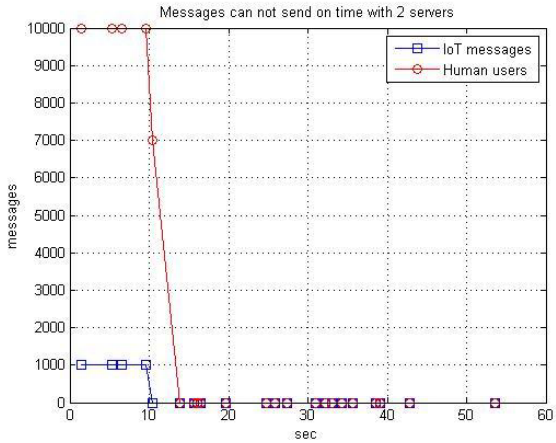

Fig. 11. The number of useless messages with two server

If we add one server for the system(α=2), most of the message will be deliveried. However it can not reduce the dropped messages before t_{cal}. The system delivers 202000 useful messages with two message servers.

For the best case in our scenario, there are 253000 messages should be delivered without the location information; however the number of useful messages is 209000. If the system tries to send all of the messages in 1 sec, it will need around 50 servers. The useful message delivery rate with one server can be calculated by equation 6. The useful message delivery rate with two servers can be calculated by equation 7.

Fig 12 show the user interface for alert message service client, the location information can be obtain by GPS、IP lookup and manual control. When the UA receive the alert message, it will look like Fig 13.

$$\frac{the\_num\_sent\_message}{the\_num\_message} = \frac{167500}{209000} = 80.14\% \tag{6}$$

$$\frac{the\_num\_sent\_message}{the\_num\_message} = \frac{202000}{209000} = 96.65\% \tag{7}$$

Fig. 12. Earthquake warning UA detect the location information

Fig. 13. Earthquake warning message with An Efficient Early Earthquake Alert Message Delivery Algorithm Using an In Time Control-Theoretic Approach

5 Conclusion

We propose replacing the private commutation protocol with Instant Message(IM) based on Session Initiation Protocol(SIP) for delivering the emergency message. By improve the message delivery algorithm with location information and in time control-theoretic approach; we can reduce the burst message traffic for network but also send the message in time with fewer servers.

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