THE STAR SLOW CONTROLS SYSTEM - STATUS AND UPGRADE PLANS

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ABSTRACT

The STAR (Solenoidal Tracker At RHIC) experiment located at Brookhaven National Laboratory has been studying relativistic heavy ion collisions since it began operation in the summer of 2000. An EPICS-based hardware controls system monitors the detector's 25000 operating parameters. The system uses VME processors to communicate with sub-system based sensors over a variety of field busses, with High-level Data Link Control (HDLC) being the most prevalent. Other features of the system include interfaces to accelerator and magnet control systems, a web-based archiver, and C++ based communication between STAR online, run control and hardware controls and their associated databases. Planned revisions to the system involve moving I/O controllers from VxWorks to RTEMS; transferring user displays from Sun Workstations to PC's and replacing aging VME processors with PC's. Experience with the existing system as well as upgrade plans are discussed. Proposals for the integration of upgrade detectors are outlined.

CURRENT STATUS

STAR Overview

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory is home to the STAR (Solenoidal Tracker At RHIC) experiment. The STAR experiment investigates collisions between ions accelerated to energies up to 200 GeV per nucleon. Collisions between polarized proton beams at various energies are also investigated at RHIC. The primary functions of the STAR experiment are the study of nuclear matter at high energy densities and the study of the spin structure function of the proton [1]. The initial STAR experiment consisted of several experimental subsystems including the time projection chamber (TPC), data acquisition (DAQ), trigger, online computing, and STAR magnet. The experiment has added several other detector subsystems. These include two electromagnetic calorimeters, one on the end cap of the STAR magnet (EEMC) and one on the barrel of the magnet (BEMC). Other subsystems are the Forward Time Projection Chamber (FTPC), the Central Trigger Barrel (CTB), the Beam Beam Counter (BBC), the Zero Degree Calorimeter (ZDC), the pseudo Vertex Position Detector (pVPD), the Time Of Flight detector (TOF), Forward Pion Detectors (FPE/FPW), the Silicon Vertex Tracker (SVT), the Silicon Strip Detector (SSD), and the Photon Multiplicity Detector (PMD) [2]. The detectors, detector electronics, and a three-story platform housing the control system electronics sit in a high radiation area in the Wide Angle Hall (WAH). This area is not accessible during operation of RHIC, which runs continuously for weeks at a time. Therefore, the slow controls system as well as the operation of STAR is designed to allow for both remote and continuous operation. The DAQ room adjacent to the STAR control room houses data acquisition electronics, control electronics for monitoring environmental conditions in the WAH and DAQ rooms, control electronics for monitoring the RHIC clock frequency, and control electronics for interfacing with the accelerator and magnet control systems.

STAR Slow Controls system

The STAR hardware controls system utilizes a Sun Ultra-10 host workstation in the STAR control room running EPICS (Experimental Physics and Industrial Control System) on a network of front-end processors. [3, 4] With one exception where EPICS 3.13.1 is used, STAR slow controls runs EPICS version 3.12.4. Software from the Sun is uploaded via the network to Motorola MVME single board computers (cards) equipped with 680x0 processors. These processors use the VxWorks version 5.2 operating system. The MVME cards housed in Wiener VME crates on the platform in the WAH and DAQ rooms play the role of EPICS Input/Output controllers (IOC's). Presently the network employs approximately 20 IOC's consisting of two types of IOC [5, 6]. Both MVME 167 and MVME162 models are used. In almost all cases, a crate houses a single IOC, though occasionally a crate supports a second IOC. A second Sun Ultra-10 on the network is configured to serve as a backup host workstation if needed. It is also used to reduce EPICS workload on the primary host workstation.

Control software consisting of the VxWorks operating system, device drivers, control database variables, and user designed control programs resides on the host Sun workstation. Startup commands for an IOC are programmed from the host using either the serial console or the Ethernet connection. When booted the IOC uploads its control software via the network from the host workstation. Any computer on the network that can access the host computer, or any EPICS configured computer on the network can be used to boot an IOC. Once an IOC is booted, failure of the host will not affect the operation of an IOC (unless an IOC is rebooted when the host is down). Since IOC's are only accessible when there is no beam in RHIC, STAR relies on the network to boot/reboot IOC's. In the WAH, the Wiener Crates are connected using a CANbus field bus, with two independent CANbus networks. The EPICS based CANbus control application using CANbus controllers for crate control provides yet a third method for booting/rebooting the electronics in a crate. This design of redundant capabilities to access processors is typical of the slow control design at STAR.

