Control and Data Acquisition Software Upgrade for JET Gamma-Ray Diagnostics

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The Joint European Torus (JET), the largest magnetic confinement plasma physics experiment in operation, has a large amount of key diagnostics for physics exploration and machine operation, which include several Gamma-Ray Diagnostics.

The Gamma-Ray Spectrometer (GRS), Gamma Camera (GC) and Gamma-Ray Spectrometer Upgrade (GSU) diagnostics have similar Control and Data Acquisition Systems (CDAQs) based on the Advanced Telecommunication Computing Architecture (ATCA) standard, featuring Field Programmable Gate Arrays (FPGAs) for data processing and management. The installed ATCA CDAQ digitizer boards are connected to the host controller through its Peripheral Component Interconnect Express (PCIe) interface with dedicated in-house developed software drivers.

During past JET-EP2 enhancements, the GRS and GC diagnostics were successfully installed and commissioned. However, the installed CDAQ software that interfaces these diagnostics to JET COntrol and Data Acquisition System (CODAS) is different, requiring higher maintenance costs. While the GRS was implemented using FireSignal, GC used Multi-threaded Application Real-Time executor (MARTe) framework.

Benefiting from the Gamma Camera Upgrade (GCU) and new GSU installation and commissioning, the upgrading of the software and controller hardware used in the GRS and GC was evaluated, aiming at software standardization between all three diagnostics for easier maintenance. The MARTe framework was selected as CDAQ software and Scientific Linux as Operating System (OS).

This paper describes the software standardization process between the diagnostics towards the usage of the same CDAQ software as well as the same OS for the controllers, which allows the operator to minimize the maintenance time, avoiding the need for system specific expertise.

Keywords: Control, Data Acquisition, Software, MARTe, JET, Nuclear Fusion

1 Introduction

The Joint European Torus (JET) gamma-ray diagnostics integrate the JET deuterium-tritium (DT) campaign in preparation for the ITER [1,2]. This diagnostic package includes the Gamma-Ray Spectrometer (GRS), Gamma Camera Upgrade (GCU) and Gamma-Ray Spectrometer Upgrade (GSU) projects.

The GRS (KM6S spectrometer) and GSU (KM6T spectrometer) projects aim at performing high-resolution gamma-ray spectroscopy with very high count rate while the GCU (KN3G camera) project expects to improve the spectroscopic properties of the existing gamma-ray/hard X-ray camera, in terms of energy resolution and high count rate capability, for DT campaign [3-8].

The GRS and the old version of GCU, the Gamma Camera (GC), were successfully installed and commissioned during past JET-EP2 enhancements. These systems are based on the Advanced Telecommunications Computing Architecture (ATCA) standard [9], which was selected for ITER fast controllers requiring demanding tasks (diagnostics, I&C and Interlock) like plasma control system [10,11].

The ATCA Control and Data Acquisition (CDAQ) system includes high frequency and reconfigurable

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digitizer modules (ATCA-TRP-400) [12] with embedded Field Programable Gate Array (FPGA) devices, connected to the host controller (ATCA-CONTROLLER-PCIe) [13] using the Peripheral Component Interconnect Express (PCIe) interface [14].

Both diagnostics have similar hardware, however, due to historical reasons, the installed CDAQ software that interfaces to JET COntrol and Data Acquisition System (CODAS) is different. While the GRS was implemented using FireSignal [15,16], the GC uses the Multi-threaded Application Real-Time executor (MARTe) framework [17,18], which may lead maintenance problems in future.

The recent upgrade in the JET gamma-ray diagnostics comprised the new GSU installation and commissioning, and the GC upgrade, contributes to the study of a new solution, aiming the usage of an updated host hardware (Motherboard, CPU, Memory and Hard-Drive) and software (Operation System and CDAQ software). To fulfill these requirements was designed the presented solution, which contributes to reduce the system specific expertise and may minimize the maintenance time.

2 Hardware environment

Błąd! Nie można odnaleźć źródła odwołania. depicts the hardware environment of the installed systems.

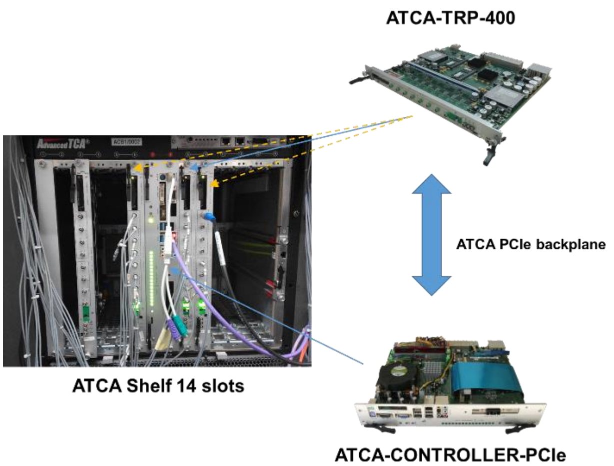

Fig. 1- Hardware Environment

2.1 ATCA-TRP-400

The ATCA-TRP-400 board was designed to perform acquisitions at high rates while featuring processing capabilities to discriminate only the relevant events. It is compliant with ATCA PICMG 3.0 specification [9] and comprises two blocks of FPGAs for data path and real time processing connected to 4 analog inputs of 13/14-bit resolution at up to 400 MSamples/s (MSPS) sampling rate and 2GB of DDR2 memory to store data. Furthermore, this module is connected to the host using the available x1 PCIe link [3,5,12].

