Trigger Menu-aware Monitoring for the ATLAS experiment

Xanthe Hoad on behalf of the ATLAS Collaboration
University of Edinburgh, Edinburgh EH9 3FD, Scotland
E-mail: xanthe.hoad@cern.ch

Abstract. We present a "trigger menu-aware" monitoring system designed for the Run-2 data-taking of the ATLAS experiment at the LHC. Unlike Run-1, where a change in the trigger menu had to be matched by the installation of a new software release at Tier-0, the new monitoring system aims to simplify the ATLAS operational workflows. This is achieved by integrating monitoring updates in a quick and flexible manner via an Oracle DB interface. We present the design and the implementation of the menu-aware monitoring, along with lessons from the operational experience of the new system with the 2016 collision data.

1. Introduction
At the ATLAS experiment [1], one of the four main experiments at the LHC, there is a need to reduce the data readout rate for two reasons. Firstly, the maximum data readout rate (1 kHz) is lower than the event rate (40 MHz) [2]. Secondly, physics processes of interest tend to be rare, so it is preferable to reduce the amount of data stored in such a way as to enhance the proportion of interesting events. The ATLAS trigger system performs this task by making fast decisions on whether to store events during data taking. The set of triggers that are available for use during a data-taking run are defined in a 'trigger menu' [2]. After data has been collected online, it is reconstructed offline into physics objects for further analysis [3]. This reconstruction occurs offline at Tier-0, the first level of the ATLAS computing grid. Trigger monitoring is performed both online [4] and offline [5], during reconstruction, in order to check the consistency of trigger information, check data quality, and to spot any issues in the ATLAS detector early. The online and offline monitoring systems, though they have similar goals, have different approaches, as they have access to different resources and types of event information. The offline monitoring system (contained in the ATLAS offline software release) takes as input information from particular triggers, and outputs histograms. As they have different functions and uses, different software releases are used offline and online. However, the use of different software releases can create issues for the offline monitoring system. Issues can arise when the online trigger menu changes, causing updates to the offline monitoring to be necessary, if the updates do not fit into the offline software release cycle. In this paper a new tool, 'Menu-aware Monitoring' (MaM), is described. MaM is designed to allow updates to be made to the ATLAS offline monitoring system, in a dynamic and software release independent way. Quick updates to the offline monitoring system are particularly needed during intensity ramp-up phases, when the luminosity received by ATLAS increases rapidly.
2. The ATLAS Trigger System
The ATLAS trigger system is divided into two parts, the hardware-based Level 1 (L1) [6] and the software-based High Level Trigger (HLT) [7, 8, 9]. At L1, fast decisions are made on whether to pass an event to the HLT for further processing, resulting in a L1 output rate of 100 kHz. At HLT level, either a ‘Region of Interest’ within the detector, identified at L1, or the full event is then reconstructed, in a similar way to how it would be offline. Algorithms are then applied, resulting in a final data readout rate of 1 kHz. A ‘trigger chain’ is a series of HLT algorithms based on a L1 seed which run in sequence. An event must pass at least one full trigger chain selection in order to be stored for analysis. Sets of related trigger chains which concern specific physics objects are devised and managed by ATLAS signature groups (so named because the physics objects leave similar ‘signatures’ in the detector). A typical trigger menu contains several hundreds of trigger chains to meet a large variety of physics goals for the ATLAS experiment, and also defines other parameters. An entire unique online trigger configuration (including the trigger menu and ATLAS online HLT software setup) is identified by a ‘Super Master Key’ (SMK). The online trigger configuration sets are stored in an Oracle SQL database that stores trigger-related information, the ‘trigger database’. Each data-taking run has an associated SMK. The trigger menu and the online software are not updated every run, so one SMK is usually used for a number of runs.

3. ATLAS Offline Trigger Monitoring
ATLAS offline trigger monitoring is designed to check the characteristics of the recorded events after they have been reconstructed offline. This is important for checking data quality, driving the development of new triggers, and evaluating new trigger software. The trigger group is organised into signature groups, dedicated to a particular set of physics objects. Each signature group maintains their own offline monitoring tools. While the tools differ between the various groups, they have a common aspect, which is that they are configured via Python configuration files. These include a list of trigger chains to monitor, as well as other parameters that can be configured depending on the trigger signature. The output of the offline monitoring system is histograms of signature specific quantities and distributions.

Changes to the offline monitoring configurations are necessary if changes to the chains used for monitoring are made. For example, there could be a trigger chain ‘A’ in the trigger menu, and an offline trigger monitoring package could be configured to produce a plot of a quantity relating to this trigger. If trigger chain ‘A’ is then removed from the menu, the plots will then be empty, motivating an update to the monitoring configurations. It is important that updates to offline monitoring are made promptly so that the monitoring output can be as useful as possible.

During intensity ramp-ups, or some special runs, the trigger menu changes more frequently than new offline software releases are released. This mean the ATLAS offline software release cycle may not be in sync with updates to the trigger menu. This can result in delays in updating offline trigger monitoring configurations, as any updates must go into a new offline software release, which must be compiled and distributed. The use of Python configuration files means that it would, in principle, be possible to make changes to the configurations without having to recompile the offline software release. However, distributing new Python configuration files throughout Tier-0 would incur a similar delay to distributing a new software release, even though it would not require recompilation of the software release. What is needed, then, is a tool that can be used to update the configurations, when needed, in a way that is independent from the software release cycles and does not require distribution throughout the software grid.

