Quake-Catcher Network – Client and Server Software

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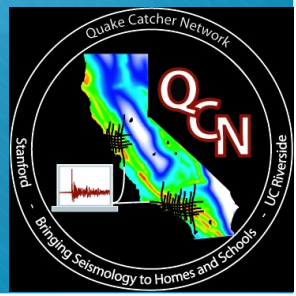


The Quake-Catcher Network

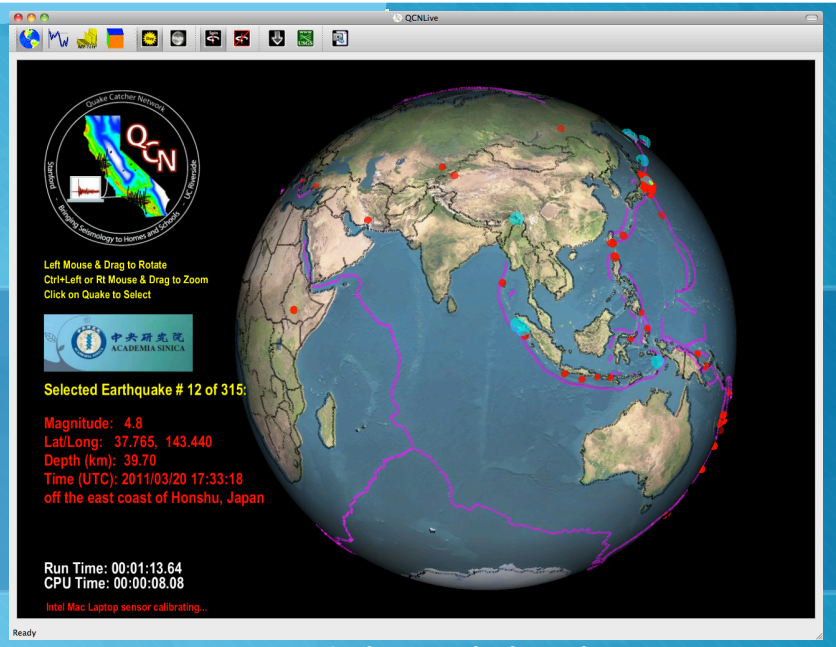
Prof. Jesse Lawrence (Stanford); Prof. Elizabeth Cochran (UC-Riverside)

- Sensors report seismic events (“triggers”) over the Internet to our servers via internal (laptop) or external (USB) sensors
- “Opposite” the usual volunteer computing projects with high computing (100% CPU) requirements
- The sensor monitoring is low CPU, but want to optimize network speed for fast trigger reporting (i.e. earthquake detection)
- http://qcn.stanford.edu

