VLBI Participation in Next Generation Network Development

eVLBI Workshop
Haystack Observatory
9th April 2002

Steve Parsley
parsley@jive.nl
Agenda

• eVLBI Network requirements
• Existing networks and future development
• Technical issues for research networks
• “VLBI-aware” network research participants
• Current status of EVN network research
eVLBI - Questions

• What are the problems?
• Which problems will just go away and which will we have to solve for ourselves?
• What can we do now?
• What should we do now?
• What shouldn’t we do now?
eVLBI - Problems

- Capacity
- Latency & Jitter
- Connectivity
- Compatibility
- Cost
- “Last mile”
What kind of Network for eVLBI?

• Ideal:
  – Totally private, homogeneous network
  – Point-point connection from each telescope to correlator.

• Reality:
  – Shared capacity on heterogeneous networks
  – Multiple domains
Agenda

• eVLBI Network requirements
• Existing networks and future development
• Technical issues for research networks
• “VLBI-aware” network research participants
• Current status of EVN network research
Key enabling technologies

- DWDM
- Wideband optical amplifiers
- Optical cross-connects
- Optical add/drop multiplexors
Existing core networks

• Four layer architecture
  – IP
  – ATM
  – SONET/SDH
  – Optical
Cisco Systems

**IP Layer**
- IP Router Mesh
- Cisco 12000 Series GSR

**ATM Layer**
- ATM Router Mesh
- Cisco MGX 8800 Series

**SONET/SDH Layer**
- SONET Rings:
  - Add/Drop Multiplexers,
  - Digital Cross-Connects

**Optical Layer**
- Point-to-Point DWDM

Cisco Systems
Future Networks

• As the unit of bandwidth allocation becomes equivalent to a wavelength TDM becomes obsolete
• Protocol layers between IP and optical transport will be eliminated
• Protocol-transparent wavelength services
• Set up/tear down, as required
Multi domain IP controlled

Administrative boundary

BGP

IP-environment

Administrative boundary

R

Optical network controlled from the IP layer.

 Courtesy of Cees de Laat, University of Amsterdam
Lambda Networks: Perfect for VLBI

- User-to-user connections like voice calls
- Virtual, dark fibre networks
- It will be possible for the path between telescope and correlator to be a dedicated chain of wavelengths.
Agenda

• eVLBI Network requirements
• Existing networks and future development
• Technical issues for research networks
• “VLBI-aware” network research participants
• Current status of EVN network research
How far off is “real” \( \lambda \) networking?

• Not now: No standards on:
  – Laser modulation
  – Spectrum width
  – Power levels
  – Bandwidth: OC-48, OC-192, ...
  – Dispersion management

• And some say never:
  – True lambda switched networks will not scale
Redefine a Lambda

• a layer-1 circuit switched network
• a $\lambda$ is a “Pipe” in which traffic can be inspected only at input and output
• Control is transferred from the core of the network to the edges
• Currently available “pseudo-$\lambda$” technologies are SONET/SDH and Ethernet
Important Technical Issues for Research Networks

✓ Transfer of control to the edge of the Network
✓ Authentication Authorisation Accounting
✓ Bandwidth on demand
✓ Dynamic provisioning of IP networks
✓ Multi domain policy
? Optical technologies
? Optical switching etc.
Agenda

- eVLBI Network requirements
- Existing networks and future development
- Technical issues for research networks
- “VLBI-aware” network research participants
- Current status of EVN network research
Who is “VLBI-aware”? 
GRIDS

Distributed computing power (approximately equivalent to 50,000 of today’s PCs) for solving problems in ‘Big Science’ areas:
• Large Hadron Collider (LHC analysis) in particle physics
• Astronomy (massive sky surveys)
• Biology (genome databases)
• Earth observations (data collected from satellites)
• Weather forecasting, and collaborative engineering
• Transparent access to multi-petabyte distributed databases at 10s of Gigabits per second.
Optical Domain Switching:
International Test-Beds

- STARLIGHT
- SURFNET (NETHERLIGHT)
- CANARIE
- TERENA/FLAG

http://www.terena.nl/task-forces/tf-ngn/testbeds.html
TERENA/FLAG Testbed Initiative

• Provide a 2.5 or 10 Gbit/s Clear Channel Wavelength to TERENA members
• Provided at minimum cost for 12 months
• Reciprocal tails to the FLAG European country PoP(s) should be funded or provided by the NREN’s where possible
• FLAG can provide limited human resources
• Test bed only - no commercial/production traffic

http://www.terena.nl/tech/projects/testbed/
• TERENA Mission
  “… to promote and participate in the development of a high quality international information and telecommunications infrastructure for the benefit of research and education.”

• TF-NGN: Task Force - Next Generation Networking
  “… established to investigate the suitability of advanced networking technologies for future implementation in research and education networks in Europe.”
TERENA/FLAG Testbed Initiative

Interested NREN’s to date

- Ireland: HEANET
- Netherlands: SURFnet
- Netherlands: University of Amsterdam
- United Kingdom: UKERNA
- CERN
- Czech Republic: CESNET
- Italy: GARR
- Greece: GRNET
- Poland: Pionier
- Canadian: CANARIE
- Germany: DFNET
- Internet 2
Optical Networking: Status in UK

Jan 2002: meeting at DTI gave clear support for development of optical switching research infrastructure in UK.

Attendees:
- STARLIGHT
- NETHERLIGHT
- eScience Directorate
- Grid Network team
- UKERNA
- Many other UK network research groups
VLBI

ger term VLBI is easily capable of generating enormous data volumes. The sensitivity of the VLBI array scales roughly as the square root of the data rate and there is a strong push to develop high-speed correlators. Rates of 8 Gbps or more are entirely feasible. It is expected that parallel fast optical correlator will remain the most efficient approach. As distributed processing may have an appeal, multi-gigabit data streams will aggregate into fewer streams and the capacity of the final link to the correlator. 

