WIRELESS NETWORK INTEGRATION INTO EPICS SYSTEMS

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Abstract

Wired connections are very often irreplaceable in large scientific facilities due to performance and reliability issues. However, those communication links suffer from several disadvantages, such as lack of flexibility during deployment or reconfiguration and deterioration of wires and physical connectors, specially in environments under radiation. The goal of the present work is to study the introduction of wireless EPICS sub-networks in a standard general wired EPICS system. This involves the study and selection of a proper wireless technology, architecture, communication strategy and security policy. To ensure the validity of the proposed approach, a thorough study of the results related parameters, such as throughput, security, repeatability and stability of the overall system is needed. Once those are considered, the next step is to decide where and when the replacement of physical connections with Wireless communication systems is suitable. The aim is to eliminate as many wires as possible without decreasing the reliability, security and performance of the current EPICS control network.

INTRODUCTION

EPICS is one of the most important control systems oriented to large scientific facilities. This standard was born and evolved through collaboration between laboratories. Nowadays, it offers solutions for most of the control needs and is compatible with a large variety of hardware platforms (PC, PXI...) and operating systems (Linux, Windows, VxWorks...). EPICS is a set of open source tools, libraries and applications to create soft real-time distributed control systems. It is a Big Physics standard based on a middleware approach, used worldwide on large scientific plants such as particle accelerators and telescopes.

Although EPICS is a mature software framework, the study and validation of new configurations of EPICS systems is very valuable, since new ideas open its evolution and improvement. In this sense, the main objective of the work sustaining this paper is the study of the inclusion of Wireless subnetworks into EPICS networks. In this paper, the first steps towards this direction are presented. Two main schemes are considered: the standard architecture of EPICS systems using only wired connections, and an EPICS System that contains wireless links. The validation of the proposed system is made by comparing their reliability to the classical scheme. Two testbenches, one for each configuration, will be implemented for such comparing process.

In order to obtain more valuable results, the testbenches include two different EPICS based systems: the first one using a classical EPICS IOC and the second one, using hardware which integrates LabVIEW RT and EPICS.

The classic EPICS methodology shows a set of distributed Linux machines implementing IOCs. They are responsible for communicating EPICS with the control system tools and devices (motors, thermocouples, data acquisition systems, switches etc.). This approach requires the development of drivers (or equivalent mechanisms as EPICS devices) for each new device, which are the interface between EPICS records (set of process variables) and hardware (or 3rd party software). These drivers can be split into two parts: Device support and driver. The first one is the interface for records and hardware independent. The second one provides low level software access to the hardware. The development of these drivers requires C language notions, EPICS knowledge (records, scan methods, Channel Access) and experience with I/O hardware (I/O registers, buses, interrupts). That means an extra effort every time a new device is added to the control structure.

The second architecture consists of using LabVIEW together with EPICS. This approach allows for avoiding the hardware dependent developing costs of the previous architecture. National Instruments (NI) hardware and software offer support for a high variety of devices and cards, therefore, there is no need to write specific drivers. Moreover, the using of LabVIEW simplifies the development of the control structures. NI provides an EPICS server integrated in the LabVIEW solution which is based on the LabVIEW DSC module, and runs on the real time system in the PXI controller. The Real Time controller publishes EPICS PVs taking data from LabVIEW's Shared Variables. This scheme shows interesting advantages, but, before adopting this method of working, it must be validated. To do so, it is proposed to perform two parallel implementations in each testbench: the first one following the classic methodology and the other one using LabVIEW.

In a second testbench, an EPICS-based wireless links system will be introduced, maintaining the two architectures. The possibility of replacing as many cables as possible is studied here. This implies to analyze when and under what circumstances is possible to do it. The replacement of wired connections for wireless communications must satisfy several requirements, specially those related to throughput, repeatability and security. The validation of this architecture is made by comparing the results of data acquisition and control to those obtained from the wired structures.

In the next section a thorough explanation of the two experimental setups for the validation of each proposed scheme is included, and some comments about the imple-

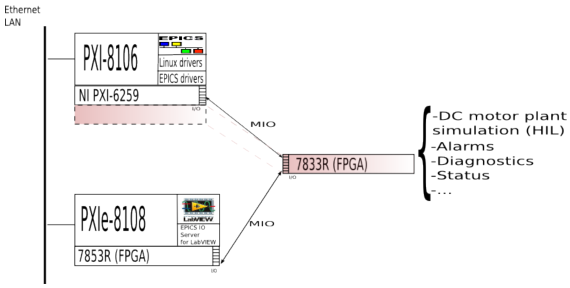

Figure 1: Control System Architecture

Table 1: Main Test Stand Settings for Wired Experiment

LabVIEW approach	EPICS classical
PXIe-8108	PXI-8106
2.53 GHz Intel Core 2 Duo	2.16 GHz Intel Core 2 Duo
1 GB RAM	512 MB RAM
LabVIEW RT	Scientific Linux 6.1
LabVIEW 2010 SP1	EPICS R3.14.12.2

mentation. The last section is dedicated to the future plans for this experiment and conclusions.

EXPERIMENT SETUP

Now, the performed experiments are described. As said before, the goal is to test the results obtained from proposed new configurations in EPICS systems in a comparative way.

