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Evolution of the SPS and LEP Communication Control Network for SPS and LEP Accelerators

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ABSTRACT

From its startup in July 89, the LEP remains the largest accelerator in operation in the world.

At the present time, the controls networks cover a very large site (more than 200 km²) integrating the SPS accelerator and interconnecting more than 1000 hosts.

This paper describes the evolution of the network architecture from the commissioning of LEP until now and future trends taking into account our experience of supporting more user requests, higher bandwidth, and more reliability also Commercial availability of more performant technology and market trends are considered.

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1. INTRODUCTION

Since its startup in 1989, LEP (Large Electron Positron) remains the largest accelerator in operation in the world.

The design of the communications network was presented at the International Conference on Accelerator and Control Systems in Vancouver, November 1989. [1]

In 1991, it was decided to replace the old computers of the Super Proton Synchrotron (SPS), and the LEP communications network was extended to also include the SPS.

The original communication system was based on the use of Token Ring networks bridged together, one main network in the control room and two peripheral Token Rings using a TDM transmission system.

The first network, the Token Ring used for technical services (LEP Service), consists of a backbone (Token Ring using Time Division Multiplexing) which bridges together the nine LEP surface buildings.

The bridge has a double functionality: to change the frequency and to isolate the fault domain.

The second network, for LEP Machine instrumentation, consists of a Token Ring and uses a TDM system serving 8 pits and 16 underground alcoves where the equipment for beam observation is located.

A outband network based on MIL-1553 standard is provided as an alternate access to the equipment for reconfiguration, reboot of computers and TDM monitoring.

The main Token Ring in the Preveessin Control Room (PCR) connects to the workstations and the PCs of the accelerator operator.

2. EXPERIENCES

The first experience with this novel network technology was positive. The networks were working as expected and the performance was adequate for the anticipated load.

The choice of Token Ring was correct, it operated smoothly and was well adapted to the technical constraints.

However, limitations became apparent:

We were forced to accept that the Token Ring did not have the commercial success expected and the commercial market is still lukewarm towards this technology.

The 802.5 (Token Ring) standard has not reached the popularity of the 802.3 (Ethernet) even after the Token Ring clock frequency was increased to 16 MHz.

The consequences of this are :

- 1- The limited choice of Workstations brands available with a Token Ring interface.
- 2- Operating systems selected (LYNX-OS, HP-UX, ULTRIX or OS-9) do not have commercial drivers for Token Ring.
- 3- A bandwidth limit due to our implementation of Token Ring using TDM at 34 Mbits.

The translation of code (Manchester to HDB3) needs a frequency of 8 Mbits and thus occupies 25% of the total bandwidth (34Mbit) of the TDM giving a real utilization of 4Mbits.

The need to change the frequency from 4 MHz (Token Ring clock frequency) to 4.224 MHz (TDM baud frequency) is mandatory to transmit the Token Ring signal using TDM and imposes a modification of all interfaces connected to the backbone and a frequency change for all bridges.

- 4- In case of incidents on the LEP Machine network, caused by the TDM or the Token Ring, there is great instability and the recuperation of the ring integrity is painful and can take a long time.
- 5- After the decision to install diskless computers, the bridged network topology did not allow limitations of broadcast traffic and so reduced the available bandwidth for other usage.
- 6- A major fault on the PCR Token Ring isolated it completely from other peripheral networks and rendered operators blind.
- 7- Using different transmission protocols made the network management very difficult and thus reinforced our decision to restrict the use of protocols to TCP/IP.

3. CHRONOLOGICAL EVOLUTION OF THE ARCHITECTURE

The architectural evolution was not only dictated by our experience but also by external aspects, influenced by user demands, implication of the accelerator evolution, availability of new technology and market trends.

We have seen several factors in the evolution of communications network topology :

3.1 Technical Control Room

The decision to create a technical control room for all technical services around the accelerators at CERN (Electricity, Cooling and Ventilation, Access, etc.) and the requested availability of this network 365 days/year necessitated a redesign of the overall topology in order to avoid network interdependence.

3.2 Sharing computer resource with the PS accelerator complex

The sharing of resources and data exchange between the LEP control system and the PS Control system, obliged us to create an internet network for accelerators, independent of the CERN public network.

The connection to it is done by means of two redundant IP-routers located in the PS Control Room and the PCR.

The liaison between these control systems was implemented by means of a 7 Km long Single-mode FDDI transmission optical fiber using only TCP/IP protocols.

3.3 Improvement of the Beam orbit measurement system

The new beam orbit acquisition system, is based on diskless VME crates running the OS-9 operating.

We installed an Ethernet/Token Ring bridge in each pit and each alcove in order to

These Ethernet segments allowed us also to install Terminal Servers and Xterminals where necessary, for local control and developments.

3.4 Replacement of Nord computers in the SPS

The upgrading of the SPS Control system [2] and the replacement of Nord computers by VME equipment running the LYNX OS operating systems, forced us to install the same communications infrastructure around the SPS ring.

