DISTRIBUTED CONTROL SYSTEM FOR BEAM LINES,
THE APPLICATION OF COMPUTER NETWORK

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## ABSTRACT

A distributed control system has been designed to control all beam lines around the 2.5 GeV storage ring at the Photon Factory. It is a computer network composed of outlying nodes and a central node which are interconnected in a star configuration via optical fiber links, with a communication rate of 9600 baud. Each beam line is controlled by its own outlying node, independently of adjacent beam lines.

## INTRODUCTION

The Photon Factory is a facility for dedicated use of synchrotron radiation at the National Laboratory for High Energy Physics. There are twenty four possible beam line ports at the 2.5 GeV electron storage ring. At present, nine beam lines are installed along lines tangent to the electron storage ring. They feed synchrotron light to the hall where many experiments, including X-ray lithography, microscopy and crystal structure analysis are carried out, simultaneously.

There are many components installed on the beam line, for example; five open-close units, two vacuum monitors, four ion pump controllers, and safety interlock systems such as cooling-water, vacuum protection, and compressed-air interlocks.

A beam line with such components must be controlled independently of adjacent beam lines by the outlying node in charge of that beam line. This is especially important for synchrotron radiation experiments which may vary greatly in their needs. In addition, all the beam lines are distributed over the 180-meter-round storage ring.

This paper describes the distributed control system, an application of computer network with a star topology, currently implemented to control all the beam lines at the Photon Factory[1]. This computer network is designed to accommodate various beam line features; i.e., by only modifying lower level software and/or hardware modules on an outlying node to adapt to different features of the beam line, systematic control at the central node is carried out with almost the same control process for each beam line.

## REQUIREMENTS FOR TEH CONTROL SYSTEM

The beam line control system must satisfy the following requirements:

1) The system must automatically collect information on the status of all beam lines.
2) The system must generate an alarm when it finds an incorrect state.
3) The system must display the current operational status of beam lines on color CRT's.
4) The system must manipulate valve/shutter units on request signals from beam line users, as well as from the system console at the central node.
5) When one beam line goes down due to an accidental failure, the system must carry out error diagnosis for fast recovery.

The distributed control system is designed based on the above requirements. Figure 1 shows the configuration of the system, where the outlying nodes and the central node are connected via optical fiber links in a star topology.

## OUTLYING NODE

The outlying node only controls a set of components attached to the beam line, in accordance with a preprogrammed process, as well as commands received from the central node, and request signals from beam line users.

This node is a Zilog Z-80A based microcomputer system with parallel input/output interfaces and dual serial communication ports. These outlying nodes are physically distributed over the storage ring. Each outlying node communicates with the central node approximately 200 meters away.

As shown in Fig. 2 the architecture of an outlying node falls into three layers: a physical layer of physical devices, a network layer, and a control layer of software modules written in ASSEMBLER.

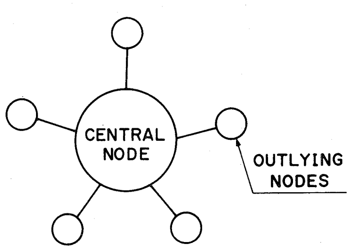


Fig. 1 Star topology.

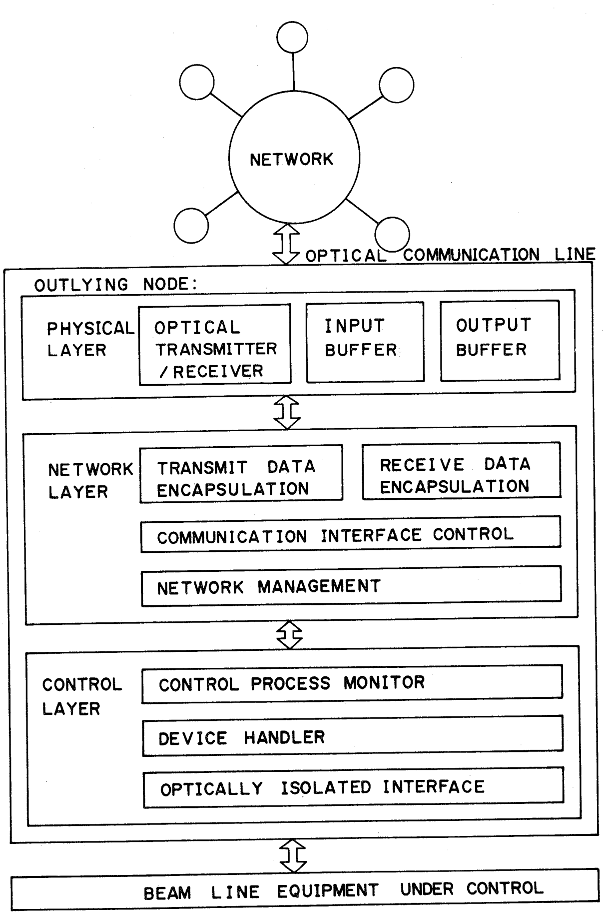


Fig. 2 Functional diagrams of an outlying node: There are three levels of layers.

