P 06

CISN Earthquake Early Warning: Implementation and Testing of the Tau_c-Pd Onsite Warning Algorithm

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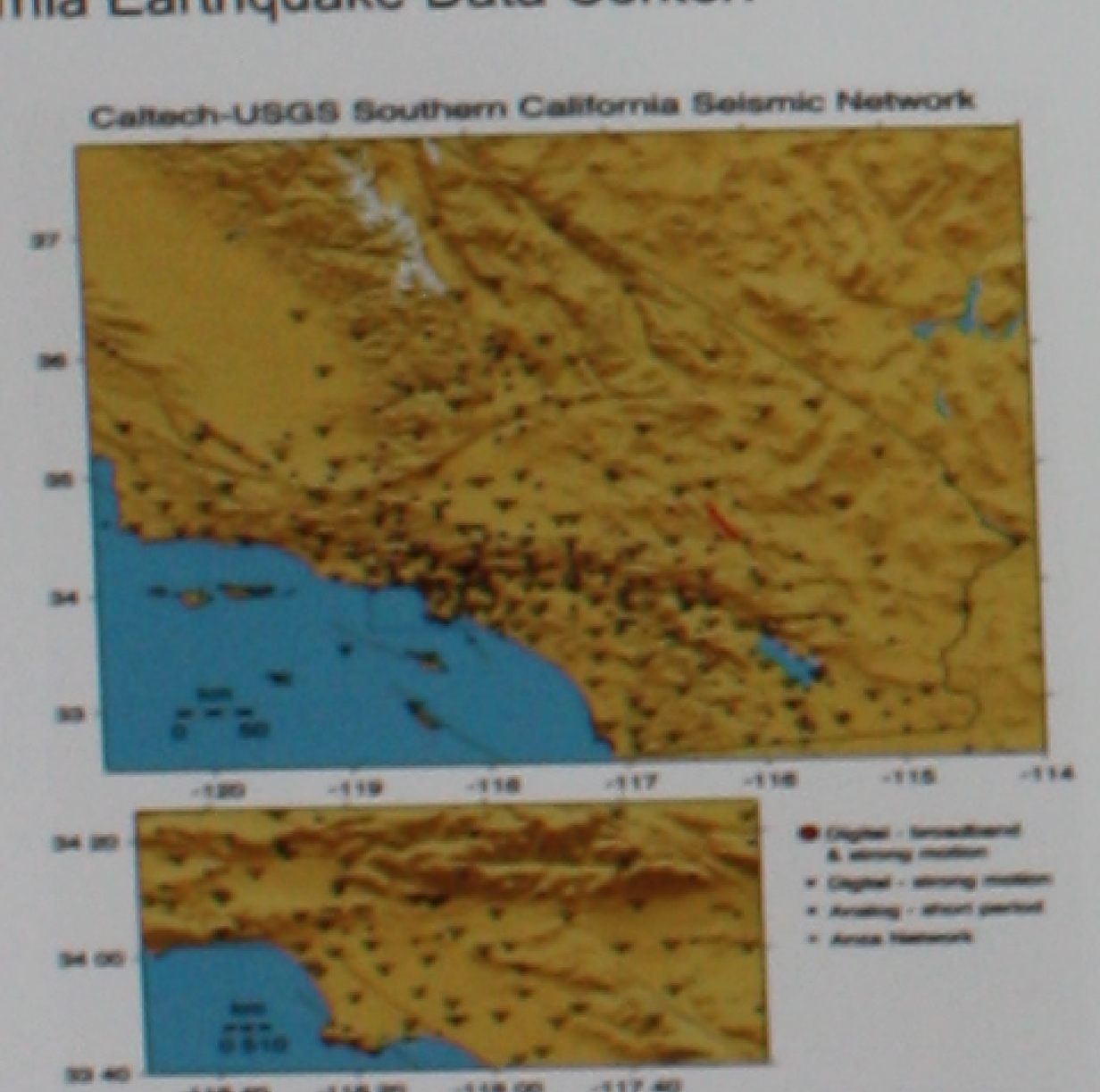
Abstract

