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The Cybersar project

INAF activities

I. Porceddu[1] and N. D'Amico[1,2]

[1] Istituto Nazionale di Astrofisica - Osservatorio Astronomico di Cagliari, Str. 54 Loc. Poggio dei Pini, I-09012 Capoterra (CA), Italy
e-mail: ignazio.porceddu@oa-cagliari.inaf.it

[2] Università di Cagliari, Dipartimento di Fisica, Cittadella Universitaria di Monserrato
e-mail: damico@oa-cagliari.inaf.it

Abstract. CyberSAR is an outstanding state of the art High Performance Computing (HPC) project. It has been proposed by the Cosmolab Consortium, which includes - mostly Sardinian based - private and government shareholders, and funded by the Italian Ministry for Education and Research (MIUR) on a competitive approach. Once completed, CyberSAR will be made by six HPC nodes, linked together through a photonic switch, for a total investment of 12 millions of euros. INAF is a Cosmolab shareholder, through the Osservatorio Astronomico di Cagliari and the upcoming Radioastronomical Station of the Sardinia Radio Telescope. A comprehensive scenario of the CyberSAR project and its relevance with respect to the HPC and INAF involment into the international VLBI network will be given.

Key words. High Performance Computers: parallel – Radioastronomy: VLBI

1. Introduction

Astronomical applications have always been heavy computing demanding. From astrometry equations solution up to modeling the chemistry of the Galaxy, or extracting physical information from radioastronomical pulsar observations, all of these have been a *de facto* highly demanding tasks from a computational point of view. And this is mostly true when considering specialized applications devoted, e.g., to synthesize interstellar molecular spectra or deriving the motion equation of relativistic targets. When considering the Sardinian specific scenario, an additional demanding task has to be taken into account: the not too far kickoff of a highly performing radioastronomical facility, the Sardinia Radio Telescope.

Send offprint requests to: I. Porceddu

2. What Cybersar is

CyberSAR is an outstanding state of the art High Performance Computing project. It has been proposed by the Cosmolab Consortium, which includes - mostly Sardinian based - private and government shareholders. It has been co-funded by the Italian Ministry for Education and Research (MIUR), under the EU PON program, on a competitive base, after the Avviso 1575/2004, where Cybersar got the top score. This is an award to the innovative proposal, where an extremely fast optical regional network will be deployed. In the following we will describe the topology and the main features of this forthcoming optical network, which will be made by six HPC nodes, linked together through a photonic switch.

3. The Cosmolab Consortium

The Cosmolab Consortium has been created through a wide and highly collaborative effort made by academic, research and private institutions. The two Sardinian Universities, Cagliari and Sassari, the INAF - represented by the Astronomical Observatory in Cagliari -, the INFN - represented by the Cagliari Section -, the CRS4 - a consortium which has the Sardinian Autonomous Region as a primary shareholder - and the two leading private ICT companies, Tiscali SpA and NICE srl, are the Cosmolab's shareholders. The Cosmolab's mission is to design, implement and install in Sardinia an embedded network infrastructure, dedicated to solve highly demanding computing tasks and management of databases. This should be accomplished by using *on the edge* technological solutions with respect to the actual HPC sites.

4. Outline of Cybersar

Goal of CyberSAR is to build a specialized HPC infrastructure, a *cyber infrastructure*, composed by a physical network of computing power sites distributed in Sardinia. Both applied and fundamental research activities will be carried out through CyberSAR: Natural sciences, Engineering, Astrophysics, Computer science are a few of the specific interests that will take advantage from this forthcoming state of the art computing facility. The network will be deployed on a complementary basis, i.e. the single nodes will strengthen the actual shareholders' facilities and will cooperate according to a *GRIDded" topology* (Porceddu & Nanni 2004a). Dedicated fiber optics channels, with a minimum bandwidth of 10Gb, will link together the CyberSAR computing nodes, so that a virtual single computing facility, able to perform at several Teraflops, could be created in order to solve demanding tasks. The whole network, and then each node too, will be designed in order to be ready to solve very generic although computationally demanding task. An open architecture, mostly from the software point of view, which could allow offering CyberSAR as a number crunching machine to general users.