The control software of the main workstation utilizes many EPICS host applications and channel access clients to control the STAR subsystems. These applications include the CANbus control application, the Motif Editor Display Manager (MEDM) applications, the sequencer, the alarm handler client (ALH), and the data archiver client. Not all experimental information need during operation is measured by STAR, nor is all the information measured by STAR exclusively used by STAR. For this data, a stand-alone channel access interface, CDEV, is used to exchange data between STAR and the RHIC controls system. All of these applications and programs run on the host workstation.

Each subsystem has at least one workstation in the STAR control room on the controls network. These serve as operator interfaces (OPI's) to the control system. During RHIC operation, these OPI's are used for the control of the STAR detector subsystems via their respective MEDM displays. The alarm handler is displayed on the host workstation. Subsystems control displays can be accessed using the alarm handler display.

The host workstation has been the development platform for most MEDM display applications. These applications reside on the host in application directories where they are organized along subsystem lines. Currently two versions of MEDM are used to access the display applications. In addition to the subsystem displays, the alarm handler (ALH) display, and CANbus crate control displays also reside on the host. While most IOC's load control software exclusively from the host workstation, some of the subsystems have "system expert only" control software residing on their workstations. This includes DAQ and trigger code.

New subsystems have been developed in remote locations and this has led to electronics developers creating their own initial controls systems for testing. A few subsystems have retained these initial pieces of software. One subsystem uses TCL/TK code and displays, which they utilize outside the EPICS MEDM system. A second example is a subsystem that operates its VME crate control outside the CANbus control system. Two of the STAR subsystems have developed complete control systems with independent host workstations on the network. These are essentially mirror images of the primary host workstation, and controls environment. Instead of loading VxWorks, and control software from the primary host, IOC's for these subsystems load software from their respective hosts. These two subsystem hosts run independent MEDM display applications, as well as independent alarm handlers. IOC channels from these subsystems are included in the STAR alarm handler and the STAR controls system host controls the VME crates.

MOTIVATIONS FOR CHANGE

Aging Software and Hardware

By many measures, the STAR controls system is aging. The STAR controls system was designed over ten years ago, and implemented during the commissioning run for STAR in 1999. Since that time, the VxWorks version has never changed, and the EPICS version of the control system was upgraded from 3.11.9 to 3.12.4. Version 3.12 of EPICS base was rolled out in 1995. During this time the EPICS has steadily been upgraded and evolved. There was a major revision of EPICS from version 3.12 to 3.13 in 1996. The current EPICS release, 3.14, became available in 2002, and release 3.15 is due out soon [7]. Many EPICS tools and applications have been revised as well. Further, many new EPICS tools and new applications have been developed. While in some cases these are backward compatible to release 3.12, most are not. We have found it necessary to implement some new subsystems using release 3.13.1 in order to take advantage of pre-existing EPICS collaboration device driver and device application code. The use of an outdated version of EPICS impacts STAR slow controls in numerous ways. It limits the support available from the EPICS collaboration regarding the maintenance application tools, and the implementation of new application tools. Migration to the current EPICS release is clearly advantageous.

Any further upgrade of the EPICS system past 3.13.1 will require a change to a newer version of VxWorks or an alternative operating system. A VxWorks upgrade for STAR implies an upgrade from version 5.2 to Tornado 2.0. The number of subsystems and subsystem IOC's has grown steadily. Several new subsystems will be likely be added to STAR in the immediate future. A new VxWorks Tornado 2.0 license to meet the immediate needs and near future needs of STAR appears to be costly. Fortunately, the current release has made the EPICS core portable to other operating systems, and IOC's can run on VxWorks, Solaris, GNU/Linux, HP-UX, RTEMS and Win32.[5] This enhancement is a strong motivation for STAR to migrate to the current EPICS release, and away from VxWorks.

In a similar fashion, the VME crate base MVME IOC's are also aging. Most IOC's are a decade old. While few have failed, occasionally an IOC has had to be replaced. The detector subsystems currently operating at STAR are constantly evolving. This typically requires adding a second IOC and additional VME crates to share load. Currently we buy outdated MVME's to meet our control needs. Upgrading STAR IOC's using a VME type solution is not cost effective. Further, in many cases an IOC is only used to access the front-end electronics via a serial port. This type of approach appears to be an ineffective use of resources. The ability of IOC has to run on so many architectures under the current EPICS release is again a strong motivation for change.

As with the MVME IOC's, the Sun workstations have proven reliable but are also aging. When the controls system was designed and implemented, Sun workstations with Solaris operating systems were the standard solution in the EPICS world. Today many EPICS users have moved to PC's and there has been substantial development work done for EPICS on this platform. This also true of many of the subsystems at STAR, where PC's have been adopted rather than Suns running Solaris. In addition, the STAR technical support staff are more accustomed this platform.