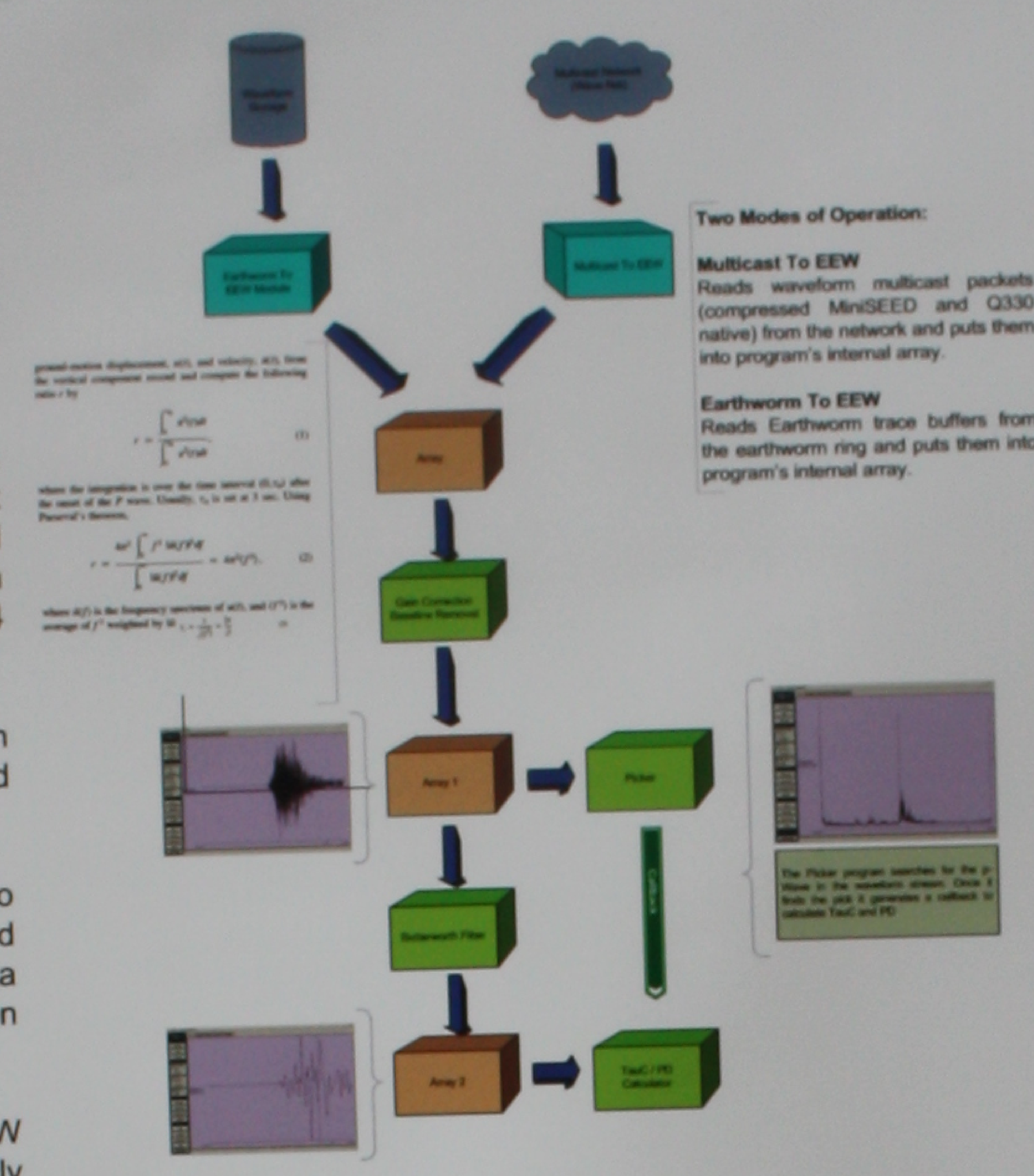
- We have implemented a test bed for real-time testing and enhancement of the Tau_c-Pd on-site warning algorithm (Kanamori, 2005; Wu et al., 2007) for earthquake early warning (EEW) in California using the infrastructure of the California Integrated Seismic Network (CISN).
- The purpose of the EEW test bed is to implement a processing system that provides low latencies for the EEW and superior performance when deployed in a dense network.
- The implementation of the EEW test bed processes the waveform data provided by CISN. The test bed relies on our waveform packet capturing technology and rapid processing within single multi-threaded program. Often, EEW results, i.e. Tau-c and Pd values and therewith estimates on magnitude and peak ground velocity, are available within 4 to 5 seconds after the P-wave arrival at a seismic station.
- The Tau_c-Pd algorithm testing has been operational in Southern California for the last 2-3 years. During this time, we have gathered important performance data.
- We have recently deployed our on-site algorithm testing system at two additional processing sites in northern California (UC Berkeley and USGS Menlo Park). This enables us to process earthquake data statewide using multiple computer systems, databases and notification systems.
- We are working on new tools and technologies to make our EEW development system more efficient. To provide early warning as rapidly as possible is a high priority. A field processor called SLATE will be deployed at selected stations in the CISN network to calculate algorithm parameters on-site to make the system more distributed and fault tolerant. Using this approach, we also anticipate significant performance gains in terms of latency. We are also planning on developing iPhone application for providing prototype alerts to end-users.

