Development and Testing of the Earthquake Early Warning Information Push Platform Based on MQTT Protocol

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Abstract: With the implementation of national seismic intensity rapid reporting and early warning, China will build a nationwide earthquake intensity reporting and early warning network by 2022.The push of earthquake warning information services for the government, the public and various industries, and it is an effective means to mitigate earthquake disasters. This paper develops and builds an end-to-end platform for earthquake early warning information service based on the MQTT protocol, so as to realize the whole process of information push, processing, subscription and warning output. The time-delay test results show that the platform push delay is less than 1s under internet conditions.

1. Introduction

China has launched the *National Earthquake Intensity* Rapid *Reporting and Early Warning Project*, which will build the world's largest earthquake intensity rapid reporting and early warning monitoring network with a total number of more than 10,000 stations. This will significantly improve the country's service capacity of earthquake prevention and disaster reduction[1]. The project will eventually provide earthquake warning information services to the government, the public and various industries through the push of earthquake warning information. China's existing means of rapid earthquake reporting are mainly published by the traditional MAS information machine, the speed of which is about hundreds of messages per minute, and the timeliness is basically in the minute level. Moreover, its coverage is limited, and it has a big gap with the second level requirement of earthquake warning publishing, so it is difficult to play the actual effect of warning[2]. This paper mainly introduces the implementation method of issuing earthquake warning information via the Internet based on MQTT (Message Queuing Telemetry Transport) protocol [3], and develops and builds an end-to-end platform for earthquake early warning information service, so as to realize the whole process of information push, processing, subscription and warning output of earthquake early warning information.

2. Introduction of Earthquake Warning Information Releasing Protocol

2.1 Transport protocol

The publishing of earthquake early warning information mainly considers the characteristics of high concurrency, low time delay and different push information for different objects. After comprehensive consideration of various information push methods based on the network, such as GCM, HTTP polling, XMPP, etc., this paper believes that MQTT-based push method is the most suitable [4]. MQTT uses TCP/IP to provide network connectivity and enable message transmission to the load content shielding. Its main advantage is to minimize protocol exchange and reduce the demand for network bandwidth. What’s more, it adopts publish/subscribe message mode to provide one-to-many message pushing and release application coupling.

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2.2 Data transmission flow

The data transmission flow of earthquake early warning information mainly includes user data transmission flow of receiving end, publishing user data transmission flow and data transmission flow of center administrators.

User data transmission flow of receiving end: Receiving end user registration; Sending user information; Receiving early warning information and response information. The receiving end users actively connect with publishing port1833, and write the user information packet to the EEW/USR topic after authentication, and update the user information packet every 60 seconds. At the same time, Selecting the subscription topic EEW/BUL or EEW/XML, and when receiving the subscription topic information, send a reply to the topic EEW/ACK. The specific process is shown in figure 1:

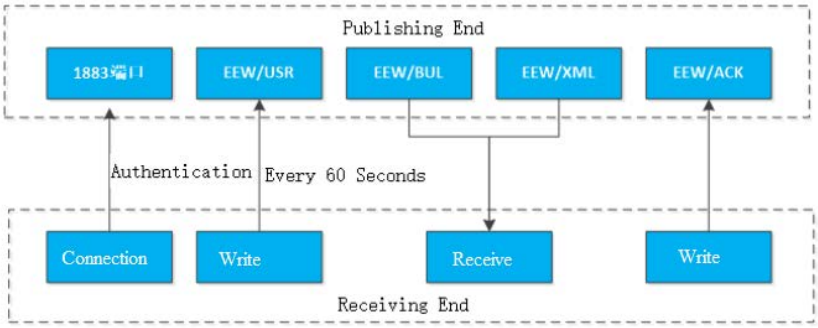

Fig1.Data Transmission Flow of the Earthquake Early Warning Information

Publishing user data transmission flow: After the publishing users have authenticated the connection to the MQTT server, an early warning is issued to the subject EEW/BUL or EEW/XML.

Data transmission flow of center administrators: Once the administrator has authenticated the connection to the MQTT server, the topics EEW/USR, EEW/ACK, EEW/BUL, and EEW/XML will be subscribed and the corresponding packets will be received.

2.3 Early warning information content

The publishing end uses Byte package and XML package to push early warning information. The Byte package contains only basic information about seismic parameters, such as the time of the earthquake, latitude and longitude of the epicenter, magnitude, and focal depth. The XML package contains more information, such as early warning information, seismic parameters, early warning region and scope, early warning time and distribution, early warning key objects.

