SEI 03 GeoNet: A Platform for Rapid Distributed Geophysical Sensing

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Overview

The science objectives are to use a rapidly installable wirelessly linked seismic network to measure earthquake or volcano sources in the near field to understand the underlying physics, or in buildings to understand earthquake damage. To accomplish these objectives, we collaborated with Reftek to construct a new generation digital acquisition system (DAS) based on the CENS-developed LEAP (low-power energy aware processing) system and a newly developed low-power A/D converter from Texas Instruments (TI).

In preparation for GeoNet, we have used the Peru networks to test the software including improving Disruption Tolerant Shell (DTS), measurement of radio link quality (ETT), network logging, an embedded web interface based on Emstar for deployment and maintenance, network timing, a new routing protocol that caches the routes across sleep cycles for a fast startup. The Peru network has already been installed and we can add to it GeoNet nodes for further testing and debugging.

The objective is to understand the basic physics of earthquakes and their effects. Presently we can not predict earthquakes. With the information we seek we hope to predict aftershocks and use that information to eventually predict main shocks. Because main shocks at a given location happen about every 200 years, it has been impossible to build up statistics on possible precursors. Modern understanding of the earthquake source is that an aftershock sequence is a time-compressed version of long term seismicity. If there are repeatable predictive behaviors before an event, an aftershock zone is where we are most likely to measure them. By knowing the time and location of a large aftershock, as well as giving warning, we can instrument buildings and infrastructure to measure structural failure during strong shaking.

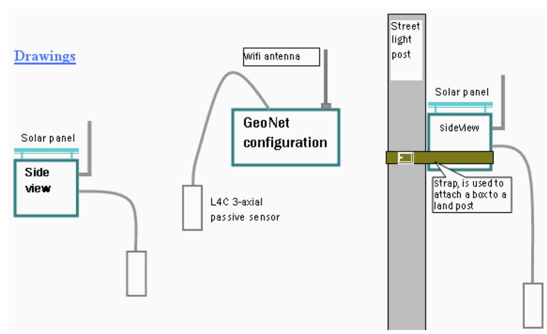

Fig.1. Schematics of possible field instalations.

We propose to develop and install an intelligent wireless seismic network, a 'SeismoScope (inverted telescope)' to make FlexiRAMP recordings of earthquakes and their aftershocks. Our SeismoScope must be flexible to be installed quickly in an aftershock zone after a large event (for example in the west Americas) or, in the interim, in regions with high probabilities of main shocks. It must be made of lightweight components, low power, and radio linked so that the data can be analyzed immediately and (real time) warnings issued. This type of rapid response is termed FlexiRAMP, Flexible Rapid Array Mobilization Procedure. At present permanent network stations are too coarsely spaced to understand the earthquake process. We are missing coherent energy that can be measured if the stations are much closer, for example 1 km apart

The recently developed ETAS (Epidemic Type Aftershock Sequence) model describes earthquakes as a stochastic branching sequence of triggered events. It was used successfully this year, after the April 6, 2009, Friuli earthquake in Italy, to predict where damaging aftershocks would occur, but stations were too few and too widely spaced, to make detailed measurements. Given this new paradigm, after a large earthquake, for example in the western US, Mexico, or Peru (where we have installed networks) we will install the SeismoScope to record the thousands of aftershocks that occur. Very often the largest aftershock in a sequence is 1 magnitude smaller than the main shock, e.g., a magnitude 8 is followed by a magnitude 7. We will use our network to detect how the shocks leading up to the M=7, are distributed in space and time, with the objective of developing ETAS prediction algorithms based on seismicity.

Through CENS, in a multidisciplinary project involving four UCLA Departments, the PIs have designed a novel FlexiRAMP node and have had two built by the leading manufacturer of seismic recorders (Refraction Technology of

Texas) (Fig 2). As well as installing the network across country, once time and locations of aftershock shaking has been predicted, a portion of the equipment will also be installed in buildings and infrastructure. This will provide engineering data on design factors, necessary for buildings to remain operational after earthquakes, that are critical

Figure 2. Seismic node for FlexiRAMP Wireless seismic network delivered by Reftek. We propose a 100 station radio-linked network to monitor earthquakes. The digital system and software is of UCLA (Earth and Space Sciences, Civil Engineering, Electrical Engineering, and Computer Sciences) design Reftek president Paul Passmore and engineer Phil Davidson).

for saving lives and minimizing economic impact.

