Crowdsourcing an Earthquake Early Warning System for the Indian Subcontinent

Abdul Aleem [1], Paul George [2], Prasanna Natarajan [3], Anirban Mondal [3], PhD, and Girish Agrawal [1], Ph.D., P.E., G.E., M.ASCE

[1] Dept. of Civil Engineering , [2] Dept. of Electrical Engineering , [3] Dept. of Computer Science and Engineering : Shiv Nadar University , Dadri , India

The Costs of Earthquakes

Date	Earthquake	Moment Magnitude	Deaths (approx.)	Injuries (approx.)	Total Damage (approx.)
April 25, 2015	Nepal Earthquake	7.8	8964.	21952	$10 billion
October 8, 2005	Kashmir Earthquake	7.6	86,000–87,351	69,000–75,266	$5 billion
December 26, 2004	Indian Ocean earthquake (Tsunami)	9.1	230,000–280,000	500,000	$15 billion
January 26, 2001	Bhuj Earthquake Gujarat	7.7	13,805–20,023	1,66,800	$1.5 billion

Table 1. Major earthquakes impacting Indian Subcontinent

- **57%** of the land surface in India is vulnerable to Earthquakes
- By 2050, Around 200 million city dwellers in India will be exposed to high risks from earthquake.

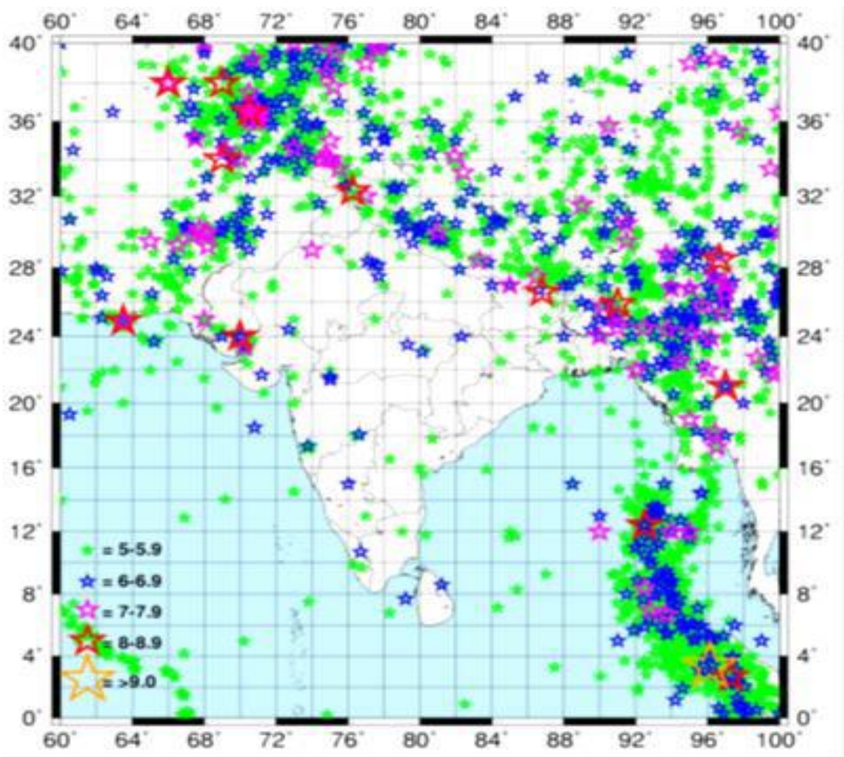

Figure 1. Earthquakes (M>5) in the Indian Subcontinent

Earthquake Early Warning Systems

Earthquake Prediction – NOT POSSIBLE

- Seismologists are still in the early stages of understanding earthquake processes

Earthquake Prediction "seems to be the Alchemy of our times"

(Robert J. Geller, Professor of Earth and Planetary science, University of Tokyo)

