UPGRADE OF SACLA DAQ SYSTEM ADAPTS TO MULTI-BEAMLINE OPERATION*

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Abstract

This paper presents details of a major overhaul of the DAQ (data acquisition) system for user experiments at SACLA (SPring-8 Angstrom Compact Free Electron Laser [1]). The DAQ system has been providing a common experimental framework to various SACLA users since March 2012.

In 2014, SACLA introduced a third beamline to increase the capacity of experiments that can be performed. With respect to the DAQ system, it is a challenge to operate multiple experiments simultaneously. To ensure that the increased capacity of experiments can be handled, the network architecture was redesigned so that controls and data streams are made independent. A new tag supply system, which guarantees reliable synchronization, was implemented. In addition, a 90 TFLOPS supercomputer was installed to meet the growing demand for offline analyzing power.

INTRODUCTION

At SACLA, the DAQ system is required to store shot-by-shot information synchronized with an X-FEL (X-ray Free Electron Laser) beam of 60 Hz at maximum repetition rate. The data throughput goes up to 6 Gbps with images (e.g., X-ray diffraction images) obtained from twelve sensors of an MPCCD (multiport charge-coupled device [2]). The data are stored in a hierarchical storage system capable of more than 7 PB at the last stage. The DAQ system incorporates prompt data processing performed by a 14 TFLOPS PC cluster.

For multi-beamline operation, the control and data streams are duplicated and separated for the beamlines, i.e., they are made independent. In addition, the architecture of the control line is reformed to reduce risk of mishandling. The new tag supply system implemented for synchronization has been operating stably. In the offline part, a 90 TFLOPS supercomputer was installed to boost data analysis capacity.

In the following section, first, we provide an overview of the system; then, we describe recent major upgrades. Further, we briefly discuss features to be implemented in the near future, and finally provide a summary.

DAQ OVERVIEW

The SACLA DAQ system has been described in detail elsewhere [3]. The DAQ system consists of online and offline parts, which have been described in the following sub-sections.

Online Part

Figure 1 shows a schematic view of the online part of the SACLA DAQ system. Image data are transferred over the 10-gigabit Ethernet to a cache storage system, which has multiple writing servers to handle the high throughput. In the data stream are the data-handling servers, which can analyze image data on time. One of important functions on the data handling server is sending live view images to user terminals for the monitoring purpose. Many other small-sized data such as photo diode amplitudes of beam monitors and pulse motors' position of various instruments are stored in the database. The database is also used to store experimental conditions. Because at SACLA, the X-FEL target specimen is likely destroyed by a single shot and certain experiments are sensitive to a slight variation of the beam characteristics, the DAQ should be able to recall and provide the information related to each shot. To this end, all components of the DAQ are synchronized with X-FEL beam shot and data are stored with a unified tag number assigned to each shot.

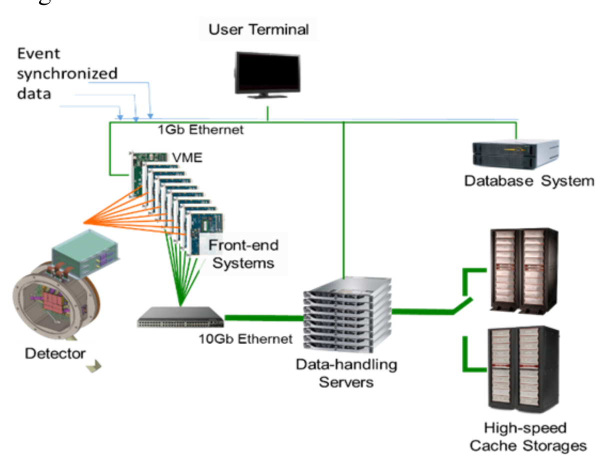

Figure 1: Online part of the SACLA DAQ.

From September 2013 to July 2014, 300 TB of image data were stored through the cache storage, and two cache storages were switched just once.

Offline Part

Figure 2 shows a schematic view of the offline part of the SACLA DAQ system. Through the offline part, SACLA provides a platform for analysis. Users can access the data stored in the cache or in the archive system along with various parameters stored in the

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database. The HDF5 format is selected as the common data format for users, and a translator that translates the experimental format into the HDF5 format is provided. A computing farm with many nodes is set up for data analyses. Users use a job scheduler to submit their tasks. A part of the system newly installed in 2014 is explained in the next section.

