Peer-to-peer (P2P) Earthquake Warning System Based on Collaborative Sensing

Eduard Heindl
Business Informatics
Furtwangen University
Germany

***Abstract*- We describe a completely new concept of earthquake warning. The collaborative system is based on distributed computers that are interconnected by a network like the Internet. Modern computers may have multiple sensors to detect movements. These sensors where integrated to detect a shock movement before the hard disk may be hurt. Another sensor for movement is the hard disk itself, due to its extreme precise spatial resolution, the readout process is very sensible to minor acceleration of the disk. We can collect all this data to understand the movement of the computer system. Since there are many other sources of acceleration beside an earth quake, we have to use the collective detection of many independent systems. For fast and efficient detection we describe a P2P solution to solve this part. The fact that earthquakes generate different types of movement makes it in principle feasible to predict a major movement a few ten seconds before the disaster happens.**

I. INTRODUCTION

Earthquakes are one of the most disastrous nature threats. Earth quakes killed more than two million people during the twentieth century [1, 2]. Even a warning short before the event could reduce the casualties significantly. We should know for example, that about ten percent of the damage results from fire, a shutdown of gas supply could reduce the fire risk significantly [3]. If there are ten seconds left, people could leave small buildings or move below a desk, which significantly reduces the risk or a lethal injury.

There is a chance to open this small time window, if we have earthquake detectors just at any place where people live. These detectors are our computer systems and the data extraction should work with a cooperative P2P network. P2P networks are well known for tasks like file sharing, telephony and other user communication applications. The power of P2P is not exhausted by this application; we could use some additional features that have been overseen so far. It is a matter of fact, that personal computer systems get more and more sensing capabilities, including a microphone, a camera, shock detectors for hard disc protection, acceleration and position detection e.g. for game control, temperature and fingerprint sensors, and continuously more [4].

II. EARTHQUAKES

Earthquakes are generated by different types of movement within the lithosphere. The center of the primary event happens in a depth from zero to a few hundreds kilometers. The depth depends on the geological situation, as a rule of thumb, most earthquakes are generated within two hundred kilometers beneath the surface.

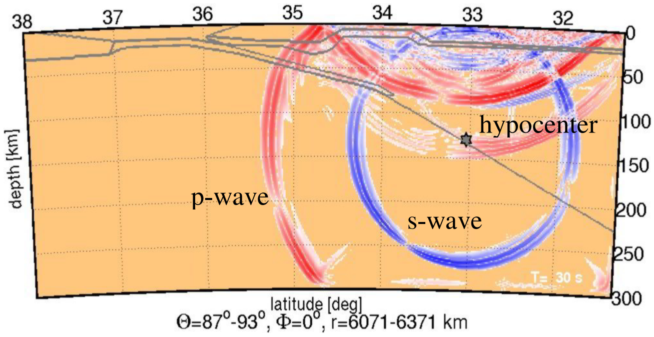

Figure 1. Earthquake wave propagation[1]

If an earthquake happens, different types of waves are generated. The p-waves are pressure waves and have the characteristic, that they have the highest speed, about 8000m/s.

This type of wave is the first signal, that reaches the surface and this waves are usually not destructive. The reason is, the movement is orthogonal to the surface and buildings are well prepared to this type of force.

After the p-wave, the s-wave arrives at the surface, due to the lower propagation speed (about 4000m/s). The time gap depends on the depth of the seismic source. The simulation in Figure 1 gives an impression, how the different types of waves propagate through the earth crust. The first wave, the p-wave (left), started at the stared source in about 130 km depth, hit the surface and is partly reflected. The second wave, the s-wave (circle) just reaches the surface at 33 deg latitude and could in reality generate serious destruction.

III. THE SENSOR NETWORK

The only chance to warn people in the central area of destruction is the availability of a tight sensor network. There are attempts in California, Japan and other places [5, 6], to set up hundreds of seismic sensors to generate a real-time notification. To bypass the problem of this expensive and only locally available network, we try to use already installed sensors that might solve the same problem [7].

The usage of local sensors as shock sensors in laptops or the data error rates of a hard disk have both the disadvantage of a very high noise level. This means that every sensor detects,

[1] http://www.geophysik.ruhr-uni-bochum.de/imperia/md/images/personalhome/katja/ref2_divpcurlsv_30.jpg

due to different reasons, like touching the computer, moving around, and small shakes of a building resulting from traffic, many events that look like a seismic event. To solve this problem, the key is coincidence of the event! To detect these coincidences within a very short time, it is necessary to communicate between as many systems as possible within an area. After the communication the system has to determine, if there was a coincident event.

IV. Calculation of Coincidence

The calculation of the coincidence has to consider, that the p-wave propagates at a speed of 8000m/s within the surface and due to geometric effects even faster on the surface. To solve this problem, every peer has to inform its geographic neighbors if it detects any event. The incoming information is then calculated with different possible geometric situations of the wave propagation.