3. Push Platform Development and Construction

The push platform consists of four parts: simulated hypocenter, publishing end, MQTT SERVER end and receiving end. The main implementation functions are as follows: Artificial vibration generates seismic parameter information by triggering simulated hypocenter. The publishing end receives the seismic parameter information and writes to the MQTT SERVER. The receiving end automatically calculates the predicted arrival time and predicted intensity of the earthquake through the information processing of the subscribed early warning information. When the estimated intensity exceeds the set threshold, the receiving end will send out acoustic and photoelectric warning information.

3.1 Simulated hypocenter

The REMOS-SIT4 intensity instrument developed by our team is used to simulate the hypocenter[5]. The intensity meter uses the threshold trigger waveform mode. After triggering, the PGA, PGV, and PGD values of different channels are calculated every second, and the intensity of the instrument is also calculated.

3.2 Publishing end

The publishing end implements two main functions:(1) Establishing a long TCP/IP connection with the intensity instrument to obtain the location information of simulated hypocenter and trigger parameter information (time, magnitude and instrument intensity). (2) Establishing TCP/IP connection with MQTT SERVER and publish the early warning parameter information to MQTT SERVER.

3.2.1 Publishing end parameter obtainment

Port 1973 is real-time monitored by the publishing end. The intensity instrument actively connects to the publishing end and registers. After successful registration, the publishing end obtains the basic parameter information of the intensity instrument and has the control authority. By controlling the authority, the intensity instrument is set as the trigger waveform model.

In the non-trigger mode, the intensity instrument sends state packets to the publishing end every 10s. When the intensity instrument detects event triggering, it will immediately send the triggering information packet and triggering waveform packet to the stream server until the end of event triggering. It then continues to send status packets to the stream server every 10s.

3.2.2 Publishing end quality control selection

For earthquake early warning information, it is necessary to pay attention to both message loss and warning timeliness. MQTT protocol quality control mainly includes QOS0: send at most once; QOS1: send at least once; QOS2: send only once.

When the quality QOS0 is sent out, no matter whether the server receives it or not, if the message is lost, the early warning information will be missed, which is obviously not desirable. The requirement of quality QOS1 is to push at least once, and repeat if it fails. The publishing end initiates a push message to the server. When the server sees that the QOS of message quality is 1, it sends back the publish confirmation (PUBACK) message to the publishing end. When the publishing end receives the response (PUBACK), the push process ends. When the server fails to process the information of the publishing end in time and the publishing end fails to obtain the publish confirmation message in time, it will consider the sending failure and resend the information. Therefore, it is possible for the server to receive the same publish message multiple times, and for the client end to receive multiple repeated early warning messages.

The quality control QOS 2 means the message will be only sent once. The specific flow is shown in figure 2.

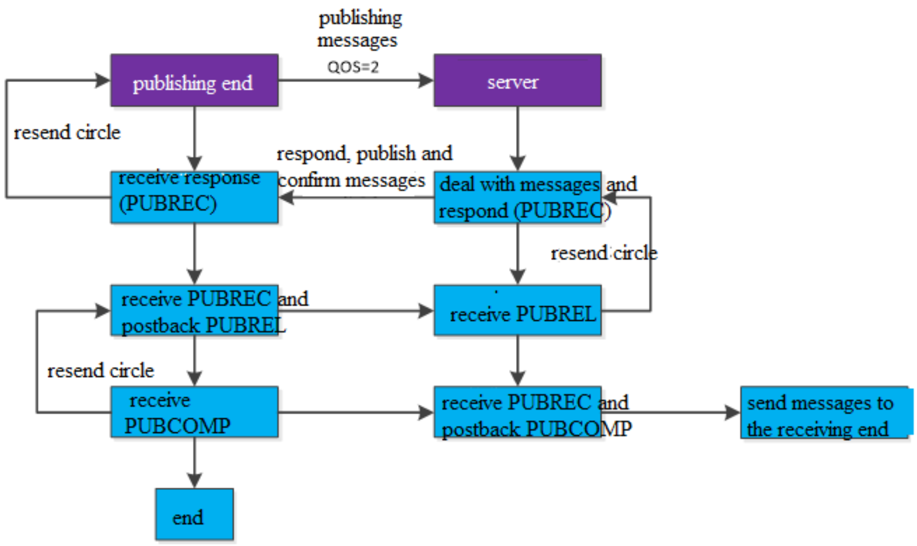

Fig2. QOS2 Quality Control Process of MQTT Protocol

The publishing end initiates a publishing message to the server, and when the server sees that the message quality QOS is 2, it sends back a PUBREC message to the publishing end. After receiving the response (PUBREC), the publishing end sends back the PUBREL message. After receiving the PUBREL message, the server sends back the PUBCOMP message. After the publishing end receives the PUBCOMP message, the process ends.