The control process monitor's basic functions include:

1) Open or close a beam line on request from either the central node at the operation room, or synchrotron radiation users at the experimental hall.
2) Obtain and check status of valves/shutters on the beam line.
3) Get vacuum data from up to five points, so as to monitor the ultra high vacuum condition.
4) Get information on the safety interlocks of the beam line, as mentioned in the introduction.
5) Communicate with the network.
6) Get commands from the central node and execute them.
7) Transmit information on the current status of the beam line to the central node.
8) Diagnose an error when it occurs in the beam line and send the results to the central node.

Under normal conditions, the outlying node controls all components of the beam lines without central control intervention. When its control process monitor directly receives a Beam-Line-Open-Request (BLREQ) signal from the beam line users, the monitor in turn checks whether the status of the beam line satisfies desired conditions or not. If all conditions are met, the monitor then sequentially opens all the valves/shutters on the beam line. After completion of each opening, the monitor transmits the current status information to the central node via the network. When any one of the valves/shutters fails to open, the monitor closes all the valves/shutters, and invokes an error diagnosis process after sending error messages to the central node.

Figure 3 depicts the hardware architecture of an outlying node. To attain minimum cost and complexity, it consists of two printed circuit boards with microcomputer logic and a valve/shutter interface. A Zilog Z-80A CPU, parallel input/output interface and GPIB interface logic are implemented on the microcomputer logic board.

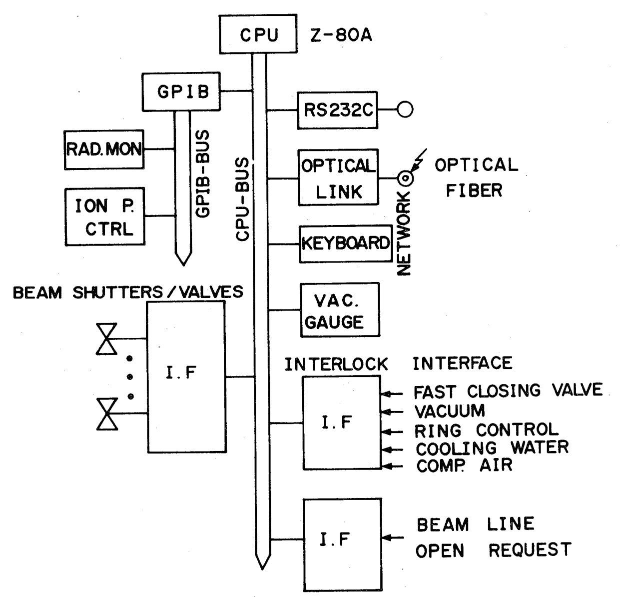


Fig. 3 Hardware architecture of outlying node by which complete control of a beam line is executed.

CENTRAL NODE

The central node consists of a DEC (Degital Equipment Corporation) LSI-11/23 microcomputer running RT-11 Operating System for control and monitoring beam lines, two microcomputer systems, NEC PC-9800's with Intel 8086, for color graphic display, and a network controller with expandable communication ports for network management. The layout of the central node is illustrated in Fig. 4.

The central node carries out the process in accordance with the requirements 2) through 6) in the section II.

The major part of the software programming (approximately 80%) for the central node is implemented in FORTRAN. The rest is written in ASSEMBLER, for reasons of time and memory space optimization. The whole software is fabricated in a number of modules so as to allow ease and flexibility in making changes.

Control information on the status of all beam lines is monitored at the central node via the network every minutes. This provides an advantage for detecting a temporary malfunction in the control system by checking whether one item of the status information is lost or not.

The current operational status of the beam lines is transmitted to a graphics microcomputer at the operation room. The PC-9800 microcomputers provide support for the graphics displays which have a resolution of 640 × 400 pixels with 8 color depth for graphic display and 80 × 25 color characters for alphanumeric display on a 14 inch CRT. The operators can select from several frames to obtain either an overview, or detailed report on specific areas of the status of the particular beam line.

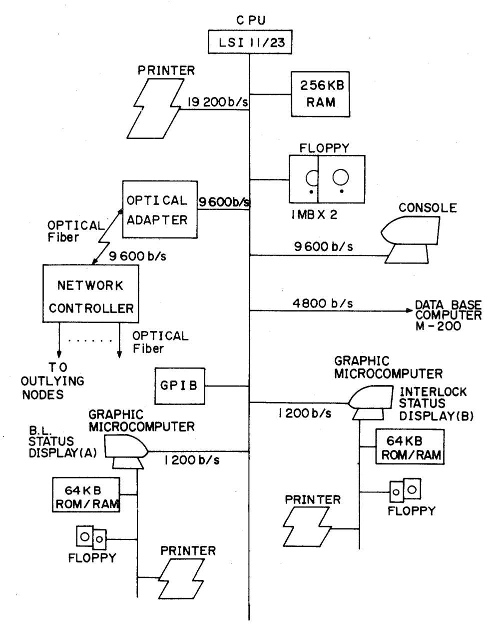


Fig. 4 Block diagram of the central node.

REFERENCE

1. N. Kanaya, "Design of the distributed control system for beam lines at the Photon Factory", IEEE Trans. on Nuclear Science, pp:957-962, Vol. NS-31, No.3, June, 1984.