To understand the situation we use figure 2. If the hypocenter of the earthquake is at P_0, the epicenter is in point P_1, the place, where the earthquake wave reaches the surface of the earth. If a sensor is at point P_2, the signal is delayed. To calculate this delay depending on the radius r, we can calculate:

$$R_2^2 = r^2 + R_1^2 \quad (1)$$

A short calculation results in the delay time ΔT, where v is the speed of a p-wave and R_1 is the depth of the hypocenter.

$$\Delta T = \frac{r^2}{8 R_1 v} \quad (2)$$

If a significant number of peers detect an event within the coincident window ΔT the information is distributed to the next hierarchical level of peers, the consolidating peers see figure 3. They calculate the source of the earthquake and if the signal is still significant, an immediate warning is sent to the participants.

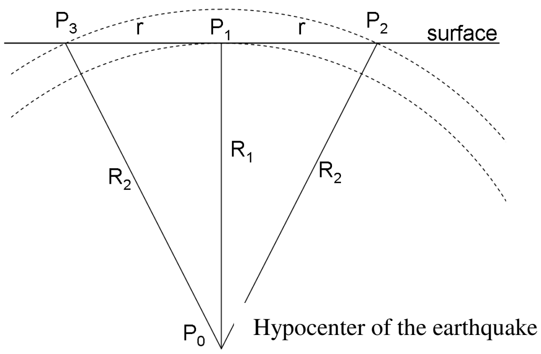

Figure 2. Geometric situation to calculate the coincidence

V. Workload of a Single Peer

Every peer measures continually the sensing device, e.g. the hard disk error rate at every second. If the error rate is beyond a certain limit, and this limit has to be learned by the peer, it sends over the internet connection this information, including place, time and strength of the signal, to its neighborhood. The neighborhood is selected from a list of geographic next peers. The peer listens now to the network and waits for other signals sent by its neighborhood. After reception of a single other event, the peer starts a first calculation of coincidence.

Therefore it calculates the spatial distance between itself and the other sensing peer and the time distance between the two events. If the time distance is within the possible speed of an earthquake wave, the signal is coincident as shown above.

The workload for the measurement seems small, as there is only a single operating system request for one set of sensing data within a second. In a standard environment, the rate of shaking events should be very small, except for laptops on the move. In this case, the sensor should detect a moving situation and not communicate this to other sensors for a while. If the system is quiet again, the sensing should continue.

The communication bandwidth is very small, if the peer has learned how strong a significant signal is. The absolute number depends on the environment, if a peer is in a very quiet environment, it might only detect every day or less a significant signal, if it is within an office building with lots of vibrations it might send every few minutes a detected signal.

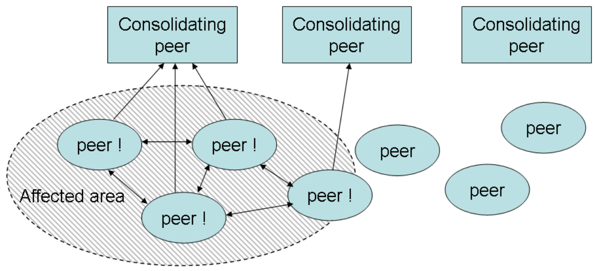

Figure 3. Peer to Peer network

VI. Network Structure

There are many peers with local interconnections. In the case of significant coincident signals this information is submitted to a consolidating peer. Figure 3 shows the activity within an event.

First, some peers in the affected area detect a signal (peer signed with “!”). Immediately, they communicate with each other and send, after detection of coincidence, the signal to their consolidating peer. The left consolidating peer can now decide, if a warning and other actions are necessary. The consolidating peer in the center did not receive enough signals to alert; the right one didn’t receive any signal.

VII. Conclusion

It is feasible to build a global earthquake warning system based on a peer to peer network. The distribution of the software will be fast, if the participants of the system receive the warning first. After the implementation of the first generation of this system, a lot will be learned how the signals appear and when a real alert should be given and hopefully, a lot of lives could be saved.

REFERENCES

[1] USGS, *Earthquakes with 1,000 or More Deaths since 1900,* http://earthquake.usgs.gov/regional/world/world_deaths.php

[2] T. Groeve, and D. Ericsson. *An evaluation of the performance of the JRC Earthquake Alert Tool,* May, 2005, JRC, http://dma.jrc.it-/services/gdas/Performance_of_Earthquake_Alert_Tool.pdf

[3] *Examples of Response to an Earthquake Early Warning, Japan Meteorological Agency,* 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100-8122, Japan, http://www.jma.go.jp/jma/en/Activities/eew2.html

[4] Sylvie Barak, *Earthquake-predicting laptops could save lives, the Inquirer,* 2 April 2008, http://www.theinquirer.net-/inquirer/news/351/1029351/laptops-give-early-warning

[5] Allen, M. R., Kanamori, H., *The Potential for Earthquake Early Warning in Southern California*, Science 2 May 2003, Vol. 300. no. 5620, pp. 786 - 789

[6] Perlman David *(2007), California's earthquake warning system lags* those in Europe, Japan, http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2007/12/11/MN4OTRN8S.DTL&type=printable

[7] Heindl, E., *Erdbebenwarnsystem mit verteilten Festplatten im Internet,* patent claim European Patent Office, PCT/EP2007/009514