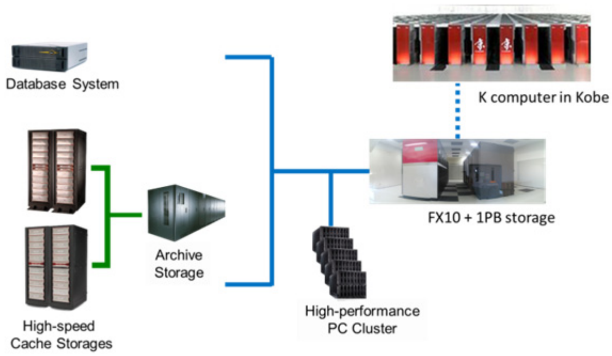

Figure 2: Offline part of the SACLA DAQ.

Monitoring

Online processes are monitored by a custom-made monitoring system. For example, in case the shot-tag counter on one subsystem malfunctions, it sets off an alarm.

UPGRADES

In this section, recent major upgrades made to the SACLA DAQ system are presented. The new tag supply system increases the reliability of event synchronization. The network architecture is redesigned to maintain the data throughput during multi-beamline operation and for the new centralized control system. A supercomputer system is installed to meet the increasing demand of offline analyzing power.

Tag Supply System

Each subsystem uses the common tag number associated with a single X-FEL shot. Before the introduction of the tag supply system, a local count system was used, which occasionally lost the correct count. The new system is based on a tree structure, and a tag-data-master delivers the tag number associated with an X-FEL shot to all subsystems. The tag supply system, which has been described in detail in [4], has been working stably since April.

Network Architecture

To handle multi-beamline experiments, the network segments were reformed. Figure 3 shows the new design of network segmentation. The large-volume (image) data streams to the cache storages are physically separated between beamlines to achieve the peak throughput independently. However, they are merged at the stage of archiving so that the offline analysis has one single gateway.

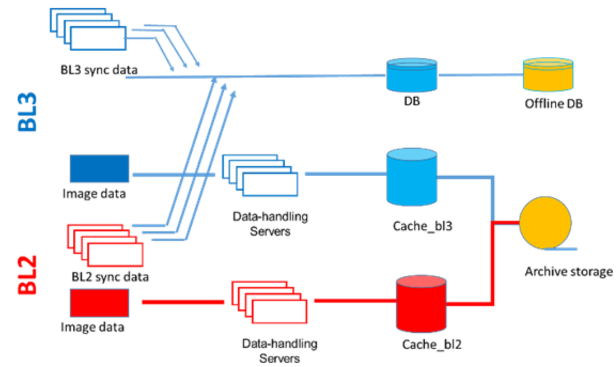

Figure 3: New network segmentation design based on the concept of a multi-beamline DAQ system. The large-volume (image) data stream is assigned a separate network segment for each beamline.

The other goal of this overhaul is related to the control line to build an architecture that prevents accidental modification of critical DAQ settings by end-users, such as timing offsets or interference with other beamline users. In the original system, accidental modification of critical DAQ settings was possible because anyone could freely access operator consoles in the DAQ segment. In the new architecture shown in

Figure 4, the control scheme is secured by the VLAN settings for beamlines and access groups. The BL-master server is the hub of all commands to each component, where the access control is applied in a centralized way. For example, it is possible to create a list of motor axes limited only for facility use. The messaging scheme is based on MADOCA II [5] [6] framework. To hop more than one message server, MADOCA II has implemented its extension.

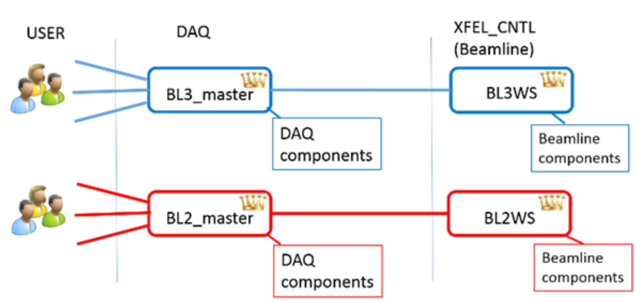

Figure 4: The separation of beamlines and access groups is secured by the VLAN settings. The access control is centralized at BL-masters and BLWSs.

FX10 System

As experimental technique get sophisticated and the user time is increased with the new beamline, more computing power is required for analysis. In March 2014, a 90 TFLOPS supercomputer was installed in the campus. The system consists of 384 computing nodes of the "FUJITSU PRIMEHPC FX10" system, and storage

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systems of 500 TB, 100 TB, and 1 PB for global, local, and external use, respectively. Its CPU architecture was chosen to match with the K computer [7], which is a 10 PFLOPS machine at RIKEN AICS, located 100 km away from the SACLA site. Therefore this system at the SACLA site can be used to develop analysis routines, before executing more computationally heavy analysis on the K computer.

