Networking for the Large Hadron Collider

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HEAnet Conference, Limerick
11 November 2004
Outline

• I’m going to tell you about a scientific adventure
• (One of) the largest in the world
• The science is fascinating
• … but the human and computer networking is even more extraordinary

• At the end I’ll talk a little about Ireland and CERN
The Welsh

The Scots have their whisky, the Welsh have their speech
And their poets are paid about ten pence a week
Provided no hard words on England they speak
Oh Lord! What a price for devotion!

From Surrounded by Water (D. Behan)
Other disciplines

- I was asked to mainly talk about particle physics and its networking challenges.
- I’m well aware that there is more to life than particle physics, and that many other disciplines also have fascinating research challenges to face.
- Another person, another time.
- And we all have to work together to explain this to our bosses and politicians.
CERN in Numbers

• 2500 staff
• 6500 users
• 500 Fellows and Associates
• Budget ~1000 MCHF (~650 M€) per year

• Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

• Observers: India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and Unesco
Distribution of CERN users (2003)
In 50 years, we’ve come a long way, but there is still much to learn...
CERN: the World’s Most Complete Accelerator Complex
(not to scale)
CERN: the World's Most Complete Accelerator Complex
The 15-m long LHC cryodipole
Magnet – Cryostat Assembly
Science depends on high-technology engineering

LHC cryogenic magnet transport
Many other CERN technology spin-offs

- IT – Web – Grids
- Non-invasive imaging
  - For medicine
  - For security
  - For materials science
  - Chips
Surface access to the ATLAS pit
Lowering part of the ATLAS tile calorimeter into the cavern
March 2004
CMS experiment - assembly
Anatomy of a Detector
The Result of a Collision
LHC data

- 40 million collisions per second

- After filtering, 100 collisions of interest per second

- A Megabyte of data digitised for each collision = recording rate of 0.1 Gigabytes/sec

- $10^{10}$ collisions recorded each year = 10 Petabytes/year of data
LHC processing

- **Simulation**: start from theory and detector characteristics and compute what detector should have seen

- **Reconstruction**: transform signals from the detector to physical properties (energies, charge of particles, ..)

- **Analysis**: Find collisions with similar features, use of complex algorithms to extract physics…
Computing for LHC

- **Problem:** CERN alone can provide only a fraction of the necessary resources

- **Solution:** Computing centers, which were isolated in the past, should now be connected, *uniting the computing resources of particle physicists in the world!*
What is the Grid?

• The World Wide Web provides seamless access to information that is stored in many millions of different geographical locations.

• In contrast, the Grid is an emerging infrastructure that provides seamless access to computing power and data storage capacity distributed over the globe.
Robert Cailliau (+Tim BL and Ted Nelson)

Photo: Hakon Lie
LHC Computing Grid (LCG)

**Mission:**
- Grid deployment project aimed at installing a functioning Grid to help the LHC experiments collect and analyse the data coming from the detectors

**Strategy:**
- Integrate thousands of computers at dozens of participating institutes worldwide into a global computing resource
- Rely on software being developed in advanced grid technology projects, both in Europe and in the USA
How will it work?

• The Grid relies on advanced software, called *middleware*, which ensures seamless communication between different computers and different parts of the world.

• The Grid search engine will *not only find the data* the scientist needs, but *also the data processing techniques* and the computing power to carry them out.

• It will distribute the computing task to *wherever in the world there is spare capacity*, and send the result to the scientist.
LHC Computing Grid (LCG)

People:

- Over 150 physicists, computer scientists and engineers from partner research centres around the world

Timeline:

- 2002: start project
- 2003: service opened (Sept)
- 2002 - 2005: prepare and deploy the environment for LHC computing
- 2006 – 2008: acquire, build and operate the LHC computing service
Mission:
• Testbed for cutting edge Grid software and hardware
• Industry consortium for Grid-related technologies of common interest
• Training ground for a new generation of engineers to learn about Grid

Partners:
• CERN
• Enterasys
• HP
• IBM
• Intel
• Oracle
Benefits for Science

• More effective and seamless collaboration of dispersed communities, both scientific and commercial

• Ability to run large-scale applications comprising thousands of computers, for wide range of applications

• Transparent access to distributed resources from your desktop, or even your mobile phone

• The term “e-Science” has been coined to express these benefits
Grid Applications for Science

- **Medical/Healthcare** *(imaging, diagnosis and treatment)*

- **Bioinformatics** *(study of the human genome and proteome to understand genetic diseases)*

- **Nanotechnology** *(design of new materials from the molecular scale)*

- **Engineering** *(design optimization, simulation, failure analysis and remote Instrument access and control)*

- **Natural Resources and the Environment** *(weather forecasting, earth observation, modeling and prediction of complex systems)*
CERN as Educator

