RELIABLE AND GEOGRAPHY-AWARE PEER-TO-PEER MULTICAST FOR EARTHQUAKE EARLY WARNINGS

Risa Suzuki*, Koichi Shimizu*, Ken'ichiro Kimura**, Chuzo Tsumura**
Md. Enamul Haque*, Noriko Matsumoto*, Norihiko Yoshida*
** Department of Information and Computer Sciences*
Saitama University
255 Shimo-Ohkubo, Saitama 338-8570, JAPAN
*** Com&Com Inc.*
3-3-7 Tenjin, Fukuoka 810-0001, JAPAN

ABSTRACT

In Japan, the Earthquake Early Warning (EEW) was started for an aim of fending off a major disaster by people's preparation. To get this system more useful in Internet, this paper proposes a new EEW system using peer-to-peer (P2P) networks. P2P networks have an advantage of the load distribution. However, using P2P networks as the infrastructure has some drawbacks: low reliability and transfer latency. In order to solve these drawbacks, this paper proposes the reliable geography aware P2P multicast tree, which can give the certainly and fast warning to all registered users. This multicast tree is periodically improved and maintained its reliability and transfer latency by the autonomous dynamic reconstruction based on the performance of nodes. Additionally in this phase, the geographical element is evaluated because of the earthquake propagation mechanism. Note that this system is applicable not only to the EEW system but also to every system which need its reliability and transfer latency.

KEYWORDS

Peer-to-Peer, Earthquake Early Warnings, Reliability, Transfer Latency, Geographical Locality

1. INTRODUCTION

Japan is one of the countries with the highest risks for major earthquakes. To reduce their damages, Earthquake Early Warning (EEW [Japan Meteorological Agency]) began in 2006 by Japan Meteorological Agency. The organization has many seismographs across Japan country. Once any seismograph detects a preliminary tremor of an earthquake, the seismograph sends data to the organization, then based on these data, the organization estimates the magnitude of the earthquake. The organization issues a warning to reduce damages. This system is effective when people recognize the warning before the arrival of the main tremors.

EEW can be obtained through TV and radio and the Internet service, although the Internet service is only for limited users. With the Internet service, the users can get customized information, however this service requires users to prepare dedicated terminals and software. The client-server model is the easiest way to establish EEW systems on the Internet. However, this model has drawbacks of load concentration on the server, and it is expensive to handle the server overload. Hence, this research aims at constructing a load distributed transfer system. This paper shows a new approach of the multicast with a peer-to-peer (P2P [Miller, 2001]) network. Some streaming services with P2P multicast have already been achieved [PeerCast P2P Broadcasting; SHARECAST2Plus]. In a P2P network, nodes act as both data senders and receivers, and data is delivered to all the nodes by data relay autonomously.

In the EEW system's application, fast transfer is needed. We do not have much time after the EEW announcement before the arrival of main tremors; actually it is almost several seconds or a few tens of seconds. In order to satisfy reliability and fast transfer, a streaming multicast tree is constructed beforehand in this system. For the improvement of reliability, the connections with multiple parent nodes are established. For the improvement of transfer latency, periodical reconstruction is repeated based on the performance of nodes to keep the optimal load balance in the streaming tree. The periodical dynamic reconstruction adjusts the number of child nodes based on the performance difference [Shimizu, 2009]. Additionally, an earthquake has the geographical locality in its propagation. Using this feature, geographical clusters are formed in the streaming tree, thus the system can announce the local information or select the region where the earthquake is related [Suzuki, 2009].

Section 2 shows the streaming tree model, and Section 3 describes improvement of reliability. Section 4 explains improvement of transfer latency. Then, Section 5 proposes tree construction based on geographical locality. Section 6 shows some experiment results. Finally Section 7 is concluding remarks.

2. STREAMING TREE MODEL

In our proposal, nodes in the streaming tree can be categorized to three types as follows:

Central server: This server is the root of our networks. This server has two main duties. One is to manage registration of all nodes. Central server has a "node table" whose purpose is to manage of all the nodes. The other is to receive the earthquake data from Japan Meteorological Agency, deliver it to Regional servers, and to trigger the tree reconstruction.

Regional servers: This server is placed at each geographical region to optimize the tree using the rough regional knowledge. Regional servers receive data from Central server, and deliver it to directly connected Normal nodes. Every Regional server has a "child table" whose purpose is to manage child nodes.