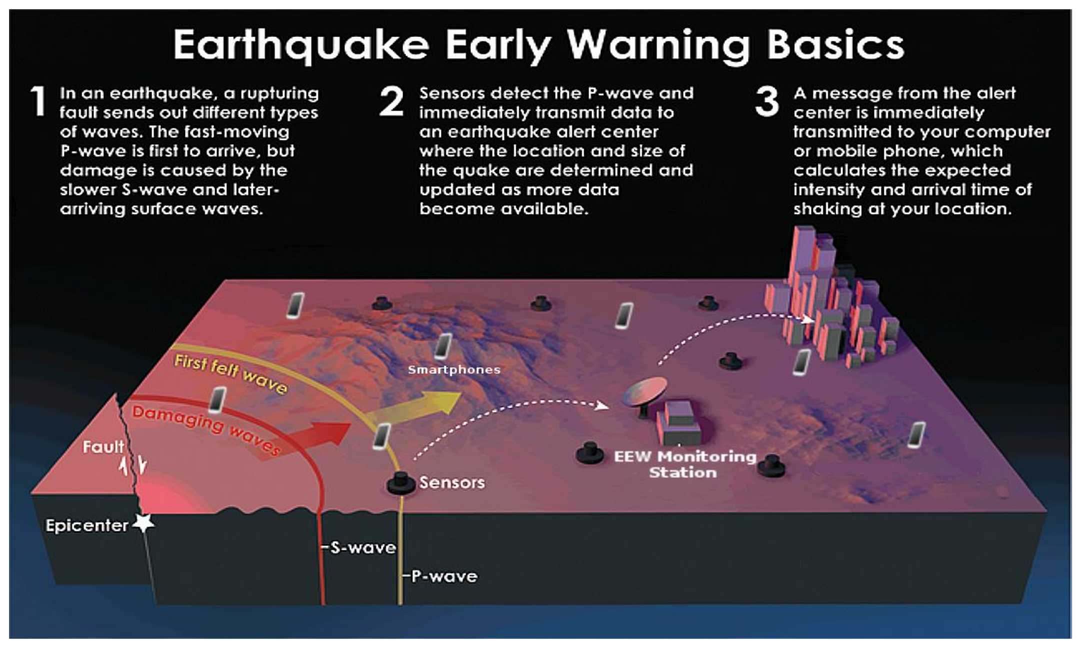

Figure 2. Working of EEWS (Adapted from USGS)

- Earthquake Early Warning System (EEWS) describes real time earthquake information systems, which can provide warning before the ground starts shaking significantly.
- The warning time ranges from 10 seconds to 120 seconds depending upon the relative distance between the earthquake source, the locations of the sensors, and the area at risk.

Constraints in Indian Setting

- This recommended seismic station density for India is a minimum of 2,560 stations. One seismic station for every 400 sq km.
- The cost of such a system will be in hundreds of million dollar which is not feasible for a developing country like India.

	California	Japan	India
Number of Seismic Stations	377	1089	82
Area (1000 sq km)	423	377	3200

Table 2. Comparison of Seismic Station Density

Proposed SNU-EEW Systems

The proposed SNU - EEW system leverages many enabling technologies to satisfy the anticipated density and cost targets. It can broadly be seen as three different components:

1. Ground motion data sources using low cost MEMS sensors .
   - Static – using stationary nodes
   - Mobile – using smartphones
2. Algorithms for detecting P-waves & estimating earthquake features.
3. A central server to poll the sensor network, calculate secondary earthquake features and broadcast warnings.

