TRIGGER MONITORING IN ATLAS

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The Trigger and Data Acquisition system for the ATLAS experiment has to reduce the 40 MHz of LHC bunch crossing rate (1 GHz of interaction rate at $\mathcal{L} = 10^{34}\mathrm{cm}^2 s^{-1}$) to $\sim$ 200 Hz of recording rate. This is achieved through a complex distributed system realized by an hardware implemented Level-1 system, followed by a farm of PCs for the High Level Trigger selection, which is performed in two steps: Level-2 and Event Filter.

Monitoring the trigger behavior and its performances through all the trigger level is of fundamental importance to assess the quality of the data taken, to give fast feedback for the trigger configuration, to monitor the stability of the HLT farm components.

In this paper the online monitoring tools of the ATLAS trigger system will be presented starting with the most basic ones that monitor the technical functionalities of the system as for example the trigger rates. More sophisticated tools to assess the data quality of the selected physics objects are shown too. First experience has been be collected during the cosmics data taking period in 2009.

Keywords: Trigger; Data Acquisition

1. Introduction

The ATLAS[1] experiment is a multipurpose experiment at LHC investigating the fundamental nature of matter and the basic interactions that rule our universe. The ATLAS detector will analyze *proton-proton* collisions up to $\sqrt{s} = 14\,\mathrm{TeV}$ produced by LHC. A highly selective trigger and data ac-

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quisition system is required to reduce the LHC interaction rate of 1 GHz[a] to the manageable recording rate of $\sim$ 200 Hz.

To achieve these challenging requirements a large system for trigger and Data Acquisition (TDAQ) has been designed and deployed in the past years. The TDAQ system is monitored both in its software and hardware components and on the physics quality of the data collected.

In this article, after a short introduction of the ATLAS trigger system, the various ingredients of the Online Monitoring Framework of the TDAQ system are described.

2. The ATLAS Trigger and Data Acquisition System

The ATLAS trigger system[2] is composed of a hardware implemented Level-1 (L1) system, followed by a farm of PCs for the High Level Trigger (HLT) selection, which is performed in two steps: Level-2 (L2) and Event Filter (EF). The HLT farm is currently composed of $\sim$ 1000 nodes, a third of its expected final size.

Using muon and calorimeter coarse data, the L1 trigger reduces the input rate down to 75 kHz (upgradable to 100kHz) within 2.5 μs of latency. The L1 is also responsible to identify the correct LHC bunch crossing and the geometrical Region of Interest (RoI) pointing to data that will further be analyzed at full granularity by the L2 system. Only data within the RoI will be considered at the next level reducing the transfered rate by $\sim$ 98% of the full event size. After the acceptance from L2 with a rate of 1 kHz, the event is build by the Event Builder (EB) and sent to the the EF. At this level, the full event is reconstructed with *quasi* offline algorithms, detector calibrations and geometry. The output bandwidth is $\sim$ 300 MB/s, with an event size of 1.5 MB this results in a recoding rate of s $\sim$ 200 Hz.

The online selection is performed composing a *chain* of different trigger algorithms at different trigger levels.

For practical reasons, trigger chains selecting the same physics object (*e.g.* muon, electron, jet,...) are regrouped in the so called *Trigger Signatures.*

3. The TDAQ Online Monitoring Framework

The ATLAS TDAQ Online Monitoring Framework is realized based on different software tools. These applications are independent and partially

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[a] At the luminosity of $\mathcal{L} = 10^{34}\text{cm}^2\text{s}^{-1}$ with 25 ns interval bunch crossing 23 additional pile-up events are expected.

redundant allowing a stable supervision of the system on one hand and a fast and reliable recognition of possible problems on the other. They do basic information sharing among the various applications as well as high level application as complex graphical user interfaces (GUI). The focus has been given to performance and scalability of the monitoring infrastructure.

3.1. *Basic Services*

The *Information Service* (IS) application allows the sharing of information among the various monitoring applications. It is the backbone of the Online Monitoring Framework. Data shared can be simple variables and more complex classes. In particular, the *Online Histogramming Service* (OHS) based on IS, permits the sharing of histograms data type. *Information Providers* insert or update information while *Information Readers* read specific values. Monitoring applications can also subscribe to the repository being alerted if changes or modification in the data occur. Both IS and OHS are built on top of a common Inter Process Communication service implemented in CORBA.[3]

3.2. *Monitoring Applications*

The monitored quantities from the L2 and EF processing tasks distributed among the $\sim$ 1000 CPU of the HLT farm are stored on histograms that need to be summed up into a single histogram. This task is performed by the *gatherer*[4] that has to sum 600.000 histograms *per* HLT rack considering that each application creates 2.500 histograms and 250 applications run *per* each HLT rack.

