THE PRESENT STATUS OF THE NAC CONTROL SYSTEM

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Abstract

The control system used for the k=200 MeV cyclotron and its two injector cyclotron facilities at NAC is a PC-based distributed control system that has been in operation since 1990. The system currently consists of 45 PCs grouped into functions of operator consoles, instrumentation nodes, Internet servers and database servers, communicating over an Ethernet LAN. The PCs run OS/2, Windows NT and DOS operating systems, and use NetBIOS and TCP/IP to communicate over the network. To keep up with the short life cycles of PC hardware and software technologies, an upgrade and integration strategy was designed. This paper briefly looks at the control system design, the strategy followed for upgrading hardware and the integration of new software technologies into the existing environment.

1 INTRODUCTION

The National Accelerator Centre (NAC) operates a k=200 MeV variable-energy Separated-Sector Cyclotron together with two injector cyclotrons [1]. One of the latter is a light ion injector while the other has two external ion sources: an Electron Cyclotron Resonance (ECR) ion source for heavy ions and a polarised ion source. A PC-based distributed control system [2] was designed to replace the ageing minicomputer control system, and has been in operation since 1990 [3]. This system is described in the next section

2 THE DISTRIBUTED CONTROL SYSTEM

The new system was designed to be as homogeneous as possible and originally had six separate parts, namely the network, system nodes, instrumentation nodes, console nodes, graphics nodes and database nodes. Because many people are familiar with WWW browsers, a decision was made to add a seventh part to the control system, namely Internet Servers. The logical layout and the design choices for the original system are discussed in more detail in references [2] and [3].

2.1 The Network

The standard used for the network infrastructure is Ethernet. Because of the probabilistic nature of Ethernet the communication strategy is designed to keep the traffic on the network as low as possible. Currently the average loading is about 3% and the average of the peak loading, over 10-minute intervals, at about 8%. Under normal operating conditions, sporadic peaks of up to 30% are measured.

The network protocols used between the computers are NetBIOS/NetBEUI and TCP/IP. The original system was designed to use only NetBIOS which then led us to develop a generalised software bridge that converts requests between the two protocols (see *figure 1*).

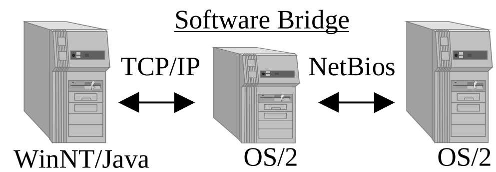

Figure 1. Software bridge to connect WinNT and Java applications to the rest of the control system

The media used for the backbone is “thickwire” (10BASE5) coaxial cable. The original system was designed so that the computers connect to the backbone via a transceiver and a transceiver cable (AUI drop cable).

The network interface cards with the 15-pin connectors required by the AUI drop cable are becoming obsolete so we have had to look at alternative media. Fiber optics are preferred but are too expensive at the moment. Because of this we decided to do tests with Category 5 UTP cabling using a 10/100 Hub connected to a transceiver via an AUI/UTP media converter in electronics areas where the EMI levels are high. The scheme has been tested with a mixture of 10Mbits/sec and fast Ethernet cards for a period of six months up to the present and seems to be successful.

The current network configuration and topology is shown in *figure 2*.

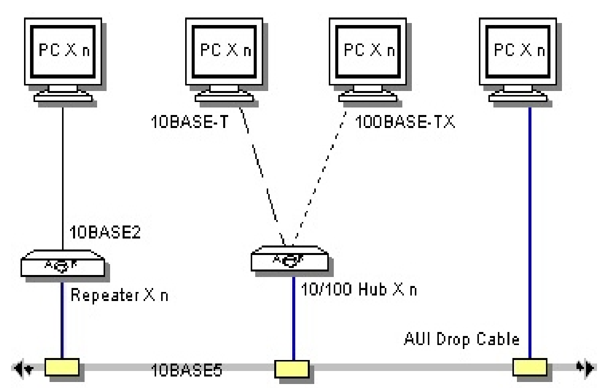

Figure 2. Control System Network Media and Topology

2.2 System nodes

The decision to use PCs for the nodes still proves to be good. The costs have remained low despite a dramatic increase in the performance of the hardware, and they have proved to be reliable.

The only problem we have at the moment is the phasing out of the ISA expansion slots on PC motherboards. The PC SABUS[1] Differential Driver modules for connecting the PCs to the electronics of the control system use these slots.

Various possible solutions such as a PCI Differential Driver card and devices that convert existing PC I/O port data to Differential Driver signals, such as USB, Ethernet, Parallel and Serial ports were investigated

The PCI solution can be implemented within a matter of months but IBM and INTEL are both working on a replacement for the PCI bus. This solution thus needed a longer-term solution as well.

USB is still in its infancy, which will result in a long and painful development cycle for both hardware and software.

The Ethernet to Differential Driver conversion is very attractive because of the stability of the Ethernet architecture as well as the ease of software development, but we will run into bandwidth problems because of our current network media and control system architecture.

Because of the simplicity of the parallel port solution we have decided to take this route for the short term. For the long term we will probably use a network device with a micro controller, but further investigation is necessary.

The new parallel port device will utilise Field Programmable Gate Array (FPGA) technology and the specification is such that additional features like analogue input and digital I/O could easily be implemented if needed.

Initially only OS/2 was used in the control system but Windows NT version 4 (WinNT) has proved itself to be stable and reliable, if no third-party (other than NAC-developed) software nor Microsoft products such as MS Office are used or installed. Because of the short software development cycles needed and the software development tools available for WinNT, we decided that all new software projects, where C++ or Pascal is used, would be developed to run on WinNT and not OS/2.

