

Common Readout Unit (CRU) - A New Readout Architecture for the ALICE experiment at the CERN-LHC

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Introduction

To cope up with the increasing luminosity of the CERN Large Hadron Collider (LHC), the ALICE experiment is planning a major upgrade of the detectors during the Long Shutdown-2 (LS2) period, which is at present foreseen to start in mid 2018 [1]. The increased luminosity will significantly enhance the physics reach of the experiment. The luminosities for Pb-Pb collisions will increase from $1 \times 10^{27} \text{ cm}^{-2} \text{ s}^{-1}$ to $6 \times 10^{27} \text{ cm}^{-2} \text{ s}^{-1}$ corresponding to collision rates of 50 kHz. The upgrade strategy is based on collecting greater than 10 nb^{-1} of Pb-Pb ion collisions. ALICE will also collect 6 pb^{-1} of p-p collisions and 50 nb^{-1} of p-Pb collisions, both at a levelled collision rate of 200 KHz. Due to this increased interaction rate there is a need for increased readout rate. The maximum readout rate of the present ALICE detector is 500 Hz of Pb-Pb events but the overall goal is to readout 50 kHz Pb-Pb collisions and 200 kHz p-p and p-Pb collisions. Hence the detectors and electronics of need to be upgraded to handle the higher high rates. To tackle this requirement, a new approach based on Common Readout Unit (CRU) is being developed for data concentration. In this work, we discuss the features, implementation and planning of the CRU.

Features of Common Readout Unit

In the present system implementation in ALICE, detector data link (DDL) [2] provides a standard on detector source interface unit (SIU) that connects the detector read-out electronics optically to the Read-out Receiver Cards (RORC) located in the Data Acquisition (DAQ) systems. For the upgrade ALICE will use the standard system interfaces. The DDL will be

upgraded to a higher bandwidth link and multiplexed through CRU. The Common Readout Unit integrates three different interfaces. It will provide an interface between the on-detector electronics/front-end links and the DDL connecting to the online computing system as shown in figure 1.

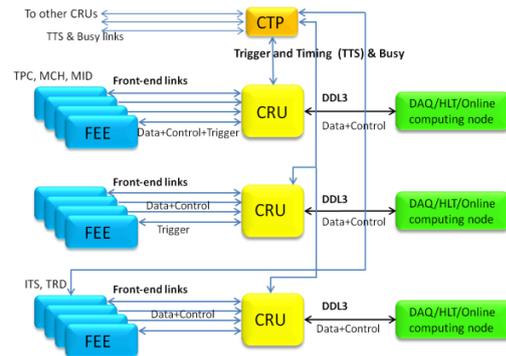


Fig. 1 ALICE Data Acquisition scheme using Common Read-out Unit

The CRU interfaces the trigger and timing distribution network. The on-detector interface is based on the radiation hard Gigabit Transceiver (GBT) links [3] as shown in the figure 1. Detector data with control signals and trigger signals could be transferred on the same link to minimize the number of physical links present or on separate front-end links. Investigations are going on.

Trigger and timing information and busy information (specifies the individual detector busy time during data taking) are distributed via CRU, but for the operation of the detectors which are critical to the latency of trigger, the trigger and timing information are transferred

directly from Central Trigger Processing unit (CTP) to the detector via separate physical links. In case the trigger rate exceeds the detector read-out capabilities the read-out systems indicate this situation by affirming a busy signal. CTP will handle one busy signal per detector. The busy signal is transmitted to the CTP system which stops the transmission of the corresponding detector until the problem is rectified. This design will not stop the entire ALICE DAQ in case there is a problem in one detector. For the detectors not upgrading their interfaces, backwards compatibility to Run 1 and Run 2 system will be provided.

Depending on sub-detector specifications, detector data sent to the CRU are multiplexed, processed and formatted. The number of different link technologies presently used for the data read-out, detector control, trigger and clock distribution, etc. will be reduced. It will aggregate the digital data from very high number of sources to high bandwidth optical data links, to increase the throughput and also to optimize the system level cost and preserve smart features of the present DAQ system during the consecutive upgrades.

Implementation Planning

The application specific functionalities like protocol conversions of the different link types, multiplexing, embedding control and trigger information, etc., require CRU to be implemented as electronics boards with custom designed, programmable functionality based on up-to-date Field Programmable Gate Array (FPGA) technology [4].

Hardware integrity of CRU as FPGA boards has been checked with two basic alternatives, depending on the physical location of the CRUs. These are the “CRU placed in the Cavern”, close to the detectors and in close proximity to radiation zone or the “CRU in the Counting Room” far from the radiation zone and will receive data from the detectors via optical fibers as shown in figure 2. In the counting room, electronics is not subject to radiation, thus state-of-the art high performance FPGAs can be employed, also no radiation tests campaign is needed. So second option of CRU in the counting room is chosen.

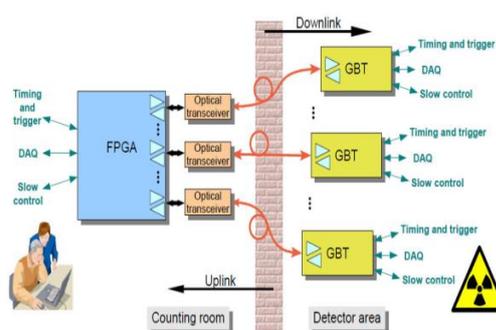


Fig. 2 CRU implementation planning using Gigabit transceiver links

In the chosen scenario, the number of GBT links required is higher as compared to CRU in cavern, this increases the cost. But in the absence of proper radiation tolerant hardware for the CRU in cavern and extra installation cost of the infrastructure in the cavern, CRU counting room option will be preferable. As a baseline location of CRU would be in the ground level counting room, thus it will be accessible during operation. Also there will be no additional electronics, cabling, cooling needed to be installed and maintained on the detector. The GBT link based CRU located in the counting room presents a more robust system with higher processing power, flexible towards future requirements and lower impact on the cavern infrastructure. Therefore, ALICE chose the CRU in counting room as the preferred solution. CRU in the cavern is considered as an alternative solution.

Different constituent modules of CRU and their design possibilities have to be evaluated. Further design exploration for the first prototype is underway.

References

- [1] Technical Design Report for Upgrade of the ALICE Read-out & Trigger. CERN-LHCC-2013-019 / LHCC-TDR-015, 12 MAY 2014.
- [2] Report on the ALICE Detector Data Link: method used, protocol and design status. ALICE collaboration.
- [3] Implementing the GBT data transmission protocol in FPGAs. S. Baron, J.P. Cachemiche, F. Marin, P. Moreira, C. Soos
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