Multi-Threaded Evolution of the Data-Logging System of the ATLAS Experiment at CERN

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The ATLAS Trigger & DAQ System

The current Data Logging system: overview

Purpose

5 PCs receive data from the Event Filter system and write it to local disks. Each event is:

- analyzed to determine the “tags” applied by the EF trigger
- “processed”
- written to the appropriate file(s) according to the tags

Details

- The event tags are determined by the trigger algorithms at the EF
- Every event is written to multiple files, one per each of its tags
- File checksum is calculated while writing $\Rightarrow$ CPU-intensive!

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The current Data Logging system: limitations

- The current Data Logger implementation is essentially **single-threaded**:
 - ▶ multiple threads receive the events from the EF
 - ▶ a single thread does the processing and writing
- This design is very unlikely to scale, even on the hardware currently in use
 - ▶ the throughput is currently network limited, but if that limit is removed the inefficient CPU usage will be the bottleneck
- It is a major blocker for the addition of new features requiring more CPU power than a single core can provide
 - ▶ due to this *event-level data compression* currently needs to be performed off-line, as an additional step

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New design: general considerations

- The workload is *embarrassingly parallel*: the incoming data are already divided in events

Constraint

The raw data file format is strictly sequential

⇒ **It is impossible to do concurrent writes to the same file**

The sequential file format is necessary to calculate the overall file checksum *before* writing to disk, aiding in the detection of write errors

- Multiple events can be written to different raw data files concurrently, but *no more than one event can be written to each data file at once*

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New design: idea!

- Split the workload in **tasks**
- For each event:
 - ▶ one task does the processing
 - ▶ multiple tasks do the writing
(for each tag, a task writes the event to the corresponding file).
- Use a **single thread pool** to execute the tasks
- Schedule the tasks cleverly to **avoid locking**
- At any given time:
 - ▶ any number of processing tasks can run
 - ▶ for each raw data file, only one task writing to it can run

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New design: finally, a diagram!

New design: Intel Threading Building Blocks

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Testing: performance & resource utilization

- The new implementation was tested and compared with the old one in a testbed sporting older hardware with respect to the production system
- The testbed was configured to operate a Data Logger machine at saturation
- The dataset used consisted of real event data, with 1 to 4 tags assigned to each event
 - ▶ changing the number of tags per event changes the number of files the Data Logger has to write each event to

Testbed Data Logger PC

2x dual core Xeon 5130
4 GB
3x 3ware RAID5 array
2x GbE NIC

Production Data Logger PC

2x quad core Xeon E5520
24 GB
3x Adaptec RAID5 array
2x GbE NIC

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Testing: performance & resource utilization

The “hard” limit on the throughput of a single Data Logger is given by the network bandwidth: $2 \text{ Gb/s} \simeq 250 \text{ MB/s}$

Old single-threaded implementation

- Can operate at network saturation only for a single tag per event
- Above 2 tags per event, the load generated by its **single thread exceeds what a single CPU core can take**
- The throughput decreases accordingly

Testing: performance & resource utilization

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New multi-threaded implementation

- The **throughput** is almost **unaffected by the load**
- Its 4 threads spread the workload on the 4 CPU cores: any of them does not use more than 60% of a core
- Leaves plenty of legroom for additional CPU intensive processing $\Rightarrow$ compression

Testing: scalability

- **On-line event compression**

radically changes the landscape:

- ▶ throughput is much lower
- ▶ all workloads saturate the CPU
- ▶ compr. time $\gg$ checksum time

- One can examine the throughput as a function of the number of CPU cores (threads) used

- ▶ scaling is (almost) linear

- The throughput *of the compression alone* was measured on the testbed and on the production machines

- ▶ the results *suggest* that enabling on-line event compression on the production machine is feasible

Data Logger machine	Compression-only throughput
Testbed 4 threads	71 MB/s
Production 4 threads	81 MB/s
Production 8 threads	161 MB/s

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- Test results are promising: it was demonstrated that it exploits the full power of modern CPUs
- The design will be fully validated using the full DAQ system with a view to adopting it for the 2012 data taking period

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Other design constraints

Operations are driven by the received event data

The Data Logger can only rely on the information it gathers by examining the received events

No assumptions about the data flow

- Cannot assume that the rate of received events is somehow balanced across the spectrum of the possible tags
- The flow of events with one tag can vary during a run and even stop completely

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Other possible designs: thread pool with locking

Other possible designs: chain of responsibility

Risk of starvation!

Other possible designs: one thread pool per file

Too many threads!