I/O Subnets for the APS Control System*

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Abstract

Although the Advanced Photon Source Control System allows for microprocessor–based Input/Output Controllers (IOCs) to be distributed throughout the facility, it is not always cost effective to provide such capability at every location where an interface to the Control System is required. I/O subnets implemented via message passing network protocols are used to interface points and/or equipment to a somewhat distant IOC, thereby reducing the number of required IOC's and minimizing the field wiring from the equipment to the Control System. For greatest flexibility, the subnets must support connections to equipment that requires several discrete I/O points, connections to GPIB and RS232 instruments, and a network connection to custom designed intelligent equipment. This paper describes an approach that supports all of these interfaces with one subnet implementation, BITBUS™. In addition to accommodating several different interfaces on a single subnet, this approach also circumvents several limitations of GPIB and RS232 which would otherwise restrict their use in a harsh, industrial environment.

I. THE APS CONTROL SYSTEM

The APS Control System provides for VME–based Input/Output Controllers to be distributed throught out the facility and interconnected via Ethernet to one another and also to Unix–based Operator Interface consoles.[1] Although this distributed architecture allows for intelligent processors near the major subsystems, I/O subnets are frequently required to interface directly to the equipment and communicate I/O information to the nearest IOC.

II. CURRENTLY SUPPORTED SUBNETS

A. Allen Bradley Remote I/O

The Allen Bradley Remote I/O Subnet allows the use of Allen Bradley's 1771 Series I/O modules. These units are inexpensive, rugged, and well proven in harsh industrial environments. This subnet allows field cabling to be kept to a minimum by providing the computer interface close to the equipment. A fiber optic network is available to provide isolation to areas where potentially dangerous voltages and/or EMI/RFI interference may exist. Unfortunately, since this network and the I/O chassis are proprietary designs of Allen Bradley, it cannot be customized to meet some of the unique requirements encountered in accelerator control. Any requirement other than typical process or industrial control operations currently supported by Allen Bradley modules cannot be supported with this implementation.

B. GPIB

Sophisticated test and measurement instruments frequently used in laboratories routinely provide GPIB as their interface to external equipment. Utilizing GPIB extensively in an industrial environment presents some serious challenges and potential problems. The distance limitation of 20 meters implies that the IOC must be located relatively close to the instruments. Extenders (both fiber optic and twisted pair) are available, but most efficiently used when a *cluster* of GPIB instruments are far away from the controller. If several GPIB instruments are located far away from each other, the use of multiple extenders is prohibitively expensive. Another concern is the noise susceptibility of the non–balanced signals within the GPIB cable. Industrial environments are potentially very noisy with respect to EMI/RFI, ground spikes, and power line transients. Since GPIB originated as a laboratory instrument interface, it was not designed with such an environment in mind. Differential signal lines, ground isolation between nodes, and error detection capability (such as parity or CRC's) are techniques that are frequently used to improve the reliability of a network in a harsh environment, but have not been included in the GPIB interface standard.

III. REQUIREMENTS FOR ADDITIONAL SUBNET SUPPORT

Several requirements for the APS cannot be adequately met by the currently supported subnets. These requirements are briefly discussed below.

A. Power Supply Control Units

The numerous power supplies throughout the APS facility will be controlled by small intelligent Power Supply Control Units (PSCU's). In the Storage Ring alone it is planned to have

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200 PSCU's. Each IOC in the Storage Ring (20 are planned) will need to interface to 10 PSCU's. The basic requirements for this "subnet" are:

- Multi–drop network that supports at least 10 nodes over a distance of 50 m
- Immunity from switching power supply noise
- Ground isolation between nodes
- Low cost per node (due to the large number of nodes)

B. APS Custom Equipment with Embedded Controllers

Several pieces of equipment that are custom built per ANL specifications are sophisticated enough to use embedded controllers for equipment control. Interfacing this equipment to an IOC via a subnet would allow for a clean and inexpensive connection. An example of this is the five Klystron/Modulators located in the Klystron Gallery of the LINAC area. Each has an embedded controller and requires approximately 50 parameters to be passed to/from an IOC. The Modulators are approximately 50 feet apart. The basic requirements for this "subnet" are:

- Multi–drop network that supports at least 5 nodes over a distance of 70 m (200 ft)
- Immunity from EMI/RFI environment
- Ground isolation between nodes (preferably fiber optic)

C. Distributed RS232 Instruments

Several instruments that will be specified for use may only provide an RS232 interface. Residual Gas Analyzers, Stand–alone Single–Loop Controllers (PID control), Ion Gauge Controllers and Digital Display Panels are examples of some things that will require a simple RS232 connection to an IOC. A subnet that would provide multi–drop support over a large distance with appropriate error detection and noise immunity would allow a clean interface to these distributed RS232 instruments.

