Learning from High Energy Physics Data Acquisition Systems
Is this the future of Photon Science DAQ?

Matt Weaver, August 3rd, 2012
Outline

Introduction

HEP System Architecture
  Triggering
  Trigger Readout Design

Online Processing
  Software Filtering
  Analysis / Feedback

Discussion
High Energy Physics experiments have a long history of acquiring very large volumes of data and reducing them to manageable large volumes of data. New Photon Science facilities are capable of generating equally large volumes of data. New FEL facilities plan to generate beam rates comparable to HEP event rates.

The longer experiment time scales and larger collaborations in HEP allow for well-planned data acquisition and storage strategies. In Photon Science, experiment time scales are short (~week); hence, the facility needs to provide the data acquisition and storage systems.

Can we adopt ideas from High Energy Physics DAQ to reduce our data volumes or increase the performance of our systems?
## Comparing FEL and HEP data rates

<table>
<thead>
<tr>
<th></th>
<th>Beam Rate</th>
<th>Readout Rate</th>
<th>Event Size</th>
<th>Recorded Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LCLS</strong></td>
<td>120 Hz</td>
<td>120 Hz</td>
<td>10 MB</td>
<td>2 PB/yr</td>
</tr>
<tr>
<td><strong>SACLA</strong></td>
<td>60 Hz</td>
<td>60 Hz</td>
<td>12 MB</td>
<td></td>
</tr>
<tr>
<td><strong>XFEL</strong></td>
<td>27 kHz</td>
<td>3 kHz</td>
<td></td>
<td>50 PB/yr</td>
</tr>
<tr>
<td></td>
<td>(10 Hz * 2700 [5MHz])</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BaBar</strong></td>
<td>238 MHz</td>
<td>4 kHz / 300 Hz</td>
<td>50 kB</td>
<td>1 PB/yr</td>
</tr>
<tr>
<td><strong>ATLAS</strong></td>
<td>40 MHz (20 MHz)</td>
<td>100 kHz / 200 Hz</td>
<td>1.5 MB (1.4 MB)</td>
<td>10 PB/yr (3 PB/yr)</td>
</tr>
<tr>
<td><strong>ATLAS</strong></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
HEP System Architecture Overview

The Detector (multiple sub-systems)

Sensor + Elex

Readout Computer

Data network

Control network

Online Processing

Beam Line Data

Storage Array

Offline archive
Beam rate exceeds readout link capability
ATLAS : 60 TB/s
(XFEL LPD : 10 TB/s or 60 GB/s avg)

Reduce rate by selecting interesting events for readout; i.e. triggering.

Trigger decision is based upon detector response and other beamline information.

ATLAS : 40 MHz → 100 kHz [150GB/s]
(20 MHz → 65 kHz)
Comparing Photon Science and High Energy Physics Data Acquisition

Readout Design Trigger Dataflow

A global trigger decision is made from contributing detectors and other sources.

"Level 1" Trigger

Timestamp Distribution + Deadtime monitor

Detector data must be cached in a pipeline during trigger decision time, no data can be lost.

Many commercial sensors do not have trigger latency buffers.

Requires engineering / device integration.

Upon trigger decision, event data is tagged (timestamp) for synchronization with other detector data and transferred to a readout buffer awaiting transfer on the readout link.

BaBar 12 µs

ATLAS 2 µs
HEP System Architecture
Online Processing

The Detector
(multiple sub-systems)

Sensor + Elex

Readout Computer

Data network

Control network

Offline archive

Online Processing

Storage Array

Level 1 Trigger

Timing

Comparing Photon Science and High Energy Physics Data Acquisition
Online Processing
Event Builder

Assemble detector data into complete events for analysis online

Readout Computer

Detector A

Detector B

Detector C

Sometimes event build is done in steps:

detector elements → detector (XFEL LPD “train builder”)
detectors → event

Event 1
Detector A
Detector B
Detector C

Event 2
Detector A
Detector B
Detector C

Event 3
Detector A
Detector B
Detector C

Event 4
Detector A
Detector B
Detector C

Event 5
Detector A
Detector B
Detector C

Event 6
Detector A
Detector B
Detector C

Comparing Photon Science and High Energy Physics Data Acquisition
Detector readout rate exceeds recording capability
ATLAS : 150 GB/s

Interesting event selection requires software algorithms
“Level 2” partial event analysis
“Level 3” full event analysis

Large processing farms (1000's of CPUs) requiring advanced infrastructure for startup / configuration.

Large investment of manpower developing safe and efficient algorithms for event selection.

ATLAS : Level 1 → Level 2 → Level 3 → Storage

100 kHz  3kHz  200 Hz
HEP detectors are:

- custom-built
- Large effort to automate performance monitoring
- tightly integrated to the accelerator
- Provide feedback for accelerator operation as well

Large processing farms need tools for collecting results of distributed analysis for feedback display.

Development of online analysis software must conform to the analysis environment

{ data interface, histogramming tools }

How can photon science reduce the effort needed for online analysis software development

( common tools among facilities? )
Discussion

What is the appropriate interface between detector readout and data acquisition system?

no separation: detector brings its own DAQ  
facility specific: detector only works at one facility  
What is a workable common interface to DAQ/timing system?

Can new detectors be compatible with a “Level 1” trigger design?

{ trigger latency pipeline, event tagging, trigger data path,  
fewer commercial solutions }  

Do we demand data reduction via software filtering from experimenter's that are already short on setup time, or can the facility provide some predefined choice of filters?

Should online detector monitoring software conform to some standard to allow reuse in different facility software environments?

Common distributed histogramming tools  
Common data interface