Advanced seismological digital network in Bulgaria

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Introduction

In September 2005 Geophysical Institute of Bulgarian Academy of Sciences after procurement procedure selected the Refraction Technology, Inc. to upgrade the existing National Operative System for Seismological Information (NOTSSI) to a modern digital seismological network.

At the beginning of December 2005 all equipment supplied was installed on seismological stations and acquisition and processing software was operating in the data center. The network became operational on 08.12.2005 and on 21.12.2005 the Deputy Prime Minister and Minister of the State Policy in Disaster Prevention Mrs. Emel Etem attended the official opening ceremony of the new seismological center.

Modernized network description

The main task of NOTSSI is to provide reliable detection and precise location of earthquakes that may cause damage or may be felt on the territory of Bulgaria. The main responsibility of NOTSSI is to provide rapid and precise information to the government authorities in case of strong earthquakes. The modernized seismic network based on broadband seismometers and on-site digital acquisition systems meets this important duty.

The real-time data acquisition at the NOTSSI field stations (fig. 1) is performed by 10 3 channel and one 6 channel RefTek 130, two Q330 and one Quanterra 380 data acquisition systems (DAS). Real-time data transmission from field stations to the Center for Data Collection and Analysis (CDCA) located

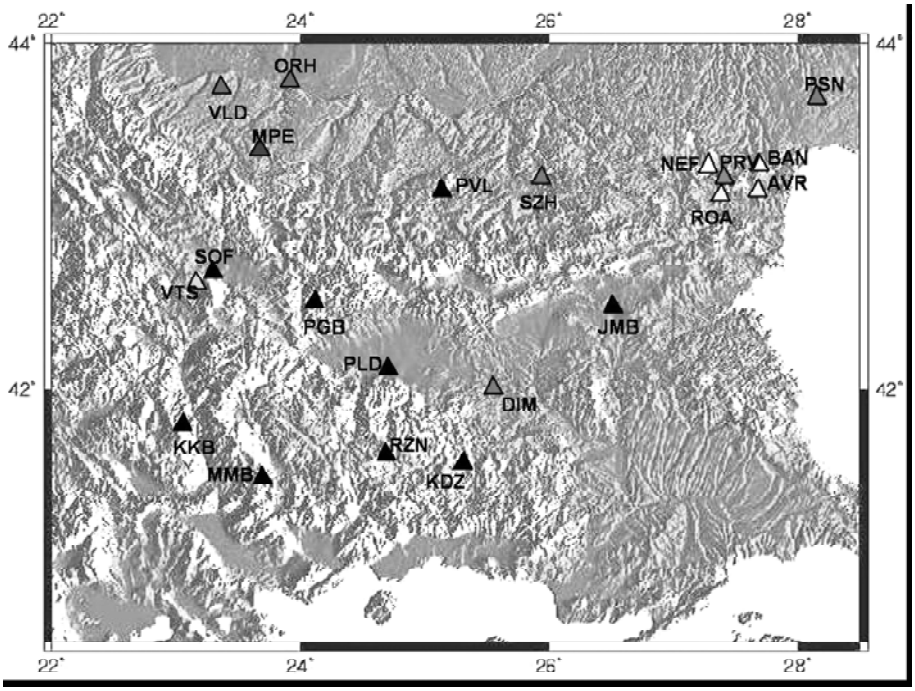


Fig. 1. Current status of Bulgarian seismological network (upgraded stations VTS, KKB, MMB, PGB, PLD, RZN, KDZ, DIM, JMB, PRV, PSN, SZH, PVL, SOF)

in Sofia is accomplished via VPN provided by Bulgarian Telecommunication Company. Real-time data acquisition is performed using REFTEK's full duplex error-correction protocol RTPD. The data from the Quanterra recorders are fed into RTPD in real-time via SeisComp/SeedLink protocol. This design provides very reliable digital data transmission. For example for the period from December 7, 2005 to March 10, 2006 the network reliability exceeded 99.99%. Only two short breakdowns (each about 20 minutes) occurred during this period. The communication breakdowns do not cause any data loss at the CDCA. The data are backed-up on the field station recorder and are retransmitted to the CDCA immediately after the communication link recovery.

The re-transmission of the backed-up data takes very short time, however even this short time delay requires several levels of network redundancy. The real-time transmission redundancy is accomplished via dedicated ISDN line. In addition, an optical line with a different route will be installed. In case of either primary optical line or ISDN connection failure automatic re-direction of the data flow will be made.

The real-time acquisition and data processing hardware redundancy at the CDCA is performed by two clustered SUN servers with swappable software module which re-directs the real-time data flow in case of either server failure. Network control and monitoring are performed by RTCC and RTPMonitor user interfaces which are running on two SUN Blade 1500 Workstations. Both RTCC and RTPMonitor serve up html pages that can be displayed in any standard web browser allowing the end-user to monitor the network status and control the acquisition parameters anytime and anywhere from any computer connected to the Internet.