D. Distributed GPIB Instruments

Advanced Test and Measurement equipment will routinely be used for monitoring and controlling different parameters of APS operation. Examples include Digital Oscilloscopes, Network Analyzers, Precision Timing Generators, RF Power Meters, and Frequency Counters. Ultimately it will be required to interface this equipment to an IOC, even if it is not close to an IOC. A subnet that would accommodate GPIB devices but allow for long, noise immune cabling between instruments would be a significant advantage during the project's lifetime.

E. Single Point I/O

Since the APS facility covers more than 40 acres, it is likely that I/O points to be interfaced will be quite spread out. Although such instances can well be accommodated by field wiring, having the capability to (cost effectively) interface to a handful of I/O points would provide greater flexibility in the design of a subsystem. Attaching an inexpensive module to a subnet that would provide 16 I/O points at a particular location is likely to be a requirement.

IV. NEW SUBNET PROPOSAL

Each of these requirements for additional subnet support has a possible solution. The Power Supply Subnet can be one of many networks, including Ethernet, GESNET, BITBUS, or simple RS232. Distributed RS232 instruments can be supported with Multi–drop RS232 networks available from many vendors. Equipment with embedded controllers can be specified to provide GPIB or RS232 interfaces. Distributed GPIB instruments should be grouped together in racks and an extender used when the distance from the IOC exceeds the recommended distance. Allen Bradley chassis can currently provide small amounts of I/O in random areas, but this approach is not cost effective for just a handful of points.

Providing unique solutions to each of the above requirements dramatically increases the hardware and software that will need to be developed and/or maintained throughout the lifetime of the project. It also increases the unique hardware and software for a given subsystem, making it less likely that anyone other than the engineer who implemented the system could support it.

Ideally, a single subnet could be implemented that would support all of the above listed requirements. With a common solution, cost would probably be less (due to the quantities required) and maintainability would be significantly enhanced.

A. Subnet Architecture

The requirements previously discussed could be implemented with the *single* subnet architecture illustrated in Figure 1. The subnet network is distributed from the IOC throughout the area of interest. Three types of "gateways" can be connected to this subnet: Single Point I/O Gateway; RS232 Gateway; and a GPIB Gateway. In addition, any intelligent node (such as embedded controllers) that implemented this interface could be connected directly to the subnet. This network should have the following characteristics:

- based on a non–proprietary commonly accepted network standard, so components are commercially available
- multi–drop network that supports > 25 nodes
- immune to random electrical noise
- error detection and recovery
- provide ground isolation between nodes
- allow fiber optics for total isolation when required
- fast enough to support a reasonable number of nodes

With this approach, the IOC would communicate to GPIB instruments over the same network it uses to communicate to RS232 devices. The data to be sent to the devices would be encapsulated within the defined subnet protocol. The individual gateways would extract (and possibly buffer) the data and

