THE ARCHITECTURE OF THE LEP CONTROL SYSTEM

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1. Introduction

There are several reasons why it is not possible to lay down an exact layout of the Control System for Phase 1 of LEP at the present time. These include the absence of a detailed evaluation of the control requirements, uncertainty as to the extent of the involvement of microprocessors in the components of LEP, and the need to keep the cost down to the minimum without sacrificing essential facilities. The aim at this stage is to provide designs for a series of building blocks from which the minimum suitable system can be built when the initial requirements are known, but which also allows expansion to meet the increased requirements as the machine is developed, without having to waste the previous effort expended in both hardware and software.

The purpose of this note is to give a brief description of the various types of modules required to implement such a system, and to show the range of possible complexity for the different applications.

As mentioned above, the extent to which microprocessors will invade the LEP components is not yet clear, but for the purpose of this note it will be assumed that either all equipment can exchange simple messages with the control system, or provision is made to communicate with simple equipment via separate crates with controllers that can exchange messages with the control system.

2. Control System Hierarchy

The control system will be composed of two layers of networks, the upper level consisting of a network of process computers and the lower layers networks of equipment controlled by a process computer. This is illustrated in Fig. 1. The computer network will be of the interconnected multiple star type, and the equipment network will be of the multidrop highway type. The physical connections will be made by a number of means, including the integrated communications system described in LEP Note 196, but to avoid confusion, we will only consider the logical links in this note, and ignore the physical means by which they are provided.
The computer network must be compatible with those of the SPS and PS, so that direct connections can be made, but the physical and lowest protocol layers can be different, to take into account international standardization since the SPS system was designed. The higher level protocol allows any computer to initiate a transaction with any other computer in the system, without having to obtain authority from a higher level, or to book a communications channel. Thus there is no prearranged master of the system, so that, for example, a console computer running a control program can take temporary command of the system, calling for the execution of parts of the program in other computers, relinquishing command as soon as execution is completed.

Brief specifications for the computer and equipment networks are given in the appendices, and the modular process computers are described in the next section, before considering the range of possible layouts.

3. The Process Computers

The process computers, which will take the place of the NORD 10/100 mini-computers in the SPS system, will consist of a crate and module system with a suitable standard backplane bus and arbitration scheme for interconnecting the modules.

The range of modules must include the following:

3.1 Data Link Unit (DLU)

Exchanges messages with a network node and performs all checks and obeys SPS higher level protocol. Lower level to conform to HDLC and physical level to be compatible with CCITT norms. Stores messages until they can be passed to other modules or transmitted out.

3.2 Highway Control Unit (HCU)

Forms the master for a multidrop highway. Exchanges messages with equipment connected to drops. Polls as necessary to obtain interrupts. Provides clock and timing events as required.
3.3 Display and Control Unit (DCU)

Provides facilities for drawing BW/colour displays and interfacing to touch buttons, tracker balls, etc.

3.4 Mass Storage Unit (MSU)

Provides file manager and driver for mass storage, able to use either on-board semi-conductor store or external disc, etc.

3.5 Processing Unit (PU)

Consists of CPU with RAM and ROM. Essentially only one type needed, but more than one type, with differing power and memory capability, are allowed, if functionally interchangeable.

These modules can be used, inter alia, for the following processes, according to the software loaded:

- NODAL interpretation
- Scheduling and supervising the other modules in the crate
- Data module operation
- Message routing and supervision.

The numbers of modules of these different types which are used to make up a PC will vary according to application, and the table below shows the requirements for some typical applications.

<table>
<thead>
<tr>
<th>Type of PC</th>
<th>MODULES</th>
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<tbody>
<tr>
<td></td>
<td>DLU</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Console</td>
<td>1</td>
</tr>
<tr>
<td>Process control</td>
<td>1</td>
</tr>
<tr>
<td>Library</td>
<td>1</td>
</tr>
<tr>
<td>Alarm</td>
<td>1</td>
</tr>
<tr>
<td>Message transfer node</td>
<td>*</td>
</tr>
<tr>
<td>Test unit</td>
<td>-</td>
</tr>
</tbody>
</table>

* indicates one or more modules as required
( ) indicates may be fitted where stand alone local control is required
Normally, control programs called from the library can run in any console PC, and, since these PCs can be attached to any node of the network, there is no geographical limitation on the placement of control consoles which give the full possibilities of controlling all the LEP equipment. However, only a limited number of full consoles can be provided, and there will be the need for some simpler and more widespread local-control facilities for testing, commissioning and fault-finding.

These can be provided at a number of different levels. A mini-console connected to a DCA module in a process control PC could run programs in the interactive NODAL module virtually identical with those which run in the full console. A VDU or equivalent could also be connected to a drop of the multidrop highway and run programs in the interactive NODAL module, in cases where the graphics and touch-button facilities are not required. At the lowest level, a piece of equipment could be disconnected from the multidrop highway and connected to a test box.

4. Possible Lay-outs

The LEP equipment can be divided into three categories: general services, machine equipment and experimental support. The general services, electrical supply, cooling, ventilation, access control and radiation monitoring, need to continue to operate when the machine is shut down, and so their control and surveillance should be decoupled as much as possible from the machine and experimental areas control. At the minimum, this can be provided by having a single process control PC for these services, controlling a multidrop highway in each building, to which all service-type equipment is connected, as shown in Fig. 2. A mini-console and local disc store connected to the PC would give stand-alone control facilities if the network was closed down for modifications at any time. At the other extreme, the maximum layout that could be envisaged would have a separate services node in the computer network, with a PC in each of the buildings, controlling one or more multidrop highways, a separate services library, one or more full consoles and a separate PC for access control, as shown in Fig. 3.