The monitoring information produced for each run has to be archived for further cross check with offline analysis. This is performed by the Monitoring Data Archiving.[5] Histograms produced online are stored in ROOT files on a local data cache. The local data cache is later transfered to permanent data storage. This is done asynchronously with respect of the end of a run to minimize the time needed to terminate a data taking run.

ATLAS is a worldwide collaboration and it is vital to access the trigger monitoring information outside the ATLAS Control Rooms. One possibility is to produce web pages using a Web Monitoring Interface (WMI) containing monitoring information. Currently three plugins exist showing run status, data quality and trigger rates information. Another possibility is to mirror in real time a partition with IS servers containing the available information. All the online monitoring tools using that information can thus be run outside the ATLAS Control Rooms.

To efficiently display and manipulate the large number of histograms produced, the Online Histogram Presenter (OHP) application has been implemented using QT and ROOT.[6] Histograms are presented in a tree structure or in configurable predefined windows that are automatically updated when the histograms change in OH. Also reference histograms can be displayed superimposed to the produced histograms. OHP works with a mixed pull/push mode in the interaction with the OHS server(s). Notifications are pushed from the OHS server to OHP every time a histogram is updated and only when the histogram is actually displayed, the histogram object is retrieved from the OHS server. A sophisticated cache mechanism minimizes the required network bandwidth.

The Operational Monitoring Display (OMD) is a powerful application that is able to read informations stored in IS. It performs operations (like summing, averaging *etc.*) and displays the quantities elaborated in time-trends, bar charts, table *etc.* It is highly user friendly configurable with a *Drag'n Drop* approach.

Monitoring the trigger rates is of fundamental importance during the commissioning and data taking. In fact variation of trigger rates is a fast indication of changes or problems in individual ATLAS subdetectors, the TDAQ system or the beam conditions; thus a powerful and reliable rate measurement is required.

The Trigger Rate Presenter (TRP) is a package that calculates, displays, monitors and archives the trigger rates and informations relative to the HLT farms. The TRP package is based on a Client-Server architecture and is composed by many applications. The key ideas in the design of the package have been the modularity of the various applications and the scalability. The *adapters* read the IS informations and calculate the rates for all the trigger levels. The trigger rates are calculated for all the trigger chains. The HLT rates are calculated for 10s interval for each L2 and EF application and than gathered together. The *adapters* perform therefore all CPU intensive applications. The calculated rates are stored in a specific IS server that keeps in memory for a couple of hours the measured trigger rates. The Graphical User Interface written in Qt displays the rates in time trends and tables. The user can select any box to graphically display the timetrends. A plugin exports the trigger rates to web pages that show the rates in real time the rates for the last 24 hours. Using the MDA mechanism, an application archives permanently the trigger rates in ROOT TTrees then stored for offline analysis. Monitoring the trigger rates with TRP is essential to adjust the trigger prescale factors to optimize the available bandwidth and eventually react to changes in the LHC beam conditions or some ATLAS subdetector.

The data quality monitoring of the selected data based on the physics objects is performed with automatic checks by the Data Quality Monitoring Framework (DQMF). It is composed by a core package that checks the produced histograms (width and mean of the distributions, Kolmogorov-Smirnov difference with respect to some reference histograms,...). A quality flag for each trigger signature is calculated and stored in the Condition DB to be further used to assess the quality of data for physics analysis. A highly configurable Data Quality Display shows the DQ results obtained with the DQMF and focus the attention of the shifter on the histograms failing the automatic checks. The information is organized hierarchically going from the top level, that shows the various ATLAS subsystem status, to the Trigger Signature status, down to the lowest level the checks performed on the single histograms. Within the standard reconstruction, a dedicated trigger monitoring is implemented, producing histograms according to the online ones. They are also evaluated automatically using an offline DQMF system delivering the same DQ flags for the trigger as the online DQMF.

4. Conclusion

The monitoring framework for the ATLAS trigger is in place and works reliably. It has been used extensively during the combined cosmics data taking of 2008 and 2009 and will be of fundamental importance for a successful commissioning of the TDAQ system.

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