New Subsystems coming on line

All of these reasons for change are becoming increasingly important as new detector subsystems are added to STAR. [8] Under the present environment, as new subsystems come on line and evolve they are constrained to use the VME crate MVME solution, they must choose between the Sun and PC. They must acquire a VxWorks license. New systems are faced with substantial overhead and a potentially inefficient use of funds. It is important that we remove this integration barrier for developers. Further, past history has shown that the current controls environment has been a barrier for developers working remotely to integrate the controls systems they have created for testing into STAR standard solutions.

NEW SYSTEM

Requirements

The upgraded STAR slow control system must meet several requirements. First, the system must be backward compatible with the current system. Second, STAR has almost a decade of experience with EPICS; as a result, the logical choice for a new system is an EPICS based system. This is particularly true in that a few of the initial subsystems are not good candidates for upgrade. Some of these subsystems utilize their own in house version of EPICS data base records, device support, and driver support. These subsystems will not likely be replaced, or redesigned. Consequently, any new system must be able to operate in conjunction with our current system. Compatibility provides the ability to migrate to the new system in stages. Third, the new system must allow for the upgrade of the IOC operating system in a cost efficient manner. The new control system must allow for the migration away from a VME crate based MVME approach. Fourth, the new system must be available to developers to use in the early stages of development. It must facilitate migration to the STAR controls system. Finally, the new system's performance must be well understood. Any new system must utilize components and features that have been tested and deemed reliable.

Software

Control software will migrate to EPICS version 3.14 and RTEMS version 4.6. This solution provides numerous advantages. It will maximize compatibility with current EPICS based control software, allowing STAR to use most of the old applications with minimal conversion. Under this system, applications that run using the current system and applications that have been migrated to the new system can be operated simultaneously. For example, EPICS tools such as MEDM display and the alarm handler will be able to run on both systems. Subsystems with applications that require substantial conversion, or those that cannot be transitioned, can remain on the old system. The parameters monitored and controlled by these applications will still be accessible to the new system. Those detector subsystems that choose not to transition can still do things the "old" way. Migration to EPICS 3.14 will allow for upgrades to the alarm handler, archiver, and display manager tools. With this solution, the output of the front-end electronics running old control software will be compatible with the same front-end electronics when the run software converted to the new EPICS release. Finally, this solution eliminates the cost associated with VxWorks licensing.

Hardware

In parallel to the redesign of the STAR control software, several changes will occur in the hardware employed by the control system. First, we will replace the current Sun host workstation with a PC running EPICS with the RTEMS operating system. The control room operators will access controls displays and the alarm handler displays from this PC. At boot time, an IOC will have the ability to load the RTEMS operating system and subsystem application software from the control room PC in essentially the same way that an IOC currently boots using the Sun. Second, some VME crates and IOC processors on the platform in the WAH currently running VxWorks will be replaced by PC's running the RTEMS operating system. These PC's will also be loaded with EPICS, and the control software applications for their respective subsystem. In this way, we will have the ability to boot from the network or run an IOC locally if needed. Third, control room computers being used as OPI's will be configured to run EPICS and a display manager. They will have the dual ability to access displays from the host workstation, as well as the ability to access a platform PC that will run a display manager to generate displays.

Such a hardware configuration offers several advantages. It is cost effective in that it offers the hope of lower hardware costs for upgrading systems, and lower overhead costs for new systems. Under this design, only two PC's are required for most systems rather than an OPI workstation, a VME crate and MVME IOC. This "two PC solution" provides additional advantages during the development of controls for new detector subsystems. This configuration will allow for quick adoption within the implementation standards of STAR by both current users and developers working on new subsystems. A distribution kit for these subsystems should be available in December. Finally, since each subsystem's control software will reside locally on an IOC, this configuration also offers a dual system for IOC control. As a result, it increases the redundant capability of the control system.

SUMMARY

The STAR control system was designed a decade ago. It has operated stably and for that reason, the architecture of the system has been fundamentally unchanged since the first experimental run at RHIC in 1999. With the addition of new subsystems, monitoring by the control system has grown from 8000 channels to more than 25000 channels. The control system is an EPICS based system built on Sun workstations with Solaris architectures. The system uses old Wiener VME crate based MVME processors for IOC's. Both the hardware and software components of the control system are aging. The system is at a stage where it is difficult and expensive to add new detectors. An upgrade of the EPICS base to the most recent version combined with the adoption of RTEMS as the IOC target architecture will produce many advantages and benefits to the STAR collaboration. A plan is now in place for moving I/O controllers from VxWorks to RTEMS, transferring user displays from Sun Workstations to PC's, and replacing aging VME processors with PC's.

ACKNOWLEDGMENTS

This work was supported in part by the United States Department of Energy under contract numbers DE-FG03-96ER40991, the Creighton College of Arts and Sciences and the Dean of the Graduate School, Creighton University.

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