4. The ‘Menu-aware Monitoring’ tool
‘Menu-aware Monitoring’, or MaM, is a tool devised to allow offline monitoring configurations to be changed outside of the offline software release cycle. The aim of MaM is to overcome the
possible time delay between a signature group deciding that they want to update their offline monitoring configuration and the updated configuration being in place during reconstruction, caused by the different ATLAS software release cycles. MaM achieves this by providing the functionality to ‘patch’ the offline monitoring configurations with snippets of Python, corresponding to the configuration changes desired. Updates can be made via MaM to any aspect of the offline monitoring configurations that are configurable via the Python configuration files. This includes list of trigger chains to be monitored, but can include any other parameters a signature group has made configurable in this way, for example, histogram axis limits. The primary use case of MaM is to be able to update the monitoring configurations when a menu change that affects the triggers used for monitoring occurs.

MaM provides users with functions to create and store these patches, and allows them to be applied automatically or manually during ATLAS reconstruction. The monitoring configuration patches are stored in the Oracle SQL trigger database, which can be updated at any time, and is not constrained by the ATLAS offline software release cycle. The schema of the database is shown as Figure 1. A single monitoring configuration patch for a single signature is identified by a ‘Slice Monitoring Configuration Key’ (SMCK), where a ‘slice’ is another term for a ‘signature’. A bundle of patches that to be used with a particular offline software release is identified by a Monitoring Configuration Key (MCK). MaM allows users to create links between MCKs and SMKs in the trigger database, specifying that a particular set of patches should be applied when a run has been taken with a particular trigger configuration. In this way, a link between the offline monitoring configurations and trigger menu can be made. These links can be updated when needed, meaning that offline monitoring configurations can be kept in sync with the online trigger menu.

**Figure 1.** The MaM database schema, showing the four tables and the columns they contain. An ‘SMCK’ is a ‘Slice Monitoring Configuration Key’, specifying a single monitoring configuration patch for a single signature, an ‘MCK’ is a ‘Monitoring Configuration Key’ that specifies a set of monitoring configuration patches, and an ‘SMK’ is the ‘Super Master Key’ that specifies the complete online trigger configuration.

4.1. Creating and storing monitoring configuration patches
ATLAS reconstruction runs in Athena, the ATLAS offline software framework [10]. The trigger monitoring tools, like all Athena tools, are managed by Tool Service (ToolSvc) and their configuration parameters are accessible via ToolSvc.
Patches are produced by, firstly, making changes to copies of the monitoring configuration files within locally checked out copies of the offline trigger monitoring packages. Athena is then run in interactive mode, and MaM’s Python functions are used to set up and then extract the new configurations of the tools. MaM creates patches by comparing the modified, extracted tool configurations to the default tool configurations in the same ATLAS offline software release. The patches are then uploaded to the MaM database, where they can be grouped and linked to SMKs as required. As well as the monitoring tool configurations themselves, MaM stores other information such as the patch creator (‘(S)MCK_CREATORT’) and a comment (‘(S)MCKCOMMENT’) in order to improve usability.

4.2. Application of monitoring configuration patches

In order to automate the application of monitoring configuration patches during ATLAS offline event reconstruction, there is code within the ATLAS online software that archives the MCK that is linked to the SMK for each run. At the start of a data-taking run, this software checks the ‘MCK_TO_SMK_LINK’ table in the MaM database to retrieve the MCK, and stores it in the ATLAS Conditions Database (‘COOL’), where details about each run are stored. As SMK-MCK links can be updated, but only one link to a particular SMK can exist at a given time, this step is needed so that there are no unintended consequences if the link changes whilst the run is being reconstructed offline. Storing the MCK in COOL also ensures that the correct patch is applied if the run is reconstructed again later.

During reconstruction, MaM checks in the COOL to find the MCK that should be applied. Then, MaM checks whether the software release that the patch was created in (stored in the ‘(S)MCK_ATHEA_VERSION’ columns) matches the software release that reconstruction is running in, and only applies the patch if these values match. From one software release to the next, the exact behaviour of each monitoring configuration parameter and the parameters themselves might change, so applying a patch from one release in another might have unintended consequences. In order to apply a patch to a running offline monitoring tool, it is enough to overwrite the values of the configuration parameters in ToolSvc. Therefore, when asked to apply a patch, MaM checks which configuration parameters have values in the patch, checks if the relevant tool is running in ToolSvc, and if so, updates the value of each configuration parameter in ToolSvc. The offline monitoring tools then run with patched configurations and produces the histograms needed to monitor data quality.

5. Conclusion

‘Menu-aware Monitoring’ is a flexible tool for patching ATLAS offline trigger monitoring configurations. The purpose of MaM is to keep the ATLAS offline trigger monitoring up to date with respects to rapid changes of the online trigger configuration, which might occur during intensity ramp-ups and special runs. Ensuring that the trigger monitoring configuration is relevant for the data taking environment means that data quality can be monitored more accurately, resulting in improved data quality. MaM is currently in commissioning and is expected to be available starting during the ATLAS detector commissioning phase in early 2017.
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