[Images of radio telescopes and a diagram of VLBI configuration]
Agenda

- eVLBI Network requirements
- Existing networks and future development
- Technical issues for research networks
- “VLBI-aware” network research participants
- Current status of EVN network research
eVLBI - Problems

• Capacity
• Latency
• Connectivity
• Compatibility
• Cost
• “Last mile”
What now?

• Limited tests using data from a small number of telescopes.
• Develop “edge” technology to send and receive data in real time at the maximum rate currently possible.
• No special protocols, no special network tuning (unless these are part of network development)
• Respect the limitations of existing technology
2 colours @1Gbps from Dwingeloo to Amsterdam Internet Exchange @SARA

16 km of new fibre

180km to SARA via Global Crossing installed link
Network layout for lambda service

SARA
- Lambda switch (or patch panel)
- OC48c
- 3rd party lambda
- International OC48c-carrier, To be subcontracted by SURFnet

ASTRON/JIVE
- OC48c
- GbE
- Ethernet switch
- 3rd party lambda

Emmeloord: optical amplifier in-line

98 km 89 km

Operated by SURFnet

Gigabit Ethernet switches are not part of lambda service & are outside SURFnet domain
Call for Applications with Insatiable Bandwidth Appetites!

“We hereby challenge the international research community to demonstrate applications that benefit from huge amounts of bandwidth!”
vlbiGRID Timeline

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st replay test</td>
<td>2 days</td>
</tr>
<tr>
<td>DD assemble &amp; test</td>
<td>10 days</td>
</tr>
<tr>
<td>Test Observation</td>
<td>1 day</td>
</tr>
<tr>
<td>Disk/Tape correlations</td>
<td>25 days</td>
</tr>
<tr>
<td>Usable I/F and data available</td>
<td>0 days</td>
</tr>
<tr>
<td>Bench GE tests</td>
<td>25 days</td>
</tr>
<tr>
<td>SURFnet link contract signed</td>
<td>0 days</td>
</tr>
<tr>
<td>Digging for fibre link</td>
<td>60 days</td>
</tr>
<tr>
<td>Dwingeloo installation</td>
<td>5 days</td>
</tr>
<tr>
<td>Link to basement</td>
<td>5 days</td>
</tr>
<tr>
<td>Ams - Dwingeloo link ready</td>
<td>0 days</td>
</tr>
<tr>
<td>Ams - JIVE tests</td>
<td>25 days</td>
</tr>
<tr>
<td>UK - Ams link ready</td>
<td>0 days</td>
</tr>
<tr>
<td>UK - JIVE tests</td>
<td>10 days</td>
</tr>
<tr>
<td>Stand preparation</td>
<td>25 days</td>
</tr>
<tr>
<td>Stand set-up</td>
<td>1 day</td>
</tr>
<tr>
<td>iGrid</td>
<td>3 days</td>
</tr>
</tbody>
</table>

- **SURFnet link contract signed**
- **Usable I/F and data available**
- **Ams - Dwingeloo link ready**
- **UK - Ams link ready**
First, simple replay Test

Manual Command Line:
- Record
- Replay
- Advance/Retard N bytes

Test/develop:
- SU lock to data
- Error rates
- Manual servo
Record and replay real data in parallel with tape.

Correlate:
- Normal tape station/station
- Normal auto
- Tape/Disk – same station
- Disk/Disk – two stations
Bench tests at JIVE

Replay disk data and Tx to “receiver” unit via GE
Correlate with data from second unit directly from disk
Test/develop buffering and servo technique

Move source unit to SARA and then Manchester when links become available
Develop remote signaling to start replay (In the limit we can use the telephone and a finger)
iGRID “Visualisations”

• Poster displays
  – VLBI technique & Science
  – VLBI community
  – iGRID partners: Jodrell Bank/JIVE/Westerbork

• Web – Cam displays
  – Telescopes
  – JIVE operations
  – Fringe display
Beyond iGRID

- Link from Haystack via Chicago/SURFnet
- Link to far east via TransPac
- Dwingeloo connection can be upgraded to multiple lambdas with multi-gigabit/s capacity
OC48c – SURFnet (Dedicated to research)

2.5Gbit/s, July 2002

Chicago

Amsterdam

OC48c SURFnet Summer ‘02

CERN
Revisiting the truck of tapes

Consider one fiber

- Current technology allows for 160 $\lambda$ in one of the frequency bands
- Each $\lambda$ has a bandwidth of 40 Gbit/s
- Transport: $160 \times 40 \times 10^9 / 8 = 800$ GByte/sec
- Take a 10 metric ton truck
- One DLT contains 50 Gbyte, weights 200 gr
- Truck contains (10000 / 0.2) $\times$ 50 Gbyte = 2.5 PByte
- Truck / fiber = 2500000 / 800 = 3125 s $\approx$ one hour
- For distances further away than a truck drives in one hour (50 km) minus loading and handling 50000 tapes the fiber wins!!!
References

- Scaling Optical Data Networks with Cisco Wavelength Routing - White Paper, Cisco Systems, Inc.
- Wavelength Routing in Optical Networks - White Paper, Cisco Systems, Inc.
- The Drive to IP on Optics - White Paper, Nortel Networks
- “The Lambda Demarc: When and For What?” - Tom Nolle, CIMI Corp
- The New Service Enabled Packet Network - White Paper, Tenor Networks
- Packets and Photons: The Emerging Two-Layer Network - White Paper, Juniper Networks