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"SeismoSAT" project results in connecting seismic data centres via satellite

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Abstract. Since 2002 the OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale) in Udine (Italy), the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in Vienna (Austria), and the Agencija Republike Slovenije za Okolje (ARSO) in Ljubljana (Slovenia) are collecting, analysing, archiving and exchanging seismic data in real time. Up to now the data exchange between the seismic data centres relied on internet: this however was not an ideal condition for civil protection purposes, since internet reliability is poor. For this reason, in 2012 the Protezione Civile della Provincia Autonoma di Bolzano in Bolzano (Italy) joined OGS, ZAMG and ARSO in the Interreg IV Italia-Austria project "SeismoSAT" (Progetto SeismoSAT, 2014) aimed in connecting the seismic data centres in real time via satellite. As already presented in the past, the general technical schema of the project has been outlined, data bandwidths and monthly volumes required have been quantified, the common satellite provider has been selected and the hardware has been purchased and installed. Right before the end of its financial period, the SeismoSAT project proved to be successful guaranteeing data connection stability between the involved data centres during an internet outage.

1 Introduction

The area at the border between Slovenia, Austria and North-East Italy is seismically very active and was struck by many destructive earthquakes in the past. OGS, ZAMG and ARSO are running seismic networks in the area primarily for civil defence purposes. However, the single seismic networks cannot determine precisely and efficiently enough earthquakes occurring at the borders: thus since 2002 OGS, ZAMG and ARSO decided to use the same software suite Antelope (Bragato et al., 2010) as the main tool for collecting, analysing, archiving and exchanging seismic data in real time, initially in the framework of the EU Interreg IIIa Italia-Austria project "Trans-national seismological networks in the South-Eastern Alps" (Bragato et al., 2004). For many years the data exchange between the seismic data centres relied on internet: this however is not an ideal condition for civil protection purposes, since the reliability of standard internet connections is poor. Generally, internet connections can provide high bandwidth at relatively small cost, but could suffer of disruption of service in case of strong natural events like big earthquakes. Same is true for mobile GPRS/UMTS data links, where data connection reliability is even less. Satellite links, apart from the problem of antenna dislocation by strong earthquake, if provided with reliable power supply can provide more robust data connections. The SeismoSAT project makes use of satellite technology as back up for the primary internet data link between data centres. Slovenia does not belong to the Interreg Italia-Austria area of intervention: for this reason, ARSO joined the SeismoSAT project as an "associated partner", which – according to Interreg rules – cannot be funded. ARSO participation in the project is therefore limited in benefiting only indirectly from improvement in the robustness of the data exchange between the other data centres. The SeismoSAT project concluded successfully the financial period on 31 March 2015 with the last stress test of

Figure 1. 2 SeismoSAT map with seismic stations in red and data centres in blue.

internet outage, showing the project capability of automatically switching to the backup satellite links. The SeismoSAT project was funded by the Interreg IV Italia-Austria (Interreg IV Italia-Austria, 2007) program based on the European Regional Development Fund (European Regional Development Fund, 2000).

2 Project implementation

Figure 1 shows a map of the data centres (in blue) connected by the SeismoSAT project with the corresponding seismic stations (in red). Each data centre is collecting data from the stations of its seismic network, sends a copy of it to the other two data centres and receive a copy from each other of the other two data centres. Data is primarily sent via normal internet, with the option to switch over satellite when necessary. Total upload bandwidths required are OGS 240 Kbit s^{-1}, ZAMG 176 Kbit s^{-1}, PCBZ 96 Kbit s^{-1}, while download bandwidths required are OGS 136 Kbit s^{-1}, ZAMG 168 Kbit s^{-1}, PCBZ 208 Kbit s^{-1} (Pesaresi et al., 2014a).

As the satellite provider, the KA-BA satellite terminal from Sosat (Austria) has been selected. Its main characteristics are:

- max. 18 432 kbit s^{-1} download, 6144 kbit s^{-1} upload
- 1 public IP address and 60 GB data volume
- Annual link availability: > 99,5%
- RTTs Satellite round trip time: < 600 ms
- Data Interface: Lan/Ethernet
- Security: Time Division Multiple Access (TDMA)
- Modulation: 16-APSK

It proved to be the best choice in Europe for internet via satellite with data volumes like the SeismoSAT project with good technical support in the Interreg area (Pesaresi et al., 2014a).