Visits

Accelerator School

Doctoral Student

Exhibitions

Academic Training

Communications Training

Physics School

CERN-Latin America School

Apprentices

Computing School

Technical Student

Technical Training

Teachers programmes

Summer Student

Fellows

Management Training
Bringing Nations Together

“...the promotion of contacts between, and the interchange of, scientists...”
LHC transfer line (warm) magnets from BINP, Novosibirsk
(Delivery of the final magnets in 2003)
INTAS 572 – CMS Forward ECAL crystal support structure
INTAS 483 - ATLAS EndCap muon system tests
Brought together INTAS and ISTC projects
CERN’s external networking update

Olivier Martin, CERN, Switzerland
Main Internet connections at CERN

- Swiss National Research Network: 2.5Gbps
- SWITCH: 1Gbps
- IN2P3: 1Gbps
- WHO: General purpose, A&R and commodity Internet connections (Europe/USA/World)
- Europe
- USA
- CIXP: Commercial
- GEANT (1.25/2.5Gbps)
- USLIC 622Mbps
- DataTAG: 1Gbps
- NetherLight: 10Gbps
- ATRIUM/VTHD: 2.5Gbps
CERN’s Distributed Internet Exchange Point (CIXP)

**Telecom Operators & dark fibre providers:**
- Cablecom, COLT, France Telecom, FibreLac/Intelcom, Global Crossing, LDCom, Deutsche Telekom/T-Systems, Interoute(*), KPN, MCI/Worldcom, SIG, Sunrise, Swisscom (Switzerland), Swisscom (France), Thermelec, VTX.

**Internet Service Providers include:**
- Infonet, AT&T Global Network Services, Cablecom, Callahan, Colt, DFI, Deckpoint, Deutsche Telekom, Easynet, FibreLac, France Telecom/OpenTransit, Global-One, InterNeXt, IS-Productions, LDcom, Nexlink, PSI Networks (IProlink), MCI/Worldcom, Petrel, SIG, Sunrise, IP-Plus, VTX/Smartphone, UUnet, Vianetworks.

**Others:**
- SWITCH, Swiss Confederation, Conseil General de Haute Savoie (*)
Transatlantic 10GigE experiments

- On September 15, 2003, the DataTAG project was the first transatlantic testbed offering direct 10GigE attachments, through Juniper T320 routers using 10GigE emulation.
  - New Internet2 landspeed record established on October 1
  - Single 5.44G TCP/IP v4 flow between CERN & Chicago
  - More will come.....

- On October 6, 2003, a second transatlantic 10GigE lightpath using a 10G-WAN-PHY solution with Force10 & Cisco ONS15454 equipment was also deployed between CERN & Ottawa through Amsterdam & Chicago
  - Partners: CERN, Surfnet/Netherlight, Canarie

- To the best of our knowledge, there are no other transoceanic 10GigE experiments in the world,
  - both can be seen during Telecom World 2003

- ANY QUESTIONS?
Record now at 6.63 Gbps over 15'766 km between CERN and Caltech
World’s longest native 10GE connection

October 20, 2004. Engineers in Japan, Canada, USA, The Netherlands, and CERN completed the world’s longest native 10 Gigabit Ethernet circuit for the transmission of data from the Japanese Data Reservoir project to the CERN research centre in Geneva, Switzerland. The length of this light path is approximately [28,500] km and spans 17 time zones. …

The Data Reservoir system also achieved a 9 Gbps disk-to-disk data transfer with 9 Xeon servers at each end of the connection. This performance figure has not been reported before on an intercontinental disk-to-disk situation.

[Credits to GLIF, multiple manufacturers and funding agencies]
CERN and Ireland

- I’m not Irish …. and this is a very personal view …
- Ireland and Luxembourg are now the only major European countries not members of CERN
- You become a member of CERN because you believe in a shared approach to very fascinating and fundamental questions
- You do not join in order to make money
- The technological spin-offs will help your economy, but the science and not the technology must be your prime motivation
- The Finnish experience (it joined CERN in 1991) has been very positive – even on economic grounds, I believe
- Particle physics is very much a participative activity – with the research groups requiring excellent support from local industry
- Where industry typically means many small(ish) scale high-tech companies
CERN and Ireland (2)

• Three years ago Ireland had no active particle physics teams
• No longer the case – Ronan McNulty (UCD) is in the audience
• His group expects to participate actively in LHC data analysis – that means taking part in today’s data challenges and tomorrow’s analyses
• That will need excellent networking support
Concluding remarks

• NRENs are important for the development of the European economy
• HEAnet will be important for the development of the Irish economy
• Get out there and stress the facilities available to you
• And become politicians – explain to your dean and VC and TD what you need!
CERN...

- Seeking answers to questions about the Universe
- Advancing the frontiers of technology
- Training the scientists of tomorrow
- Bringing nations together through science