About Southern California Seismic Network

- SCSN has been monitoring earthquakes in Southern California since the 1920's.
- Currently, using seismometers at over 396 sites, we monitor ground motion from the U.S./Mexico border north to a line which passes approximately through San Luis Obispo and Big Pine. Of the 396 sites, more than 50 are imported from other seismic networks. Instrumentation includes simple short-period vertical stations, modern broad-band stations, and accelerometers.
- All data are recorded by computers at Caltech. Earthquakes are detected, picked, located and assigned a magnitude in near-real time. Our data are archived and distributed to the researchers and general public by the Southern California Earthquake Data Center.



Software Architecture



Step 0: Retrieve acceleration data from Wave Net and put it in internal Array 1.

Step 1: Remove baseline (using 60 second LTA) and apply gain correction to the acceleration data.

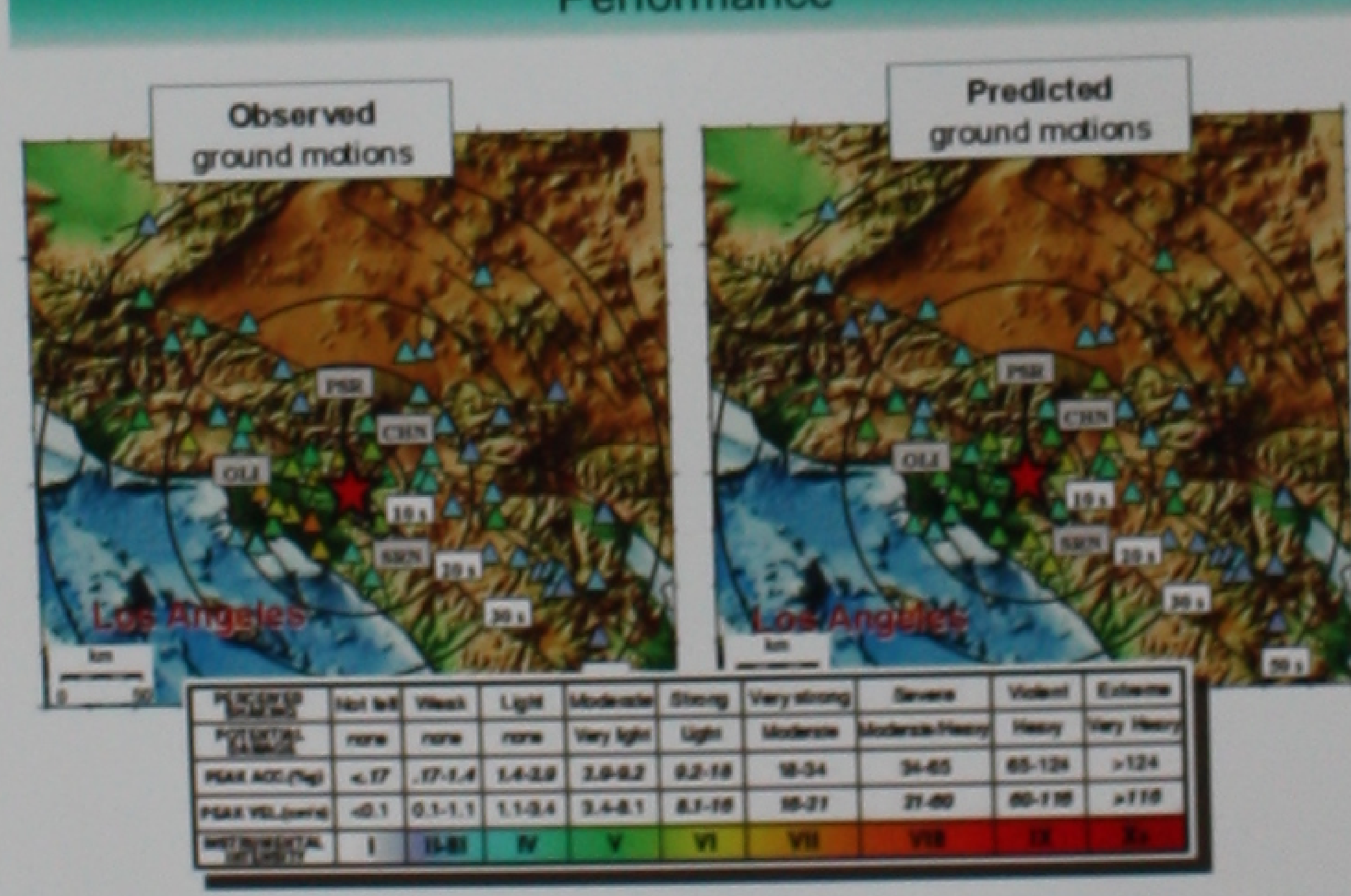
Step 2: Read waveforms from the array and if the data is acceleration waveforms convert it to velocity by doing integration recursively.

Step 3: Apply High-Pass Butterworth filter to the velocity data.

Step 4: Convert data from velocity to displacement by doing integration recursively and write it in Array 2

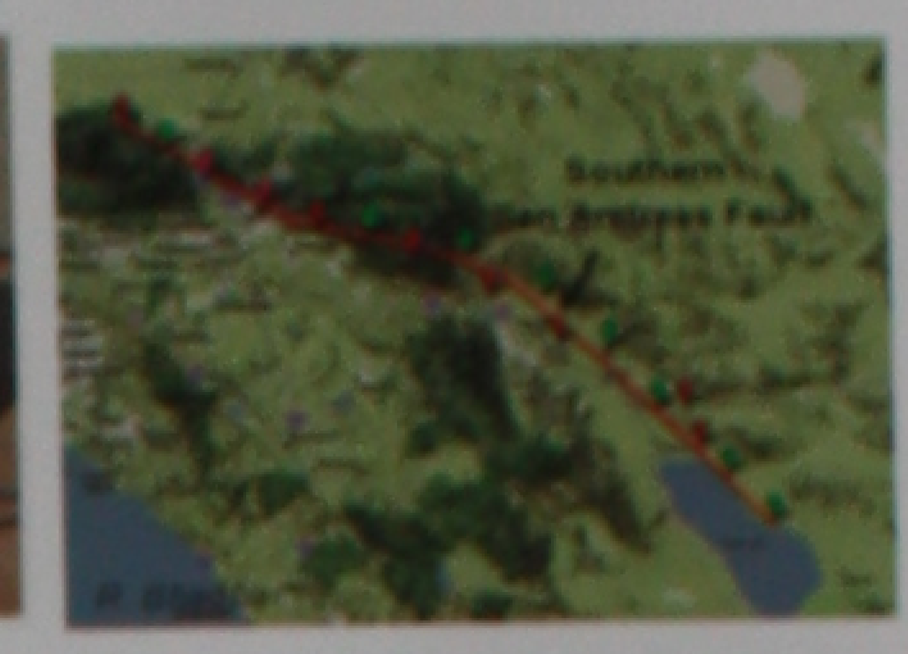
Step 5: When the p-Wave arrives, wait for 3 seconds and retrieve last 3 seconds of data from Array 2 to calculate TauC and PD.