The automatic switching between the default internet and the back-up satellite data links is done at hardware level: for this reason, all SeismoSAT partners data centres have been equipped with the Cisco 2921 router with VPN, IPSEC, ISKMP, ICMP, BGP and SSH capabilities (Pesaresi et al., 2014b). The automatic switching between the default internet and the back-up satellite data links is practically realized with the usage of several VPN tunnels between the SeismoSAT data centres: two between each couple of data centres, one via internet and one via satellite. The Cisco 2921 router, by constantly checking which of the two IP connections has the best metrics, choose automatically internet when available and switches also automatically to the back-up satellite links when internet is down.

Figure 2 shows the final schematic of the IP connections topology of the SeismoSAT project. Continuous lines are over internet, while dashed ones over satellite. The dynamic routing is realized with the Border Gateway Protocol (BGP, 2015). The SeismoSAT project had to account for different LAN configurations at the three data centres. From Fig. 2 it can be noted that the Cisco 2921 router has been installed at OGS in Udine inside the firewall, while at the ZAMG in Tyrol/Vienna is outside the firewall. Configuration at the Protezione Civile di Bolzano data centre is also different with natting.

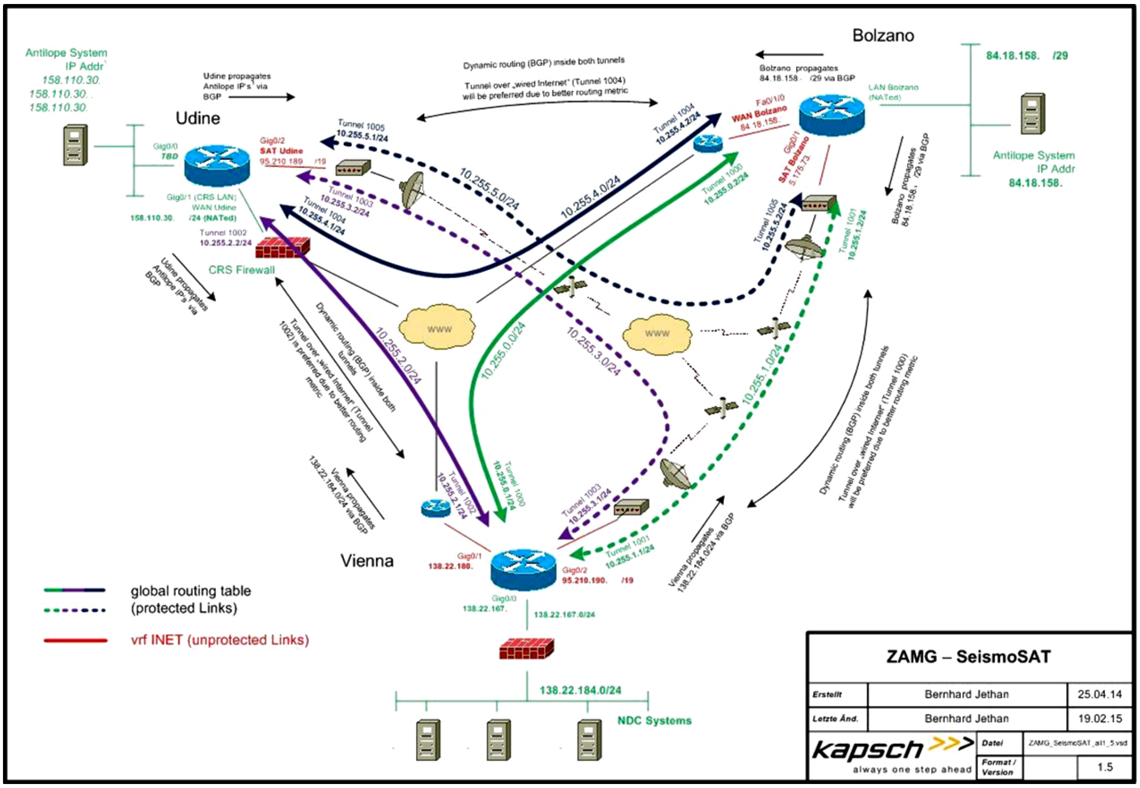

Figure 2. SeismoSAT IP connections schematic.

