NEW DEVELOPMENTS ON TORE SUPRA DATA ACQUISITION UNITS

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Abstract

The Tore Supra data acquisition system (DAS) was designed in the early 1980s and has considerably evolved since then. Three generations of data acquisition units still coexist. As cost and maintenance of different operating systems is expensive, it was decided to explore an alternative solution based on an open source operating system (OS) with a diskless system for the fourth generation. In 2010, Linux distributions for VME bus and PCI bus systems have been evaluated and compared to Lynx OS™ real time OS. The results obtained allowed to choose a version of Linux for VME and PC platform for DAS on Tore Supra. In 2011, the Tore Supra DAS dedicated software was ported on a Linux diskless PCI platform. The new generation was successfully tested during real plasma experiments on one diagnostic, called DCEDRE.

INTRODUCTION

The Tore Supra data acquisition system (DAS) (Fig. 1) was designed in the early 1980s [1] and has considerably evolved since then. Three generations of data acquisition units still coexist. Totalizing now 50 diagnostics and subsystems, the data acquisition units are operated simultaneously. The first generation was based on Multibus systems with an Intel processor and RMX™ operating system. Since 1995, most of these systems have been replaced by VME bus systems equipped with Motorola PowerPC processor boards running a Lynx OS™ real-time OS to obtain a more powerful architecture. The third generation was developed to perform extensive data acquisition for infrared and visible video cameras that produce large amounts of data to handle. It was supported by industrial PC over a Microsoft Windows™ OS.

The first two generations, Multibus and VME bus systems, are diskless with real time OS (RTOS). Diskless systems are desirable for reliability and maintainability as they share common resources like kernel and file system. The advantages of these architectures are:

- a common kernel
- a common file system
- easy updating and backup
- reliability (no hard disk)
- can be installed closest to the detector
- insensitive to the magnetic field
- easy to deploy

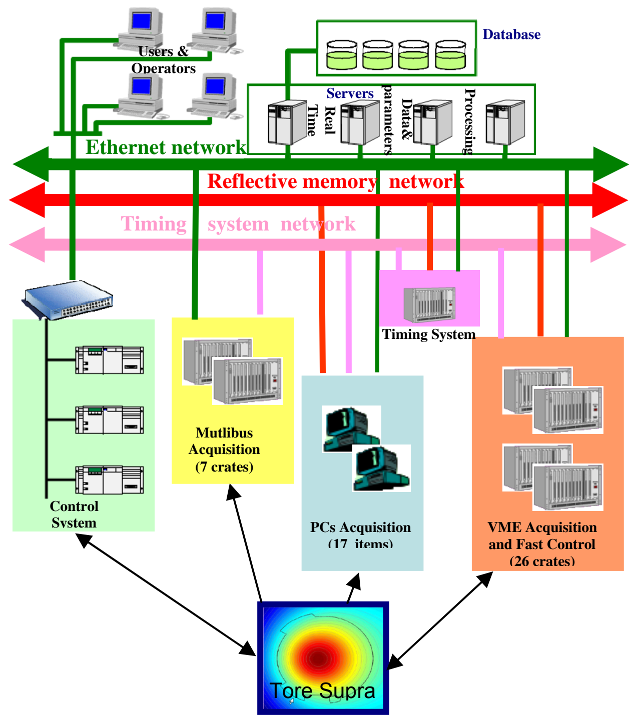

Figure 1: The Tore Supra data acquisition system.

These facilities considerably reduce the maintenance cost. Moreover, open source real-time operating system are now available that may provide free and convenient solutions for DAS. As a result, it was decided to explore an alternative solution based on an open source OS with a diskless system for the fourth generation. Currently, Linux OS is fairly mature to be used on DAS with pre-emptive and real time features on x86 architecture. In 2010, Linux distributions for PCI bus systems have been evaluated and compared to LynxOS real time OS. The latency and time response to any hardware interrupt has been achieved with x86 and x86 multi-core architecture target processors. The results obtained allowed to choose a version of Linux PCI platform for DAS on Tore Supra. These aspects and the new diagnostic DCEDRE are detailed in the following of the paper.

DAS NEEDS ON TORE SUPRA

Two kinds of DAS with different level of determinism are used on Tore Supra, hard real time systems and soft real time systems. The real time plasma control system (hard real time system) on Tore Supra has a constraint of 2 ms cycle time. For example, one of Tore Supra safety components is provided by a spectrometer measuring the level of copper and iron [2]. The acquisition unit allows heating systems to adapt in real time the injected power into Tore Supra through a feedback on these levels of impurity. The acquisition unit must provide continuous values every 4ms. The data acquisition and computed results must be completed within this interval.