It now consists of a 7 Km TDM /Token Ring transmission backbone, to which 8 surface buildings and 2 experimental areas are attached with a Token/Ethernet bridge in each building.

3.5 IP-routers vs. Bridges

Diskless machine usage and broadcast transmission of real-time synchronisation messages, requires good network isolation, to avoid congestion, in particular with Ethernet.

To avoid this, bridges have been replaced by IP-routers, consequently the addressing scheme has been changed, using subnetting methods.

We have selected the Proteon CNX500 [3] IP-routers. This equipment allows the routing of Apollo Domain Packets over Token Ring as well as Ethernet.

3.6 Multimedia connection in PCR and TCR

The general trend in the control rooms is to use Workstations, personal computers and Xterminals with an Ethernet interface.

As the Token Ring to Ethernet transition should be made progressively, and should avoid the use of multiple network types, the control rooms have been rewired completely with a multimedia cabling system.

The network distribution is done by means of a star multimedia transmission system from a central HUB [4] supporting Ethernet, Token ring and Copper FDDI (CDDI). The result is a very flexible and highly reliable system.

IP-router interconnection is done by means of two special Ethernet segments (one for operational traffic and one for development traffic) not accessible to users.

3.7 Network Management

To achieve reliability and good connectivity, it is vital to have a high performance tool giving the operators a clear overview about the network situation.

Also, network management tools should be usable by non-network specialists with limited functionality and should also be accessible from everywhere on the site.

The SPS and LEP complex has more than 1000 hosts distributed over 200 km² and some of them are inaccessible during machine operation.

At the start of the project, an in house network management system was developed, with the intention of covering our requirements.

The manpower for this approach was expensive and also difficult to adapt and maintain to new topologies.

Since then, different commercial network management products have been investigated. They all use the defacto standard SNMP as a management information

After many evaluations, we selected the Hewlett Packard Node Network Management software running on HP OPEN VIEW [6]

We succeeded in integrating the network reconfiguration program and the monitoring of the TDM through the MIL1553 outband network [7].

4. EVOLUTION

This evolution is first of all dictated by the necessity to increase the bandwidth, in view of the increasing number of hosts and applications.

There are many phases in this evolution

4.1 Control Room PCR

The actual backbone FDDI in the PCR ,will be extended allowing us to interconnect all IP-routers and important servers.

Two hubs will perform the bridging and the distribution of Ethernet segments to the workstations

4.2 Accelerators level

The first priority will be to dissociate the TDM from the communication network avoiding problems mentioned in chapter 2.4.

More efficient usage of the TDM, is foreseen to give more bandwidth for private point to point communication, by liberating the Token Ring channel.

Optical fibers will be the standard way of connecting to the surface building.

Up to now, the usage of optical fibers in the LEP tunnel was impossible due to the degradation of transmission characteristics of the fiber resulting from radiation.

To avoid this, two solutions were envisaged :

- either by using radiation resistant fiber (Expensive) or
- protecting the fibers against radiation

We evaluated the second solution by placing 1.5 Km of optical fiber in the central drain tube which is located 50 cm under the LEP concrete foundation. The beam injection area has been selected due to high level of radiation. Dosimeters have also been placed to measure the integrate dose.

After 1,5 years, no particular symptoms of attenuation have been discovered and the dosimeters have just been taken out to be analysed.

Extrapolation will then be done to compute the predicted dose when LEP 200 is started.

Initially it appears that the first results are promising, and further investigation will continue by connecting adjacent alcoves.

The network distribution is based on 8 FDDI optical fiber loops which start from the PCR and pass through existing cable ducts. Other optical fibers have to be installed for two of the LEP sites.

Each LEP access point will serve the two adjacent alcoves by means of Ethernet on optical fiber through the central drain.

4.3 FDDI or ATM ?

This question is more and more frequently asked and we think we will be able to resolve the issue in a sequential manner.

In order to support users demands quickly, we will proceed as follows:

As a first step, connection from PCR to sites will be made by single-mode FDDI to cover the distance.

At each site a hub will allow us either to distribute FDDI or Ethernet for local installations.

Due to the small number of computers in the alcoves, an Ethernet connection using optical fiber will be installed via the central drain pipe.

The Asynchronous Transfer Mode (ATM) standards, TCP/IP on ATM and ATM using Single-mode, are not yet firmly established and many aspects remain obscure.

The choice of HUB will be made taking into consideration the future possibilities of ATM, and thus the investment could be partially recuperated.

5. CONCLUSIONS

The SPS and LEP communication networks are continuously evolving to satisfy the requirements of the LEP200 and the future LHC.

They must be adapted to the requirements of more users, engineers and physicists.

Starting with 300 hosts in 1990, we now have 1000 hosts distributed on several distant sites.

The bandwidth used has practically increased by a factor 10 over the last 3 years.

To maintain the quality of the communication service, it is urgent to consolidate our network by buying and investing in appropriate technologies.

It is only at that price that reliability and availability of the networks can be maintained.

Acknowledgement

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