Wired Testbench for Testing EPICS Environments

The experimental setup emulates a reduced local controller. This includes data acquisition, sequencing and control. Two plants simulating a DC motor are implemented as Hardware in the Loop (HIL) using NI PXI-7833R multifunction card, which includes a Virtex II FPGA. Taking advantage of the parallel computing offered by the FPGA, a complete set of signals is generated. In an early stage, the typical signals involved in a local controller are present such as interlock signals, diagnostics, etc. These signals will be the Process Variables (PVs) of the EPICS system. The generation of these signals can be performed by other devices such as signal generators, but, in order to have a high level of flexibility within same device, an FPGA has been chosen for this task. Different type of signals are generated (digital, analog, waveform), periodically changing as well as acting against external stimulus.

Two control systems are set up. The first one corresponds to the LabVIEW approach and the second one to the EPICs classical one, as shown in Figure 1. The settings of the test stand can be found in Table 1. Both perform the same control actions and data acquisition, but the way of working is different. The following paragraphs describe each implementation:

- The first hardware setup consists of a PXI chassis from National Instruments (PXIe-1082) with a PXIe8108 controller (Pharlap ETS) running LabVIEW Real-Time operating system. A NI 7853R Multifunction RIO with a Virtex 5 FPGA acts as I/O hardware. The control actions are defined in a LabVIEW program running in the PXI controller, where a PID control is performed for HIL DC motor simulation and its equivalent plant model runs on the FPGA in charge of emulating signals. LabVIEW also acts as an EPICS server through the *EPICS IO Server* for LabVIEW. This publishes desired control signals to a EPICS network via Channel Access protocol, creating new Process Variables. This method allows the developer to focus on the control without worrying about drivers, since these are provided with the NI hardware and software and the process is almost transparent for the user.

- The second setup corresponds to the classic methodology, which is taken as a reference. The IOC is running in a NI PXI-8106 embedded controller with Scientific Linux 6. A NI PXI-6259 DAQ card is used for I/O tasks. As explained before, this device requires its own drivers, for both Linux (SL6) and EPICS. Both can be found in the ITER CODAC Core System v3.0 public version, [1]. Once installed and configured, the 6259 card is ready to be used. The IOC database is defined including all the system PVs. A sequencer implementing a Finite-State Machine is set. A PID control for the DC motor is performed in the *Operation* state of the FSM, through the EPICS PID record. The rest of the signals are also managed in this state.

The test stand must be continuously operating the two configurations in parallel for a long period in order to get reliable results concerning repeatability issues. Therefore, the desired parameters are stored in a database during run time, for comparing wired and wireless approaches. Figure 2 shows the current experiment setup running. Special care should be taken when system fails, since reliability is one of the most important issues to be addressed with this experiment. In addition, the performance of publishing process variables of different type is also measured for both approaches.

Additionally, once the previous experiments' results are obtained and studied, we should be able to do a very preliminary analysis to validate or discard the use of LabVIEW environment together with EPICS, with high reliability requirements.

Wireless Communications Into EPICS Architecture

The next task is to study the possibility of introducing wireless technologies into EPICS systems. Wireless communication offers many advantages, as reduced costs, mobility, scalability and ease on maintenance. Cabled equip-

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Figure 2: Overview of experimental setup

ment means little flexibility in placement and is very expensive in both money and effort whenever reorganization or new installation is needed. Therefore, when cabling is not really needed for performance reasons, wireless monitoring and control is a good option, due to the speed of implementation. But, in any case, reliable, fast and secure communications must be assured in every place of a large scientific facility. At the end, the typical Ethernet cable that communicates the I/O machine set with the operator station is replaced by wireless links.

In addition, this approach allows the development of mobile monitoring applications, capable of running on modern smartphones and tablets. This kind of applications could help when maintenance operations are required at plant level, as for example fault finding and commissioning stages.

In this point, two configuration are proposed:

In the first one, a standard WiFi technology is chosen for deploying a testbench equivalent to the wired version. The IEE 802.11 protocol is widely used in industry and its use in control tasks is raising day by day [2]. It offers enough bandwidth for the needed requirements and the possibility of implementing different security mechanisms. The implementation of this alternative suits properly in current experiment. The LAN is defined by the router, which offers both wired (Ethernet) and wireless (WiFi) communication to the laboratory network. An additional experimentation with this kind of approaches can be found in [3], where a EPICS network is monitored from a mobile device. In this case, an extra effort must be done for communicating the mobile device with EPICS.

The second step is to find the most appropriate wireless technology to replace cables in an EPICS system. This implies a deep study of the system requirements and different wireless flavor characteristics in order to choose the most suitable technology concerning performance, reliability, power consumption etc. The wireless testbench will be deployed based on the selected technology.

FUTURE WORK

At the present time, the first version of the wired testbench is mounted and giving initial data. In addition, the wireless testbench using WiFi technology is expected to be working very soon. However, a second wireless version will be implemented after a revision of possible technologies more appropriate for replacing wired connections in typical environments using EPICS networks.

Special attention will be paid to wireless security. The interface between the two physical layers will be secured to avoid a backdoor to the control system. Effective control security policies, [4], will be applied and translated to the wireless environment.

All those tests involve a reduced number of PVs and simple architectures, and, then, give information which is able for a partial validation of the conclusions. For this reason, if the initial test results encourage to take forward the present study, a second stage will include a more complex scheme with much more PVs and a richer hardware configuration, including experiments with a high volume of PVs, similar to the ones presented in [5].

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