2.2 ATCA-CONTROLLER-PCIe

The ATCA-CONTROLLER-PCIe host controller is compliant with the ATCA PICMG 3.0 specification [9]. The design is based on a PCIe switch connected to the ATCA full-mesh backplane and to micro Advanced Technology Extended (ATX) motherboard with an Intel® Core™ i3-4170 Processor, 4GB DDR3 and 500 GB HD [13].

2.3 ATCA Chassis

The ATCA Chassis has 14 slots, with redundant shelf managers. All (three) diagnostics have installed similar host controller connected to the digitizers boards through the ATCA PCIe backplane.

3 CDAQ System Uniformization

During the JET-EP2 enhancements the GRS and GC diagnostics were successfully installed and commissioned using Firesignal as CDAQ Software [16] and Linux Fedora 8 as Operating System (OS), interfacing to the hardware with dedicated in-house developed software drivers. However, some years later, during the GC diagnostic enhancement for development of the real-time processing system to the JET hard X-Ray and Gamma-Ray Profile monitor [6], the GC CDAQ software was upgraded to MARTe [17], keeping the same operating system and Linux Device Driver compatibles with MARTe, avoiding the replacement of a stable and tested version without valuable benefit at the time.

Benefiting from the GCU and new GSU installation and commissioning, the upgrading of the software and controller hardware used in the GRS and GC was evaluated, aiming at software standardization between the two existent diagnostics and the new diagnostic to install, once keeping three different solutions are hard to maintain.

Concerning the controller hardware, the proposed solution was the upgrade of the motherboard, CPU, memory and hard-drive to an up to date solution detailed in previous section, replacing the old Intel® Quad-Core CPU, 2 GB of DDR2 memory and 320 GB HDD [13].

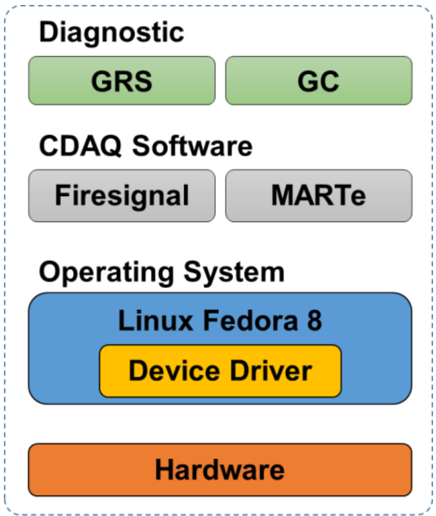

Fig. 2 - Existing Software Architecture

Fig. 2 depicts the software architecture of the existent systems, which is not fully compatible with new installed hardware, since Fedora 8 is no longer compatible with recent motherboards.

Concerning the software update, it was studied the uniformization between the three systems to use a transversal solution. The Scientific Linux 6.7 was selected as OS, once it is supported by JET CODAS, making the compatibility with other installed systems, forcing the Linux Device Driver upgrade to the new kernel version. For the CDAQ software, MARTe framework was selected because: (i) fulfills all the diagnostics requirements; (ii) is used in other JET diagnostics; (iii) is popular in the fusion community by its usage in several machines, which contributes for its continuous development [19-25]. Fig. 3 depicts the new software architecture using Scientific Linux as OS and MARTe as CDAQ Software which includes the MARTe core, the CODAS Interface Library to connect the diagnostics to CODAS, the developed GAMs and IOGAMs for data acquisition and processing, the configuration files and startup files.

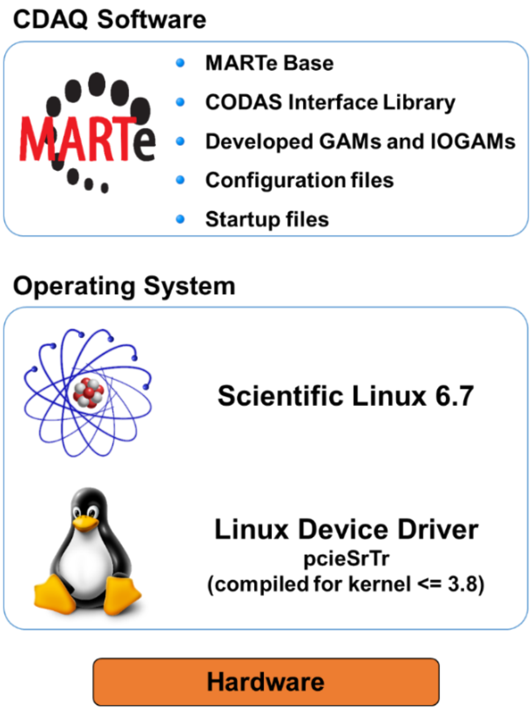

Fig. 3 - Software Architecture

4 JET CODAS Integration

The CODAS Interface Library provide features to connect MARTe to JET CODAS, enabling MARTe to receive/reply messages from /to JET CODAS and send the diagnostic data files. Fig. 4 depicts the coupling between MARTe and JET CODAS, showing the CODAS messages and the steps of a JET Pulse/MARTe Cycle:

