THE SELF-ORGANISING SEISMIC EARLY WARNING INFORMATION NETWORK

J. Zschau[1], M. Picozzi[1*], C. Milkereit[1], K. Fleming[1], K-H Jäckel[1], and the SAFER[1,2,3] and EDIM[1,2,3] working groups

(1) Section 2.1 Earthquake Risk and Early Warning, GeoForschungsZentrum Potsdam, Germany (2) Dep. of Informatics, Humboldt University Berlin, Berlin, Germany (3) Bogazici University, Kandilli Observatory and Earthquake Research Institute, Earthquake Engineering Department , Istanbul, Turkey

INTRODUCTION

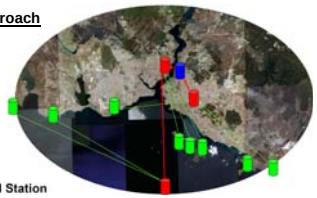
Rapid urbanisation, the interconnection of economies and increasing dependence on technology makes modern society ever more vulnerable to natural disasters, especially considering the growth of so called mega cities (defined by the United Nations as metropolitan areas with populations exceeding 10 million). Early warning systems as one means of mitigating the potential human and economic losses resulting from natural disasters. Currently, several parts of the world have some form of earthquake early warning system (EEW) either in operation or under development (e.g. Taiwan, Japan, California, Istanbul, Bucharest, Mexico City). However, these systems usually involve the use of a relatively low numbers of high quality sensors (from several to 10's of units), a fact largely dictated by the high cost of such instrumentation. In addition, these systems usually require the communication of their data to centralised processing and archiving facilities.

The development of a new approach for the early warning started from the vision to provide to the society a diffuse, low-cost system relying on modern wireless technology, what we call the Self-Organising Seismic Early Warning Information Network (SOSEWIN). It will be characterised by the following features:

- Each seismological sensing unit (SN) is comprised of low-cost components (bought off-the-shelf), with each unit costing ~ 600 €, in contrast to 1,000's to 10,000's for standard seismological stations;
- Each SN undertakes its own seismological data processing, preliminary analysis and archiving, while also having the capacity to measure other environmental parameters (e.g. noise, temperature etc.);
- The reduced sensitivity of the SNs arising from the use of lower-cost components will be compensated by the network's density, which in the future is expected to number 100's to 1000's of units over areas served currently by the order of 10's of standard stations (Figure 1b);
- The SOSEWIN will be a decentralised, self-organising ad-hoc wireless mesh network (WMN);
- Its self-organising capability will allow it to adapt continuously to changing circumstances, e.g. the addition/removal/malfunctioning of nodes, interference in communications due to local (and possibly time-varying) phenomena, loss of sections of the network following an earthquake.
- Instruments will also be purchasable by the public. Thus, the SOSEWIN early warning network will also be able to integrate additional data from private persons.

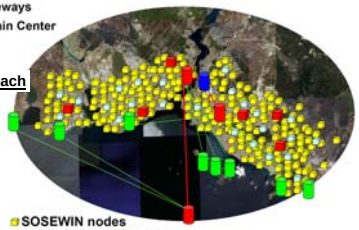
The SOSEWIN vision

EEW - Standard Approach



Classical Seismological Station
Secondary Centers - Gateways
Kandilli Observatory – Main Center

EEW - SOSEWIN Approach



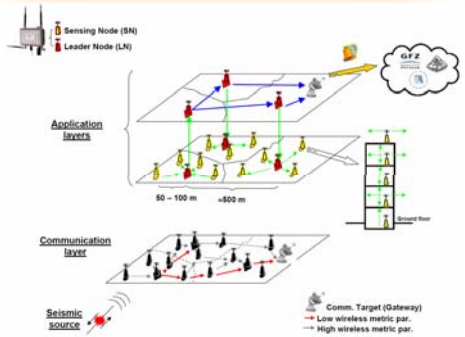
SOSEWIN nodes
Public SOSEWIN nodes
Gateways

Development of a new seismic network for EEW, made up of *low-cost* sensors that will eventually be purchasable by a range of end users, giving *very dense urban networks.*

SOSEWIN will complement existing EEW networks.

The mesh sensor net is reliable and also operates if individual sensors are destroyed, allowing the system to still detect the earthquake.

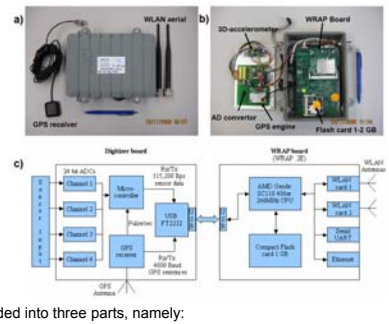
SOSEWIN Architecture



The general arrangement of the SOSEWIN is characterized by a two-level architecture consisting of an upper ***application layer***, and a lower ***communication layer***.