Performance



Distribution of (a) observed and (b) predicted values of peak ground velocity (PGV) at 60 CISN stations triggered by the EEW software during the July 29 2008 Mw 5.4 Chino Hills earthquake.

About SLATE



The Kinematrics Slate Field Processor:

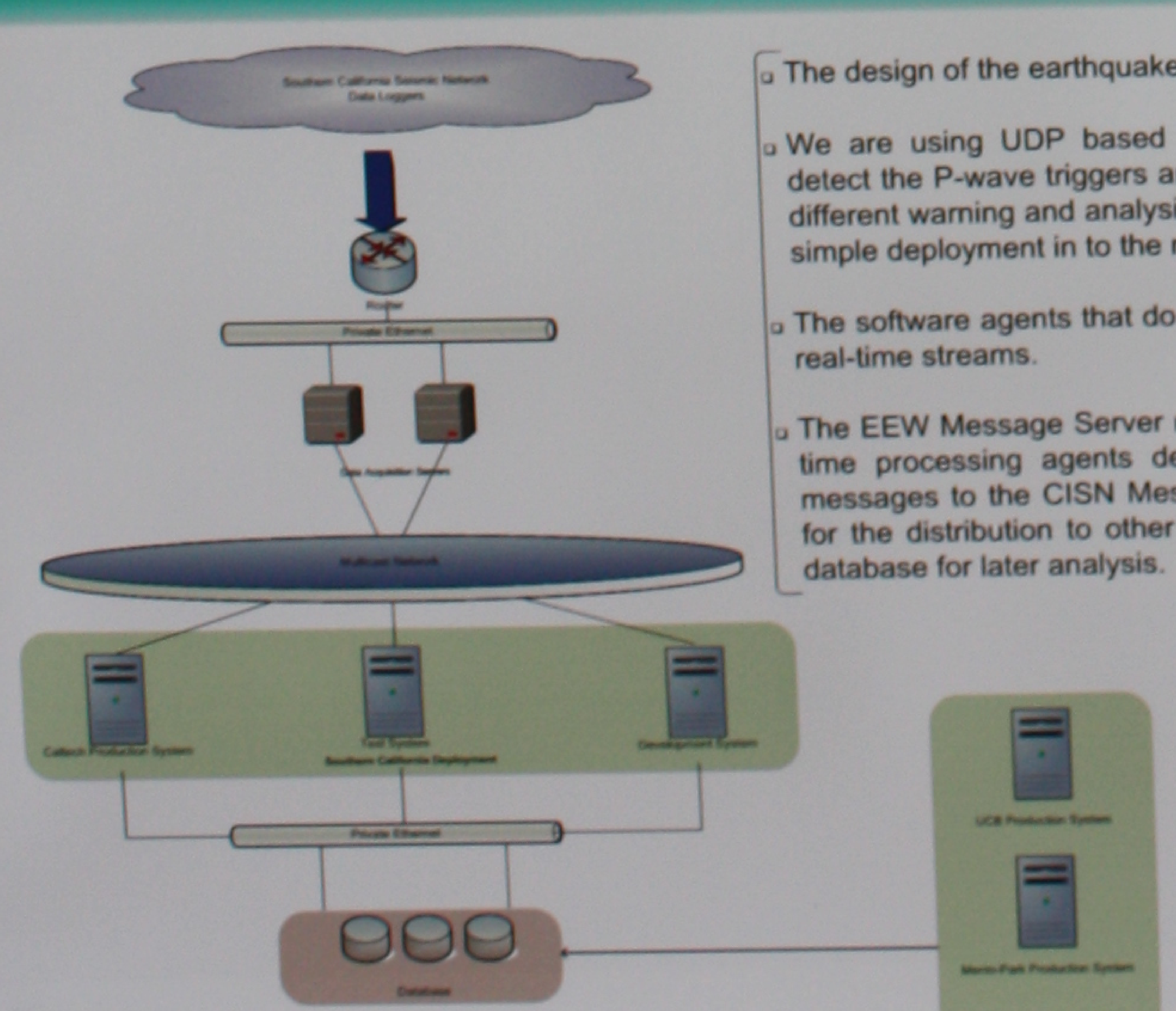
- rugged, low-power, embedded Linux computer
- ARM instruction-set CPU (400 MHz Intel PXA255 Xscale)
- 256MB SDRAM
- compact or SD Flash for persistent storage
- power consumption: 0.4W (idle) to 0.9W (both Ethernet ports active)
- operational temperatures: -20 to +60 Celsius.

