UPGRADE OF THE SPRING-8 CONTROL NETWORK FOR INTEGRATION OF XFEL

T. Sugimoto, M. Ishii, T. Ohata, T. Sakamoto, and R. Tanaka,
Japan Synchrotron Radiation Research Institute (JASRI/SPring-8), Sayo, Hyogo, Japan

Abstract

Nowadays, TCP/IP and local area networks are used as control field buses in large-scale accelerators. At SPring-8, which is a large-scale accelerator facility, many network-connected devices are used to operate the accelerator complexes. In 2011, a RIKEN X-ray free electron laser (XFEL) facility will be established at SPring-8. This new facility will be able to operate independently; in addition, it will also be able to operate in combination with the present SPring-8 facility. However, since it is difficult to integrate the new control system with the existing control system of the XFEL facility, we upgraded the control network in SPring-8. In this paper, we report on the concept and considerations of the new control network.

INTRODUCTION

SPring-8 is the largest synchrotron radiation facility in the world. It consists of a linear accelerator, a booster synchrotron, main storage ring, and a NewSUBARU storage ring with which SPring-8 shares the linear accelerator. A prototype free-electron laser (FEL) facility is also located at SPring-8.

Recently, several new synchrotron radiation facilities have been constructed around the world. One of these facilities is the RIKEN XFEL project in Japan, which is located beside SPring-8. We propose to simultaneously use X-rays from both of these facilities in order to introduce new scientific applications such as pump-and-probe experiments. Further, we plan to use the linear accelerator of the XFEL facility as a low-emittance injector to the main storage ring of SPring-8.

A new control system for the XFEL will be activated in 2010 in order to perform early commissioning of the accelerator. While constructing the new XFEL control system, we must consider the existing control systems in relation to the new system. At the beginning of the commissioning, the new XFEL control system would have to be independent of the other accelerator control systems because considerable research and development will have been performed on the new control system. In contrast, it would be necessary to integrate the new and the existing control systems when the facility is operational, in order to take advantage of the combined applications of both facilities. All the above proposals would necessitate an upgrade of the entire control system.

As the control network of SPring-8 was a small-scale control network 10 years ago, it was originally designed as a single segment without any routers for high reliability. However, this resulted in the exhaustion of IP addresses. Since the control network was a 21-bit masked segment, only 2000 nodes could be connected. Presently, more than 1200 nodes are registered in a single segment, and approximately 50 nodes are registered every year. Hence, the 21-bit-masked single segment is not sufficient to expand the control system.

Furthermore, the increase in the number of network-connected devices in the original single-segment network had resulted in several problems such as packet flooding and hang up of devices. Thus, we decided to upgrade the control network from a single-segment layer 2 (L2) topology to a multi-segment layer 3 (L3) topology. For the upgrade, we considered several factors such as the physical network, logical network, IP address range assignment, routing, and naming convention.

In this paper, we report on the concept of a new control network topology and the upgrade status of SPring-8. The new topology is also aimed at providing measures against network vulnerability in embedded devices.[1]

ACCELERATORS

The operation modes of the accelerator at SPring-8 are closely related to the control network topology, because the SPring-8 and the XFEL facilities are initially used independently and are dependent on each other at later stages. Therefore, the network design should be considered. The relation among the various LANs such as the general purpose office LAN and the data acquisition LAN for beamline users should also be considered.

Existing Accelerators at SPring-8

Before we consider the network topology, we should analyze the operation mode of accelerators at SPring-8. The SPring-8 facility, in essence, is composed of three accelerator complexes of Linac, a synchrotron, and a main storage ring. The NewSUBARU is another storage ring that shares the Linac. In contrast, the SCSS test accelerator is an independent linear accelerator and has no connection with SPring-8 or the NewSUBARU storage ring. Thus, SPring-8 and the NewSUBARU storage ring are dependent on each other, but the test accelerator is independent of other accelerators.

XFEL Project

In 2011, the XFEL will be connected to the accelerator complex in SPring-8; this will result in a very complicated relation among the existing accelerators. In the first phase of the commissioning, the XFEL is an independent accelerator facility. After the first phase, the two accelerator complexes must be operated in sync for the pump-and-probe experiments. Furthermore, because of an extremely low emittance and bunch length of the order of subpicoseconds, we plan to use the XFEL Linac as an electron injector to the storage ring of SPring-8.

Independence of the test accelerators is important in the first phase of XFEL commissioning, whereas synchronization between the XFEL and SPring-8 control systems is important after the second phase. Moreover, one accelerator complex should be in operation, even if the other complex is suspended for maintenance of the control network or if it is experiencing other network troubles such as broadcast storms and irregular route distributions. These network troubles can be avoided by suitably designing the control network.