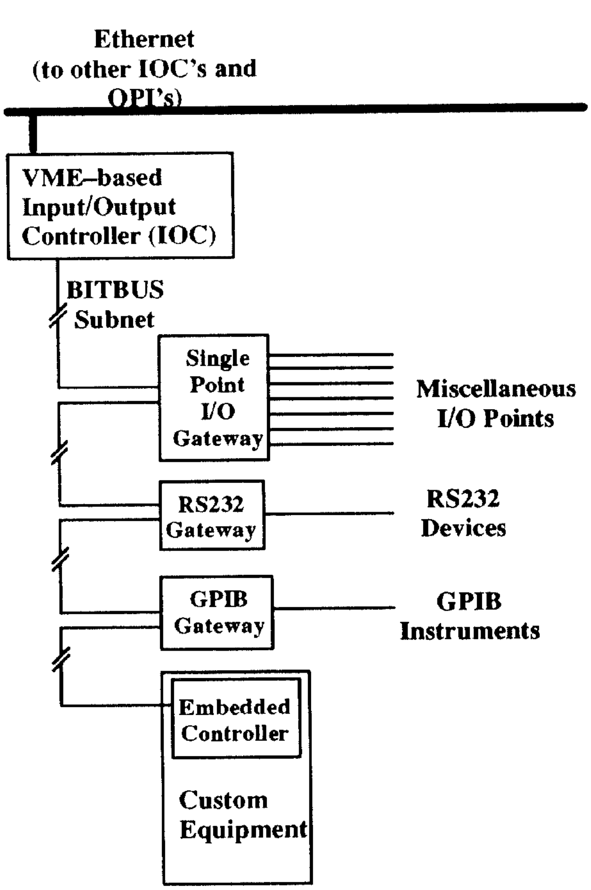

Figure 1. New Subnet Proposal

complete the transmission over the particular interface. This approach also solves a potential problem of slow devices "tying up the network" that may exist in other implementations.

B. BITBUS as the Backbone

Several networks come to mind as possible alternatives for implementing this idea: Ethernet, BitBus, Arcnet, MilStd 1553, or even RS232. When evaluating these networks in the areas of cost, performance, and available products, BitBus seems to emerge as the most promising. In fact, three of the four types of interfaces shown in Figure 1 are currently available from commercial sources for BitBus.

The BitBus Interconnect Serial Control Bus was introduced by Intel to provide high speed transfer of short control messages in hierarchical systems. It quickly became popular in industrial applications as a "field bus" that allowed distributed I/O equipment to be connected to a single host. It is likely to be accepted as an IEEE standard (IEEE P1118), which will further increase its popularity. The goal of the BitBus Interconnect is to provide a message passing interface between tasks at the master node and tasks at multiple slave nodes. The salient features of the specification include:

- Electrical Interface: RS485 (differential twisted pair)
  Self–clocked 62.5Kb/s @ 1200m or 375Kb/s @ 300m
  Fiber Optic tranceivers available
- Data Link Protocol: subset of SDLC
  Single master/multiple slave topology
  Provides CRC error detection and message sequencing
  Provides automatic retry on detection of errors
- Message Protocol
  Destination address includes Node and Task
  Predefined messages for I/O and memory commands
  Data length up to 248 bytes per message

C. Product Availability

Almost all of the components required to implement the capabilities illustrated in Figure 1 are commercially available (discussed below). Although a GPIB Gateway product has not been identified, vendors have expressed an interest in providing such a product. Besides commercially available products, Intel markets a microcontroller (8044) that implements the BitBus protocol on a chip that can be used to provide a Bitbus Interface to custom designed equipment. This, of course, is an advantage of basing the subnet on a commercial standard rather than a proprietary product.

D. 'Proof of Concept' Test Stand

A Test Stand was constructed to demonstrate the feasibility of the concept illustrated in Figure 1. Only commercially available hardware was used (custom software was required). The products used were :

VME Bitbus Card: Xycom XVME–402 Bitbus Controller

Single Point I/O Gateway: Phoenix Contact Interbus–C IBC–EU (Bitbus Interface) and IBC EDIO (Digital I/O)

RS232 Gateway: Micronetics International, Inc; Bitbus/RS232 Gateway

GPIB Gateway: Micronetics International, Inc Analog Data Manager; National Instruments GPIB SBX card; custom software by Micronetics

Embedded Controller: GESPAC G64 chassis with 68000 processor card and FILBUS controller *< this part of the test stand was not fully implemented at the time of this writing >*

V. CONCLUSION

BITBUS is currently being considered as a viable approach to attaching equipment to an IOC in the APS Control System. With the appropriate gateways (either developed or purchased), BITBUS could be used to connect distruted GPIB instruments, RS232 instruments, intelligent controllers, and single point I/O panels via the same data network, thereby greatly enhancing maintainability of the system. Distance limitations and noise susceptability of GPIB are circumvented, as well as the point–to–point nature of RS232.

VI. REFERENCES

[1] M. J. Knott, "The Advanced Photon Source Control System" these proceedings.