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Distributed Mass Data Acquisition System Based on PCs and Windows NT for LHD Fusion Plasma Experiment

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RESEARCH REPORT
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Distributed Mass Data Acquisition System Based on PCs and Windows NT for LHD Fusion Plasma Experiment

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Abstract

A new data acquisition and management system has been developed for the LHD experiment. It has the capability to process 100 MB $\sim$ 1 GB raw data within a few tens seconds after every plasma discharge. It employs wholly distributed and loosely-tied parallel-tasking structure through a fast network, and the cluster of the distributed database servers seems to be a virtual macro-machine as a whole. A PC/Windows NT computer is installed for each diagnostics data acquisition of about 30 kinds, and it controls CAMAC digitizers through the optical SCSI extenders. The diagnostic timing system consists of some kinds of VME modules that are installed to remotely control the diagnostic devices in real-time. They can, as a whole system, distribute the synchronous sampling clocks and programmable triggers for measurement digitizers. The data retrieving terminals can access databases as application service clients, and are functionally separated from the data acqusition servers by way of the switching Ethernet.

1 INTRODUCTION

The "Large Helical Device (LHD)" started its discharge experiments in March 1998 [1], and now it is one of the largest fusion experimental device with the latest diagnostic equipments.

The LHD data acquisition and management system for plasma diagnostics, which is named as *LABCOM system*, was designed to process $\sim$ 1 GB raw data produced by the typical discharge of about 10 second duration in every 3 minutes. At the beginning of the LHD experiment, the total amount of the plasma diagnostics raw data was only 20 $\sim$ 30 MB per each shot, while half a year later it has rapidly grown up to about 200 MB/shot.

All of the LHD helical, poloidal field coils are made of the superconductor, and the quasi steady-state operation of about one hour long will be also planned in the near future. Then, the total amount of the plasma data will be certainly enlarged due to the longer duration.

The huge amount of experimental data forced us to adopt the fully distributed data acquisition and processing system, rather than the ordinary concentrated ones. A necessary condition for the LHD data processing system is to acquire and process whole diagnostic data within 100 seconds after every discharge end. In order to satisfy it, the LHD data acquisition system was obliged to utilize the massively parallel processing (MPP) structure and reduce the data processing load of the individual element, such as data I/O ports or CPUs.

The principles of the new LHD data acquisition and management system are as follows [2];

1. completely parallel distribution for each diagnostics device,
2. functional separation by means of network client-server model,
3. 100Mbps FDDI-based fast switching network,
4. object-oriented method for programming manner and data storages,
5. commercial-based distributed databases.

The primary objective to apply the distributed structure is to improve the data transfer throughput by using multiple paths and CPUs. Modern technologies of high-performance personal computers (PC) are quite suitable for distributed and parallel data processing system.

In addition to the parallel distribution, the functional separation will be also effective to provide the advanced graphical user interface (GUI). The computer loads of the data visualization or complicated analysis are often unrelated to the data processing sequence following after a discharge experiment. Popular 2-dimensional or 3-dimensional analysis and visualization makes heavy CPU loads, and a private CPU for each user will become more desirable. As a good solution to this problem, the network client/server model can be preferably applied between data acquisition servers and user-interface clients.

Fast network connections are indispensable for the mutual data transfer among those separately arranged computers. Especially among the data acquisition server computers, the fast mutual linkage and close concurrent cooperation would realize a virtual macro-machine, which the client computers can send the data requests to and receive results from. In other words, this virtual machine uses fast network links as its internal system bus. They exactly organize a massive parallel-tasking multi-processor system with loosely-tied communications [3].

2 INSTRUMENTATION OF LABCOM SYSTEM

The distributed structure is applied in both parallel and functional meanings for the LHD data management servers. It utilizes two kinds of server computers shown in Fig. 1; One is the data acquiring and storing computers