An important advantage of the system is the possibility to incorporate real time data flows from other (foreign) stations and arrays. Recently, the data flows from CTBTO (Keskin array -Turkey), stations from Thessaloniki (Greece), Romania and Macedonia seismic networks are incorporated in the real-time data stream in the National Data Center and can be used together with NOTSSI data.

To achieve security of the acquisition, processing and data storage processes a three layer network is design at the CDCA (fig. 2).

The new system corresponds to the highest European standards in earthquake monitoring and data processing and fulfils the requirements of the National authorities and society.

Some results

During the eight months of 2006 the SNDP real-time system detected 9857 events out of which 9.8% were earthquakes. Over 350 of the detected and located earthquakes occurred in Bulgaria. All others were regional or teleseismic earthquakes.

An important advantage of SNDP is the simple access to the data disk loop for seven days and the possibility to operate with the waveforms from the disk-loop for rapid manual locations. In this way

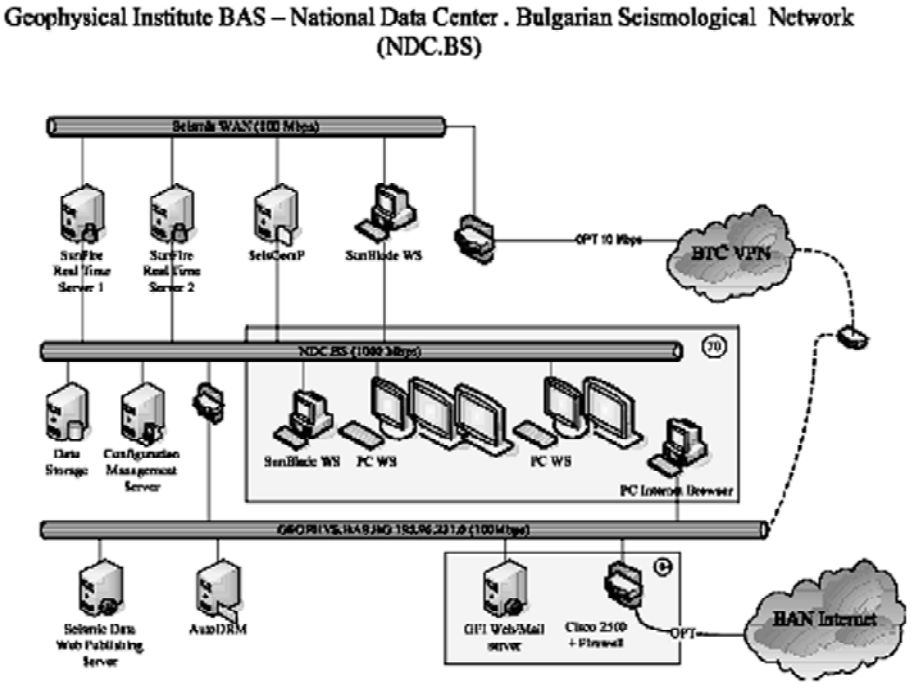


Fig. 2. CDCA three layer network

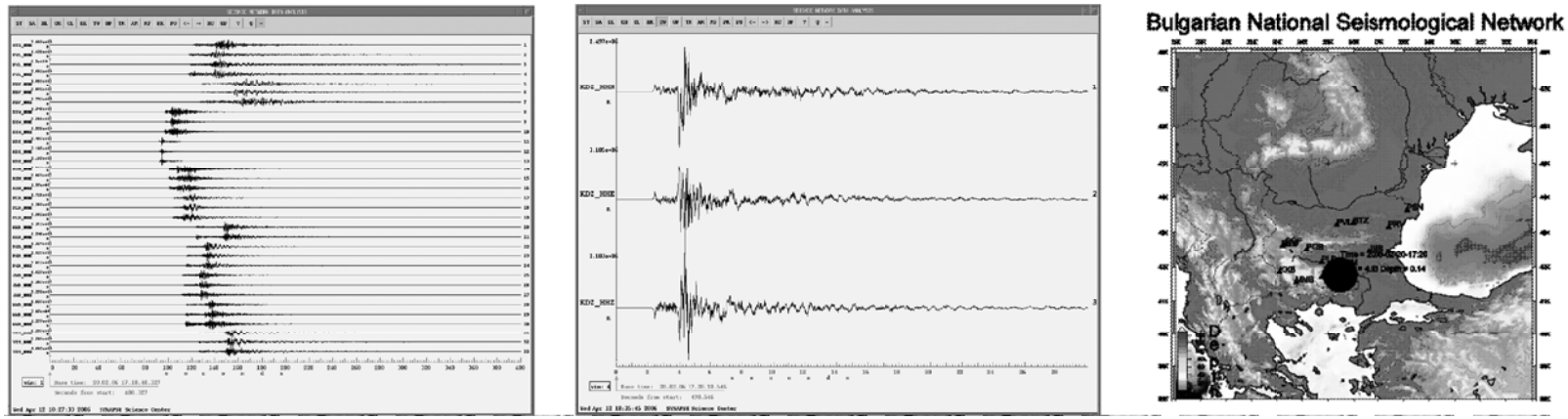


Fig. 3. Records and real-time location of 20.02.2006 earthquake (M=4.8)

