IMPROVEMENT OF TORE SUPRA REAL TIME PROCESSING CAPABILITY USING REMOTE PCS

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Abstract

The Tore Supra Data Acquisition System is based mainly on VME bus acquisition units using Lynx OS 3.1 as operating system. While the real time operation of the acquisition is more and more demanding, some units are no more to handle in parallel the data flow rate and the RT processing. Furthermore, the time delay between two fast acquisition phases must be reduced to be able to catch fast plasma events. A new DAS layer containing Linux-PC has been implemented to cope with these needs by enhancing the data processing capability while the existing acquisition system is preserved.

INTRODUCTION

The Tore Supra tokamak is the largest superconducting magnetic fusion facility in operation. It has been devoted to long-duration high-performance discharge research. The Tore Supra real time measurements and control (RTMC) system has been upgrade in 2001 [1]. It is designed to deal with continuous acquisition during the plasma discharge, fast acquisition triggered on a time window (sampling frequency up to 2 GHz) and Real Time (RT) data processing for plasma control [2]. The simultaneous control of an increasing number of plasma parameters [3] aiming at tokamak operations in a fully steady state regime makes fast acquisitions and RT data processing more and more demanding. The Tore Supra Data Acquisition System (DAS) comprises 44 acquisition units. Most of them are based on VME bus and use Lynx 3.1 as operating system with a Power PC 300MHz CPU board. The main issue is related to fast acquisition operation (typical time window duration is 2s) that makes the data flow rate increasing from about 100 kB/s up to 8 MB/s which could not be handled with the present system. Furthermore, the time delay between two fast acquisition phases must be reduced to be able to catch fast plasma events occurring at almost the same date. As a result of this mode of operation, the amount of real time data has been increased by a factor of 6 during the last 6 years. While the calculation power of the acquisition units is fixed, some of them are not able any more to handle in parallel the data flow rate and the Real Time processing.

Since 2001, a work has been initiated to identify the DAS limitation and define solutions to improve its performance in order to satisfy the new requirements from plasma physic studies. This paper deals with the upgrade of the Tore Supra RTMC system. The section 1 describes the present limitation encountered with the VME based acquisition units. The section 2 dicusses the architecture of the DAS using remote PCs. The third section is devoted to the performance of the real time data processing using remote PCs.

LIMITATIONS OF VME ACQUISITION UNITS

The Raw analog data from the diagnostic sensors follow a series of hardware and software processes before being stored in the Tore Supra database (see Fig. 1). Each of them is time consuming and limits the maximum available data flow rate. During the fast acquisition phase triggered on a plasma event, the average data flow rate delivered by the diagnostic increases up to 8 MB/s. The signal is digitized by ADCs and stored by a 2 MB (1 Msample) flip flop buffer before being sent to the CPU via the VME bus. As the DMA transfer has not been implemented for triggered acquisition in the driver of the ADC boards, the maximum available flow rate was limited to 1 MB/s. Therefore, in such condition, the flip flop buffer is filled in less than 300 ms.

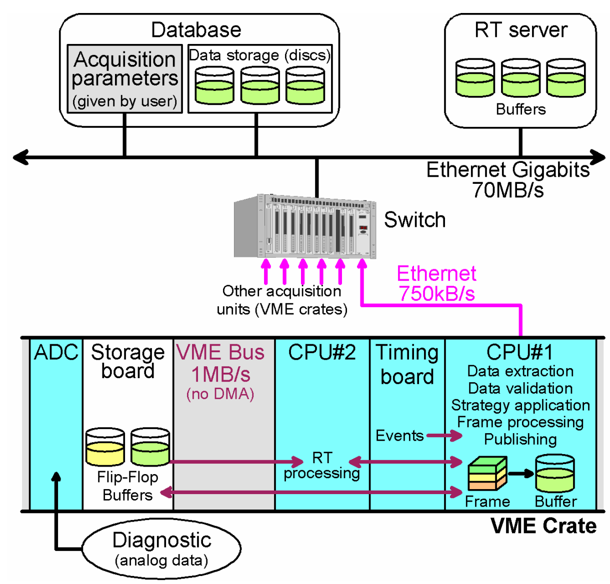

Figure 1: Tore Supra DAS architecture

The acquisition parameters are defined by the user. They are uploaded in the CPU before each plasma discharge. Two CPU boards are used in the VME crate. The second processor (CPU#2) is used for RT data processing and management of actuators via a control loop and dedicated algorithms. It runs a single task during the plasma operation with a response time of a few milliseconds. The application program in the first processor (CPU#1) is made up of several tasks such as the timing chronology of the plasma discharge, the packaging of the raw or processed data in frames to be sent on

Ethernet network, the communication with the RT server to transmit the frames and, the management of the events. Intercommunication between the processors is fulfilled by the VME bus through shared memory. The duration of the frame processing in the first CPU requires typically 1.86µs per octet (maximum flux rate is 525 kB/s). Leaving the VME crate, the frames are sent via a 750 kB/s Ethernet TCP/IP protocol connection to a switch concentrating information from about 15 diagnostics (at Tore Supra, 3 switch are used). Then a 70 MB/s Ethernet link is used to transmit data to the RT server and the data storage. The main limitations (see Fig. 2) are concentrated in the VME crate and the Ethernet link to the Switch.