(1) MARTe is initialized with a base configuration but, before the JET Pulse, receives the configurations from the pulse schedule editor (Level-1) and set-up the acquisition boards.
(2) MARTe receives the trigger to start acquisition and start acquiring to the memory.
(3) During the JET Pulse, MARTe acquires data to the board memory.
(4) MARTe receives from CODAS the end pulse command and stops the acquisition.
(5) After the pulse, threads are launched to get data from board memory and store the retrieved data in the host hard drive. To make the system stable, the threads (one per channel) run sequentially, avoiding out of memory crashes.
(6) Several minutes after the end of pulse, CODAS retrieves the data from local HDD to JET Data Archiver.

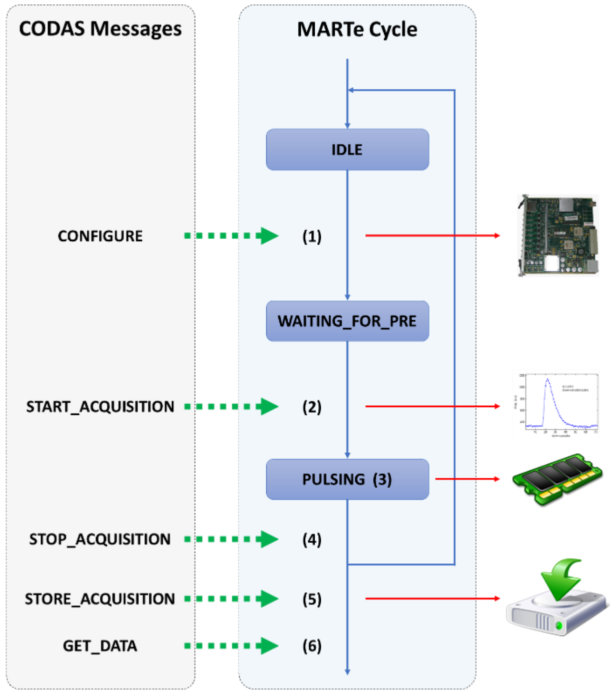

Fig. 4 - MARTe Integration with JET CODAS

5 File mirroring

During the uniformization process it was designed a directory structure hierarchically organized and common to all diagnostics. Using this approach, the configurations can be mirrored between the other diagnostics which contributes to make all diagnostic hard-drives compatible, reducing the maintenance expertise.

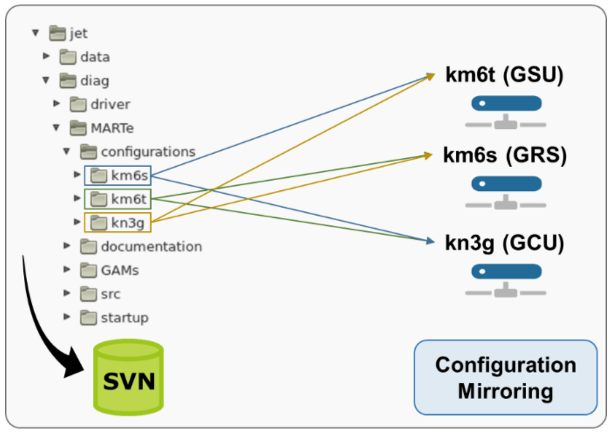

Fig. 5 - Directory Structure

Fig. 5 depicts the directory structured under the project root directory (*jet*). The installed software in all diagnostics is the same for except the configurations directory in which are stored the MARTe configuration files, specific for each diagnostic. Using file mirroring of this directories, a hard drive from one diagnostic can be used in each other with simple startup configurations to change the active diagnostic.

In addition, during the development phase all code was synchronized with svn [26], enabling a fast installation of a new diagnostic. If some change is done in the structure, or in versioned files, it can be easily synchronized with other diagnostics using the svn features.

6 Conclusions

This solution was designed to standardize the hardware and software of the three diagnostics:

- The usage of the same hardware may minimize the number of spare modules and reduces the device driver maintenance expertise.
- The software standardization minimizes the system specific expertise and can reduce the data backup devices. The provided file mirroring between systems enables the usage of a hard drive from one diagnostic to each other. In few steps, the configured startup diagnostic can be changed. The replacement of a malfunctional hard drive can be done using a backup from other diagnostic, avoiding the maintenance of 3 diagnostic backups.

The tests show that MARTe environment is a valuable and stable framework to manage diagnostics with post pulse data transfer like the presented ones. The data is stored to the board memory during the pulse and at the end is copied to the host and to the network archiver.

The presented solution was successfully tested for Scientific Linux 32 and 64 bits and is fully and stable running from JET Pulse #91137@20/07/2016.

In the future, new added functionalities and changes in the core code will be synchronized with three diagnostics, contributing to maintain all systems up to date and enable automatically code reutilization from one diagnostic in each other.

Acknowledgements

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