DAQExpert

An expert service to increase CMS data-taking efficiency

Maciej Gladki
maciej.gladki@cern.ch

ON BEHALF OF THE CMS DAQ GROUP

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Track: 1. Online and Real-time Computing
CMS DAQ - Data Acquisition

- read out the data
- bunch crossing 40 MHz rate
- event size 1-2MB
- 2-level triggering
- hardware trigger selects 100 kHz
- full events built at 200GB/s
- 35,000 cores in HLT farm select O(1 kHz)
DAQ operations

- System issues are expected
  - Controlling 100s crates of electronics, detectors
  - hardware/software/network problems
  - datataking is stuck
  - recovery procedures
  - operators in control room 24/7
  - on-call experts 24/7
- Human factor
  - operators will make mistakes under time pressure
  - operators will add latency
  - on-calls don’t like to be woken up in the middle of the night
- We need a tool to automate it
DAQExpert service

- Enables system experts to define potential dataflow problems and recovery procedures
- Identifies the problem from monitoring data
- Provides shifters the guidance
- The goal is to improve data taking efficiency
Datataking efficiency

- CMS: 95.87% uptime, 4.13% downtime
- Counts during Stable Beams
- 2184 hours of Stable Beams delivered in 2018 (25% of the year)
- Total downtime was 90h
  - power supply, infrastructure, LHC, DAQ...
- Downtime attributed to DAQ: 46h
  - Sub detectors 93%, central DAQ 7%
  - Scope of DAQExpert (rest is outside of its influence)

*based on 2018 data*
Dashboard

- Main DAQExpert view for control room
- Suggestions to shifters (with sound alarm)
  - Reduce reaction time
  - Avoid wrong decisions
- Suggestion format
  - Description of the problem
  - What’s best action to take

Corrupted data received

Run blocked by corrupted data from FED 619 received by RU ru-c2e14-29-01.cms which is now in failed state. Problem FED belongs to partition EB- in ECAL subsystem. This causes backpressure at FED 644 in partition EB+ of ECAL

Automatic recovery available!

Steps to recover

- Stop and start the run with Red recycle of subsystem DAQ & Green recycle of subsystem DAQ using L0 Automator
- Recovery details
  - Finished:
  - Automator status: approved

- If this doesn’t help: Stop and start the run with Red recycle of subsystem ECAL & Green recycle of subsystem ECAL (Try up to 2 times)

- Problem fixed: Make an e-log entry. Call the DOC of ECAL (subsystem that sent corrupted data) to inform about the problem

- Problem not fixed: Call the DOC of ECAL (subsystem that sent corrupted data)
Reasoning

- Expert knowledge encapsulated in logic modules (LM)
- Each LM defines
  - name and description of the problem
  - recovery procedure
  - dataflow problem condition
- Input data for condition
  - monitoring data
  - output of other LMs
- Modularity and imperative language
```java
/**
 * Logic module identifying corrupted data received
 */

public class CorruptedData extends KnownFailure {

    public CorruptedData() {
        this.name = "Corrupted data received";
        this.description = "Run blocked by corrupted data from " +
            "FED(s) {{PROBLEM-SUBSYSTEM}}/{{PROBLEM-PARTITION}}/{{PROBLEM-FED}}";
        this.recovery = new RecoveryProcedure(" <<StopAndStartTheRun>> with <<RedAndGreenRecycle::DAQ>> ",
            "If this doesn’t help: <<StopAndStartTheRun>> with both " +
            "<<RedAndGreenRecycle::DAQ>> and " +
            "<<RedAndGreenRecycle::{{PROBLEM-SUBSYSTEM}}>> ");
    }

    @Override
    public boolean satisfied(DAQ daq, Map<String, Output> results) {
        for (SubSystem subSystem: daq.getSubSystems()) {
            //... find a RU - Read out Unit that is failed
            if (!"Failed".equalsIgnoreCase(subSystem.getSubSystemName())) {
                //... find a FED that has received corrupted data
                if (subSystem.getFedDataCorruption() > 0) {
                    contextHandler.register("PROBLEM-FED", subSystem);
                    contextHandler.register("PROBLEM-SUBSYSTEM", subSystem);
                    //... register other context information
                    result = true;
                }
            }
        }
        return result;
    }
}
```

*parts of the code have been removed in order to increase readability*
Impact 1

- Guidance to operators → reduces intervention time
- Reaction time is significant part
- Main metric to measure impact of DAQExpert
Impact 2

- Gradually introduced during Run2
  - DAQExpert introduced in 2017
  - Improvements in 2017 and 2018 (coverage and UX)