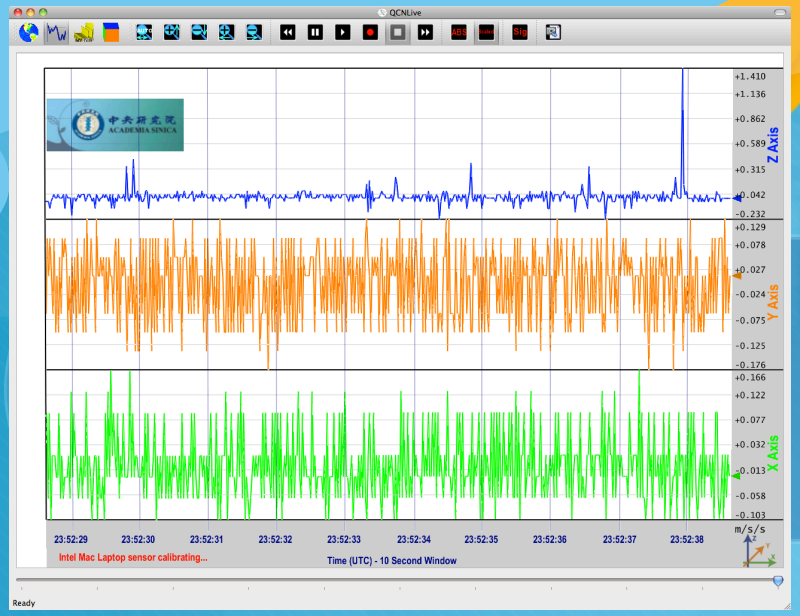
Client Software

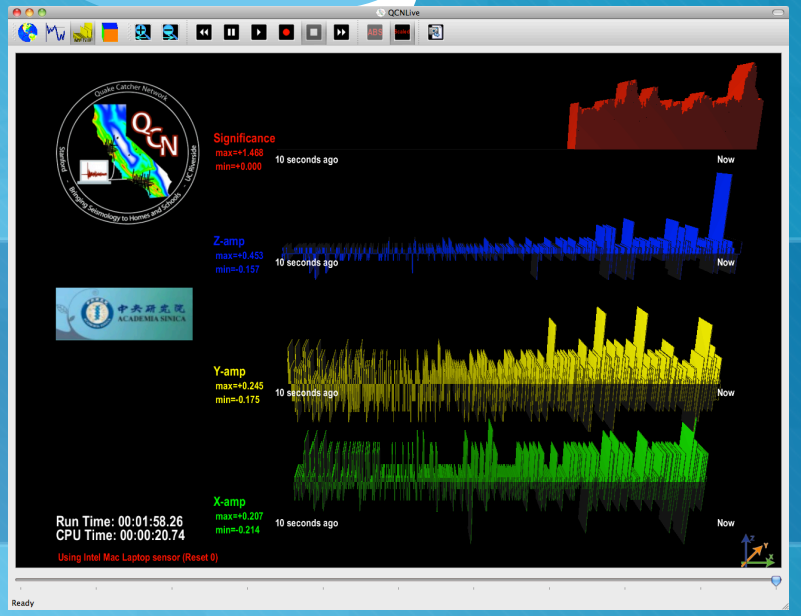
- Really two clients –
  - the standalone QCNLive program – for educational initiatives, or local monitoring (can save continuous stream of sensor data)
  - the BOINC-enabled client for live monitoring and reporting to our servers and earthquake detection if numerous triggers from an area are recorded

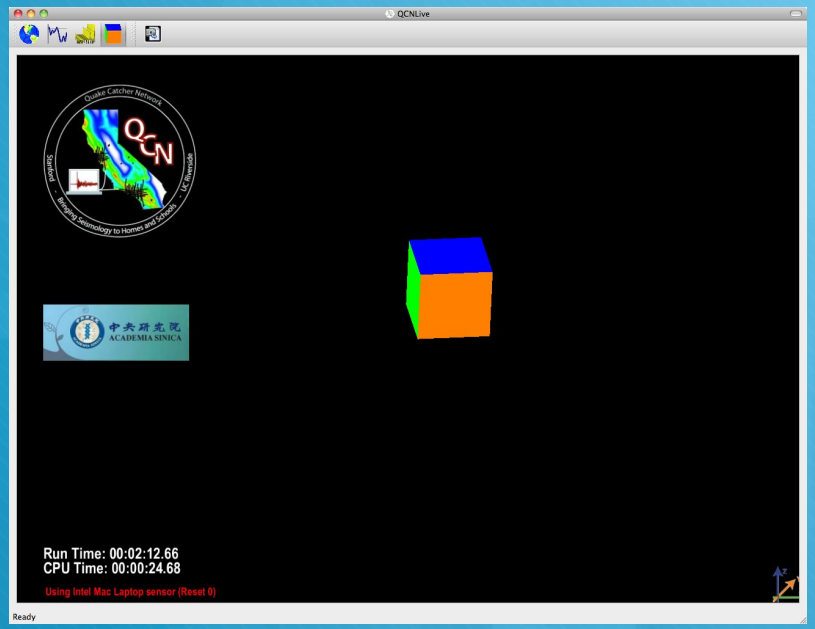
QCNLive

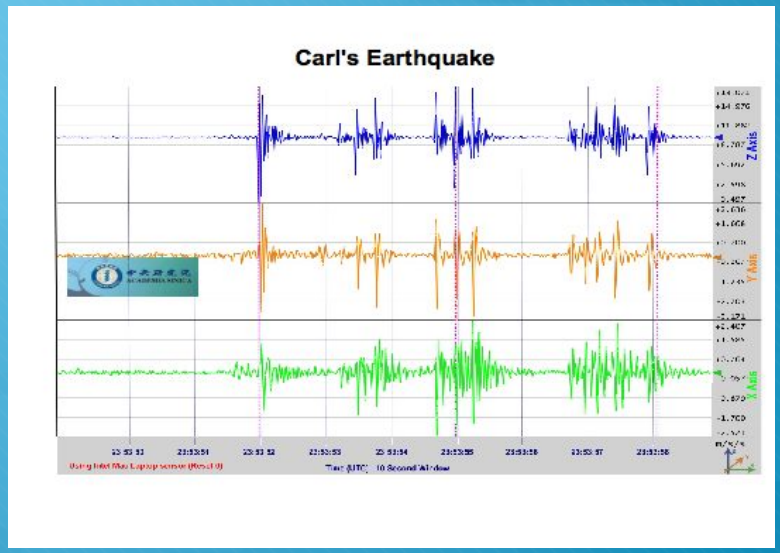


- Based on the QCN/BOINC screensaver with added features for user intervention
- 4 views – quake globe, 2d/3d sensor, shake cube
- Earthquake information updates hourly (or manually)
- Now uses Qt (formerly wxWidgets), C++, cross platform (Windows, Mac OS X, Linux)
- Can “brand” with your school/museum logo
- Freely available: http://qcn.stanford.edu/downloads

