Implementation of the DAQ software in the ALTI Module of the ATLAS TileCal

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Abstract. The Tile Calorimeter (TileCal) is the central hadronic calorimeter ($|\eta| < 1.7$) of the ATLAS experiment, made out of iron plates and plastic scintillators. The TileCal is divided into three barrels along the beam axis, each of which is azimuthally segmented into 64 wedge-shaped modules, staggered in the $\phi$ direction. TileCal online software is a set of Trigger and Data Acquisition (TDAQ) software, and its main purpose is to readout, transport and store physics data originating from collisions at the Large Hadron Collider (LHC). The ATLAS Local Trigger Interface (ALTI) module is a new electronic board, designed for the ATLAS experiment at CERN, a part of the Timing, Trigger and Control (TTC) system. It is a 6U VME module which integrates the functionalities of four legacy modules, currently used in the experiment: Local Trigger Processor, Local Trigger Processor interface, TTC VME bus interface and the TTC emitter. ALTI module will provide the interface between the Level-1 Central Trigger Processor and the TTC optical broadcasting network to the Front-End (FE) electronics of each of the ATLAS sub-detectors. There is a need to develop and integrate the ALTI software in the Tile online software. Performance tests and maintenance of the ALTI module software will be carried out during the Long Shutdown 2 period (LS2), in preparation for Run 3 data-taking period.

1. Introduction

The LHC ATLAS experiment shown in figure 1, is one of the two general-purpose detectors and it investigates an extensive range of physics, from the search of the Higgs boson to physics beyond the Standard Model. The TileCal is a central hadronic calorimeter of the ATLAS detector that provides energy and position of hadrons [1]. The TileCal utilises the Trigger and Data Acquisition (TDAQ) system of the ATLAS detector for data collection. The trigger system selects events with distinguishing characteristics that might be interesting for physics analyses. It is structured in a 2-level architecture, Level-1 (L1) and High Level trigger (HLT) system. The L1 trigger reduces the rate of accepted events from an input rate of 40 MHz (25 ns) to 100 kHz [2, 3]. It is further processed in the HLT, to reduce the rate of recorded events from 100 kHz to 1 kHz [2]. ATLAS is upgrading the TTC hardware with new electronics. The ALTI module is being integrated into the TileCal TTC system, in preparation for Run 3 data-taking period. In order to operate the ALTI module in the TileCal, there is a need to develop and integrate the ALTI software in the Tile online software. The TileCal online software is a set of TDAQ software, used for the operation of the Tile Calorimeter. Its main purpose is to readout, transport and store physics data originating from collisions at the LHC.
2. Motivation for the ALTI project
The ALTI is a new module designed for the ATLAS experiment at CERN, a part of the TTC system [5]. It integrates the functionalities of the four existing modules shown in figure 5, which are currently used in the experiment: Local Trigger Processor (LTP), Local Trigger Processor interface (LTPi), TTC VME bus interface (TTCvi) and the TTC emitter (TTCex). The LTP receives timing and trigger signals from the CTP through the Link-in cable and distributes them into the TTC system of the sub-detector through NIM outputs. The LTPi provides an interface between the CTP and LTP to allow combined parallel running between various sub-detectors as opposed to the ATLAS global run. The TTCvi module serves the purpose of configuring the FE electronics and interface the local and the global TTC system. The TTCex is a laser-based module which converts TTCvi commands into optical signals that arrive to the FE and BE electronics. During LS2 upgrades (2019-2021), new sub-detectors will require TTC modules. It has become increasingly difficult to produce spares for these four modules, and the current spare modules have obsolete and ageing components. ALTI module will provide the interface between the L1 Central Trigger Processor and the TTC optical broadcasting network to the FE electronics of each of the ATLAS sub-detectors. The ALTI module will combine and upgrade the functionalities of the 4 modules while preserving backward compatibility.

3. Architecture and functionality of the ALTI module
The ALTI module is a 6U VME module that occupies two slots in a TTC VME crate. It is made up of two Printed Circuit Boards (PCB): a motherboard and a mezzanine board. Detailed documentation for the PCBs, schematics and mechanical descriptions, are available on the CERN Engineering and Equipment Data Management System [6]. The logic is implemented in the motherboard and it includes the Xilinx Artix-7 XCA200T FPGA [7], the Inter-Integrated Circuit (I2C) network, the power supply network, Random Access Memory and other discrete logic and integrated circuits. The motherboard is composed of VME bus connectors, two LVDS-LINK input connectors, six small form-factor pluggable modules and the calibration request RJ45 connector. The mezzanine is connected to the motherboard via a Samtec high-speed ground plane socket, which carries 180 signals, three power supplies and a ground. It accommodates all of the coaxial input, output connectors and the two LVDS-LINK output connectors. A functioning prototype of the ALTI module is shown in figure 3. A more detailed description of all the functionalities can be found in the ALTI specification document [8].
Figure 2. The four legacy TTC modules will be replaced by the ALTI module.

Figure 3. The ALTI module inserted in the TTC crate of a test-bench at CERN.

4. ALTI software
The TDAQ system provides the software infrastructure for L1 trigger, DAQ and HLT systems. Software packages for L1 trigger and TTC modules are part of ATLAS TDAQ. These packages include the low-level software for control, configuration and monitoring of the modules. High-level run control application software, built on top of the low-level APIs is also included in the ATLAS TDAQ. VME-addressable TTC legacy modules (LTPI, LTP and TTCvi) and the other modules, have a similar low-level software organization. The ALTI module has its low-level software organized in a similar way. The ALTI package depends on several software packages specific to the TDAQ Read-Out Driver Crate DAQ and the Level-1 Central Trigger. The TileCal ALTI low-level software has been developed in order to provide access to the ALTI functionalities. Several TileCal software packages have been modified and the TileTTC class has been developed, to provide access to the TTCvi and the ALTI low-level software as seen in figure 4. The Object Kernel Support database, an object-oriented database with storage based on XML, has been modified to include new variables for the TileTTC class. C++ is the main programming language and GitLab is used as the source code repository.

Figure 4. TileTTC class provides an interface between the TTCvi and the ALTI class.
5. ALTI Software Validation Testing
Software validation testing is underway. On running the test bench partition shown in figure 5, the HLT rate is 9 Hz, similar to the HLT rate set for the four legacy TTC modules setup. A TileCal specific pattern generator implemented for the ALTI module, generates test trigger signals every 3564 Bunch Crossings (BC) as expected. During the calibration runs, the DVS tests for pedestals are successful as seen in figure 6, where all channels have noise levels lower than the threshold values. However DVS tests for Charge Injection Scan failed, with data being discarded during the calibration runs. This indicates the possibility of the the trigger word to have been incorrectly programmed. It causes the Read-Out Driver to fail to retrieve the LIID and BCID, and hence fail to correlate the BCID with the data from the FE electronics. Investigations are underway and more tests are to be conducted, in order to validate the software.

6. Summary
During LS2, TileCal is undergoing maintenance and upgrades in preparation for Run 3 (2022-2024) data-taking period. As part of the ATLAS Phase-1 upgrade, TileCal is replacing the legacy TTC system with the new ALTI TTC system. The ALTI module integrates the functionalities of four legacy TTC modules: LTP, LTPi, TTCvi and the TTCex. The ALTI module has shown an improvement in its monitoring capabilities and the pattern generation functionality presents a more efficient memory management system. The TileCal ALTI online software has been developed and rigorous tests are currently being conducted with the ALTI system, to ensure high performance and efficiency during the Run 3 data-taking period.

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