The DAQ needle in the Big Data Haystack

Technology Convergences in the post-LHC era

Emilio Meschi - CERN/PH
ON THE AUTOMATIC REGISTRATION OF \( \alpha \)-PARTICLES, \( \beta \)-PARTICLES AND \( \gamma \)-RAY AND X-RAY PULSES

"...visual or audible methods of counting are quite trying on the nerves because close attention is necessary on account of the probability law of emission of the particles, and long methods of counting are essential because the method is a statistical one"  
Alois F. Kovarik - Phys. Rev. 13 (1919) 272-280

"Typical detectors are...more than 100 000 electronics channels... Raw data per event can reach several megabytes due to more common use of time sliced digitising... forcing] data compression... to keep the transmitted data to a level acceptable to storage devices...the purpose becomes...gathering all events of physics interest with minimum background... and... minimum deadtime. One should have in mind that the data acquisition system (not including front-end electronics) amounts to about 5% of the detector cost..."
Ph. Gavillet - NIM A235 (1985), 363-379

"The Fastbus- and VME-based tree architectures of the eighties run out of steam when applied to LHC’s DAQ requirements. New concepts and architectures change rack-mounting backplane buses to high-speed point-to-point links, abandon the centralized event building and use switched networks and parallel architectures instead, and replace mainframes and workstations with cheaper PC farms."
J. Toledo et al. - Microprocessors and Microsystems 27,8 (2003), 353-358

What are the main points of today?
- Ever increasing channel count
- Smaller and smaller bunch spacing
- Large mass of persistent data
- Experiments with life span of several decades
  - Human Factor

Parallel backplanes vs. point-to-point, switched networks, commercial hw
Data center locations

We own and operate data centers around the world to keep our products running 24 hours a day, 7 days a week. Find out more about our data center locations, community involvement, and job opportunities in our locations around the world.

Americas
- Berkeley County, South C.
  Council Bluffs, Iowa

Europe
- Hamina, Finland
- St Ghislain, Belgium
- Dublin, Ireland
- Eemshaven, Netherlands

Source:
http://www.google.com/about/datacenters/inside/locations/
Since LHC

HEP no longer alone at the forefront of data manipulation and even data analysis
- telecommunications
- commercial data mining
- machine learning

Yet future challenges are formidable and resources limited
- among others:
  - “human” cost of creating and maintaining custom electronics and software over life span of experiments may become prohibitive

As in the past: use “conventional” (new and old) technologies in non-conventional ways

Take a holistic look at the problem: from the front-end to offline analysis
Two examples

• Optical links
• Big Data Analytics
The detector readout dilemma

Physics and Machine

Data reduction
Complexity
Depth of pipelines
Rad-hardness
Material budget
Space
Engineering

Number of detector channels

Readout

Power consumption
Power dissipation

COST

Cooling

Physics and Machine
Of course…Silicon Photonics…

• i²C interfaces in one the optical chips failed at 165 krad. → That is the weakest link in radiation hardness of the optical chip
• The transceivers were fully operational after the loss of i²C connections till we power-cycled them
  ❖ They were sending data at 10 Gbps without bit errors
  ❖ Laser and the voltage regulator chip resisted irradiation well.
  ❖ Modulators and fast photo-diodes were fully operations at TID~380 krad.
• Biases of MZIs were very stable → Likely the optical part of the chip has radiation tolerance higher than 1 Mrad.

Source: A Paramonov et al. WIT2014
...makes one immediately think of brute force readout of entire detector

• Unless read out at crossing frequency, large fraction of b/w used for trigger data
• High-speed bidirectional links – do we want to use them in only one direction?
  • bring “calibrations” to detector
  • bring **algorithms** to detector
• intelligent detectors - built **with in mind the way we analyse them** – e.g.
  • “stub” tracking in silicon strips detector
  • layer-to-layer interconnects with local processing
Big Data analytics

Commercial applications analyze vast amounts of unstructured data

- **Bandwidth** will soon surpass those of a typical DAQ
- Applications require “quasi-real-time”

Distributed search engines / “NoSQL” databases

We start using them today…

---

Cern-IT cloud infrastructure

[Diagram showing various components like HDFS, Elastic Search, Kibana Dashboards, Fume, Gateway, Lemon, Syslog, Other Applications, and their connections.]

CMS F3 monitoring

[Diagram showing a central monitor, drilldown, history archive, regular queries, ES, httpd, user in LAN, user in WAN, DSL, and an appliances section labeled “tribe.”]

See S.Morovic talk later in this session

Big Data analytics

But distributed search engines are not limited to monitoring

The principle can be applied to e.g.:

• search the data we want in the detector (as opposed to “partial event building” of old)
• build online “event directories”
• execute complex algorithms comparable to our high-level pattern recognition (e.g. clustering)

What if we could embed a distributed search engine in our detector front-end (…or nearby) ?
All DATA-DRIVEN tasks based on Internet hardware and software services. The required performances are anticipated by the data processing and data communication trends.
Even More Exotic Stuff

- “Artificial retina” for 40 MHz tracking

- Wireless readout
  (2014 JINST 9 C11002)

- Low-power conventional Multi-Gigabit links
  (2014 JINST 9 C12011)

- Free-space optical links
  (http://www.sciencedirect.com/science/article/pii/S1875389212018998)

- Wireless powering and readout
  (arXiv:1310.1098v1)

…just to name a few
B/w out of IP virtually unlimited
Impractical location for surface infrastructure
Human factor
5ns interbunch with timestamping

On-detector pattern recognition (e.g. “retina”)

Quasi-FE data organising pipelines with indexing

Free-space radial optical (or radio) links

Multi-layer stub identification
5ns interbunch with timestamping

On-detector pattern recognition (e.g. “retina”)

Data-organising pipelines with indexing

Free-space radial optical (or radio) links

Multi-layer stub identification

http://simoneferrarogd.deviantart.com/art/Doodle-google-space-60-freak-213457167


2040?
Summary

Any, or all, or some combination of this may or may not come true one day

»Det er svært at spå, især om fremtiden«

Danish Proverb
…or Niels Bohr…
…or ‘Yogi’ Berra…
…or Jaques Chirac…

Perhaps:

»Correct attribution is hard, especially for the past«

D. Arnold

The interest of trying to guess how our future DAQ systems will look like lies not in the final attribution, but in the criticism, discussion and ultimately *thinking* a particular guess will elicit

See you all hopefully in twenty(?) years to verify what, eventually, actually came to pass
Off topic: modular electronics

“Nuclear” physics experiments  Computer architectures  Telecom
Mechanical and Electrical Standard  Backplane(s)  Lots of on-board Intelligence  Large throughput High speed links

Use of modular electronics in central DAQ
The fabric interface connections in 14 slot full mesh ATCA backplane. Each line represents a multi-lane bidirectional channel rated for up to 40~Gb/s.