Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 43 (2009) 717–720
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Advanced data acquisition system for SEVAN

Suren Chilingaryan [a,*], Ashot Chilingarian [b], Varuzhan Danielyan [b], Wolfgang Eppler [a]

[a] *Institut fuer Prozessdatenverarbeitung und Elektronik, Forschungszentrum Karlsruhe, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany*

[b] *Cosmic Ray Division, Alikhanyan Physics Institute, Alikhanyan Brothers st. 2, Yerevan 36, Armenia*

Received 29 December 2007; received in revised form 4 April 2008; accepted 5 October 2008

Abstract

Huge magnetic clouds of plasma emitted by the Sun dominate intense geomagnetic storm occurrences and simultaneously they are correlated with variations of spectra of particles and nuclei in the interplanetary space, ranging from subtermal solar wind ions till GeV energy galactic cosmic rays. For a reliable and fast forecast of Space Weather world-wide networks of particle detectors are operated at different latitudes, longitudes, and altitudes. Based on a new type of hybrid particle detector developed in the context of the International Heliophysical Year (IHY 2007) at Aragats Space Environmental Center (ASEC) we start to prepare hardware and software for the first sites of Space Environmental Viewing and Analysis Network (SEVAN). In the paper the architecture of the newly developed data acquisition system for SEVAN is presented. We plan to run the SEVAN network under one-and-the-same data acquisition system, enabling fast integration of data for on-line analysis of Solar Flare Events. An Advanced Data Acquisition System (ADAS) is designed as a distributed network of uniform components connected by Web Services. Its main component is Unified Readout and Control Server (URCS) which controls the underlying electronics by means of detector specific drivers and makes a preliminary analysis of the on-line data. The lower level components of URCS are implemented in C and a fast binary representation is used for the data exchange with electronics. However, after preprocessing, the data are converted to a self-describing hybrid XML/Binary format. To achieve better reliability all URCS are running on embedded computers without disk and fans to avoid the limited lifetime of moving mechanical parts. The data storage is carried out by means of high performance servers working in parallel to provide data security. These servers are periodically inquiring the data from all URCS and storing it in a MySQL database. The implementation of the control interface is based on high level web standards and, therefore, all properties of the system can be remotely managed and monitored by the operators using web browsers. The advanced data acquisition system at ASEC in Armenia was started in November, 2006. The reliability of the multi-client service was proven by continuously monitoring neutral and charged cosmic ray particles. Seven particle monitors are located at 2000 and 3200 m above sea level at a distance of 40 and 60 km from the main data server.

Keywords: Data acquisition; Particle monitor; Detector networks; IHY

1. Introduction

Galactic Cosmic Rays (GCR, mostly protons and heavier nuclei) may be accelerated in our Galaxy by supernova explosions, in jets ejected from black holes or by other exotic stellar sources. After traveling millions of light years in our Galaxy they arrive in the solar system as a steady flux. On the other side, our Sun is a very variable object which changes radiation and particle flux intensities on many orders of magnitude within a few minutes. Because of the Sun's closeness the effects of changing fluxes have a major influence on the Earth, including climate, safety and other issues (see for example, Carslaw et al., 2002). Therefore the solar flux of cosmic rays can be described as a modulation of the stable galactic cosmic ray "background". The Sun modulates GCR in several ways. The explosive flaring processes on the Sun result in the ejection of huge amounts of

* Corresponding author.
E-mail address: Suren.Chilingarian@ipe.fzk.de (S. Chilingaryan).

0273-1177/$34.00 © 2008 COSPAR. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.asr.2008.10.008

solar plasma and in the acceleration of the copious electrons and ions. These particles constitute so-called Solar Cosmic Rays (SCR). The SCR reach the Earth and initiate the creation of secondary elementary particles in the terrestrial atmosphere, increasing the counting rates of particle monitors by several percents. This effect is called ground level enhancement. Other, non-direct solar modulation effects influence also the intensity of GCR. The solar wind "blows out" the lowest energy GCR from the solar system, thus changing the GCR flux intensity inversely proportional to the Sun's activity. The very fast solar wind from the coronal holes, huge magnetized plasma clouds and shocks initiated by coronal mass ejections, are traveling in the interplanetary space and interact with GCRs. On arrival at the Earth, the magnetic field of the plasma cloud depletes the GCR, measured as decrease of the secondary cosmic particles, so-called Forbush decrease (Munakata et al., 2000).