NEW NETWORK DESIGN

There are three network groups at SPring-8: the office automation LAN (OA-LAN), beamline user LAN (BL-USER-LAN), and accelerator control network (Control-LAN). These network groups have been assigned IPv4 Class-A, Class-C, and Class-B private addresses, respectively. When the routing with other network groups is considered, the Class-B private address is preferred for the new Control-LAN.

Presently, IEEE802.1Q Virtual LAN (VLAN) is one of the important technologies used for constructing networks. The network addresses in the new Control-LAN correspond to the VLAN IDs with a very simple relational expression. Details of the relation are described below.

Definition of the Local Area Network

Figure 1 shows the various network groups at SPring-8. The “local area network” is segregated in order to protect it from any network trouble that arises in another network. The OA-LAN, BL-USER-LAN, and Control-LAN are segregated using firewalls. The Control-LAN contains all the devices that are related to accelerator operations. Even if a router between the Control-LAN and another LAN is not functional, the accelerator controls are not affected. The Control-LAN consists of four sub-group LANs—SP8-LAN, XFEL-LAN, Safety-LAN, and DMZ-LAN—and these LANs are classified on the basis of their functions as given below:

- SP8-LAN: This is a control network for the basic SPring-8 components (three accelerator complexes of Linac, the synchrotron, and the main storage ring), the NewSUBARU storage ring, and the test accelerator. In the future, we also plan to separate the test accelerator as another sub-group LAN.
- XFEL-LAN: This is a new control network for the XFEL to be integrated to the Control-LAN.
- Safety-LAN: This is a data acquisition network for radiation monitors.
- DMZ-LAN: This is a demilitarized zone network between the OA-LAN and the Control-LAN. The programs are developed in this LAN. The DMZ-LAN is also used to provide operation information to the OA-LAN and the Internet.

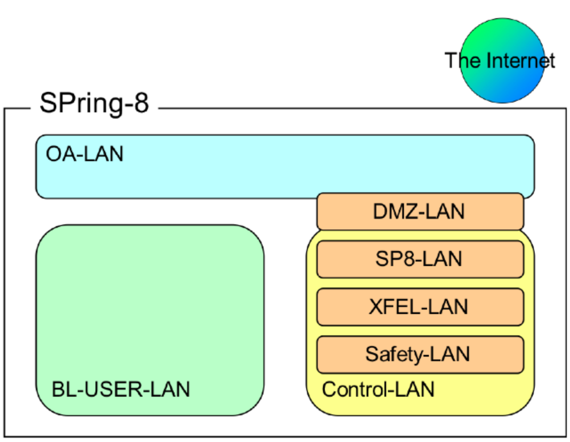

Figure 1: Network groups in SPring-8 site.

To segregate the four LANs, we assign independent logical and physical networks to these LANs.

Logical Network

Each LAN is assigned a Class-B private IP address with a /16 address range, as given below:

- SP8-LAN: 172.20.0.0/16, 172.24.0.0/16
- XFEL-LAN: 172.16.0.0/16
- Safety-LAN: 172.25.0.0/16
- DMZ-LAN: 172.26.0.0/16

It should be noted that the SP8-LAN has two /16 address ranges; this is because 172.24.0.0/16 is used in the obsolete (single-segment) control network and is kept for compatibility. Up to 65000 nodes can be connected to each logical network. This number is sufficiently large, in contrast to the obsolete network, in which up to 2000 nodes could be connected, and which would eventually lead to exhaustion of IP addresses. Since the second octet of IP addresses (16, 20, 24, 25, or 26) are assigned to the various network groups, the routing table is very simple. Furthermore, because of this simple routing table, a dynamic routing protocol is used instead of a static routing protocol; thus, the control network is free from the risks of irregular route distribution.

The /16 address range is too large for use as a single segment. If such a large range is applied as a single segment, vulnerable devices may be affected by broadcast storms, packet flooding, or heavy traffic load.[1] To avoid such problems, the LANs are segmented into small logical networks. We also define a segmentation rule among LANs to reduce the management cost:

- Subnet mask: /23 (up to 500 nodes can be connected)
- Default gateway: adjacent address of broadcast address. (e.g. 172.20.9.254)
- Reserved range for maintenance: addresses of the fourth octet at and beyond 240. (e.g. 172.20.8.240-254, 172.20.9.240-253)

Each network segment corresponds to an important component of the facility; for example, 172.20.8.0/23 is assigned to the Linac, 172.20.16.0/23 is assigned to the synchrotron, and so on. The third octets are assigned at intervals of four or eight to reserve spaces for future expandability. We also use third octets of network addresses, 0, 2, and 252, for special purposes. The network with the third octet as 0 denotes the routing segment, 2 denotes the network service segments such as