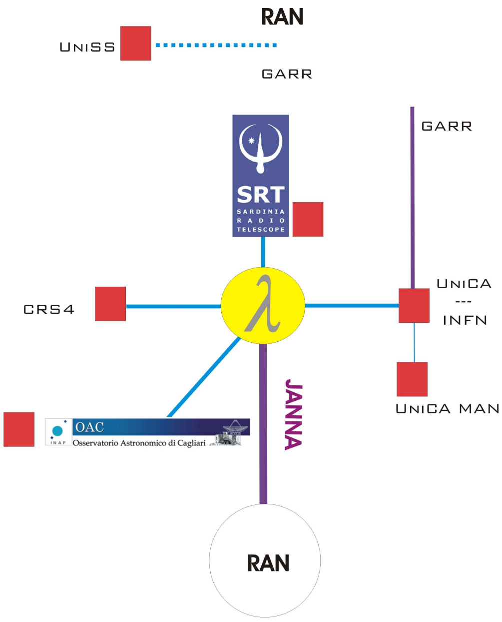

Fig. 1. Topology of the Cybersar network

5. Cybersar topology

The scheme reported as Figure 1 provides the essential topology of the CyberSAR project; computing nodes will be located at the shareholders' premises. In the INAF case, there will be two different nodes: the one hosted by the Astronomical Observatory and the other node will take place at the Sardinia Radio Telescope Station. Both INAF nodes will exchange data by means of a photonic switch, which will be hosted by Tiscali at the "Sa Illetta" headquarters. The Cagliari University and INFN will share the physical location at the Campus in Monserrato, which is already connected to the Metropolitan Area Network (MAN) in Cagliari. CyberSAR will rely on the

Sardinian regional network, actually under deployment, and will take advantage of the Janna project as long as it will need to access wide Internet. Janna, a Consortium/Project participated by the Sardinia Autonomous Region, will provide broadband connectivity to the island, by means of two submarine fiber optical cables.

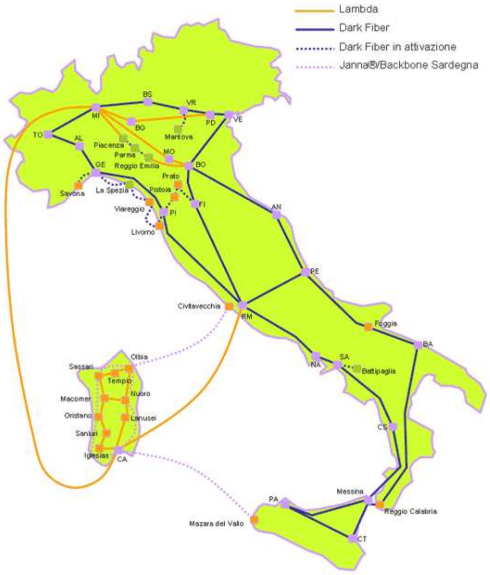

Fig. 2. Topology of the Janna network

6. Cybersar technological "atout"

The leading idea of CyberSAR is certainly the final capability of integrating the single computing nodes as a single one, which will be able to perform several Teraflops. According to the proposed activity, each CyberSAR node will communicate each other by means of dedicated fiber optic channels, allowing a an internal bandwidth of more than 10Gb per second. A photonic switch, which is already under test at the CRS4 headquarters, will handle the internal data exchange and negotiate the in/out coming data. This will be a pretty new, powerful, computational scheme, a so called "Bandwidth Unlimited Computing"; this state of the art scenario is similar to the United States National Science Foundation funded experiment known as "OptIPuter". CyberSAR should be able to test, first in time, an Italian "Lambda-GRID" deployed on geographic scale. This may be seen as the next step of the GRID topology, evolving from IP-based networks towards lambda-based infrastructures. We certainly need to optimize the protocol and general specifications in order to use at its best this potential computing power, well behind the actual software management of a traditional GRID network. This will be part of the CyberSAR research activity, also considering the need for managing the huge amount of data which will be released by the researchers inside CyberSAR. Therefore "application-driven" tests will trigger the development of such management algorithms: among these, forecast of meteorological events, real time processing of radioastronomical data, geophysical applications for earthquakes analysis, etc.

7. INAF and Cybersar

There are several scientific inputs that did trigger INAF to join Cosmolab Consortium and contributes to CyberSAR. A few of these inputs come from teams that do already use massive data processing techniques, tools and facilities, e.g. the Pulsar team and the Astrochemistry group. Furthermore, the new 64-meter radio telescope known as Sardinia Radio Telescope, which is under construction near by Cagliari, will require a computing front-end, mostly, even not only, when will be part of the European VLBI Network. The INAF OAC cluster account for 68 dual core dual processor AMD Opteron 64bit computing nodes. The SRT cluster, which is being installed, will have 60 quad core dual processor Intel based computing nodes (Porceddu & Nanni 2004b). The relevant number of total CyberSAR computing nodes, which are expected to be more than 500, might also be negotiated as a national resource, whenever a GRID scenario is taken into consideration.