Hybrid particle monitors at Aragats Space Environmental Center (ASEC, Chilingarian et al., 2003) measure both charged and neutral components of secondary cosmic rays and provide a good coverage of different species of secondary cosmic rays with different energy thresholds. A multivariate correlation analysis of the detected fluxes of charged and neutral particles is used for analysis of geoeffective events, i.e. Ground Level Enhancements, Forbush decreases, Geomagnetic Storms and for reconstruction of the energy spectra of SCR Chilingarian et al., 2005. The particle monitors are located in the two research stations on the slopes of Aragats Mountain at altitudes 2000 and 3200 m above sea level and are connected with the data analysis center in Yerevan by means of a wide-range radio network. The Cosmic Ray Division of Yerevan Physics Institute has started an ongoing process of establishing a world-wide network of detectors operating at different latitudes, longitudes and altitudes.

2. Advanced data acquisition system

The Advanced Data Acquisition System (ADAS, Chilingaryan, 2006) is developed having in mind the distributed nature of GCR detection networks often consisting of multiple detectors located in difficult to access places world-wide. The most attention is devoted to the possibility of autonomous operation, error recover and remote management capabilities.

To simplify cooperation of research groups and open a way for integration with other particle detection networks the intercomponent communication is released on top of high level standards. The hybrid XML/Binary format is used for the data storage and exchange. The experimental data are represented by raw vectors. MySQL columns are used in the data storage subsystem and space-separated ASCII vectors for the data exchange. Each vector includes associated timestamp, estimated data quality and references XML metadata describing meaning of each column.

The data acquisition system is constructed from uniform components communicating over well-defined interfaces. The main component is called Unified Readout and Control Server (URCS) and takes care for readout of experimental data from SEVAN particle detectors, preliminary analysis, and distribution of the data to other components. Along with the treatment of experimental measurements the URCS server provides a set of interfaces for controlling both detector electronics and software behavior. Web Services are used to facilitate both control and data dissemination. The provided web frontend delivers to the operator a full set of remote management capabilities.

In addition to the URCS servers the ADAS incorporates alarm and data storage subsystems running on the local file servers. The alarm service is used to issue e-mail notifications about severe conditions of Space Weather or/and failures of detector electronics. The data storage subsystem is periodically inquiring the data from all URCS servers and storing it in a MySQL database on reliable servers in each of the SEVAN sites. To ensure data safety the server hard drives are configured as a mirroring RAID system.

Furthermore, the stored data are analyzed by off-line software and made available for the physical analysis by means of Data Visualization Interactive Network (DVIN, Eghikyan and Chilingarian, 2005). Fig. 1 presents the overall system design.

2.1. Frontend computers

In order to improve the system stability we are using identical Minibox M100 (VIA C3 533 MHz, 512 MB RAM) computers based on the VIA Eden platform at all research stations. The computers are equipped with Gentoo Linux and are running kernel (2.6 family) optimized for real-time applications. The major advantage of the platform is the complete absence of moving mechanical parts. The system has passive (fan-less) cooling. Instead of a hard drive, a Compact Flash (CF) memory card is used. A small LCD keypad is embedded into the computer case. It provides basic management capabilities and primarily used to represent current system status and to notify operators about critical failures.

A small memory buffer of embedded hardware is only able to hold few minutes of detector data. Therefore, it is extremely important to perform software update as fast as possible. The usage of CF cards is drastically simplifies and speeds up a process of software installation and upgrade. The installation can be performed on any computer equipped with CF card reader. The setup application asks several questions about the system configuration (Name, IP address, Type of Hardware, etc.) and then installs software and configuration files on a provided CF disk. Then upgrade is done by replacing the currently working CF card with a newer one (implies computer reboot). This operation is very simple and might be performed within several minutes by the technical shift look-