which govern the CAMAC digitizers and databases, and the other is the diagnostics controlling computers which interactively manage and continuously monitor the diagnostic devices in real-time. The former uses so-called AT-compatible PC and Windows NT OS, and the latter does 68040-based VME and real-time OS Tornado, which is previously known as VxWorks. Both kinds of server computers will be independently stationed for every diagnostics of 20 or 30 kinds.
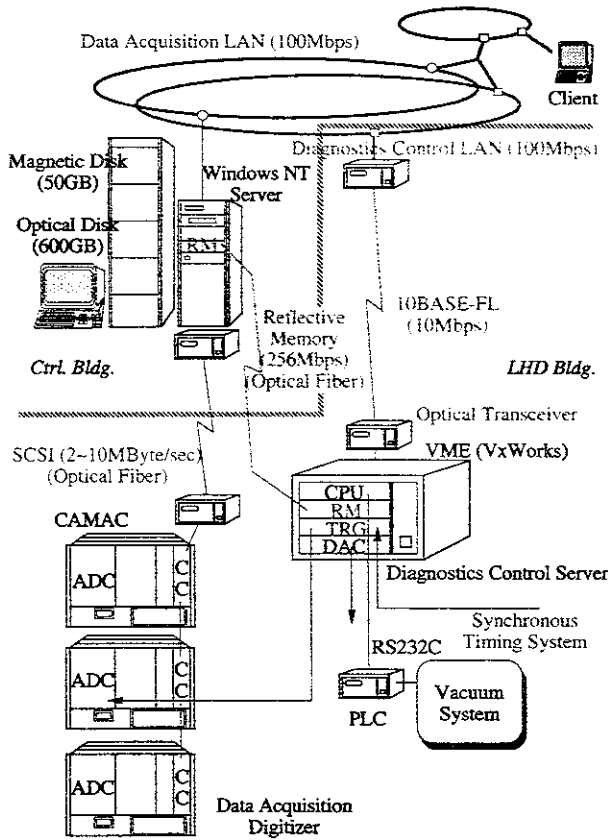

Figure 1: A basic element of the CAMAC data acquisition and VME device control/monitor system: This set will be applied for each kind of the LHD diagnostics device.

2.1 CAMAC Data Acquisition on Windows NT

The primary purpose of the LABCOM data acquisition system is to measure the plasma physical parameters, and their data analysis generally require fast data sampling rates as to follow the plasma dynamic behaviors. They manages the CAMAC digitizers and transfer, transform and store the experimental data, where all of the processing sequences are executed in the pre- and post-experimental periods as they were pre-programmed. These procedure flow of the data management are often recognized as so-called the batch processing.

Sub-components of the LABCOM data acquisition can be classified into the categories as listed below,

1. digitizing by CAMAC modules
2. SCSI data transfer with optical extender
3. PC/Windows NT data acquisition server computers
4. data cross-referencing by virtual shared memory
5. object-oriented database on every server computer
6. harddisk array and media-changeable mass-storage

As for the digitizer modules for LHD, we have to inherit a lot of CAMAC properties which had been working in the prior experimental devices of our institute.

In order to manipulate the SCSI-connected CAMAC crate controller from Windows NT and to acquire the data from their modules, we have newly developed the CAMAC handling software[4]. This software consists of the following three parts;

1. CAMAC driver: the SCSI class-driver to control SCSI crate controller
2. CAMAC library: the application programming interface (API) to the CAMAC driver
3. CAMAC list sequencer: the application program using the CAMAC library which manages the CAMAC command lists.

In Windows NT, the SCSI device driver has a hierarchy of several drivers. The CAMAC driver is an upper class driver of the SCSI port driver, and it translates the CAMAC commands into SCSI ones.

The CAMAC driver can deal with multiple SCSI ports, and it has versions for both of Intel Pentium and DEC Alpha processors. The CAMAC library is the interface between a user program and the CAMAC driver. It is provided as the dynamic link library (DLL) in Windows NT. The function names in this library are almost compatible with KineticSystems CAMAC libraries.

The CAMAC list sequencer runs as a server process which executes the CAMAC command lists sequentially by communicating with the corresponding driver, and any process which wants to access the CAMAC can send it arbitrary requests. The list sequencer is implemented as a background service process of Windows NT.

The block data transfer between the list sequencer and the application program will be executed efficiently through the double buffering mechanism. It improves the effective transfer rate with using two buffers for avoiding the buffer accessing conflicts between the list sequencer and the client application. The total throughput of the block data transfer is about 700kB/s between the CAMAC module and the application program.