- The lower sub layer of the applications layer regulates the SN activities within their clusters (e.g. the number of SNs that lead to a group alarm, event trigger thresholds).
- The higher sub layer is the critical layer in terms of distributing alarms among LNs and issuing them to end users.
- The communication layer offers peer-to-peer communications between the nodes.

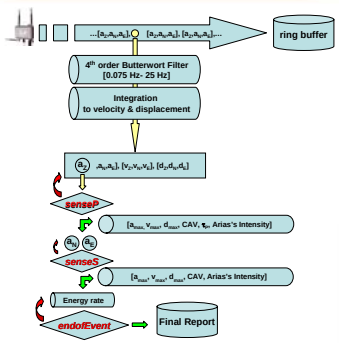
Hardware: The prototype Sensing Node



The SN is divided into three parts, namely:

- The sensors, 3 MEMS accelerometers arranged to provide three component (X, Y and Z) data, and an additional sensor to measure an environmental parameter, such as noise, temperature, water pressure etc.;
- The digitizer board, developed within the GFZ, Potsdam. The 4-channel ADC has a resolution of 24 bits, effectively providing a resolution of 19 bits. The sample rate is 100 sps;
- The WRAP (wireless router applications platform) board has the three roles of analysis, communication, and storage of data. It is an embedded PC with a 266 MHz CPU, and the operating system is Linux OPENWRT. It has one Compact Flash card that acts as the hard disk, and two WLAN (wireless local area network, 2.5 or 5GHz) Mini PCI cards.

Seismological processing



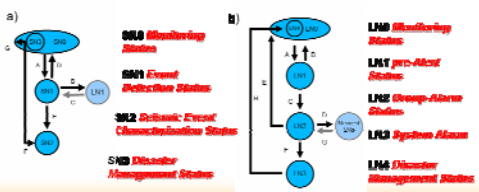
The general scheme followed for the seismological processing and analysis that is being incorporated into the sensing nodes of the SOSEWIN.

Alarm processes

The general scheme of the alerting and alarm process consists of four levels.

- **Idle**, where "all is well", i.e. sufficiently severe ground shaking has not been detected.
- **SN alert**, where an individual sensor has detected strong enough ground shaking to inform its LN (while this may in fact be the LN itself, because of the geometry of the clusters, it would most likely be one of the other SNs).
- **Group alert**, where within a given cluster, ≥50% of the SNs have triggered.
- **System alert**, where ≥3 LNs have verified that an event has occurred, with a network-wide alert now issued.

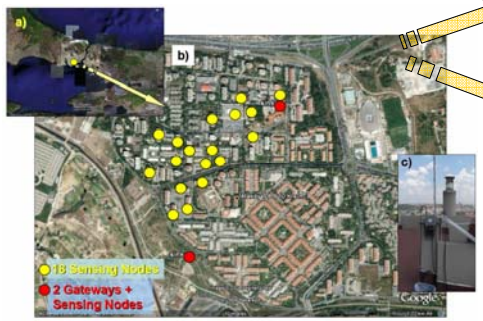
These alarm stages are described by the state machines of the SNs and LNs.



Istanbul test deployment

Istanbul is a mega city (population 14 million) that is under significant risk from earthquakes, being located at its nearest point only few kilometers from the North Anatolian Fault, along which there have been a number of large earthquakes over the past century, the most recent being the 1999 Izmit (August 17th, Mw=7.4) and 1999 Düzce (November 12th Mw=7.2) earthquakes.

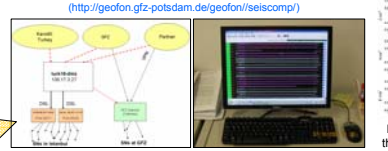
The first realistic deployment of the SOSEWIN was carried out in June, 2008, with a network of 20 stations installed in the Ataköy district of Istanbul.



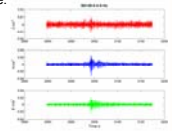
(a) Location map of Istanbul showing the Ataköy district, where the test deployment of the SOSEWIN has been carried out. (b) The location of the Sensing Nodes and Gateways for the test SOEWIN in the Ataköy district, Istanbul. (c) A typical SOSEWIN sensor installation.

SOSEWIN server at GFZ

Since 07/2008 a Seiscomp Server at GFZ collects data in real time.
(http://geofon.gfz-potsdam.de/geofon//seiscomp/)



Observed delay is less than 2s.



Example of recordings for a the 10/07/2008 event, ML 4.9 at ~ 140 km from Istanbul.

Communication performance

Acknowledgements.
The work undertaken was supported by the SAFER (Seismic eArly warning For EuRope, European Commission proposal no. 036935) and EDIM (Earthquake Data Information system for the Marmara Sea, Turkey, German Federal Ministry of Education and Research) projects. Special thanks to Bakirköy AKOM staff for their assistance in arranging for and installing the SOSEWIN

*contact Matteo Picozzi (picoz@gfz-potsdam.de)