Soft real time systems must meet deadlines with a degree of flexibility. Data acquisitions that do not realize real time control accept missed dead lines like a read on data acquisition board. To solve this problem data are stored in acquisition card memory or directly into the computer memory by a DMA transfer between acquisition card and computer. The time constraint is 4 millisecond cycle time.

Data acquisition system must support Tore Supra standards on both hardware and software, especially the real time plasma control which is based on a reflective memory network with ScramNet card from Curtiss Wright. On software point of view, the message oriented middleware (MOM) RTworks [1], that is the heart of Tore Supra DAS must be supported.

NEW DAS FOR TORE SUPRA

New Hardware

A PCI bus platform has been chosen with CompactPCI (CPCI) standard for the new architecture (Fig. 2).

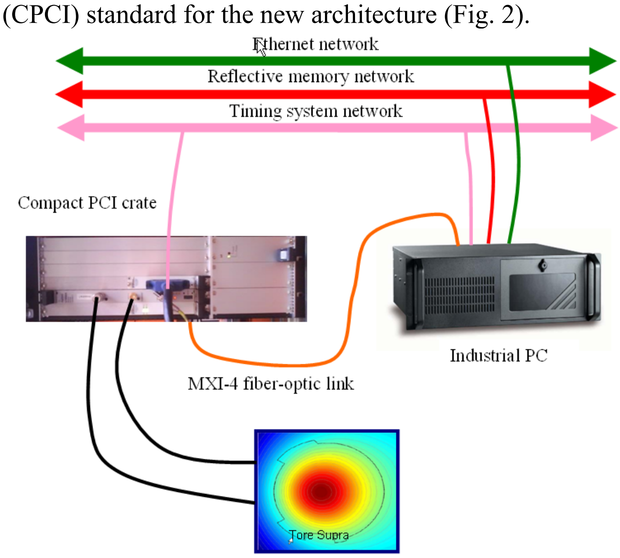

Figure 2: New DAS architecture.

CPCI bypasses the limit of five PCI slots in PC and offers a wide range of CPU and data acquisition boards. It is possible to use directly PXI cards, PCI and PMC (PCI mezzanine card) cards with adapter in a CPCI crate. The processor unit is not included in the CPCI crate. An industrial PC is connected to CPCI crate by a MXI-4 bridge from National Instruments. MXI-4 bridge provides a remote control of CPCI electronics cards from industrial PC through a fully transparent link connected with fiber-optic cabling. The separation of the I/O board from the industrial PC allows having a robust system like VME bus system and a lifespan of more than 10 years. This configuration has the advantage:

- easy upgrading of the calculation power without changing all the data acquisition
- a less noisy environment than for industrial PC for very fast data acquisition (2GHz).

For a reduced DAS development time, electronic cards providers are selected for hardware availability and drivers quality, so the development time is now down to half between design and delivery.

New OS, Linux

The first milestone was to find a Linux distribution. The target system for PCI bus system are x86 multi-core processor with industrial PC. X86 processor is widely used in Linux community which has led us not to use commercial distribution. A custom solution has been developed.

The main challenge will be to develop a diskless system. A diskless system on Tore Supra (named client) starts with Ethernet networks. Client has only memory and its file system is hosted on a server. The client-server architecture is showed on Figure 3. At startup, a client downloads the kernel on the server. The file system is common to all clients to facilitate the management. The user application development is realized on a compiler.

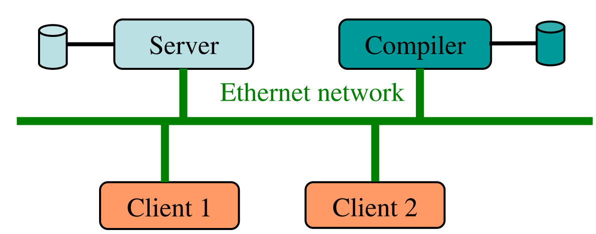

Figure 3: Client-server model on TS.

The target boot is based on PXE (Preboot eXecution Environment) boot. Some unnecessary services such as energy saving, virtual memory are disabled that slowdown the system. A hard RTOS solution will be evaluated in 2012 with Xenomai real time extension for Linux.