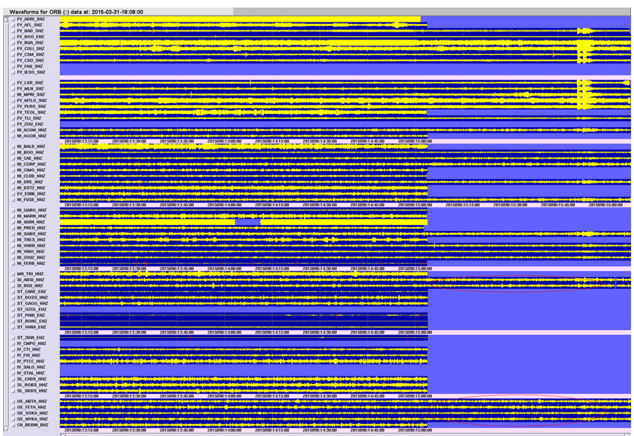

Figure 3. Stress test. With internet down, P1 ZAMG (code OE_*) and P2 PCBZ (code SI_*) seismic stations acquired at LP OGS data centre.

3 Final test

The final test was conducted thanks to a lucky coincidence: by chance, exactly on the last official day of the SeismoSAT project, on 31 March 2015 the OGS data centre in Udine suffered from an internet outage of several hours. Luckily the SeismoSAT infrastructure was already up and running at that time, so that seismic real time data acquisition and monitoring was not severely affected, neither at ZAMG in Tyrol/Vienna and Protezione Civile in Bolzano, nor at OGS in Udine.

Figure 3 shows a live snapshot of real time seismic waveforms acquired during the natural outage test at the OGS data centre in Udine. On the left are shown the network_station_channel labels: the OGS network code is NI, the ZAMG network code is OE and the Protezione Civile di Bolzano code is SI. From Fig. 3 it can be noted that the yellow waveform traces of the real time data acquisition at OGS in Udine stopped around 15:00 UTC for some of the stations of various seismic networks, but NOT for the SeismoSAT partners ZAMG in Tyrol/Vienna (network code OE) and Protezione Civile di Bolzano (network code SI): those yellow waveform traces appear continuous if Fig. 3 (and circled in red for reference). It must be noted that on this snapshot not all of the seismic station involved in the SeismoSAT project are showed, since it is taken form a live monitor using only a few sample stations. This proved that SeismoSAT Cisco routers correctly automatically switched over satellite data links. Similar tests were artificially conducted at each of the other data centres, thus confirming the well-functioning of the SeismoSAT project.

Table 1 shows in detail for each network_ststion_channel data latencies during the internet outage at the OGS data cen-

Table 1. Data latency during internet outage.

