

A Generic Streaming Data Acquisition System for High-energy Physics Experiments

Tuesday, September 21, 2021 5:52 PM (2 minutes)

The data acquisition system is a vital component in the high-energy physics experiment. To reduce duplication of work during development, D-Matrix, a generic platform, has been developed as a unified software/hardware streaming DAQ system and will be used in CSR External-target Experiments in HIRFL-CSR. Its philosophy is to abstract different tasks in the stream processing and encapsulate them as reusable modules with standard inter-module connectors. Furthermore, D-Matrix builds a unified model to integrate software and hardware design so that the system can be built from a global view. This paper presents the architecture of the D-Matrix DAQ.

Summary (500 words)

The architecture of D-Matrix is based on stream processing. It decouples and abstracts the basic processing tasks in the stream processing and presents them as independent modules in both software and hardware form so that users could switch processing platforms anywhere. Furthermore, standard inter-module interfaces and inter-platform plug-in transceivers make it possible to connect modules and platforms arbitrarily so that a customizable processing structure can easily be built. At the same time, D-Matrix describes the spatio-temporal characteristics and superior-subordinate relationship of streams in different processing stages to ease data processing and reconstruction inside modules. The underlying design of D-Matrix is split into three layers as shown in Fig. 1:

1. Source Layer

In the source layer, the majority of data are born as continuous streams and vary in the topic (Stream ID). Each stream will be loaded into a unified data container (see Fig.2 and Fig.3) which is the basis of a unified transmission and processing model. Furthermore, the concept of "Data Domain" is introduced to describe the spatio-temporal characteristics and superior-subordinate relationship in different processing stages of the stream. Developers register all streams before the system runs and provide their "Data Domain Table" which contains the attributes of streams in different domains. These "Data Domain Tables" are applied to the modules in the corresponding "Data Domain" so that the modules can correctly deal with diverse streams in different processing stages.

2. Transport Layer

The transport layer is responsible for the stream transfer between modules and platforms. It is committed to provide a point-to-point transparent channel and reduce coupling between modules. The implementation of the transport layer consists of two parts.

(1) Transfer between platforms: This is conducted by transmitter and receiver (T&R), a unidirectional plug-in module (see Fig.4). By simply replacing the plugs, T&R can send and receive data from the different underlying hardware.

(2) Transfer between modules: "Dual shared memory space" and message queues are used for data transmission between modules in a software platform (see Fig.5). As for the firmware, a customized interface based on AXI4-Stream is developed.

3. Processing Layer

Data processing in physics experiments can be divided into more specific tasks such as stream distribution and aggression (see Fig.6), event building, slow control system (see Fig.7), and data storage which could be implemented as modules to facilitate development.

In particular, the event builder is developed as a generic module which can be configured in multiple dimensions such as the event scope (see Fig.8), the combination granularity (see Fig.9), the cluster size (see Fig.10), and the trigger mode.

In conclusion, D-Matrix has been designed to provide a flexible, scalable, and efficient architecture. More general-purpose modules are in progress. Besides CEE mentioned above, D-Matrix is also used in a deep-sea geological exploration experiment and planned to be used in a neutrino-less double beta decay experiment.

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Session Classification: Posters Systems, Planning, Installation, Commissioning and Running Experience

Track Classification: Systems, Planning, Installation, Commissioning and Running Experience