Quality control QOS1 can ensure the arrival of early warning information and high timeliness. However, there will be repeated reception of early warning information; QOS2 has two more retransmission links and more publishing interaction processes, but it can ensure that the clients only receive one early warning information. Nevertheless, the timeliness is lower than that of QOS1. After comprehensive consideration, this paper chooses the publishing mode of QOS2.

3.2.3 Software development of the publishing end

The publishing end completes the information interaction between the information source and the server. The publishing end mainly includes four parts: registration management service, information management service, information processing service and information publishing service. The registration management service is mainly used for the registration management of front-end equipments and obtaining the parameter information of front-end equipments; The information management service is used to control the transmission mode of front-end equipments and obtain the early warning parameter information and real-time data information; The information processing service is used for preliminary processing of early warning parameter information of front-end equipments; The information publishing service is used for publishing docking with the server and timely release early warning information [6]. Its logical flow is shown in figure 3:

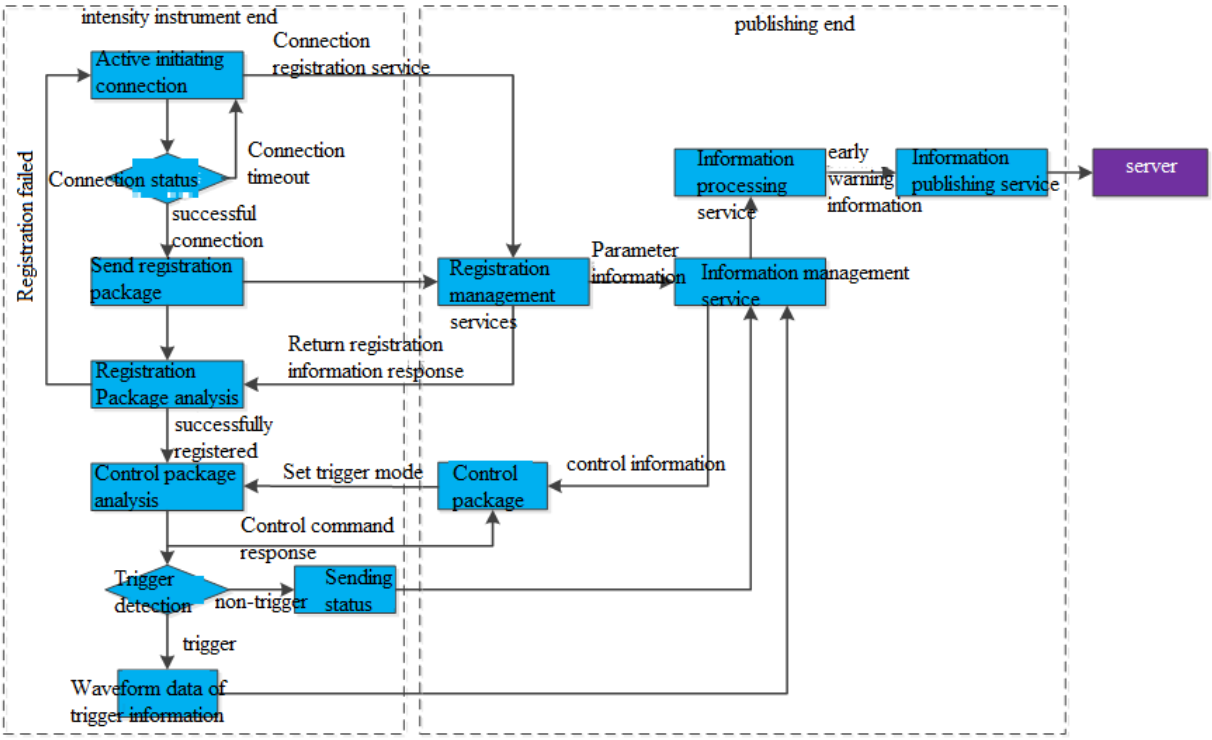

Fig3. The Logic Flow of the Publishing end Software

When the intensity instrument is triggered, the publishing end establishes a long connection with it to obtain parameter information, and flattens the first and second warning information in the seismic information cluster into a high-byte character string. Meanwhile, MQTT publishing function module is called to establish a connection with MQTT SERVER for message publishing. In order to reduce the connection pressure of MQTT SERVER, the connection automatically shut down if there’s no new messages in 60s.