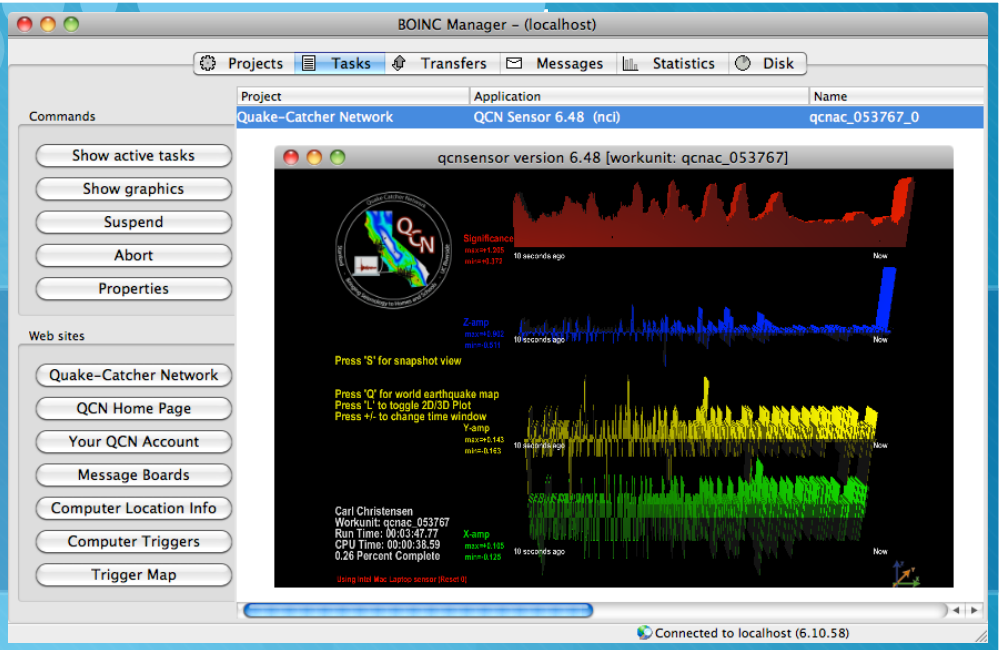

QCNLive
Z Axis
Y Axis
X Axis
Intel Mac Laptop sensor calibrating...
Time (UTC) - 10 Second Window
Ready


QCNLive
Significance
max=+1.468
min=+0.000
10 seconds ago
Now
Z-amp
max=+0.453
min=-0.157
Y-amp
max=+0.245
min=-0.175
X-amp
max=+0.207
min=-0.214
Run Time: 00:01:58.26
CPU Time: 00:00:20.74
Using Intel Mac Laptop sensor (Reset 0)
Ready


QCNLive
Run Time: 00:02:12.66
CPU Time: 00:00:24.68
Using Intel Mac Laptop sensor (Reset 0)
Ready