- The Kinemetrics SLATE field processor is a linux based system that we are planning to use for our On-Site early warning system.
- We have deployed 20 devices at the stations in the network.
- We have implemented the P-wave detection software module for earthworm system that will run on these devices.
- We are also implementing automated software update system to easily update the software on the devices easily.
- There are many advantages of using the field processor devices for the early warning system.
  - [1] The P-wave detection occurs at the site which ensures low latency and reliability.
  - [2] The processing is distributed in the network.
  - [3] Due to short messages, the communication between the device and the central sever can happen over a low-bandwidth low-latency channels.
  - [4] In case of communication failure, we can store the result of the On-Site algorithm on the device itself for later study.

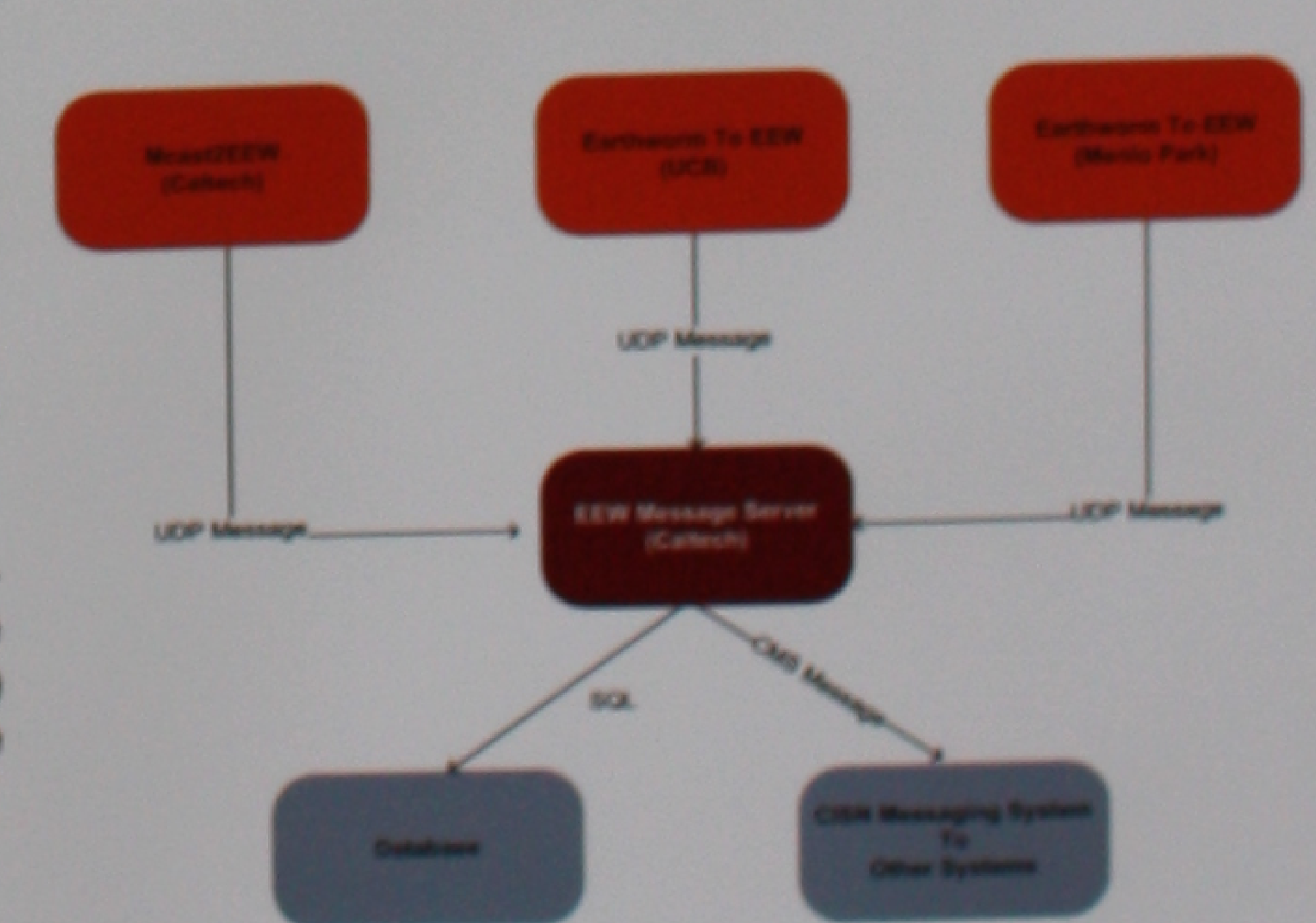
iPhone Application Development

- We are currently exploring the idea of iPhone and/or Google Android application for the Earthquake Early Warning User Agent that will alert the user about the event by providing estimated magnitude, location and quality of the estimates.
- The user agent will be continuously updated about the corrections in the estimates and other information.
- All the information will be provided in as simple graphical elements on the screen.

California Statewide System Architecture



- The design of the earthquake early warning test system is distributed.