8. Science at INAF-OAC vs. HPC

8.1. Pulsar science

Since the discovery of pulsars in 1967 and the discovery of the first millisecond pulsar (a pulsar that rotates hundredths of times in a second) in 1982, pulsars have been used to study a wide variety of physical and astrophysical problems.The applications range from gravitational physics and cosmology to neutron star seismology. In many areas, pulsars provide the only tool accessible to us to study physical environments under extreme conditions. Pulsars can be used not only to study neutron stars properties but also as tools for many physical and astrophysical studies. The local team of pulsar astronomers has used radio astronomical facilities spread out in the world. They have extensively used the Parkes radio telescope, in Australia, which led to the discovery of many hundreds new radio pulsars, including the first ever known double pulsar J0737-3039. The massive amount of data produced by pulsars detection instrumentation is one of the main scientific applications that triggered the search for HPC devices at home. A pulsar offline data processing system, built by the Italian group, is installed and running at the INAF - Astronomical Observatory of Cagliari.

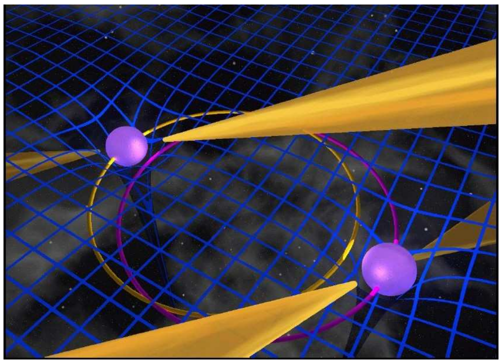

Fig. 3. Double pulsar artist's impression

8.2. Astrochemistry

The study of the photo physics, chemistry and morphology of the Diffuse Interstellar Medium (DISM) is the astrophysical background scenario, the ”big picture”, for the research activity we have carried out since 15 years. And still it is the core activity of the AstroCHemistry Group (ACHG), a joint team of the Astronomical Observatory at INAF and the Dept. of Physics (University of Cagliari). Since

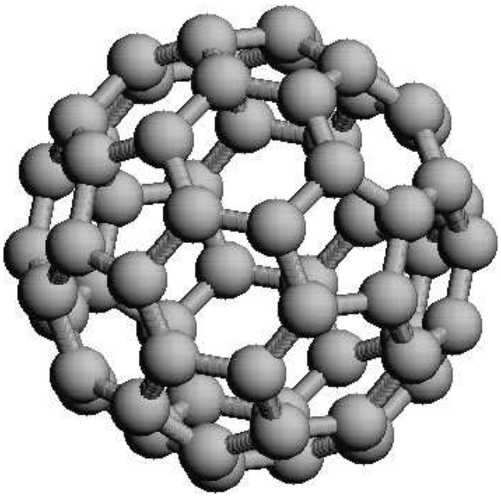

Fig. 4. Numerical approach for a fullerene molecule

late 80', this team has been growing up: starting from observational activities about Diffuse Interstellar Bands, several related topics became part of the ACHG scientific interests. As a matter of fact, DIBs' studies were a starting point for many ideas which were developed during graduate and PhD studies, so that starting from the observational know-how, numerical modeling and laboratory experiments have been carried out. ACHG internal organization allows us to optimize the use of the local hardware and software facilities. State of the art modeling of those carbonaceous molecules of astrophysical interest is actually being done at INAF-OAC, mostly using the CINECA computing resources. Such activity is really computing resources demanding, and the CyberSAR facility will greatly improve

Fig. 5. Computer graphics generated Sardinia Radio Telescope

the capability of understanding the behavior of such fundamental molecules.

9. SRT, the Sardinia Radio Telescope

Sardinia Radio Telescope (SRT) is a new general purpose, fully steerable antenna of the National Institute for Astrophysics. The radio telescope is under construction near Cagliari (Sardinia) and it will join the two existing antennas of Medicina (Bologna) and Noto (Siracusa), operated by the INAF - Institute of Radio astronomy. With its large antenna size (64m diameter) and its active surface, SRT, capable of operations up to about 100GHz, will contribute significantly to VLBI networks and will represent a powerful single-dish radio telescope for many science fields. The Sardinia Radio Telescope has a Gregorian optical configuration with a supplementary beam-waveguide (BWG), which provides additional focal points.

9.1. SRT and e-VLBI

The Sardinia Radio Telescope will join soon the EVN, European VLBI Network, a distributed scientific facility in which national radio telescopes in several countries work together. VLBI means "Very Long Baseline Interferometry", a technique that links radio telescopes to create a virtual radio telescope with a diameter of many thousands of kilometres. This giant telescope is used to create very detailed images of the radio emission from stars in our own galaxy and in the centres of other galaxies. VLBI allows radio astronomers to distinguish objects separated by about 1 millarcsecond - that's the equivalent of seeing individual astronauts on the Moon from Earth.

