DETECTOR CONTROLS FOR THE NOνA EXPERIMENT USING ACNET-IN-A-BOX

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Abstract

In recent years, we have packaged the Fermilab accelerator control system, Acnet, so that other instances of Acnet can be deployed, independent of the local Fermilab infrastructure. This encapsulated Acnet, also referred to as Acsys-in-a-Box, is installed as the detector control system at the NOνA Far Detector. NOνA is a neutrino experiment using a beam of particles produced by the Fermilab accelerator chain. To fulfill the experimental goals, there are two detectors: a 200 ton ``Near Detector'' on the Fermilab campus and a 14000 ton ``Far Detector'' 810 km away in northern Minnesota. All key tiers and aspects of Acnet are available in the NOνA instance, including the central device database, Java Open Access Clients, Erlang front-ends, application consoles, synoptic displays, and state notifications. Acnet at NOνA is used for power-supply control, monitoring detector position and strain gauges, environmental control, PLC supervision, relay rack monitoring, and interacting with the Epics PVs which instrument the detector's scientific data acquisition hardware. We discuss the challenges of maintaining a control system in a remote location, synchronizing updates between the instances, and improvements made to Acnet as a result of our NOνA experience.

INTRODUCTION

NOνA [1] is an off-axis neutrino experiment, designed to investigate fundamental questions such as neutrino oscillation parameters and the neutrino-mass hierarchy.

We were asked to provide a detector control system for the NOνA experiment's Far Detector, including miscellaneous devices, but excluding the experimental data acquisition hardware. That data acquisition hardware consists of avalanche photo diodes (APDs) connected to front-end boards connected to data concentrator modules. These components are controlled by a set of Epics IOCs.

Our local Fermilab Acnet [2] control system could have easily grown to incorporate the NOνA devices. However, requirements of the Far Detector project, most importantly being able to operate independent of the local (Illinois) Fermilab site and network in the case of network outages, dictated that we needed to deploy a separate instance of Acnet on the NOνA Far Detector computers.

We had been developing support for Acsys-in-a-Box [5], an encapsulated version of Acnet which can run on a single computer, contrasted with the Fermilab accelerator version of Acnet which has functionality distributed across many computers.

We have successfully deployed Acsys-in-a-Box for NOνA, including all the components required of a control system, such as monitor and control, alarms, user interface, save-restore, etc. Our original vision for the encapsulated Acnet was that it would be a stripped down version of Acnet, with only the most essential central services included. However, we discovered that to meet NOνA's requirements, we needed to include nearly every feature that we use at Fermilab.

USER INTERFACE

The Acnet user interface used in the Fermilab accelerator complex includes a mix of X-windows based console applications, custom Java programs, and graphical displays built with our Synoptic [3] drag-and-drop GUI builder. The traditional applications are accessed through a set of index pages, with a separate index page for different accelerators (e.g. Linac, Booster, Main Injector, etc.). These are typically mostly alphanumeric displays, although there are some graphical applications and plotting utilities. The consoles also include several programs for developers or experts to delve more deeply into the control system.

For the NOνA control room, we decided to limit the applications used to the Synoptic graphical displays. This prevents a lot of confusion for new, untrained shift operators. Only a few higher-level Synoptic displays are routinely monitored in the control room, with sub-displays available when more details on individual channels are needed. The full Acnet console environment is still available for experts.

MAJOR DUTIES

The raison d'être for any control system is the actual devices that it interfaces with. For the NOνA Far Detector, Acnet is responsible for monitoring the miscellaneous systems outside of the primary experimental data acquisition system.

Power Supply Monitor

A Wiener MPOD system is used for the power supplies and consists of 56 crates for low and medium voltage and 2 for high voltage supplies. Every crate is Ethernet-accessible. The control system must be able to read and control the critical parameters like output voltage, current and temperature for every channel. It also requires 24x7 monitoring and alarm notification. The Java Open Access Client (OAC) [4] architecture is well-suited for the implementation. The industrial, well-established SNMP protocol is used for the communication. To enhance the

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reliability and performance of the system, multi-threaded, concurrent programming is heavily used. The OAC maintains one SNMP client for every power supply crate. The name of the crate and SNMP identifiers of the control points are configured in the central device database and downloaded when the client is initialized. Every client manages its own data pool that contains the readings for the crate and updates the pool periodically with the SNMP bulk reading feature. To recover from disruption due to networking or power outage of the power supply crate, the client has a robust retry mechanism to re-establish the communication as soon as possible. The client monitors readings of the critical parameters, compares them to pre-set thresholds, and sends out alarms to the alarm system.

Position and Strain Gauges

Position and strain gauges are monitored with Phidget [6] sensors attached to various locations on the detector. The sensor readings are input to a PC running LabView with an OPC gateway. A Java OAC implements an OPC Data Access client. The client starts with downloading the OPC (Ole for Process Control) tag information from the central database and sets up multiple threads to manage data pools that cache data and update periodically. Retry logic is implemented to recover from failures such as network outages or power outages. The client also monitors whether the sensor readings are out of pre-set tolerances and sends out alarms if that is the case.