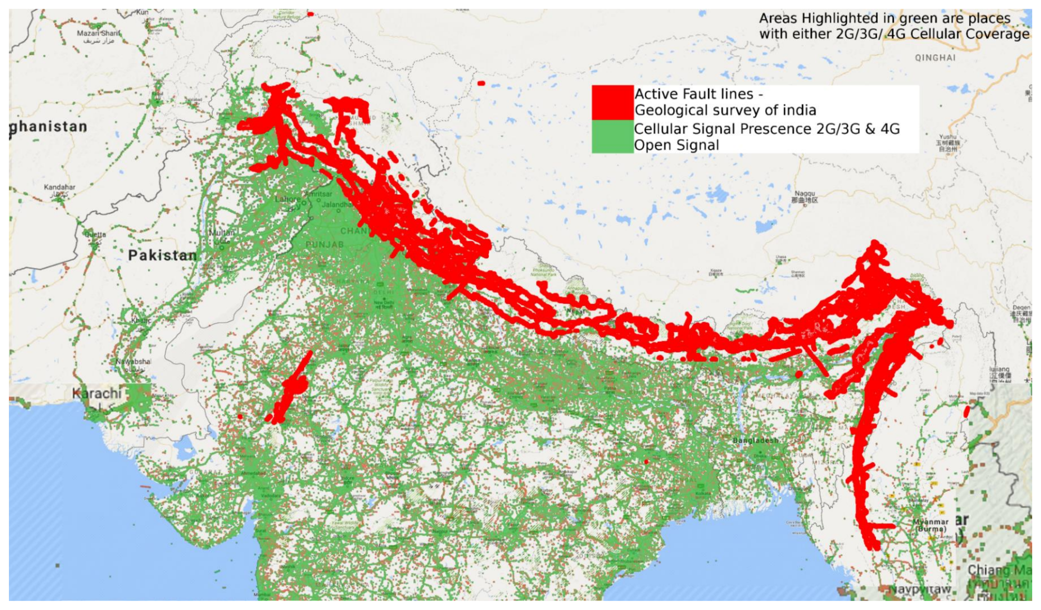

Figure 3. Cellular coverage in the Indian subcontinent

The exponential growth in cellular service coverage in the subcontinent seen over last decade helps mitigate infrastructure costs by having the EEWS to operate on top of it .

Sensor(s)	MEMS Accelerometer , Magnetometer
Accelerometer Sensitivity	+- 3g
Frequency Response	0.7Hz to 2.5 kHz
ADC Resolution	12 bits
Computation spec	Microcontrollers w/ FPU/DSP Cores .
Radio	3G/ 4G LTE – Cellular (Indian Bands) , GPS/ GLONASS / IRNSS
Secondary Storage	On board flash to archive daily data

Table 3. Minimum specifications identified for static modules

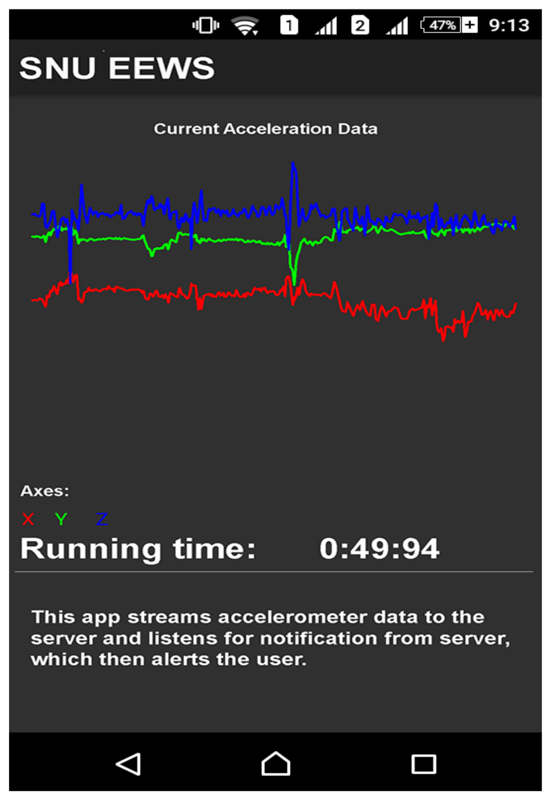

Figure 4. Screenshot of SNU EEWS Android app.

Methodology

- The end devices themselves have a primary classifier that detects a p-wave and sends the estimated earthquake parameter to the server. The server then determines whether or not the local excitation is an earthquake with the help of a polling algorithm.
- Using the τc - Pd on-site warning algorithm developed by Kanamori we find the magnitude and epicentre of the earthquake.