Normal nodes: This node is a PC owned by a registered user. Normal nodes have multiple parents and children nodes respectively, and when they receive data from any parent, they transfer the data to the children. Every Normal node has a "child table" and a "parent table" whose purpose is to manage nodes connected to it. In addition, Normal node has a "brother table" whose purpose is reconstruction.

In an implementation on a real network, the service provider would prepare Central server and Regional servers, therefore we assume these two types of servers never disappear. On the contrary, Normal nodes can participate and disappear on demand without any restrictions. Notice that the periodical reconstruction involves only Normal nodes.

Figure 1 illustrates a schematic figure of the layered structure model. In this layered structure, a Normal nodes layer connecting to Regional server directly, is called "1st layer", the layer under the 1st layer is called "2nd layer", and so on.

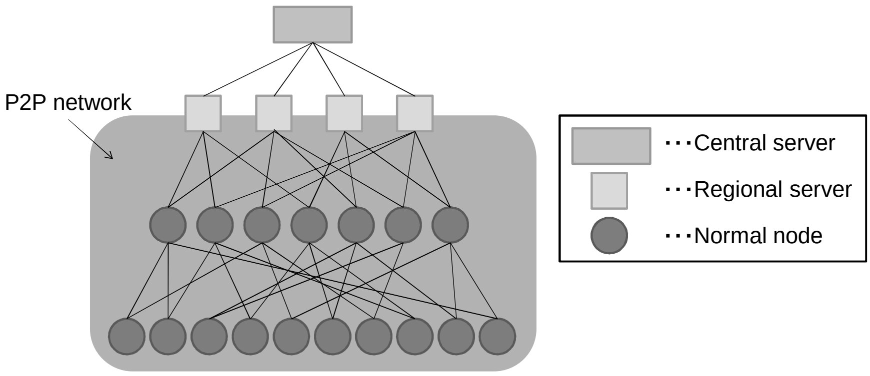

Figure 1. Streaming tree model

3. IMPROVEMENT OF RELIABILITY

In this system, Normal nodes can disappear at any time as in P2P networks. In order to assure the connectivity, the streaming tree is designed to connect with multiple parent nodes. Thus, Normal nodes can acquire the required data from other nodes even if one of the parent nodes disappears suddenly.

3.1 Participation Phase

This system performs the newcomer participation procedure by using some packets as follows:

1) *JoinRequest*
The newcomer, who wants to participate in this streaming tree, demands its parent nodes to Central server by sending this packet. The newcomer tells its own information to Central server.

2) *JoinReply*
Central server registers information of the newcomer to its "node table" and determines multiple parent nodes, which are in the same layer, of newcomer. This determination is based on the "node table". Then Central server replies information of parent nodes to the newcomer.

3) *Hello*
Based on the JoinReply packet, the newcomer sends packets of this type as requests for connection to selected multiple parent nodes.

4) *HelloReply*
Normal node (or Regional server), which receives Hello packet, sends an acceptance packet to the newcomer. The information of the newcomer is added to its "child table".

5) *FinishJoin*
The newcomer tells having established a connection to Central server. The information of the parent nodes is added to the "parent table". This procedure is repeated the same times as the number of the parent nodes. Then, Central server registers information of the newcomer's layer to its "node table".

Fig. 2 shows this procedure.

In general, the newcomer is connected to the bottom layer in the streaming tree. The maximum number of nodes in each layer is pre-determined, and Central server arranges the newcomer to put in the bottom layer until the maximum number. If the layer is full, the next layer will be formed.

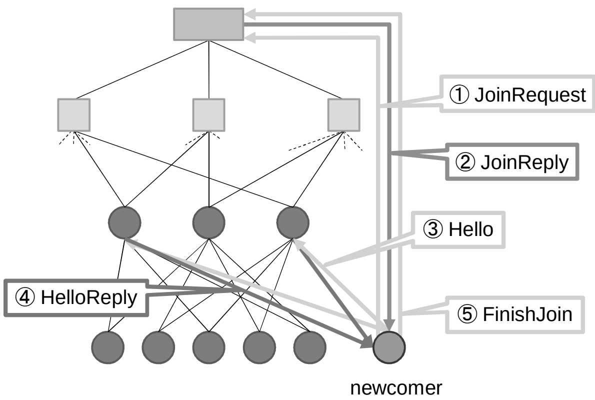

Figure 2. Node joining phase

3.2 Node Leaving Phase

When a Normal node is going to disappear from the streaming tree, it can notify to both its parent nodes and children nodes beforehand. On the other hand, if all of the connection to parent nodes is unavailable, the isolated Normal node sends a request to Central server to get new parents.