Rack Monitors

Compact RIO systems from National Instruments collect temperature, status, and airflow data for relay rack monitoring at the NOvA Far Detector. Since these Compact RIOs run an embedded EPICS IOC, we use the Channel Access protocol to collect their readings. A device driver interface for Channel Access was developed for our Erlang-language Acnet front-end framework in part to support this subsystem.

Environmental Monitoring

A Siemens PLC controls the HVAC system for the NOvA Far Detector Building. The environmental data from this PLC is made available to the global Acnet control system via a Java OAC using the OPC protocol to the Siemens system.

Dry Gas PLC System

The APDs of the NOvA data acquisition system are thermo-electrically cooled. In order to prevent damaging frost build-up, there is a PLC-controlled gas dryer system which monitors dew-points and system status. The interface to this PLC is through an Erlang based front-end using the standard Modbus/TCP protocol.

Data Acquisition Control System

The direct chain of hardware for acquiring experimental data includes Linux-based Data Concentrator Modules (DCMs). These DCMs also run EPICS IOCs for control and monitoring. The IOCs provide access to APD temperatures and thermo-electric coolers in the data acquisition hardware chain. Though initial plans were for the DCM IOCs to be totally independent of the Acnet Control System, it wasn't long before various situations were identified which required communications between the two systems. For instance, the IOC controls enabling the thermoelectric cooling and it is useful for the Dry Gas PLC to know whether cooling has been enabled. Conversely, if the PLC detects a fault, we need to tell the DCM IOC about it so it can disable cooling. Here again, the Erlang implementation of Channel Access protocol is used for the interface between Epics and Acnet.

IMPROVEMENTS TO ACNET

In order to meet NOvA requirements, we added some features to Acnet that are also applicable to and useful for the Fermilab environment. Most of these are transparent to users, but are key changes in the Acnet infrastructure.

The "virtualization of nodes" is one of the more significant upgrades. The Acnet installation at the NOvA Far Detector is limited to 4 computers, including hosting the central device database, alarms, user displays, front-ends, and data-logging. Previously, the Acnet communication protocol required front-ends and other major services to reside on separate computers. The node virtualization allows us to easily map services to different computers and allows multiple services on the same physical computer.

Another improvement allows us to make hierarchical trees of alarms. For instance, we can define a device A that will go into alarm if any of its subordinate devices A1, A2, A3, or A4 are in alarm. This is used to provide a high level overview of the alarm status of the detector which is much easier for shift personnel to monitor. When there is a high level alarm, it is straightforward to drill down through the displays to examine the specific devices in alarm.

We have developed a new implementation of our Acnet protocol transport, called acnetd, that we have been rolling out. This provides a common implementation for the Java and console environments which had previously been separate code bases. The limitations of NOvA Far Detector infrastructure required us to move forward with deploying this new implementation.

We also now allow a node-less type of remote Acnet client access. This permits features such as Accelerator Control Language (ACL) scripts running from a smart phone or other thin client using our connection applications or libraries.

We re-wrote some facets of Acnet to make them more readily adaptable for the NOvA environment, such as State, our state-broadcasting front end. The original State is a C/VxWorks application and it was rewritten in Erlang, with a 90% reduction in lines of code compared to the original C code.

Synoptic, our graphical display builder and viewer, was also improved. New features inspired by NOvA work include access to data logger data (for historical plotting) and color-coded error displays.

We've also written software specific for NOvA, such as programs to extract data from our data loggers and push it to the long term NOvA experiment archival database.

CHALLENGES

The changes and adaptations for NOvA didn't come without a few problems. The first of these was that the computers, network, and operating systems were decided upon prior to our involvement with the project. While not a major hurdle, this meant that we had to adapt to their configurations, rather than selecting the configurations easiest for us to work with. A side-effect of their newer, more powerful multi-core computers was that they uncovered some subtle concurrency bugs in our Java software infrastructure which had never come to light in our older installation at Fermilab.

The remoteness of the NOvA Far Detector site also presents some issues with communication. The remote link has more limited speed than local connections and there are occasional outages. Also, there are power outages at the far detector site due to the newness of the electrical infrastructure. We have spent extra effort making sure our software is more fault tolerant and automating recovery steps.

With this additional instance of Acnet operational, we also took steps to ensure that it would regularly receive updates of the Acnet executables without adversely affecting operations. Beyond copying executable code, database changes also need to be synchronized. Numerous scripts and procedures to copy the updates have been implemented, which have resulted in better practices for us in general.

SUMMARY

The NOvA experiment is successfully operating using a second, independent instance of Fermilab's Acnet control system. NOvA requirements have prompted us to make several improvements to the control system, which are also beneficial to the accelerator controls environment at Fermilab. A single source code base is used for both instances of the control system.

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