TESTS AND RESULTS

Tests were conducted to measure real time performance on few target systems and Linux version. Target systems tested were:

- X86 INTEL processor 2,8GHz.
- X86 INTEL dual core processor 3GHz on an industrial PC.

Different Linux version 2.6 with different preemption option were chosen to be evaluated:

- 2.6.28.10 preemptible kernel (low latency desktop)
- 2.6.26.8-rt16 Complete Preemption (Real-Time)

As referred in DAS needs on Tore Supra section a RTOS must meet deadline. Interrupt response time measurement and polling device can evaluate RTOS performance for a given target. Performance tests were also done with Lynx OS on a VME target system to compare Linux to a commercial RTOS.

The interrupt response time (Fig. 4) is the interval between the time when a hardware interrupt occur and the time when the user task wake up to run. The interrupt response time is the sum of interrupt latency, interrupt processing, context switching and task wake up.

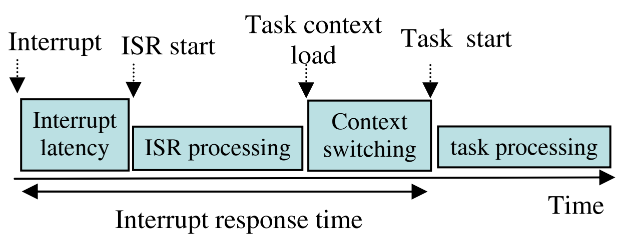

Figure 4: Interrupt response time definition.

For response time tests, user task simulates a processing consuming 100% of processing power to measure the impact on Linux to evaluate RTOS closest to reality. A 500µs interrupt frequency and 400µs processing simulation were used for this test during 1 hour.

Linux 2.6.28.10 on x86 dual core target is not far of hard RTOS Lynx OS (Fig. 5). Linux 2.6.28.10 is better in interrupt management than Linux 2.6.26.8 RT. Linux 2.6.28.1 interrupt time response is 38µs against 50µs for Linux 2.6.26.8 RT.

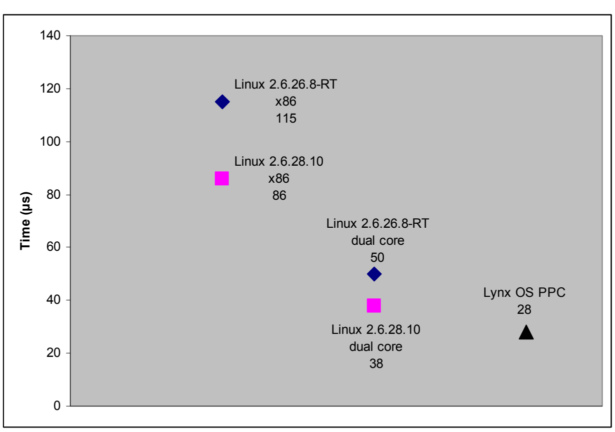

Figure 5: Interrupt time response result.

Some VME I/O (input/output) devices used on Lynx OS target do not generate interrupt to indicate that data are available. I/O devices require the application to generate the necessary request in order to interact with them. The application runs in a periodic loop and makes a request every time through the loop, called polling device. Polling is also a way to consider more quickly an event than interrupt. A test was done to find the polling frequency limit on each target system and Linux version (Fig. 6).

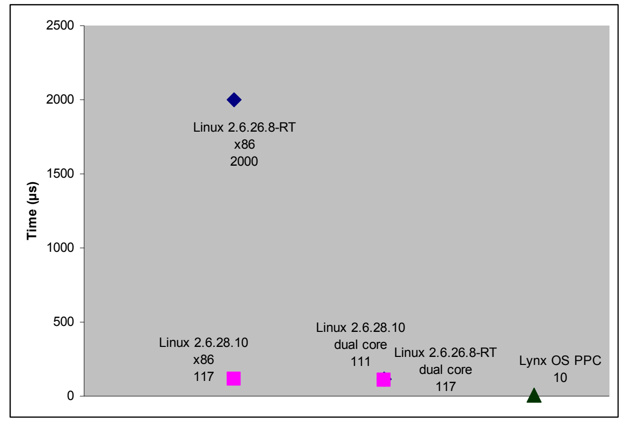

Figure 6: Polling frequency limit.

Lynx OS takes advantage on Linux. Moreover Lynx OS is completely freeze and do not reply to any request unlike to Linux. Linux 2.6.28.10 have a large advantage on x86 while both versions of Linux are equal on dual core. With upper CPU frequency than PPC, x86 dual core is close to hard RTOS performance.