Carl's Earthquake
Z Axis
Y Axis
X Axis

QCN with BOINC

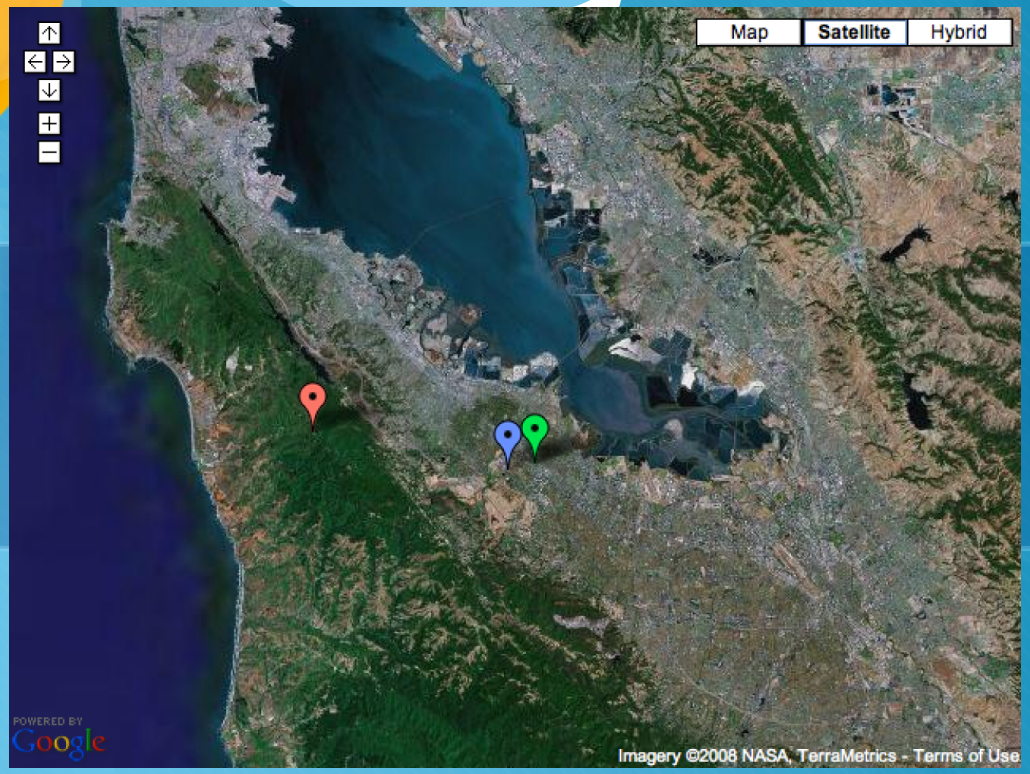


- Runs as “non-compute intensive” (nci) so coexists with full CPU jobs e.g. other BOINC projects
- Easy access to QCN website & location page
- Uses the “trickle” feature in BOINC for reporting potential seismic events (lot of “false positives”)
- User can set to run when idle (laptop esp) or run continuously (they have a mounted, external USB sensor)
- Attach to http://qcn.stanford.edu/sensor

QCN Client Challenges

- Drivers for laptops & external devices
  - Only two laptop styles supported – Mac laptops, and Lenovo Thinkpads (Windows)
  - Manufacturers have been reluctant to allow us access to their on-board accelerometer (for various reasons)
  - Even external USB manufacturers often provide “kludgy” solutions (simulated COM ports over USB) that require much work to integrate into QCN

Location



3-step Location System:

- Estimate location based on last known router (geoip)Often accurate within several kilometers
- Participants provide their "favorite five locations" using a Google Maps Interface.
- linked to IP or set a default location/address

Future: a "Where Were You?" website

Select	Location Name (optional)	Latitude	Longitude	Net (IP) Addr	Set Net Addr	Clear Net Addr
	Home	34.0971731803043	-117.72793114185	76.170.119	Set Current	Clear
	Work	33.9745572764349	-117.32615232467	138.23.128	Set Current	Clear
					Set Current	Clear
					Set Current	Clear
					Set Current	Clear
	Update info					

Timing Issues

- As well as location, very important for computing quake location
- The QCN/BOINC and QCNLive clients both utilize an external ntpdate program
- Gets an offset between our server and local time and stores locally for adjustments
- Does not interfere with host machine date/time features
- We seem to get 1/100th of a second resolution, but need to do more studies

Triggering Algorithm

Significance Level Filter:

- Compare each point to the standard deviation of the signal in the long-term window prior to the trigger

Standard Deviation

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \bar{y})^2}$$

Running Variance

$$\sigma_i^2 = \sigma_{i-1}^2 + \frac{(y_i - \bar{y}_i)^2 - (y_{i-N-1} - \bar{y}_{i-N-1})^2}{N}$$