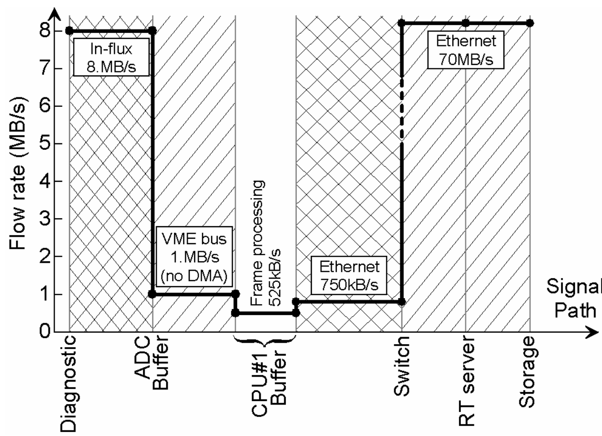

Figure 2: Maximum flow rate along the path of the data from the diagnostic to the storage

As an example, we consider a diagnostic with a fast acquisition data flow rate of 6.5 MB/s during 150 ms (1 MB of data). The minimum duration for the data to leave the VME crate (from the ADC to the switch) is 4s; 26 times longer than the acquisition itself. Thus the minimum delay between two triggered fast acquisitions is of the order of 4s. This limits strongly our ability to study fast events appearing in the plasma. The main limitation was due to the multiplicity of processes running in the first CPU and the limited power of the processor itself. Recent more powerful processor cannot be used because the operating system Lynx OS 3.1 cannot be easily upgraded.

DAS ARCHITECTURE USING REMOTE PCS

The improvement of the DAS has been performed while the hardware undergoes minor modifications, the operating system is not changed and our philosophy to acquire, compute and store the data in RT remains unchanged. First of all, a DMA transfer between ADCs and CPUs via the VME bus has been implemented in the driver of the acquisition boards increasing the available data flow rate to 20 MB/s. The network bandwidth from the VME crate to the switch has been upgraded to be able to deal with fast Ethernet (7 MB/s). To get rid of the limitation introduced by the VME processor, a new DAS layer containing remote PCs with Linux operating system and 3 GHz CPU has been implemented. The software running in VME first CPU board is split in independent parts; each of them could be distributed among different computers. The task of the CPU board in the VME crate is reduced to a simple data collection. The frame processing task is handled by a remote PC and the data distribution to the RT server and the database is ensured by a third task also in the remote PC (see Fig. 3).

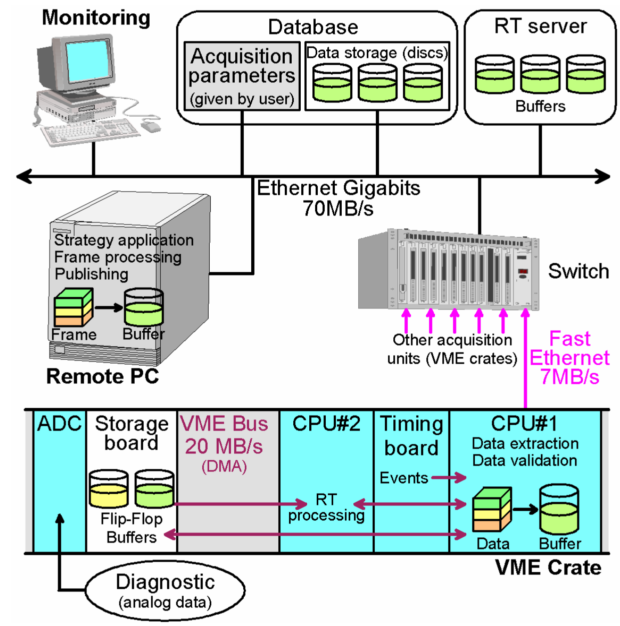

Figure 3: New DAS architecture for diagnostics using remote PCs

The communication between the CPU in the VME crate and the remote PC is made via a fast Ethernet connection and a point to point messaging model (MOM product). The communication channel stays open during all the plasma discharge in order to ensure the maximum data flux availability. In order to build the frame properly, the remote computer needs also to receive information that were previously dedicated only to the VME system. Before a plasma discharge, the acquisition parameters set by the user are uploaded in both systems. During the plasma discharge additional information is added to the message transmitted by the VME: the heading of the data contains the time stamp and the events decoded by the timing board in the VME are published as well. The remote PC receives the data from the VME and builds the frame taking into account the strategy uploaded from user parameters. The final stage is the publication of the frame to the RT server using a publish/subscribe mode. The program dedicated to the frame processing can be run in any type of remote computer (Pentium, alpha server, Power PC, etc.). Therefore, in case of a remote connexion failure, the data processing is fully handled by the CPU board in the VME crate with the limitations it implicates on the delay between triggered fast acquisitions. While the remote PC is much more powerful than the VME processors in use at Tore Supra, it is able to handle the frame processing of 3 VME acquisition units.