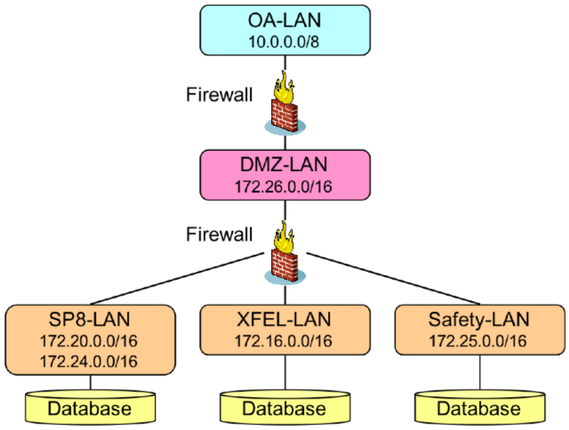

Figure 2: Physical topology of Control-LAN.

DNS, and 252 denotes the network equipment segment. If the LANs are operated using a set of common rules, the management cost can be reduced.

The second and third octets are used as VLAN IDs. The network addresses are related to the VLAN IDs as follows: VLAN ID = (2nd octet) × 100 + (3rd octet). For example, the VLAN ID of 172.20.8.0/23 segment is 2008.

Physical Network

The sub-group LANs (SP8-, XFEL-, Safety-, and DMZ-LAN) are physically segregated in order to protect them from any network trouble that arises at other LANs. All control systems are developed as closed physical networks in each LAN. However, the SP8-LAN and the XFEL-LAN will be connected to each other to perform combination operations. Thus, these LANs should be connected physically to other networks. For connecting the LANs, we use a multiport firewall as a network router. Figure 2 shows the physical topology of the Control-LAN. The network traffic between LANs is restricted by applying a security policy using the multi-port firewall.

The firewall also plays an important role in the combination operation of SPring-8 and the XFEL. In the first phase, the XFEL operates as a single closed accelerator. In the case of the combination operation, only the security policy of the firewall is to be changed in order to pass through the traffic between the two LANs; these two LANs can then be considered as one multi-segment network.

We should also consider the database system. For an independent operation of either the SPring-8 or the XFEL, each LAN uses a separate database system. When the combination operation is performed, their databases should be considered as one database. Using replication or other online synchronizing techniques, one virtual database can be shared. File servers are also shared between the two LANs.

Domain and Hostname

Domain and hostname are important factors in distinguishing network nodes. In the case of the SPring-8 Control-LAN, network information service (NIS) has been used for name resolution. NIS is a centralized maintenance method for user and name resolution. When only the control system of SPring-8 was used, the NIS concept was very suitable. However, since we plan to perform both segregated and combined accelerator operations, the centralized maintenance method is no longer suitable. Hence, we employ domain name service (DNS) for name resolution instead of NIS.

Domain names corresponding to the sub-group LANs are defined as follows:

- SP8-LAN: sp8.cntl.local.
- XFEL-LAN: xfel.cntl.local.
- Safety-LAN: safety.cntl.local.
- DMZ-LAN: dmz.cntl.local.

Each LAN has an independent zone content server; therefore, any misconfiguration of DNS will not affect the other LANs.

The device naming convention is also defined. In the past decade, naming convention had been delegated to personnel in charge of the devices. This led to a non-uniformity of names, which increased the management cost. Hereafter, newly registered devices in the Control-LAN are required to be named using one scheme:

full qualified domain name: (hostname).(domain name)

hostname: (A)-(B)-(C). The three components divided by two hyphens are

A: purpose of the device
B: object to be controlled or measured
C: serial number with two digits

With these considerations, upgrade of the Control-LAN was done.

UPGRADE OF THE CONTROL-LAN

In 2009, the Control-LAN was upgraded during the summer shutdown period in 50 man-days. The functional machine time for autumn started 1 month ago, and no network trouble has been reported thus far. The Control-LAN is now ready to integrate with the XFEL-LAN.

SUMMARY

We upgraded the SPring-8 control network to work in combination with the XFEL control system. For this upgrade, we considered the IP address range, logical and physical network, routing, and name resolution. The new control networks are segregated into sub-group LANs corresponding to accelerator complexes. Since the networks are segregated, any trouble in a certain LAN does not affect the other LANs. Using logically integrated networks, file servers, and a database, the SPring-8 and the XFEL can be operated in combination. Now the control network is ready to be integrated with the XFEL control system.

REFERENCES

[1] T. Sugimoto, M. Ishii, T. Masuda, T. Ohata, T. Sakamoto, and R. Tanaka, "TCP/IP Vulnerabilities of Embedded-system implementations", PCaPAC 2008, Ljubljana, Slovenia, October 2008, THX03.