Approach

We used the Peru networks as testbeds for GeoNet systems software research. The field objective is to have only two separate parts: DAS and a seismic sensor. The DAS would have a solar panel attached on top, battery inside (with external power plug), internal GPS antenna (with a possibility attaching an external one), external N-type connector to attach an antenna. Field installation would involve attaching the box to a post and bury the seismometer (Fig 1). It would then be a node in a wireless network of neighbors, e.g. along a dirt road that could bring event data

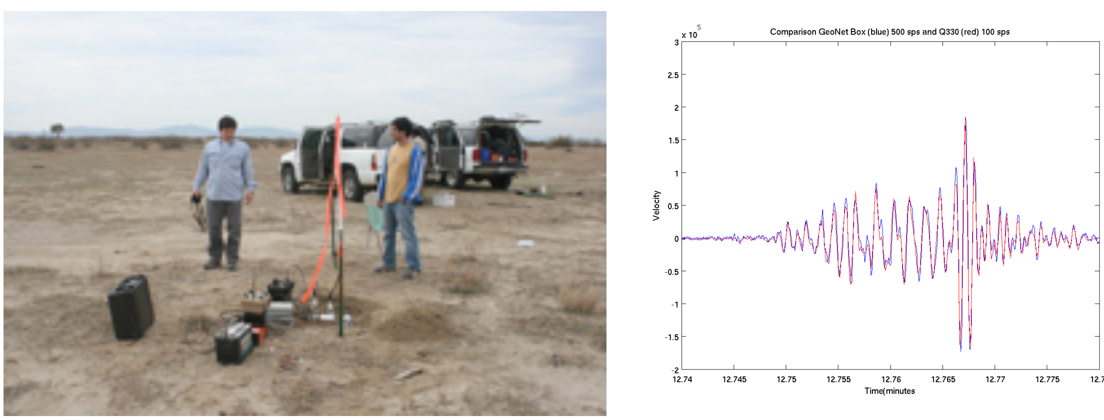

Figure 3. Test at Palmdale of new GeoNet boxes and Quanterra devices used in Peru. The upper figure shows the field layout. The lower figure shows the waveforms match very well.

out in real time, or, in the low power mode, on a duty cycle, e.g., 5 min every hour. The radios would also deliver network time, a backup to GPS.

A prototype of a GeoNet box with modular approach inside. The software design for the seismological community would include CENS networking auto routing component and the low power configuration ability of the hardware. To conserve power the processor will duty cycle between sleep and wake states. The node is based on the Linux operating system, with 802.11 capabilities for wireless networking. Software development is required for array-event detect, network and GPS timing, multi-hopping the data, and near real-time data analysis and modeling. The software system will be based on the infrastructure used in the Peru network. However, the existing software system is not directly applicable because of a number of factors introduced by the application requirements. These include duty cycling, non linear network topologies, array event detect, and the time span of the deployments. We are developing software to deal with these new factors, in particular: sleep schedule aware data delivery, disk space based routing, deployment tools, and integration with Wavescope to enable streaming, network processing, and cooperative event detection.

System(s) Description and/or Experiments

The best experiment for GeoNet is an afterschock deployment, but it could also cover any seismic experiment where rapid deployment is necessary (volcanoes, explosions of opportunity). A pool of identical instruments would be available to either install in buildings or in the field and could be standalone or where appropriate nodes in a wireless network. The objective is to measure strong shaking from the largest aftershock for both science and engineering objectives. The GeoNet/SHM requiremenets have much in common, but there are differences. Building installations do not have access to GPS time, may or may not have power. Field installations, being remote and widepread, need power. Building sensors tend to be active (Episensor). Field installations can have passive sensors, requiring significantly less power.

We are going to test 2 GeoNet stations with passive sensors (L4-C) in the Salton Sea area (California) for a week in Maarch during a gephysics field trip. This will allow us to further improve the case design and user interface. We also will test some units in our Peru network. They will be mixed with high quality broadband Guralp 3T sensors and nodes running DTS software. We will be comparing data quality and the behaviour in a larger network while having the real time access to the sites.

Accomplishments

A number of posters were presented about different features of system (software and hardware) at the AGU-2010 meeting as well as papers published. A contract for Reftek construction was signed and two prototypes were delivered. A successful field test of the GeoNet boxes was conducted at Palmdale for comparison with the Geometics digitizers (Figure 3). The LEAP board has been interfaced in the GeoNet boxes. The GeoNet boxes have been interfaced to cell phone modems. Event detect software has been written. A test is currently underway at the time of a series of explosions in the Salton Trough, in southern California. Dustin McIntire and Igor Stubailo will install the two prototypes linked by Wifi. The data from each will be aggregated and the event detect software will detect events and will send the event data and the catalogue to the CENS computing cloud as well as sending emails with plots of the events and 60 sec data to mobile phones that are on a list.

Future Directions

We will continue working on integrating duty cycling with existing software based used in Mexico and Peru. This includes further developing a robust routing algorithm that can deal with nodes with limited storage space with a complete a centralized method to dynamically schedule duty cycling and transmissions. We will develop software to deal with sleep schedule aware data delivery, disk space based routing, as well as tools for network processing and cooperative event detection. The GeoNet instruments will have application over a wide range of field applications involving wide area networks and low power processing and delivery of event data. They will run on small batteries with a laptop sized solar panel.