2.2 Digitally-Synchronized Timing System

The timing distribution system is indispensable both for the diagnostics control and the data acquisition digitizers in order to coordinate them to run synchronously on the experiment standard timing, especially if they are dispersedly installed. For the purpose of the timing coordination, the LABCOM system has developed the new digitally synchronized timing modules which applies a synchronous

base clock distribution and modulated trigger messages as digital patterns on it. Optical fibers are used for the distribution linkage because they provide the good accuracy of the transfer delay. Their basic specifications are as follows;
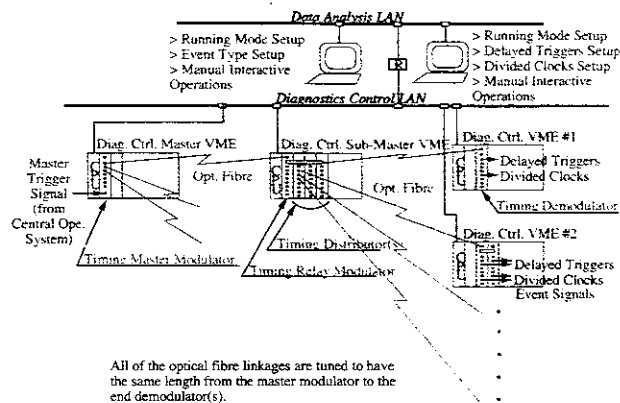

Figure 2: Digitally-Synchronized Timing System; It runs as a part of the diagnostics control VMEs.

1. Synchronous 10 MHz clock modulated by the trigger message patterns are distributed through optical fibers
2. Simple tree structure based on the modulator-demodulator pairs
3. Both of preprogrammed and user-interactive realtime signal outputs are enabled
4. Delayed trigger output covers hours-long operations
5. System flexibility of expansion as the VME modules .

They are usually used as preprogrammed, however, it requires the realtime management when handling the real-time message distribution. It enables the realtime user-interactive operation in the quasi steady-state experiments in the near future[5].

2.3 Hierarchical Data Storage

The LABCOM data acquisition system has applied the hierarchical storage management (HSM) technology. It had installed the 2 levels of the storage hierarchy in 1998: One is the local RAID of 50 GB for each server computer for 30 kinds of diagnostics, and the other is the 3 MO jukebox whose total volume goes up to 3.6 TB.

The 50 GB RAID is occupied by the database volume file of the object-oriented database management system (ODBMS), and the LABCOM data acquisition program directly store the plasma data into the database volume as the data object. The typical data storing rate into the ODBMS is a few 100 kB/s, and in order to improve the effective rate and reduce the storage volume size, the data compression mechanism of GNU-zlib library is used toward those binary mass objects. Owing to the data compression and multi-thread programming, almost all of the server PCs can finish their acquisition and store within 40 seconds after every experiment end. The compression rates, however, tightly depend on the signal forms; some integrated signal

or pulse-count measurements achieve fine rates about a few %, while some fluctuation signals never go under 50 %.

3 OPERATIONAL RESULTS AND DISCUSSION

The LABCOM system has been successfully developed with both of the strong capability of the mass data acquisition and the expansion flexibility by applying the MPP structure based on PC and Windows NT.

At the end of the 2nd experimental term, the total amount of the plasma raw data acquired by the LABCOM system was about 120 MB/shot, excepting some kinds of the standalone acquisition systems. In the following 1 or 2 years, it will easily reach the initial estimate of $\sim$ 1 GB/shot.

Late in the 2nd period, however, we had experienced the network rush during the experiments because both of the volume and number of the data retrieving by users increased much. The conventional network router between the server LAN and client one became the bottleneck, we decided to adopt the modern multi-layer switching fabrics instead. Taking the data growth in the near future into account, the continuous improvement for each part of the data acquisition system would be important to maintain the convenient speed of the total throughput.

Table 1: Operational achievement of the LABCOM data acquisition system in the 1st and 2nd LHD experimental terms; The 1st term has #1 $\sim$ #1888, and 2nd #1889 $\sim$ #7132 discharge experiments.

	1st term /MB	2nd term /MB
Halpha	4,231	41,674
Bolometer	8,276	51,114
Fast Ion Gauge	1,825	7,273
Impurity Monitor	2,169	21,568
Magnetics	12,847	90,300
Langmuir Probe	6,706	58,050
mm-wave Interfero.	4,361	-
ECH Power	3,380	-
Reflectmetry	-	23,587
Soft-X fluc.	-	25,314
X-ray PHA	-	9,420
ICH Power	-	15,577
Bremsstrahlung	-	28,162
Fast Ion	-	6,860
TOTAL	43,795	378,899

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