Significance Level

$$SL_i = \sqrt{(y_i - \bar{y}_i)^2} \Big/ (\sigma_i + wl)$$

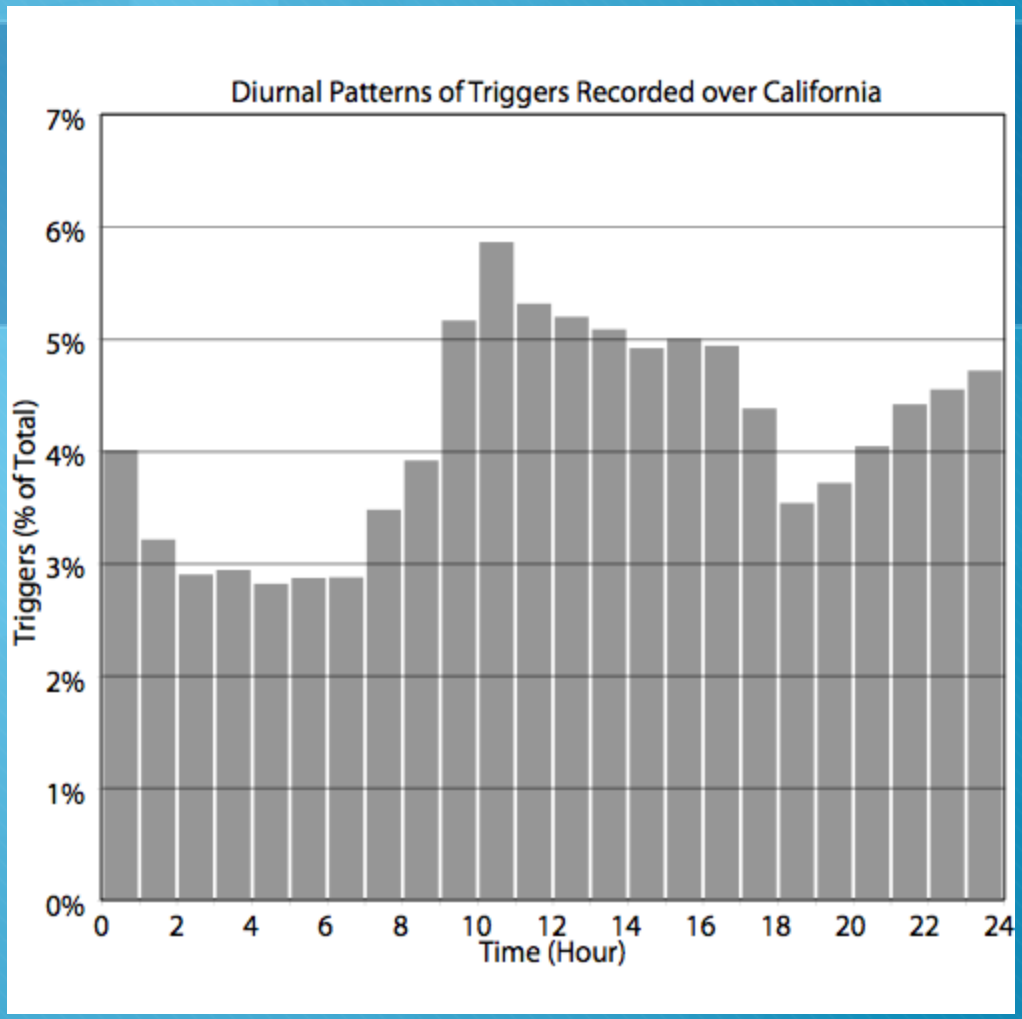
- SL = ($|y_i| / \sigma_i$) provides the confidence level (e.g. SL > 2 gives a 95% confidence) that an emerging signal is statistically not representative of the prior long-term average (Gaussian)
- Extremely Fast, all CPU in the sensor monitoring loop (50 Hz)
- Computer records 1 minute before and 2 minutes after trigger to disk (SAC file I/O)
- Now sends a follow-up trickle 4 seconds later

Trigger Statistics

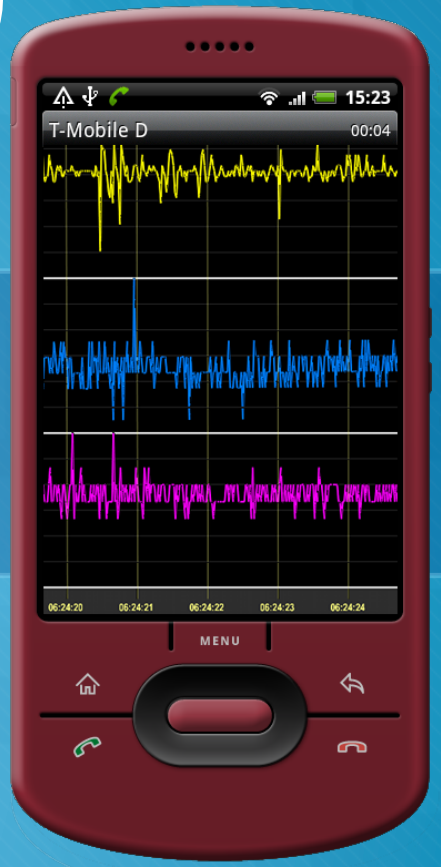
- >1100 active sensors (3/2011)
- Mac PowerPC 10
- Mac Intel 320
- Thinkpad 159
- JWF8 USB 380
- JWF14 USB 260
- MN USB 6

- Laptop 489
- USB 646 – more USB than laptops!

- Thousands of new sensors on order thanks to NSF grant
- Roughly 30-50 triggers per day from each laptop
- Number of triggers is roughly the same throughout the day (no large day/night difference)
- BOINC "trickles" – turnaround time ~3-5 s
- Most (99.99%) triggers are "false positives" – we want that .01% though!



QCN Client - Mobile



- Just started Google Android development!
- Relying on OpenGL ES (Embedded Systems) if performance is OK
- Initiate BOINC web service calls when docked
- Most Android devices have accelerometer & GPS
- Anonymously “sign up” via phone # for tracking
- Possibility for external USB sensors?
- Use for “RAMP” (Rapid Aftershock Mobilization Program) to get a lot of low-cost devices in areas

Server Software

- 5 components on 3 servers:
  - Database
  - BOINC scheduler
  - Web pages
  - Data upload (& analysis) server
  - Event detection
- The servers are basic Dell Linux servers i.e. 16GB RAM, 4 CPU, 2 gigabit network if, 1TB disk (cost about US $6K each)

Server - Database

- Added tables to BOINC – IP/lat/lng lookup, geoip, earthquakes, triggers
- New mysql – memory tables for new triggers “cached” a few minutes for quake detection
- Archiving system – only recent two months of triggers “live” due to size (60 million triggers over three years)