A Java-based application has been developed to monitor the fast acquisition processes. This program checks the status of the connexion between the VME crate and the remote PC, the status of the VME software (data packet sending) and the status of the frame builder in the remote PC. During the plasma discharge it displays information on VME processes: the number of packets sent to the remote PC and the number of packets waiting for emission on Ethernet. Information about the remote PC is also available: the number of packets received from the VME (cross check) and the number of frame that were built, sent and waiting in the buffer. This application makes part of the tools routinely used during the experiments to monitor the acquisition of diagnostic using fast acquisition.

REAL TIME DATA PROCESSING PERFORMANCE

The overall performance of the triggered fast acquisition processing from the diagnostic to the database has been enhanced by more than a factor 10 by using the decoupling of acquisition tasks (see Fig. 4).

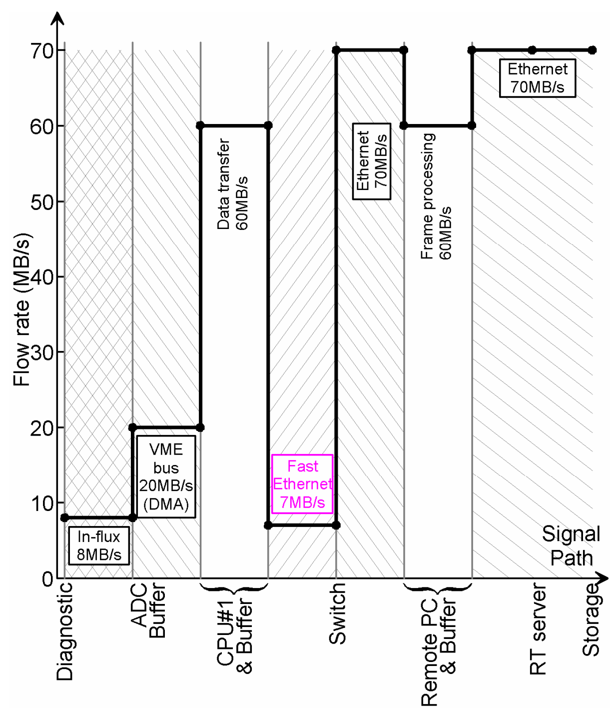

Figure 4: Maximum flow rate along the path of the data from the diagnostic to the storage in the new architecture

The present main limitation is the fast Ethernet connexion between the VME crates and the switch. Nevertheless upgrading this connexion to 70 MB/s requires the use of new CPUs supporting Giga Ethernet transfer, and Lynx 3.1 as operating system. Such processor boards are already commercially available. Finally, the last limitation we have to face to is the maximum VME bus flow rate which cannot exceed 20 MB/s with DMA mode. A modification of such constraint would require the replacement of the VME crate meaning major modification of the Tore Supra DAS. At present 2 diagnostics routinely use the remote PC solution: the Electron Cyclotron Emission (ECE) which gives the electron temperature profile and the Motional Stark Effect (MSE) which gives the current density profile. None of these two diagnostics are able to make fast acquisition without the remote PC. The ECE system has been upgraded to perform 32 points (instead of 16) temperature profiles every 1 ms. In parallel the fast acquisition is performed over the 32 channels on triggered time windows of 120 ms with a data sampling rate of 10µs. The flux of data that must be handled by the DAS is about 6.5 MB/s and the minimum delay between triggers is 0.7 s. In comparison, using only 16 channels, the minimum delay between two fast acquisitions trigger was of the order of 4s. Another example is the MSE diagnostic. The fast acquisition duration is of the order of 1 s with a data sampling of 4 µs. Although fewer channels must be recorded the data flux is almost the same than for the ECE diagnostic but it must be sustained over 1 s. Four more diagnostics will benefit from the remote PC power to perform small delay fast acquisition.

The architecture described, offers several advantages. While the data acquisition (VME) is now decoupled from the data processing (frame building), the improvement of the RT processing ability can be performed more easily because we benefit from the fast progress on the PC. The remote PC could be used for RT processing of the fast acquisition to get physical parameter as well. By adding a connection to the RT reflective memory network (Scramnet) of Tore Supra [4] these data can be used as inputs to enhance the plasma control efficiency [3]. In particular, a refined localisation of plasma instabilities due to MHD could be performed by this means, thus allowing a more accurate response of the actuators

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