- Reduces reaction time

<table>
<thead>
<tr>
<th>percentile</th>
<th>Reaction time</th>
<th>Reduction 2016 to 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2016</td>
<td>2017</td>
</tr>
<tr>
<td>95th</td>
<td>322s</td>
<td>177s</td>
</tr>
<tr>
<td>75th</td>
<td>100s</td>
<td>78s</td>
</tr>
<tr>
<td>50th</td>
<td>85s</td>
<td>49s</td>
</tr>
<tr>
<td>25th</td>
<td>46s</td>
<td>23s</td>
</tr>
</tbody>
</table>

Based on:
- 297 interventions
- data from 2016-2018
- only failures in smooth datataking (at least for 5 minutes) = operators not in alarmed state
Limitations

- Operator has a final decision
- Reaction time latency
  - Reaction time of **20-25sec**
  - Significant spread
  - Accumulates to ~4-6h of downtime per year*
- Wrong decision overhead
  - ~1h of downtime per year**
- Improper usage of tools
  - ~1h of downtime per year**
- The most impactful way to improve: bypass the operator

*based on 2017 and 2018 data (266 interventions, at least 5 mins of smooth data taking = operators not in alarmed state)
**based on 2018 August data - detailed case by case analysis had to be performed
Automatic recovery

- Recovery driven by DAQExpert service
- No operator involved
- Commissioned in the end of run 2
- First successful automated jobs observed
- Estimated to reduce the downtime by **8h/year**: 
  - Reaction time
  - Wrong decision overhead
  - Improper usage of tools
  - 17% of DAQ downtime
  - 9% of total CMS downtime

*based on 2017 and 2018 data (266 interventions, at least 5 mins of smooth data taking = operators not in alarmed state)
**based on 2018 August data - detailed case by case analysis had to be performed
Automatic recovery
- Recovery steps picked from LM recovery procedure
- Avoid human reaction time and human error
- Only the monitoring delay
Timeline of DAQExpert

2016
- DAQ Expert developed
- first release Aug

2017
+ first guidance with a new tool
+ UX improvements
+ tools for post mortem analysis

2018
+ coverage improved
+ 1 click recoveries
+ first fully automated recoveries (end of the Run 2)

2021
+ fully automated recoveries wherever possible

Run 2

Run 3
On-call help demand

- Number of night-time calls to the on-call
- Clear trend
- Result of DAQExpert guidance and other improvements to the DAQ system

* Based on data provided by IT / CS, data from 2018 partly provided
1. **Expert tool is being improved**  
   Automatic recoveries introduced in the end of Run2

2. **Successful at Run 2**  
   Minimizes reaction time of operators  
   and reduces downtime.  
   Circumstantial evidence (e.g number of night calls to DAQ on-calls reduced)

3. **Next in Run 3**  
   Expecting to reduce even more downtime with automated recoveries  
   - 17% of DAQ downtime  
   - 9% of total CMS downtime
Extra slides
The Data Acquisition (DAQ) system of the Compact Muon Solenoid (CMS) experiment at LHC is a complex system responsible for the data readout, event building and recording of accepted events. Its proper functioning plays a critical role in the data-taking efficiency of the CMS experiment. In order to ensure high availability and recover promptly in the event of hardware or software failure of the subsystems, an expert system, the DAQ Expert, has been developed. It aims at improving the data taking efficiency, reducing the human error in the operations and minimising the on-call expert demand. Introduced in the beginning of 2017, it assists the shift crew and the system experts in recovering from operational faults, streamlining the post mortem analysis and, at the end of Run 2, triggering the fully automatic recoveries without a human intervention. DAQ Expert analyses the real-time monitoring data originating from the DAQ components and the high-level trigger updated every few seconds. It pinpoints the data flow problem and recovers it automatically or after given operator approval. We analyse the CMS downtime in the 2018 run focusing on what was improved with the introduction of automated recoveries; present challenges and design of transforming the expert knowledge to automated recovery jobs. Furthermore, we demonstrate the web-based, ReactJS interfaces that ensure an effective cooperation between the human operators in control room and the automated recovery system. We report on the operational experience with automated recoveries.
Controller FSM
Key quantities to monitor

- System availability (uptime)
- MTTR (reaction time)
- Wrong decisions overhead
- External help demand
Cumulative reaction time

- >400 DAQ related, datataking-problem interventions in 2018*
- 1-3 necessary human actions per intervention
- 20-25s reaction time
- > ~3h - 7h cumulative reaction time per year

*This does not include all interventions (no assignment by OMS of <30s downtimes -> case by case analysis needed)