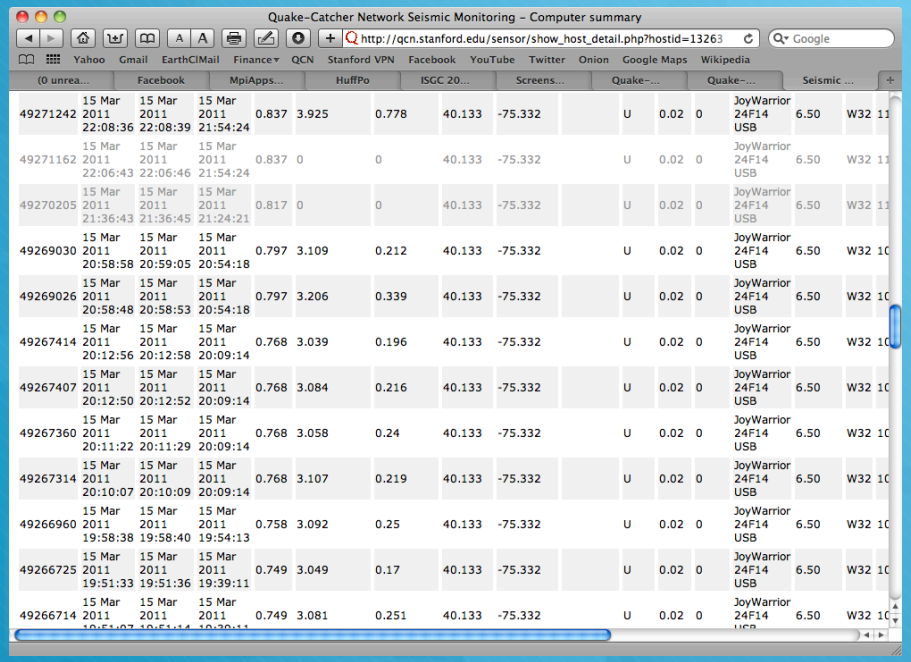
Server – BOINC Scheduler

- Handles BOINC client requests for new jobs (workunits), trickles/triggers, etc
- Customized for QCN to process trickles immediately (usually go to a trickle table)
- Few thousand lines of extra code for QCN, 4 tables for lookups etc
- Incoming trickle (trigger) gets matched via IP address to a latitude/longitude, and inserted into trigger table
- New triggers are put into a memory table (new mysql feature) for fast earthquake event detection
- ~10 simultaneous events in a region then we have identified an earthquake (still working on detection algorithms & output)

Server – QCN Web Pages

- Carried over all BOINC web pages, just customized a few to show triggers etc
- Very important for setting location of your computer (and optional IP address matchup of different locations e.g. laptops)
- In near future will show fuller display of detected quakes (currently show sensor location & USGS-detected quakes)