3.3 The MQTT SERVER end

MQTT SERVER uses apache-apollo as middleware to build services and realize automatic management of publishing and subscription [8]. MQTT server TCP interface after setup:

tcp://0.0.0.0:61613, Backstage login interface: https://127.0.0.1:61681.

3.4 The receiving end

The receiving end adopts WRT-02 early warning receiving terminal hardware independently developed by our team and based on embedded system. The receiving end mainly realizes early warning information subscription, early warning information processing and early warning information output.

The receiving end subscribes to the topics EEW/USR, EEW/ACK, EEW/BUL, and EEW/XML topics of the publishing end. After subscribing to the early warning information packet, it needs to further analyze the early warning information to calculate the local earthquake early warning time and forecast intensity[10]. Then the receiving end can output the corresponding control signal, and the calculation process is as follows:

Local seismic intensity[11]: Reserve one decimal and display as an integer.

$I = I_0 - 4.357\log10(D / 10 + 1.0)$

I_0--The epicenter intensity;D--hypocentral distance,units:km

Local early warning time:units: second,When $t \geq 0$, there is warning time; when $t \leq 0$, there is no warning time. $t = D / 3.55 - (T_{now} - T_{eq})$

D--hypocentral distance,units: km;T_{now} means present time;T_{eq} means earthquake time

Local intensity is judged after the early warning information is processed by the receiving end. When I exceeds the set threshold, warning output will be conducted. The warning output includes: 1) Popup window warning of video output interface. Different warning levels are indicated by different color blocks; 2) Sound warning. Different warning levels adopt different warning sounds, accompanied by countdown sound. 3) GPI0 warning. Different warning levels conduct different GPIO warning control.

4. The Delay Test of Early Warning Information Push Platform

For the early warning information push, time delay is one of the most important indicators to be considered. The time delay test is mainly to test the timeliness of early warning information handling, processing and publishing. This test mainly statistics the delay distribution and the delay difference under different network conditions.

The tests are conducted on both the LAN and Internet. MQTT SERVER is deployed on LAN server and Ali cloud server respectively. The intensity instrument is connected to two servers in the passive mode to release information. Two WRT-02 early warning receiving terminals are connected to two servers for information subscription, and all devices are clock synchronized through NTP.

The total time delay T refers to the time when the intensity instrument is triggered to the warning is sent by the early warning terminal. Its source is shown in table 1:

Tab1. Time-delay Source Analysis of the Early Warning Information Push Platform

Number	Description	Computing method
T_1	Intensity instrument trigger(time T_{1a})to the early warning sent by the early warning terminal(time T_{1b})	T_{1a}-Read the trigger time of the intensity instrument;T_{1b}-Read the publishing end time of the intensity instrument $T_1=T_{1b}-T_{1a}$
T_2	The time for MQTT SERVER to obtain information, mainly comes from network delay	T_{2a}-Read MQTT SERVER information $T_2=T_{2a}-T_{1b}$
T_3	Client subscription information time, mainly from network delay	T_{3a}-read clients' information $T_3=T_{3a}-T_{2a}$
T_4	Client information processing time	T_{4a}-Read the warning output information $T_4=T_{4a}-T_{3a}$
T	The total time delay	$T=T_1+T_2+T_3+T_4$

After 10 tests, the overall time delay of the information push platform is less than 0.5s on the LAN and less than 1s on the Internet, which meets the requirements for the second level of releasing earthquake early warning. This platform uses one receiving terminal. The delay will increase in the case of high concurrent client connection. However, due to the limited number of early warning messages, the delay time has little impact in the case of stable connection[12]. Besides, MQTT SERVER distributed deployment can be adopted to further improve the system performance and reduce time delay.

5. Conclusion

In this paper, the hardware equipment and software platform independently developed by the team are used to build the end-to-end platform of the earthquake early warning information push system, and the publishing, processing, subscription and warning output of earthquake warning information are completed. The overall delay of the system is less than 1s. The national intensity rapid reporting is similar to the early warning project information service overall structure, but more complex. It is Mainly reflected in: Big data comprehensive processing of the publishing end to the front-end sensor network, A communication link for multi - network fusion, High concurrency information service objects, etc. The research of this paper lays a good foundation for the team to carry out earthquake early warning information service. The team mainly focuses on optimizing the development of MQTT SERVER and carrying out the pressure test of large concurrent users in the follow-up, striving to realize the commercial application of earthquake early warning information push.

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