Sources Srcname	Thread	#pkts	Kbytes	Oldest pktid	Oldest time	Latest pktid	Latest time	kbps	Average latency
EV_ED06_HHZ/SEED	0	3678	1934.6	1296777	12:58:06	798408	15:03:48	2.1	1:04 h
FV_TEOL_HHZ/SEED	0	2322	1221.4	1296813	12:57:55	797050	15:03:40	1.3	1:04 h
IV_BRMO_HHZ/SEED	0	1835	965.2	1296795	12:58:03	797055	15:03:41	1.0	1:04 h
IV_CTI_HHZ/SEED	0	1936	1018.3	1297318	12:58:05	797418	15:03:44	1.1	1:04 h
IV_FVI_HHZ/SEED	0	1831	963.1	1297306	12:58:05	796907	15:03:41	1.0	1:04 h
IV_MABI_HHZ/SEED	0	1787	940.0	1298796	12:58:03	797024	15:03:37	1.0	1:04 h
IV_MAGA_HHZ/SEED	0	1873	985.2	1297029	12:58:05	796869	15:03:41	1.0	1:04 h
IV_PTCC_HHZ/SEED	0	1831	963.1	1297336	12:58:04	796691	15:03:38	1.0	1:04 h
MN_AQU_HHZ/SEED	0	3101	1631.1	1296982	12:58:02	797268	15:03:31	1.7	1:04 h
MN_BNI_HHZ/SEED	0	1831	963.1	1296794	12:58:02	797428	15:03:40	1.0	1:04 h
MN_TRI_HHZ/QCDAT	0	1864	902.2	1296703	12:58:02	798343	15:03:45	1.0	1:04 h
MN_TRI_HLZ/QCDAT	0	1047	506.7	1296705	12:58:00	797912	15:03:41	0.5	1:04 h
MN_TUE_HHZ/SEED	0	1831	963.1	1296751	12:58:01	797695	15:03:41	1.0	1:04 h
MN_VLC_HHZ/SEED	0	1831	963.1	1296443	12:58:00	796542	15:03:38	1.0	1:04 h
NI_ACOM_HHZ/GENC	44	11373	1311.9	1296660	12:58:06	1296381	16:07:38	0.9	2.834 s
NI_AGOR_HHZ/SEED	0	1832	963.6	1297119	12:58:04	798410	15:03:45	1.0	1:04 h
NI_BALD_HHZ/GENC	0	7549	1215.3	1297602	12:57:59	800558	15:03:47	1.3	1:04 h
NI_BOO_HHZ/GENC	44	11373	1295.5	1296593	12:58:06	1296313	16:07:38	0.9	3.122 s
NI_CAE_HHZ/GENC	44	11373	1218.9	1296575	12:58:06	1296349	16:07:38	0.9	3.122 s
NI_CGRP_HHZ/GENC	44	11373	1268.3	1296572	12:58:06	1296328	16:07:38	0.9	2.834 s
NI_CIMO_HHZ/QCDAT	0	1175	568.7	1297340	12:58:03	797421	15:03:40	0.6	1:04 h
NI_CLUD_HHZ/GENC	0	7533	822.5	1299514	12:57:58	798939	15:03:30	0.9	1:04 h
NI_DRE_HHZ/GENC	44	11373	1277.7	1296689	12:58:06	1296391	16:07:38	0.9	2.834 s
NI_DST2_HHZ/GENC	0	7546	1046.9	1296438	12:58:05	798582	15:03:50	1.1	1:04 h
NI_FERB_HHZ/SEED	0	1831	963.1	1297023	12:58:02	797626	15:03:41	1.0	1:04 h
NI_FUSE_HHZ/GENC	44	11373	1284.3	1296602	12:58:06	1296372	16:07:38	0.9	2.834 s
NI_GARG_HHZ/SEED	0	1831	963.1	1297113	12:58:04	797700	15:03:44	1.0	1:04 h
NI_MARN_HHZ/GENC	0	7600	1050.7	1303549	12:56:50	800674	15:03:29	1.1	1:04 h
NI_MPRI_HHZ/GENC	44	11373	1315.7	1296554	12:58:06	1296319	16:07:38	0.9	2.834 s
NI_POLC_HHZ/GENC	0	7550	864.3	1296432	12:58:05	798588	15:03:50	0.9	1:04 h
NI_PRED_HHZ/GENC	0	7472	972.9	1300472	12:58:05	783151	15:02:36	1.0	1:05 h
NI_PURA_HHZ/GENC	0	7572	1118.7	1296770	12:57:56	797138	15:03:43	1.2	1:04 h
NI_QUIN_HHZ/SEED	0	2861	1504.9	1297103	12:58:05	798236	15:03:47	1.6	1:04 h
NI_SABO_HHZ/GENC	44	11373	1277.6	1296563	12:58:06	1296337	16:07:38	0.9	2.834 s
NI_TRES_HHZ/SEED	0	2304	1211.9	1296515	12:58:02	798436	15:03:47	1.3	1:04 h
NI_VARN_HHZ/GENC	44	11373	1381.8	1296651	12:58:06	1296346	16:07:38	1.0	2.834 s
NI_VINO_HHZ/QCDAT	36	2670	1292.3	1296700	12:58:02	1296175	16:07:33	0.9	8.535 s
NI_ZOU2_HHZ/GENC	44	11373	1126.7	1296584	12:58:06	1296358	16:07:38	0.8	2.834 s
OE_ABTA_HHZ/GENC	54	11377	1230.6	1296462	12:58:01	1296406	16:07:37	0.9	3.834 s
OE_ARSA_HHZ/QCDAT	54	1297	627.7	1297286	12:58:01	1295510	16:07:23	0.4	18.182 s
OE_DAVA_HHZ/QCDAT	54	1341	649.0	1296984	12:57:59	1296040	16:07:28	0.5	13.765 s
OE_FETA_HHZ/GENC	54	11376	1125.7	1296459	12:58:01	1296285	16:07:36	0.8	4.834 s
OE_KBA_HHZ/QCDAT	54	1279	619.0	1297267	12:58:00	1295894	16:07:25	0.4	16.691 s
OE_KBA_HLZ/QCDAT	54	1262	610.8	1297637	12:58:02	1296026	16:07:27	0.4	14.579 s
OE_MOA_HHZ/QCDAT	54	1430	692.1	1297120	12:58:00	1295586	16:07:24	0.5	16.904 s
OE_MYKA_HHZ/GENC	54	11377	1179.6	1296453	12:58:01	1296403	16:07:37	0.8	3.834 s
OE_SOKA_HHZ/GENC	54	11377	1171.8	1296456	12:58:01	1296409	16:07:37	0.8	3.834 s
OE_WTTA_HHZ/GENC	54	11376	1415.9	1296527	12:58:02	1296412	16:07:37	1.0	3.834 s
SI_ABSI_HHZ/GENC	185	11345	1234.6	1296665	12:58:05	1296299	16:07:37	0.9	3.834 s
SI_BOSI_HHZ/GENC	185	11346	2199.8	1296636	12:58:05	1296416	16:07:37	1.5	3.834 s
SI_KOSI_HHZ/GENC	185	11345	1276.7	1296719	20:43:10	1296278	23:52:41	0.9	15 years
SI_LUSI_HHZ/GENC	185	11345	1279.8	1296671	12:58:05	1296302	16:07:37	0.9	3.834 s
SI_MOSI_HHZ/GENC	185	11346	1418.0	1296465	12:58:05	1296419	16:07:37	1.0	3.834 s
SI_RISI_HHZ/GENC	185	11346	1248.9	1296447	12:58:04	1296305	16:07:37	0.9	3.834 s