In this regard, data transfer speed is a matter of concern. Using a simulated data set, we tested the speed of data transfer to RIKEN AICS. Figure 5 shows the results of our test. In addition, we emulated a whole analysis chain including a job submission to the K computer's batch system using 800 GB of simulated data. Though the performance of the whole chain depends on the number of available nodes and the type of analysis, a single model case [8] related to one experiment (say, with 20 TB of experimental data) can be analyzed in a reasonable time (a day or so).

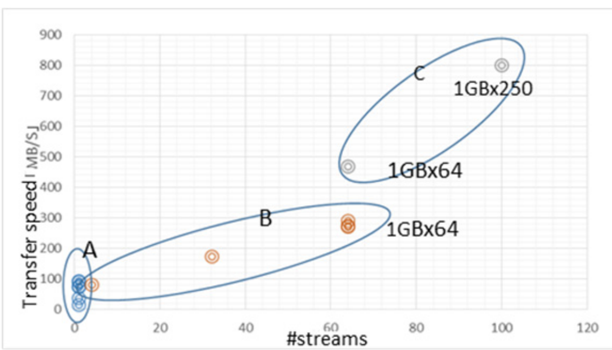

Figure 5: Speed of data transfer from SACLA to HPCI storage [8][9] at RIKEN AICS as a function of the number of parallel streams. A: gsiscp protocol (#stream= 1), several encryption types; B: gfpcopy protocol with default setting; C: gfpcopy protocol after TCP window size tuning. The highest performance was achieved when 250 1 GB-sized files were transferred using 100 parallel gftp streams.

FUTURE CHALLENGES

In this section, we briefly discuss topics to be considered for future operation.

Currently, the volume of the cache storage is sufficient to store data for a certain amount of time such that the data can be migrated to the archive system manually. However, we expect that the data accumulation rate will increase as experiments become more sophisticated. During the implementation of the next set of replacements, we are considering the introduction of a staging mechanism wherein the migration is built-in, such as a file system.

In 2015, SACLA plans to start a operation mode with rapid beamline switching in any intended pattern. In addition to the ability of multi-beamline operation discussed earlier, at least the path of the beam needs to be recorded shot by shot. A better option for the distribution may be in a manner similar to the tag number so that detectors can be prepared for every shot.

At the operation side, we expect to schedule more beam time to industrial users, where demands for proprietorship exist. We have started discussing plans to implement proprietorship without loss of convenience.

Finally, a next-generation image sensor is in the development stage [10]. It requires data transfer speeds to be increased by an order or more; thus, this will be the next major upgrade of the DAQ system.

SUMMARY

SACLA provides a common DAQ platform including online and offline parts. In 2014, several upgrades have been applied in order to make the DAQ system adapt to multi-beamline operation. The new tag system is implemented for reliable synchronization. The network architecture is redesigned—the data stream is duplicated and provisions are made to allow the addition of another stream in the future. The control flow became more secure. The offline analysis part is improved by the addition of a new 90 TFLOPS supercomputer.

REFERENCES

[1] T. Ishikawa et al., "A compact X-ray free-electron laser emitting in the sub angstrom region", Nature Photonics, vol. 6, pp. 540-544 (2012).
[2] T. Kameshima et al., "Development of an X-ray pixel detector with multiport charge-coupled device for X-ray free-electron laser experiments", Review of Scientific Instruments, vol. 85, (2014) Art. Num. 033110.
[3] M. Yamaga et al., "Control and Data Acquisition System for X-Ray Free-Electron Laser Experiments at SACLA", IEEE Nuclear Science Symposium and Medical Imaging Conference 2012 Record (NSS/MIC), Anaheim, USA. (2012).
[4] T. Abe et al., "Development of New Tag Supply System for DAQ for SACLA", 5th International Particle Accelerator Conference IPAC'14, Dresden, Germany (2014).
[5] R. Tanaka et al., "The First Operation of Control System at SPring-8 Storage Ring", Proceedings of ICALEPCS 97, Beijing, China, 1(1997).
[6] T. Matsumoto et al., "Next-Generation MADOCA for The SPring-8 Control Framework", Proceedings of ICALEPCS2013, p. 944, San Francisco, CA, USA
[7] K-computer website: http://www.aics.riken.jp/en/
[8] A. Tokuhisa et al., "High-speed classification of coherent X-ray diffraction patterns on the K computer for high-resolution single biomolecule imaging", Journal of Synchrotron Radiation, vol. 20, pp. 899-904 (2013).
[9] HPCI website: https://www.hpci-office.jp
[10] SOIPIX collaboration, Developments of SOI monolithic pixel detectors, Nuclear Instruments and Methods in Physics Research Section A, vol. 623(1) pp. 186 (2010)

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