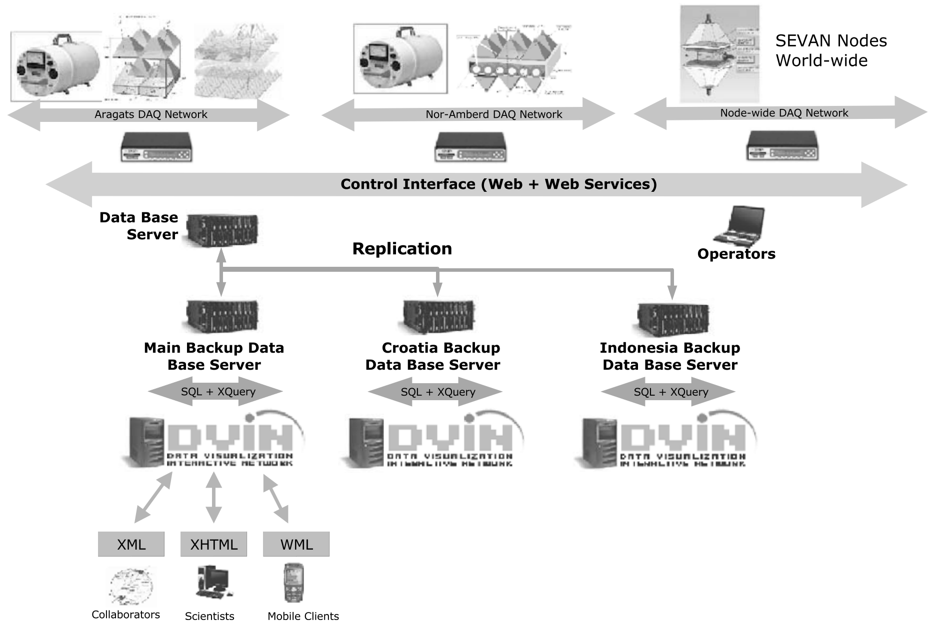

Fig. 1. Layout of the new ASEC data acquisition system. Several detector arrays are operating at Nor-Amberd and Aragats research stations. The detectors are controlled by URCS which are installed on each station. The data dissemination and detector control is facilitated by Web Services. The DVIN is used to distribute the data to end users.

ing after the stations. The experience of system operation at ASEC shows that in worst case 5 min of data are lost during software update.

2.2. Unified readout and control server

The URCS server is an autonomous component of the data acquisition network and consists of multiple interacting components. First of all it is a URCS daemon (daemon is a system service in UNIX world) which takes care of communications with the underlying electronics. Hiding detector details from other URCS components it provides a uniform way for the detectors monitoring and control.

The URCS servers are executed on the frontend computers and are able to operate without connection to the rest of the data acquisition network for long periods of time. In the case of a hardware failure the problem is logged and the URCS software performs the hardware re-initialization. Most of the possible software problems are handled internally. If a non-recoverable error is encountered the daemon leaves an emergency message in the log. In the last case it would be automatically restarted by a system daemon which is monitoring status of all URCS components.

To prevent the information loss the collected data are stored in files on the local Compact Flash card and served to the clients upon request. The amount of time the data remains stored on the server depends on the detector data bandwidth and may be adjusted by the operator.

The communication with remote components is carried out by means of Web Services running on an Apache web server. The data access is well structured. Each underlying particle monitor has own address space and may provide to the clients one or more independent data set. From the specified data set the client applications may request the latest available data or the data for desired historical period. The data channels in all data sets are described by metadata properties. These properties include information on the type of considered particles: charge, energy range, incident direction, etc. The set of properties describing all data sets belonging to a certain SEVAN site is collected in the, so called, site description and is available to the clients upon request.

2.3. URCS operator frontend

The URCS Web Frontend is used to examine various aspects of the current URCS operation, modify actual configuration, start and stop readout daemons, or access the URCS log files. The operator is able to browse the data stored on the URCS servers. The current data are presented in a fully annotated fashion using associated site descriptions. The older data are available in XML, HTML and/or CSV. The continuous data quality monitoring is feasible by provided dynamic web page which is depicting various aspects of the most recent data by means of Scalable Vector Graphics (SVG) charts. The metadata properties could specify conditions demanding the operator's intervention. If certain condition is met the interface will signal an alarm to the operator.

References

Carslaw, K.S., Harrison, R.G., Kirkby, J. Cosmic rays, clouds, and climate. Science 289, 1732–1737, 2002.

Chilingarian, A., Avakyan, K., Babayan, V., et al. Aragats Space Environmental Center: status and sep forecasting possibilities. J. Phys. G 29, 939–951, 2003.

Chilingarian, A., Arakelyan, K., Avakyan, K., et al. Correlated measurements of secondary cosmic ray fluxes by the Aragats Space Environmental Center monitors. Nucl. Instrum. Methods A 543, 483–496, 2005.

Chilingaryan, S. Universal Data Exchange Solution for Modern Distributed Data Acquisition Systems and Its Implementation for Cosmic Ray Monitor Networks, Ph.D. Thesis, 2006.

Eghikyan, A., Chilingarian, A. Data visualisation interactive network for the Aragats Space Environmental Center. In: Proceedings of the International Symposium on Solar Extreme Events, Nor Amberd, Armenia, pp. 245–251, 2005.

Munakata, K., Bieber, J., Yasue, S., et al. Precursors of geomagnetic storms observed by the muon detector network. J. Geophys. Res. 105, 27457–27468, 2000.