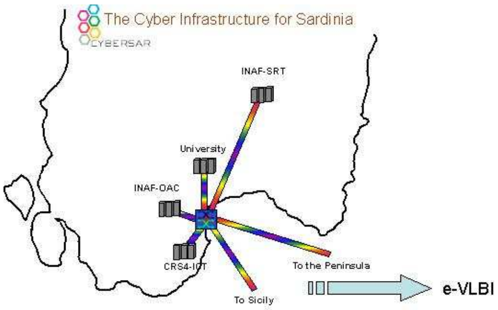

Fig. 6. Connecting SRT to the eVLBI network

VLBI requires each radio telescope has to record radio signals and relative time markers through an "ad-hoc" facility; the recording media, a heavy and big tape (MK 4 facility), is being physically sent to a correlation centre, which has to analyze together all the bunch of tapes coming from single radio telescopes. The MK 5 facility relies on more comfortable hard disk drives as recording media, although sending is still needed. In order to overcome all these messy things, European radioastronomical community goes towards an online transfer of data, the so called e-VLBI, a technique to link the telescopes together through an electronic network. The e-VLBI goal is to connect radio telescopes VLBI via broadband optical fibre networks. The first ever real-time

European "eVLBI" image was produced at JIVE in Dwingeloo on 28 April 2004. Signals from three radio telescopes of the European VLBI Network were sent directly via fibre networks into the Data Processor at JIVE and correlated, without the data at any time having been stored on disk. Therefore eVLBI has the potential to realise much higher data rates, and make data analysis in real time a possibility. In other words: live images from the edge of the Universe can be obtained. There are really big advantages when using eVLBI technique: real-time operation allows flexible dynamic scheduling to respond to *targets of opportunity* like exploding stars; wide bandwidth that is always available results in a major increase in sensitivity for radio sources at the edge of the universe wide bandwidth will fill in uv-plane and lead to higher quality images. From the Operations point of view, we have an easier data transfer logistics, a flexible scheduling, a lower operating costs and a more effective network monitoring. CyberSAR will allow

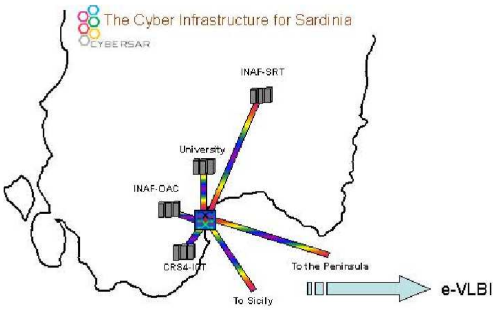

Fig. 7. On June 26th, 2007, the first succssful 512Mbps-bandwidth eVLBI experiment carried out by six european stations

SRT to enter by now in to the eVLBI activity, being in principle also able to process at home these data. The EXPReS project (Express Production Real-Time e-VLBI Service) represents the new joint, funded, proposal of the radioastronomical community to the EU in order to get support and funding for eVLBI operations. Among the goals of EXPReS, there is the *use of switched light-path technology*: this is also a CyberSAR aim, so that a collaborative effort could come.

9.2. SRT and the world wide "Pulsar Timing Array"

The perspective of having supercomputing facilities available at the SRT site, opens up the opportunity for the Italian pulsar group to be involved in a major challenging experiment, the world wide "Timing Array". Pulsars are still the only means to study relativistic gravity in the strong-field limit and thereby provide the best prospects for answering the as to whether Einstein's theory of gravity is the last word in our understanding of gravity. Some unified theories predict cosmic strings, producing a stochastic gravitational waves background. This and other corresponding signals from energetic process in the early Universe can be detected when pulsars are used as the end-points of arms of a huge, cosmic gravitational wave detector. High precision timing of network of pulsars, performed with a network of radio telescopes around the Earth, forming a "Pulsar Timing Array", allows detecting gravitational waves in a frequency range complementary to that of gravitational wave detectors as Virgo or Ligo and LISA. Participation in the Timing Array requires real-time data processing capabilities coupled with modern digital instrumentation, similar to that implemented at the Parkes radio telescope, in Australia, by the Italian pulsar group and their international partners. This allows base band coherent dedispersion of the pulsar signal, and the achievement of high precision timing accuracy.

10. Conclusion

CyberSAR is a state of the art, High Performance Computing project, devoted to deploy an advanced scenario for GRID-like topology: the Cagliari Astronomical Observatory, on behalf of INAF, is strongly committed to be an active partner of this challenge. CyberSAR will take advantage of the scientific solicitations, both from local research teams and also from exciting new challenges coming from abroad.

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