The WinNT software currently connects to the rest of the control system either via the Software Bridge described above or via direct socket connections if speed is important. We are also investigating the possibility of using a UNIX like operating system (Linux) on INTEL platforms. This investigation is still in its infancy and no decision has yet been made.

2.3 Instrumentation nodes

These nodes interface with the electronics used to control or measure cyclotron parameters. Two interface types, namely CAMAC (Computer Automated Measurement And Control) and SABUS are used.

Most of the nodes have a graphical user interface and offers a standardised interface to other applications through a variable table that uses the NetBIOS network protocol. The variable table holds all the values of the parameters controlled by a node as well as the parameters controlled by all the other nodes. The values in the variable table consists of groups of reference values and statuses, actual values and statuses, and a few fields used for housekeeping and linkage requests. The variable table broadcasts the local node’s actual values and statuses once every second over the network.

Reference group changes are either polled or interrupt-driven. If a node wants to access a reference group value it can do so either by contention for access or by direct linking. The contention is controlled by the node that controls the variable and is done on a first-come, first-served basis. A node will react to a change in a reference group by activating an application task linked to the specific reference value or status.

TCP/IP sockets are used when high-speed connections to instrumentation nodes are required as well as from WinNT nodes via the Software Bridge described above.

2.4 Console Nodes

The system controls some 1600 variables associated with the cyclotrons. The variables are logically grouped in up to 120 pages that can hold up to 33 variables each. These pages are presented to the operators on the consoles and are loaded into memory from a database at start-up. The operators can interact with these pages via a mouse and keyboard or a touch-panel and joysticks. When a page is selected for display on the console, information such as status and values of variables is selected from the local variable table. All commands to the variables are directed through the variable table via virtual circuits to the correct instrumentation nodes.

Currently the software used by these nodes are either OS/2 PM, WinNT or Java applications. The designs for the Java solutions include a Java gateway to the instrumentation nodes so that it can also run as an Applet. The gateway connects to the Java applications via Java Remote Method Invocation (RMI) and to the instrumentation nodes with TCP/IP sockets. RMI problems such as memory leaks in OS/2 browsers and default support by Microsoft’s Internet Explorers JVM will however have to be solved before the applications will be used as applets.

[1] SABUS is an RS-485 differential I/O bus and was originally developed for economic reasons as a local (national) 8-bit microprocessor expansion bus. It can extend the PC I/O bus over a distance of one kilometer with the use of differential line driver technology.

2.5 Database Nodes

One of the criteria for the control system is that it must be flexible and readily expandable. This is most easily met by using a database that holds the configuration information needed by the control system. This makes it possible to reconfigure and add information used by the console nodes at a single point.

The instrumentation nodes must however be able to operate in a stand-alone mode, should there be network problems, and can thus not rely in any way on the central database for configuration information. Each node therefore has a copy of the information used, stored on its local disk. However, information used during energy changes is stored in the central database, as more than one PC is involved in this operation and it is thus essential that the network be operable.

We are currently in the process of upgrading the control system's database management system (RDBMS) from Microsoft SQL Server version 4 to IBM DB2 universal database v5. To avoid compatibility issues between the current control software and the DB2 RDBMS, a set of dynamic link libraries (DLL's) with the same names and function signatures as the ones used for MS SQL Server were developed. By doing this we avoided re-writing and testing of existing software and will only have to replace the DLL's. Unfortunately some of the software that was compiled with the Microsoft C, version 6, 16 bit compiler has heap and stack space problems with the new DLL's and will have to be recompiled with a 32 bit compiler. This is not a straightforward task because issues such as memory management and event handling are handled differently by the different compilers.

The new neutron therapy control system currently under development will have its own RDBMS, IBM DB2, where patient and treatment data will be stored.

2.6 Graphics Nodes

A specialist operator interface was designed to provide a dynamic display of the beam profiles derived from profile grids (harps) and profile scanners, as well as a graphical representation of the Faraday cups, neutron shutters and profile monitors in the various beamlines throughout the facility. Up to six profiles can be displayed simultaneously and hard copies can be made on a laser printer.

2.7 Internet Servers

HTTP servers such as Microsoft Internet Information Server and the Lotus Domino Go Webserver are used to respond to client requests for files with Rich Text formatting tags using the HTTP protocol. Java classes can be loaded either using one of the above servers or with Java applications and servlets that act as Java class file loaders. The Java applications typically act as gateways between Applets and the rest of the control system.

3 SAFETY SYSTEMS

The cyclotron safety systems consist of an Area Clearance and Beam Safety Interlock System (SIS). The Area Clearance system monitors and controls the clearance procedures and statuses of the vaults and beam transport areas. These clearance statuses are a subset of some 2000 input and output signals monitored and controlled by the SIS. The SIS have a response time of 20 ms and stop the beam by tripping the RF of the injector cyclotrons as well as inserting various Faraday cups at strategically placed positions in the transport beam lines.

The current SIS system is DOS based and has reached its maximum capacity. An investigation regarding the upgrading of this system is currently underway.

4 Y2K ISSUES:

The control system had been upgraded and tested successfully for a period of three weeks during a previous shutdown with various dates past 1 January 2000.

REFERENCES

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[3] HF Weehuizen et al., "Proc. 1997 Int. Conf. On Accelarators and Large Physics Control Systems", Beijing, China, pp 177-179