4. IMPROVEMENT OF TRANSFER LATENCY

On our streaming tree, the data is transferred through some nodes, so it is necessary to scheme against transfer latency. The delay in transfer process occurs at each node, so balancing of the streaming tree is important. In this case, "balance" does not mean the assignment of equal number of child nodes on all nodes as like data structures [Aho et al, 1983]. In P2P networks, there is performance difference between each node so that this difference must be considered at the balancing. In this paper, the performance value is defined as the below points: throughput, communication band, and the number of child nodes. High performance value means that the node can have many child nodes.

4.1 Tree Reconstructing Phase

Dynamic reconstructions are performed periodically to adjust the balance of the streaming tree. This phase is triggered by a Reconstruction packet and proceeds as follows:

1) Central server sends the Reconstruction packet to Regional servers.

2) Regional server makes a new child table for reconstruction. This table includes the information of some child nodes chosen at random. Regional servers transmit the packet with the table to its own children nodes.

3) The nodes in the 1^{st} layer register the table information named "brother table". The node makes a new child table in the same manner as Regional server and a new table of reconnection candidates from its own brother table. The node transmits the tables to its own child nodes.

4) The nodes in the 2^{nd} layer begin the process of reconstruction, namely change of parent nodes. Then in the same manner as the nodes in the 1^{st} layer, the nodes in the 2^{nd} layer transmit the tables.

All the nodes in the following layers perform reconstruction process in the same manner as the 2^{nd} layer.

This reconstruction part, which means changing a parent node, is not applied when the below two conditions meet, so as not to make the tree unstable: (1) the average of its parents' performance values is more than a certain threshold, and (2) the difference between the performance values of an uncle node and a parent node is less than a certain threshold. By repeating this reconstruction, the balance of the streaming tree is adjusted.

4.2 Performance Value Updating Phase

Normal node changes its own performance value when the number of child nodes is changed. This change is informed to parent and child nodes by itself.

4.3 Tree Repairing Phase

Since Normal node may disappear at any time, the number of nodes in a layer may decrease under a certain threshold value. In such cases, some nodes under the layer are promoted to the layer.

5. TREE CONSTRUCTION BASED ON GEOGRAPHICAL LOCALITY

Earthquakes have geographical dimensions. This geographical dependence can be used to decide where to transfer EEW. Therefore in this system, the streaming tree has geographical clusters. Additionally in the clusters, this system adds some local limited information to EEW.

In the participation phase, each Normal node registers the latitude and longitude as the geographical information directly or indirectly. Based on the geographical distance calculated from this information, the nearest parent nodes are selected, and then the streaming tree gets the geographical clusters.

6. EXPERIMENTS

In order to verify effectiveness, namely reliability, transfer latency and the geographical locality of our proposal, some experiments were performed by simulations. The simulation was executed on a virtual network constructed in a PC using the Java language.

6.1 Experiment 1

The first experiment aims at verifying effectiveness of the multiplexing streaming tree. This experiment investigates the transmission success rate. As shown in Table 1, the disappearance rate is changed from 0.1% to 1.0%, and also the number of parent nodes is changed from 1 to 5. In this experiment, the number of repetition is 100.

Some parameters of this experiment are:

- Total number of Normal nodes is 5000.
  (The numbers of nodes at each layer are 200, 300, 400, 600, 1000, 1500, 1000 respectively.)
- The initial performance value of all the nodes is defined randomly from 1 to 10.
- The performance value is decreased 0.5 when the node gets a new child node.
- The threshold of changing a parent node is 1. If the difference of the performance value between the parent nodes and the uncle nodes is over 1, the reconstruction is performed.

The experimental result is shown in Table 1.

Table 1. Transmission success rate

	the number of parent node				
disappearance rate	1	2	3	4	5
0.1%	98.0%	99.4%	99.9%	99.9%	99.9%
0.5%	88.8%	95.9%	98.7%	99.1%	99.4%
1.0%	80.2%	91.2%	96.6%	98.3%	98.4%

In this experiment, the success rate became higher according to the increase of parent nodes. It is verified that the multiplexing streaming tree is effective to improve the reliability.

6.2 Experiment 2

The second experiment aims at verifying the effectiveness of the reconstruction procedures. In this experiment, the simulator calculates the performance value at each reconstruction. The reconstruction procedure is performed 15 times. The other parameters are the same as in the first experiment.

Figure 3 shows the result of this experiment. The vertical axis denotes the variance of performance value, and the horizontal axis denotes the number of the reconstruction.