Server – QCN Web Pages



49271242	15 Mar 2011 22:08:36	15 Mar 2011 22:08:39	15 Mar 2011 21:54:24	0.837	3.925	0.778	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	11
49271162	15 Mar 2011 22:06:43	15 Mar 2011 22:06:46	15 Mar 2011 21:54:24	0.837	0	0	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	11
49270205	15 Mar 2011 21:36:43	15 Mar 2011 21:36:45	15 Mar 2011 21:24:21	0.817	0	0	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	11
49269030	15 Mar 2011 20:58:58	15 Mar 2011 20:59:05	15 Mar 2011 20:54:18	0.797	3.109	0.212	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	10
49269026	15 Mar 2011 20:58:48	15 Mar 2011 20:58:53	15 Mar 2011 20:54:18	0.797	3.206	0.339	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	10
49267414	15 Mar 2011 20:12:56	15 Mar 2011 20:12:58	15 Mar 2011 20:09:14	0.768	3.039	0.196	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	10
49267407	15 Mar 2011 20:12:50	15 Mar 2011 20:12:52	15 Mar 2011 20:09:14	0.768	3.084	0.216	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	10
49267360	15 Mar 2011 20:11:22	15 Mar 2011 20:11:29	15 Mar 2011 20:09:14	0.768	3.058	0.24	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	10
49267314	15 Mar 2011 20:10:07	15 Mar 2011 20:10:09	15 Mar 2011 20:09:14	0.768	3.107	0.219	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	10
49266960	15 Mar 2011 19:58:38	15 Mar 2011 19:58:40	15 Mar 2011 19:54:13	0.758	3.092	0.25	40.133	-75.332		U	0.02	0	JoyWarrior 24F14 USB	6.50	W32	10
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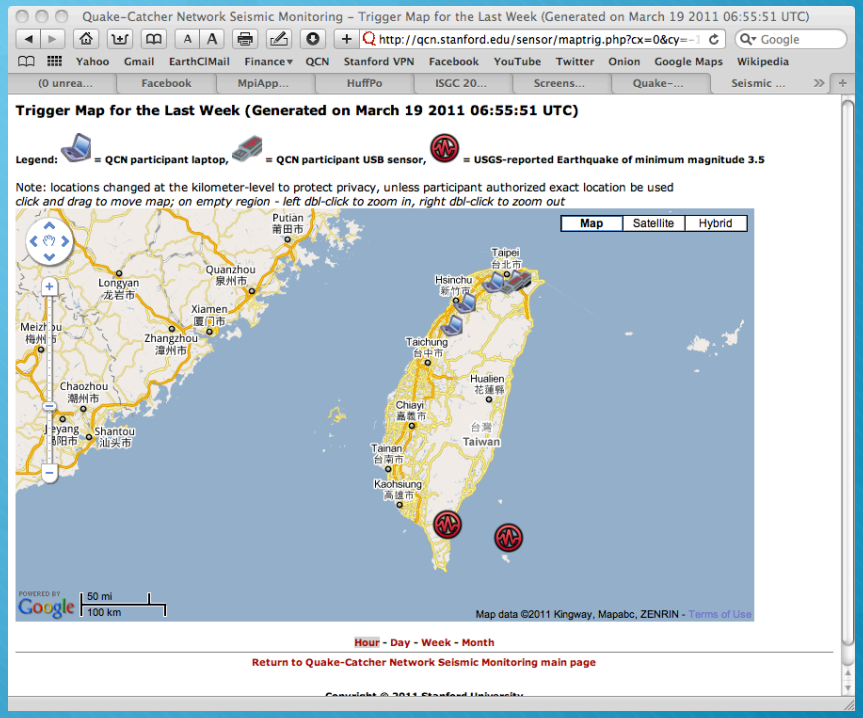
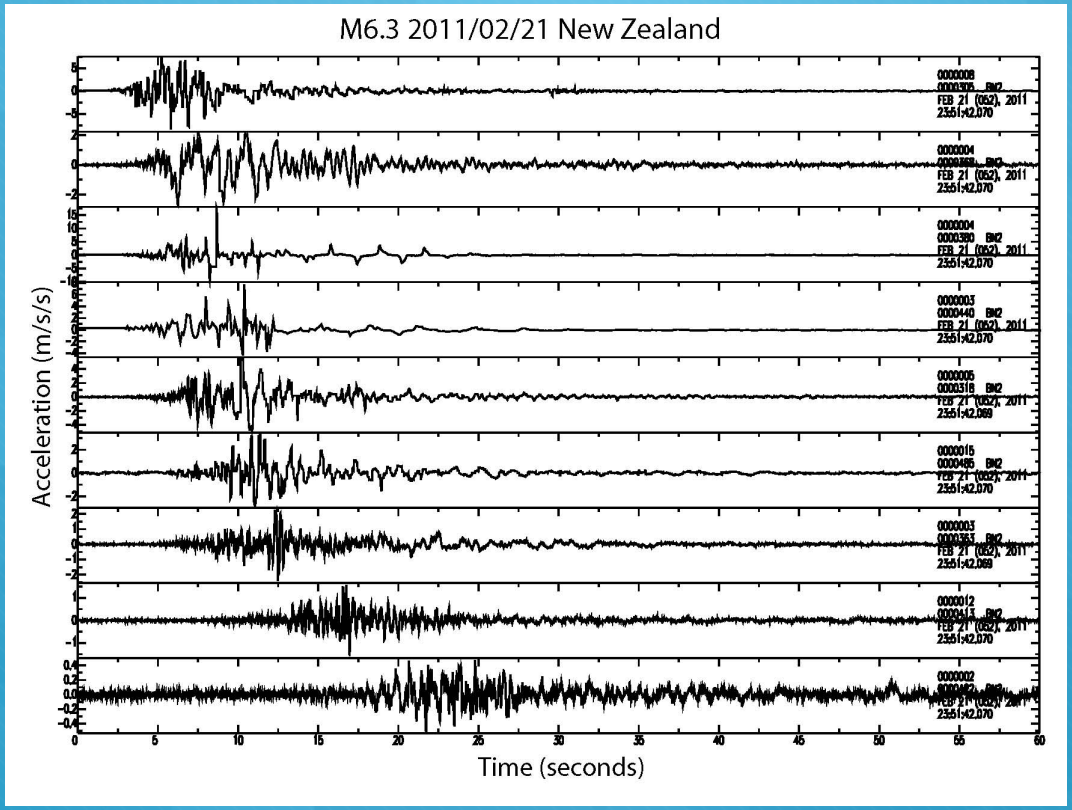