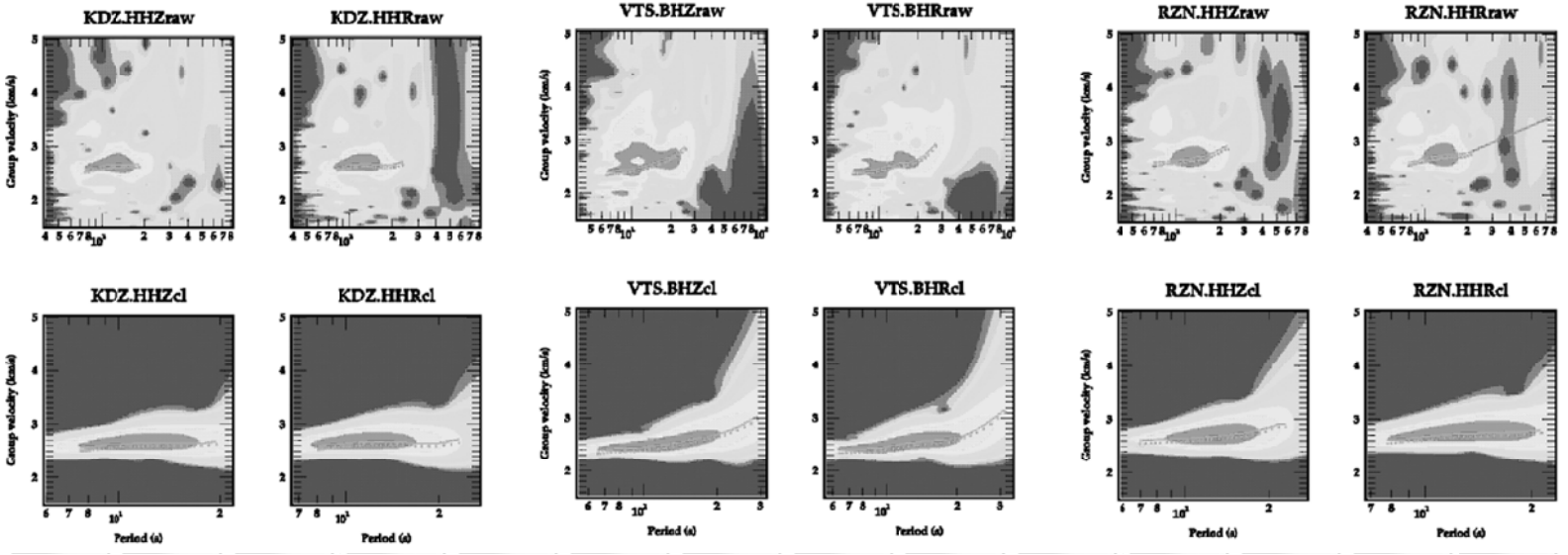


Fig. 4. Frequency Time Analyses diagrams for station VTS, KDZ and RZN

the local operator/seismologist can immediately start manual analysis in order to verify the automatic location.

The system was tested on several earthquakes felt in the territory of Bulgaria and was proven as a system which provides reliable event detection and accurate earthquake location. During the first 3 months of operation there were 15 earthquakes felt in Bulgaria. The largest event occurred on February 20, 2006 with magnitude M=4.8 in South-East Bulgaria, close to the town of Kardzali. The earthquake caused minor damage in several villages. The records of this earthquake and the real-time solution are shown in fig. 3. The station Kardzali is located in 15 km from the epicenter. This earthquake generated a large aftershock sequence which up to March 11, 2006 counted 153 aftershocks. A large part of them are recorded only on the two closest stations. The real-time system detected and located 71 aftershocks, some of them with very low-magnitudes (1.6—1.8). The number of manually located aftershocks, based on the analog recording system, was 41 events.

The present records obtained by NOTSSI permit performing of many advanced scientific procedures for data analysis of the seismic waveforms. As an example, we show (fig. 4) comparison of frequency time analysis (FTAN) diagrams of surface waves for stations Vitosha (part of VBB Mediterranean Network MedNet equipped with STS-1 seismometer), Rozen and Kardzali (equipped with Guralp CMG 40T seismometers) of earthquake in Ionian Sea (March 3, 2006, origin time 00:49:41.9).

Conclusions

After modernization, NOTSSI became a world-class digital network providing reliable, high quality real-time seismic monitoring and rapid earthquake information to both scientific communities and authorities in Bulgaria for seismic hazard mitigation.

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Модернизирана цифрова сеизмична мрежа в България

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Резюме. Представено е настоящото състояние на сеизмологичната мрежа в България след модернизацията, проведена през 2005 г. Всички сеизмологични станции от националната мрежа (НОТССИ) са оборудвани с цифрови системи за сбор на данни. Данните се предават в реално време до Националния център за обработка в ГФИ-София чрез VPN мрежа на БТК. В центъра е внедрена система за реалновременна обработка на данните. Изградена е трислойна компютърна мрежа за сбор, съхранение, обработка, анализ на цифровата сеизмологична информация. Представени са някои резултати от 10 месечното функциониране на мрежата.