In this system, the smaller the variance of performance value is the better. With the repeated reconstruction, the dispersion becomes smaller, thus this performance-based reconstruction is effective to balance the streaming tree.

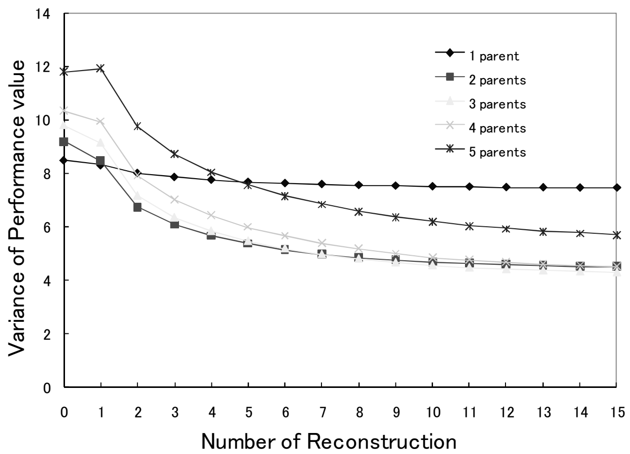

Figure 3. Transition of variance

6.3 Experiment 3

The third experiment aims at verifying the effectiveness of geography-based clusters. In this experiment, the simulator illustrates connection by geographical position using "Pajek [Network/Pajek]". The node is shown as a circle, where its color means the layer as shown in Table 2. Note that, in these figures of the result, the connections are shown only one parent node, which has the highest value, to keep visibility.

Figure 4 (left) shows the result with performance factors considered only. In this figure, there are many connections to make the network more complex. On the contrary, Figure 4 (right) shows the result with geographical nearness considered. The complexity of the connection is reduced, so this mechanism works effectively to make the geographical cluster.

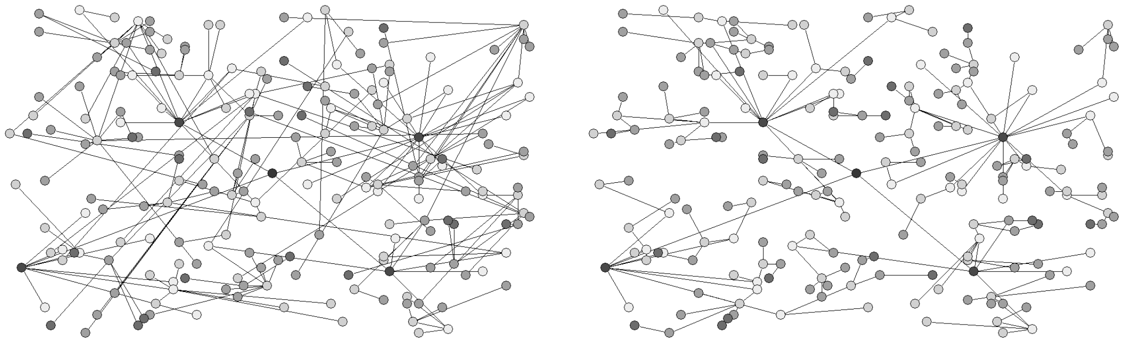

Figure 4. Network without geographical properties considered (left), and with geographical properties considered (right)

7. CONCLUSION

This paper proposed a reliable and geography-aware P2P multicast for EEW with performance-based reconstructions and multiple connections. Through some experiments, it was shown that reliability, transfer latency and the geographical locality can be improved by the performance-based multiplexing streaming tree and repeated reconstructions. Hence, this system satisfies the necessary requirement for EEW. It is left as a future work to fix performance values of nodes in a real network.

REFERENCES

Aho, A. V. et al, 1983, *Data Structures and Algorithms*, Addison-Wesley Publishing Co. Inc., Reading, USA.

Japan Meteorological Agency: http://www.jma.go.jp/jma/en/Activities/eew.html

Miller M., 2001, *Discovering P2P*, SYBEX Inc., Alameda, USA.

Network/Pajek: http://vlado.fmf.uni-lj.si/pub/networks/pajek/

PeerCast P2P Broadcasting: http://www.peercast.org/

SHARECAST2Plus: http://scast.tv/sc2plus/index.html *(in Japanese)*

Shimizu K., 2009, Peer-to-Peer Multicast Tree for Earthquake Early Warnings, Master Thesis, Saitama University, Saitama, Japan *(in Japanese)*

Suzuki R., 2009, Geography-Awareness in Peer-to-Peer Multicast for Earthquake Early Warnings, Graduate Thesis, Saitama University, Saitama, Japan *(in Japanese)*