NEW DIAGNOSTICS WITH LINUX

Linux with a system disk has been used successfully on a new diagnostic for the dust detection in 2010. It can count and quantify the dust sucked into a vacuum duct continuously 24/7. In 2011, the Tore Supra DAS custom software was ported on a Linux diskless PCI platform. The new generation was validated on plasma experiment for the so called DCEDRE diagnostic (Fig. 7).

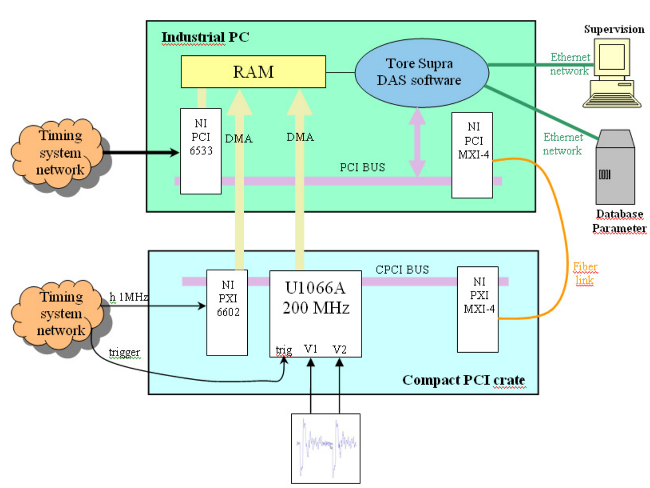

Figure 7: DCEDRE architecture.

This new diagnostic aiming at measuring the full frequency spectrum (0-200MHz) of electrostatic probes signal during high frequency power injection into the plasma gave preliminary results during Ion Cyclotron Range of Frequency (f=57MHz) heating.

Two signals are acquired on an Agilent U1066A, 200 MHz digitizer, 12 bit resolution with a wide bandwidth of 100MHz. An external trigger for timing system network starts data acquisition for 100000 samples at 200MHz samples rate. Data are time stamped with NI PXI 6602 card clocked by 1MHz timing system network.

Spectrum is obtained by Fourier transform of a set of 10^5 measurements (Δt=5ns). When the antenna is powered (P=1MW), peaks are obtained at f but also in some cases at f/2 (Fig. 8), giving some evidence of the complex interaction of the plasma edge, where the probe is located, with the wave.

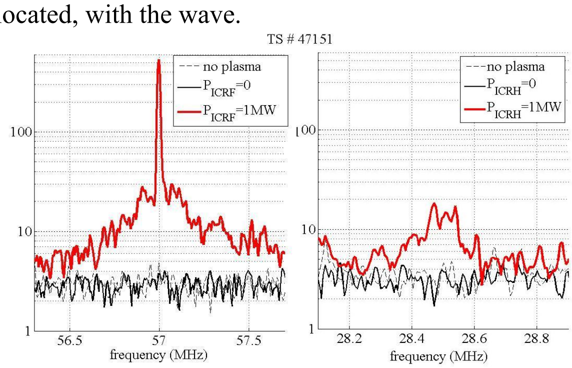

Figure 8: Blow-up of the power spectrum during ICRF heating experiment (acquisition rate: 200MHz).

CONCLUSION

This study showed that real-time Linux solutions can be used for the data acquisition systems of Tore Supra. Linux on PCI bus systems fulfils Tore Supra needs for soft real time application. Linux 2.6.28.10 preemptible kernel (low latency desktop) on x86 dual core is the best solution and obtain equivalent performance to Lynx OS on interrupt time response. PCI platforms will reduce the cost of hardware, development time and operating costs.

New Tore Supra DAS architecture is like ITER recommendation for ITER CODAC control system [3]. New DAS will be used easily for testing plant system controllers for ITER CODAC on Tore Supra experiments.

In 2011, the new diagnostic DCEDRE has validated the new diskless PCI architecture with Linux OS on experiments.

The next steps are:

- Performance tests with Xenomai in 2012.
- New diagnostics for plasma control with Linux 2.6 diskless system in 2012.
- Upgrade data acquisition unit of hybrid heating system on Linux diskless system with real time arc detection algorithm 100µs cycle in 2012.
- For x86 dual core system, to dedicate a core to Linux and the other to Xenomai.

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[3] ITER CODAC Guideline for Fast Controlers, I/O Bus Systems and Communication Methods between Interconnected Systems January 2010.