Table 1. Continued.

Sources Srcname	Thread	#pkts	Kbytes	pktid	Oldest time	pktid	Latest time	kbps	Average latency
SI_ROSI_HHZ/GENC	185	11346	1337.7	1296668	12:58:05	1296269	16:07:36	0.9	4.834 s
SL_CADS_HHZ/QCDAT	0	2647	1281.1	1297109	12:58:06	798227	15:03:47	1.4	1:04 h
SL_CEY_HGZ/SEED	0	3664	1927.3	1296826	12:58:07	798416	15:03:49	2.0	1:04 h
SL_CEY_HHZ/QCDAT	0	4110	1989.2	1296519	12:58:05	798235	15:03:48	2.1	1:04 h
SL_CEY_HNZ/SEED	0	4404	2316.5	1296496	12:58:06	798388	15:03:49	2.5	1:04 h
SL_GBAS_HHZ/QCDAT	0	2421	1171.8	1296772	12:58:05	798442	15:03:48	1.2	1:04 h
SL_GORS_HGZ/QCDAT	0	2650	1282.6	1296508	12:58:04	798437	15:03:48	1.4	1:04 h
SL_GORS_HHZ/QCDAT	0	2204	1066.7	1296767	12:58:04	798429	15:03:47	1.1	1:04 h
SL_JAVS_HHZ/QCDAT	0	2855	1381.8	1296765	12:58:04	798226	15:03:47	1.5	1:04 h
SL_KNDS_HHZ/QCDAT	0	2412	1167.4	1296514	12:58:03	798002	15:03:46	1.2	1:04 h
SL_MOZS_HHZ/QCDAT	0	2450	1185.8	1296778	12:58:05	797973	15:03:45	1.3	1:04 h
SL_ROBS_HHZ/QCDAT	0	3190	1544.0	1296550	12:58:05	798389	15:03:47	1.6	1:04 h
SL_SKDS_HGZ/QCDAT	0	2751	1331.5	1296495	12:58:04	798395	15:03:47	1.4	1:04 h
SL_SKDS_HHZ/QCDAT	0	2756	1333.9	1296511	12:58:03	798414	15:03:48	1.4	1:04 h
SL_VNDS_HHZ/QCDAT	0	2497	1208.5	1296737	12:58:04	798224	15:03:46	1.3	1:04 h
SL_VOJS_HHZ/QCDAT	0	2676	1295.2	1297121	12:58:06	798188	15:03:46	1.4	1:04 h
ST_DOSS_HGZ/GENC	0	7546	912.4	1296611	12:58:06	800962	15:03:51	1.0	1:04 h
ST_DOSS_HHZ/GENC	0	7546	913.3	1296614	12:58:06	800965	15:03:51	1.0	1:04 h
ST_GAGG_HGZ/GENC	0	7546	1006.3	1296617	12:58:06	801006	15:03:51	1.1	1:04 h
ST_GAGG_HHZ/GENC	0	7546	913.5	1296620	12:58:06	801009	15:03:51	1.0	1:04 h
ST_PANI_HNZ/SEED	0	2264	1190.9	1296732	12:58:05	798418	15:03:47	1.3	1:04 h

tre: it can be noted that latencies for SeismoSAT partner networks were normal (within seconds), while other networks suffered more than one hour of outage.

4 Conclusions

As shown in Fig. 3, the Interreg IV Italia-Austria SeismoSAT project proved to be successful before the financial closing date of 31 March 2015: the backup satellite links have been operational ever since. The Civil Defence of the Friuli Venezia Giulia region expressed its interest in extending the SeismoSAT project to its headquarters in Palmanova and is considering to guarantee the future sustainability of the project.

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