For the machine control, one can also define a minimum and a possible maximum for the connections to the equipment. The minimum solution would have a single PC in each of the buildings at the interaction points, with a number of multidrop highways controlled by each, for vacuum, RF, power supplies, beam instrumentation, etc. This is shown in Fig. 4.
The maximum lay-out could have a separate PC for each service in each building, if the load warranted it, with a local node, to which could be attached a full console, as shown in Fig. 5.

As far as the main control area is concerned, the minimum, assuming that it is located in the SPS control building, could be one or two additional consoles, a LEP library and LEP alarms, with a link to CERNET to run modelling programs in the computer centre. This is shown in Fig. 6. At the maximum, there could be more consoles, to become less dependent on the SPS, and the addition of a medium sized computer for running the modelling and simulation programs, and a separate service computer for program development and running a printer, etc.

The requirements for the experimental areas could vary from a connection from the multidrop highway in the interaction region to pass machine parameters to the experimental computers, up to a separate PC connected to a local node of the network, with timesharing facilities for the experimenters, as provided at the SPS experimental areas.

5. Conclusions

It has been explained why definite lay-outs for the LEP control networks cannot be laid down at the moment, and the building blocks necessary for a flexible approach to meet the requirements as they evolve are described.

By the use of the NODAL multicomputer operating system, and the data module concept, it will be possible to evolve from the simplest lay-outs to the most complicated without scrapping hardware, and with only very minor changes to programs.
Appendix A

Brief Specification for the Inter-Computer Network for LEP

1. It shall be a store-and-forward packet-switching network, using datagrams.

2. The network shall consist of a series of simply-connected stars, so that there will be a unique path between any two computers at a given time. Where alternative paths are available, reconfiguration will be by operator intervention.

3. The physical transmission level shall be compatible with using time-division multiplex equipment to CCITT recommendation G.703, possibly using X21 links as intermediary.

4. The line transfer rate shall be 1.024 or 2.048 Mbits/sec.

5. The frame structure and low level protocol shall follow the HDLC convention.

6. The higher level protocol shall follow that of the SPS Message Transfer System.

7. Plug-in terminal modules to the Eurocrate standard shall be provided to connect a data-link to a computer. The module must carry out all the tasks needed to accept a message from the computer, form it into packets and transmit it to a node, performing error checking and recovery procedures. It must carry out the inverse operations for an incoming message, working in full duplex.

8. A routing mechanism must be provided so that a crate with the appropriate number of terminal modules can form a node of the network, performing the necessary routing and queuing, according to priority.

9. A gateway module must be provided to connect to an existing SPS node in a transparent manner.
Appendix B

Brief Specification for the Lower Level Network to Connect to Equipment

1. It shall be of the multi-drop highway type.

2. Semi-duplex operation with a single master and multiple slaves would satisfy the requirements, but a duplex system is not precluded (see 7 below).

3. The maximum allowable length of the highway shall be at least 200 m in normal mode. It must be extendable to 10 km, making use of the time-division multiplex system.

4. The maximum number of drops on each highway shall be at least 32. The drops must be transformer coupled, and it must be possible to connect and disconnect a drop while the highway is in operation, without disturbance. The maximum length of cable allowable between a tap on the highway and the terminal equipment must be at least 5 m.

5. The system must be able to transfer messages, which will normally be short, in the form of blocks or frames. The maximum size of a block will have an influence on the polling response time (see 7 below). Longer messages must be broken up into a number of blocks by the originator and reassembled by the receiver.

6. The speed of transmission on the highway is dependent on a number of factors, but the minimum acceptable speed may be set by the requirement for polling (see 7 below). The speed should not exceed 1 Mbit/sec so that simple twisted pair cables can be used for transmission over the 200 m specified.

7. With a single master system, it is necessary for the master to poll the slaves periodically, to see if any require attention. Such a polling cycle, for 32 slaves, should not take more than 10 ms. In a full duplex system, it would be possible for the slaves (secondaries) to transmit without request from the master (primary), as is provided for in the Asynchronous Response Mode of the HDLC protocol. In such a case there must be some means of arbitration.
8. The connection from a drop on the highway to the equipment to be controlled must be provided by a card containing all the logic and processing power needed to transmit and receive messages, via the highway, to and from the master unit in a process computer assembly and to conform to the full requirements of the protocol, including responses to polling and surveillance messages. The interface to the equipment to be controlled shall take the form of an input data buffer, an output data buffer and a control register. The size of the buffers and the requirements for the control register, as well as the logic levels, need to be defined. This card should plug into a standard socket, and require only a single 5V supply from the equipment to which it is connected.

9. The highway will be accompanied by a timing distribution system, which will provide clock pulses and event identification. This distribution should use the same electrical standards and share the same connector as the multidrop highway. A version of the interface card specified above which includes the decoding logic for the timing distribution must be available for equipment needing this information.
Fig 1  The Two Network Layers.
Fig 2. Minimum Stand-Alone System For LEP Services.
Fig 3. "Maximum" layout for stand-alone services system.
Fig 4. Minimum layout for LED machine.
Fig 6. Possible layout for "Central" control.

Solid lines - minimum system.
Dashed lines - possible additions.