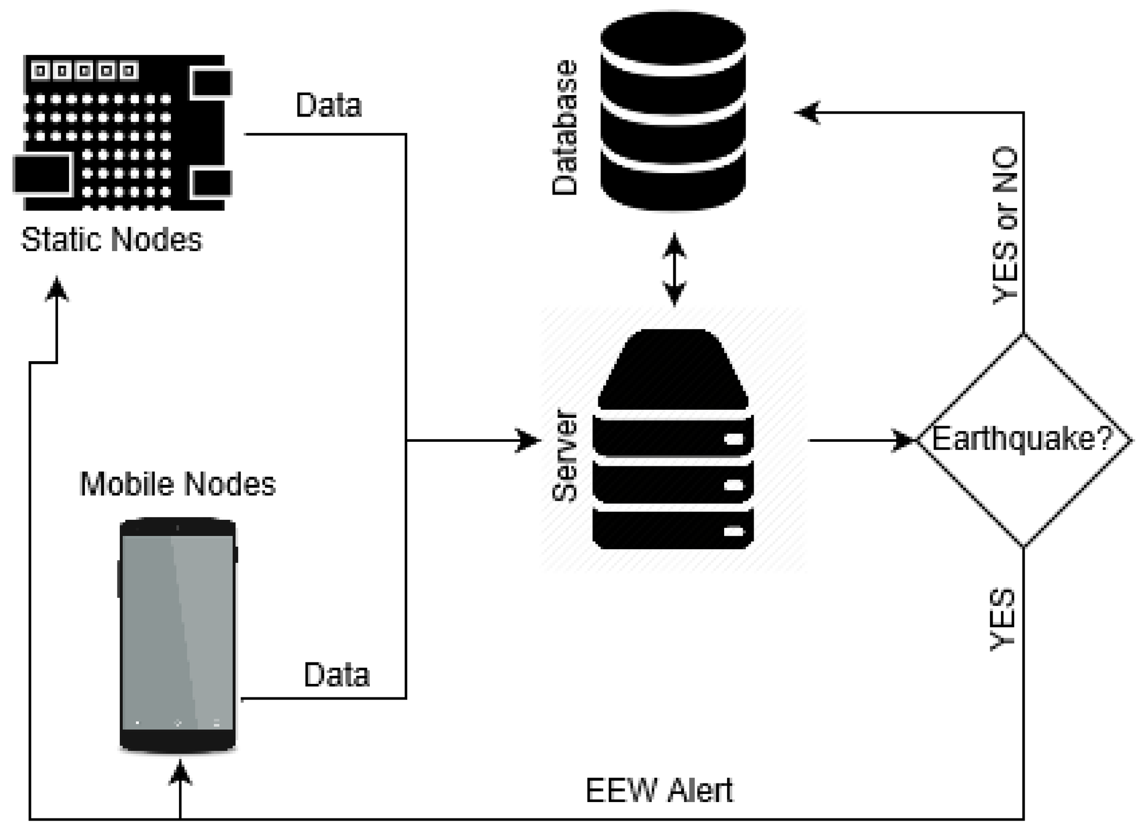

Figure 5. SNU EEWS - Overview of proposed topology

Discussion and Future work

- In the event of a potential earthquake (M>5) originating in the foothills of the Himalayas, a functional EEW system can help in saving hundreds, perhaps thousands, of lives and preventing thousands of people from getting injured.
- Such a system will be a critical part of India's sustainable development goals, to mitigate the impact of natural disasters, and develop resilient, sustainable infrastructure systems.
- The SNU EEW research group is working towards incorporating innovations in time series data classification using Recurrent - Convolutional Neural Networks (R-CNN's) into the system under development, so as to detect P-waves and estimate earthquake features with better accuracy.

References

1. Allen, R., Gasparini, P., Kamigaichi, O., and Bose, M. (2009). "The Status of Earthquake Early Warning around the World: An Introductory Overview". Seismological Research Letters, 80(5), 682-693.
2. Kanamori, H. (2005). "Real-time Seismology and Earthquake Damage Mitigation." Annual Review of Earth and Planetary Sciences, 33(1), 195-214.