- We are using UDP based communication between software agents that detect the P-wave triggers and software agents that forward the message to different warning and analysis applications. The division of the tasks allows a simple deployment in to the network.
- The software agents that do real-time waveform processing are closer to the real-time streams.
- The EEW Message Server receives UDP messages (triggers) from the real-time processing agents deployed in different networks and forward the messages to the CISN Messaging System (Message Oriented Middleware) for the distribution to other applications. It also stores the triggers into the database for later analysis.



Software Deployment

References

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[2] Böse, M., E. Hauksson, K. Solanki, H. Kanamori, and T.H. Heaton, 2009: Real-Time Testing of the On-site Warning Algorithm in Southern California and its Performance During the July 29 2008 Mw5.4 Chino Hills Earthquake, Geophys. Res. Lett. 36, L00B03, doi:10.1029/2008GL036366, 2009.

[3] Kanamori, H., 2005: Real-time seismology and earthquake damage mitigation, Annu. Rev. Earth Planet. Sci. 33, 195–214, doi:10.1146/annurev.earth.33.092203.122626.

[4] Wu, Y.-M., Kanamori, H., Allen, R.M., and E. Hauksson, 2007: Determination of Earthquake Early Warning Parameters, τc and Pd, for Southern California, Geophys. J. Int. 170, 711-717, doi:10.1111/j.1365-246X.2007.03430.x.

CISN California Integrated Seismic Network

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