Server – Data Upload

- After a “trigger” the software uses BOINC to send a “trickle” message immediately
- This is a small (~300 byte) packet of XML – event time, host time offset, x/y/z sensor reading, significance threshold etc
- If we determine that this machine was involved in a seismic event, we can send a request to upload the SAC (full waveform) files for this event (BOINC “intermediate upload” feature)
- Also have a “continual” project that sends full SAC streams via BOINC every 10 minutes (building studies, high-risk areas, sensor testing etc)
- Now also send a follow-up trickle after 4 seconds with peak event info
- QCN SAC files are small – 2MB for 3-axes per hours, .5MB compressed

Server – Data Upload - SAC



9 QCN "stations" in Christchurch NZ

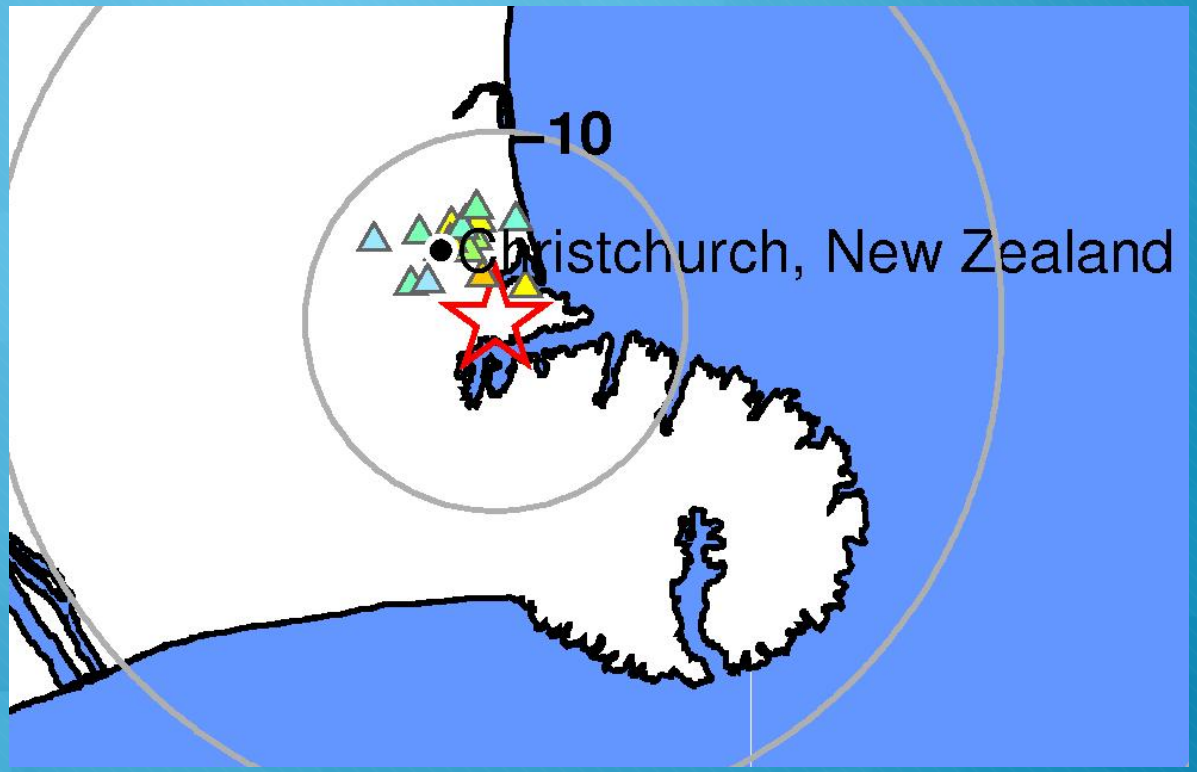
Server – Event Detection

- Processes scan the new trigger (mysql memory table) every 0.2 seconds (5Hz)
- Simple process – compares USGS-detected/reported events with our sensor network
- More complex – detect from our sensor network only
- Still a “work in progress” as we fine tune and test the detection algorithms
- We seem to get reliable events with as little as 6-8 sensors reporting

Server – Event Detection

March 14th 2011 07:29:28
22 USB Sensors
172.70, -43.59

QCN students/postdocs
Installed ~100 USB sensors
In Christchurch after the
Major quake few months ago



Summary

- QCN different from other volunteer computing projects as it's low-CPU "distributed sensor"
- QCN client uses BOINC API & features with no modifications – heavily relies on trickle & intermediate uploads
  - Potential mod – mirror trickles to multiple QCN servers (i.e. Taiwan trigger goes to server in Taiwan, and Stanford server)
- QCN has had to modify BOINC on the server, mainly for trickle/trigger processing and "live" detection/reporting
  - Future – QCN servers in different countries, with database (mysql) replication of crucial tables & trickle mirroring to Stanford & UC-Riverside
- Result – a low-cost and reliable system for remote event detection