

Multi-Domain Management: Results Achieved & Future Challenges Using the Example of GÉANT

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10th IFIP/IEEE Symposium on Integrated Management
München Germany, May 23rd 2007

GÉANT2: A European Team Effort

- The **GÉANT2 Network Footprint**: Interconnects 30 (34) National Research & Education Networks (NREN's) of the Extended European Research Area
- Concerted Activities within the **GN2 Project**: co-funded by the European Commission (DG INFSO-M) and the Consortium (30 NREN's + DANTE + TERENA)
 - (Human) Networking Activities (NA's)
 - Service Activities (SA's)
 - Joint Research Activities (JRA's)
- **Global Outreach**: Extending the Team Collaborations in all Continents
- Contributions to this keynote talk
 - **Klaus Ullmann**: DFN, GN2 Executive Committee & DANTE Board of Directors
 - **Hans Döbbeling, Dai Davies, Roberto Sabatino**: DANTE
 - **Vasilis Maglaris**: NTUA & NREN Policy Committee

R&E Networking Model in Europe

- **A 3-tier Federal Architecture**, partially subsidized by National and EU Research & Education funds:
 - The Campus Network (LAN/MAN) > 3,500 Institutions, >30 M Users
 - The 34 NREN's (MAN/WAN)
 - The Pan-European Interconnection: **TEN34 → TEN155 → GÉANT** (GN1 in EC FP5) → **GÉANT2** (GN2 in EC FP6): **Hybrid Optical Backbone (+ Cross Border Fibers)**
- **Total GN2 Cost: 40 M€/year (co-funded by the EC and NREN's)**

GN2 EC Subsidy < 10% of total European R&E Networking Cost

- **GÉANT Governance:** NREN Policy Committee
- **GN2 Project Management:** Exec, DANTE <http://www.dante.net/>

European NREN's – GÉANT: A Success Story

Some factors

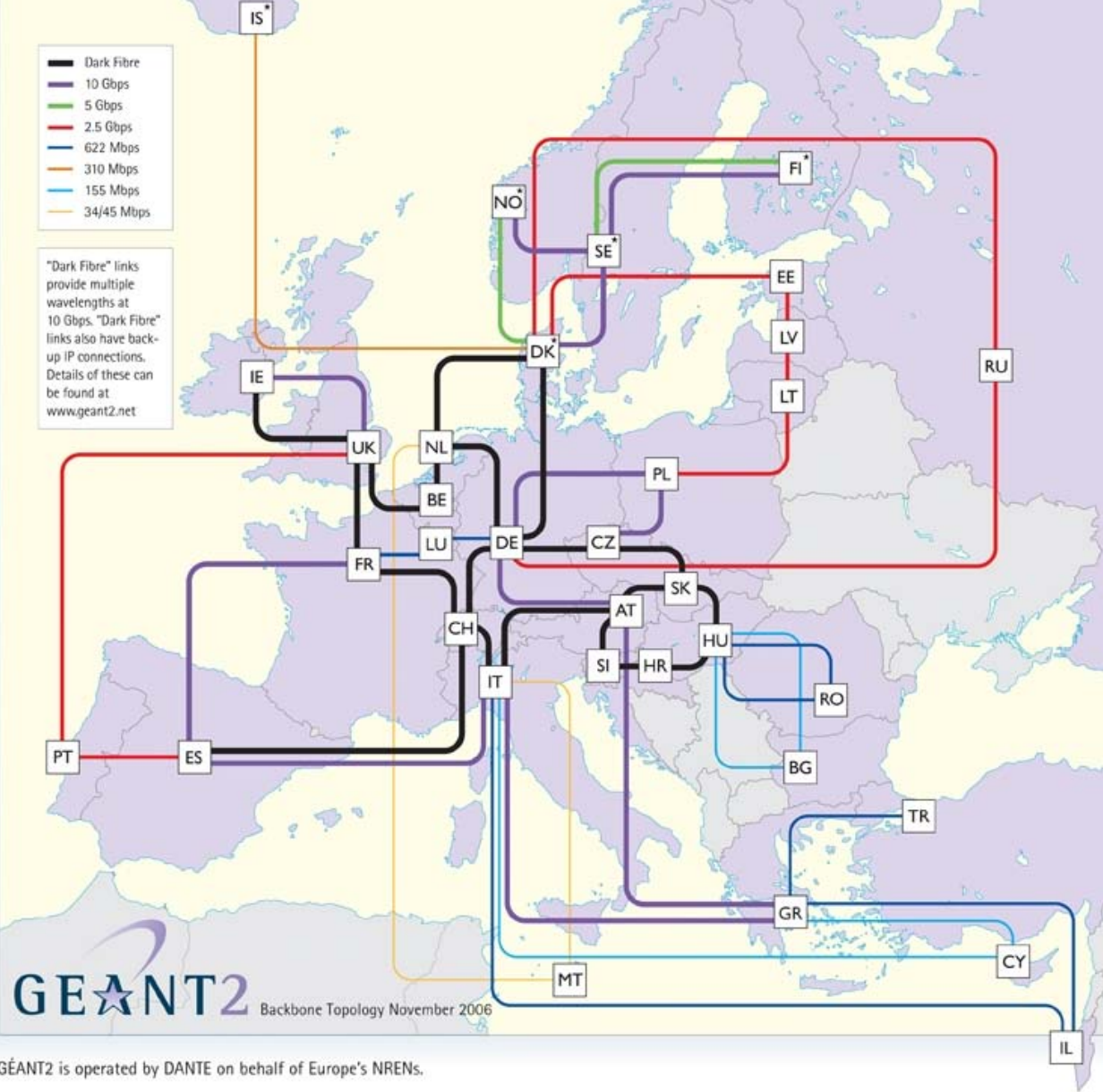
- Century old Telecom (+ 40 years ARPANet - Internet) experience: Proven strong **“Network Externalities”** → Sharing tradition
- Industry needs for **Next Generation Network** proofs of concept, synergy with R&E community: The ARPANet paradigm @ the US of America, inspiring the **“US of Europe”**
- **Foresight** of National + EU funding authorities, triggered by NREN planning – SERENATE, EARNEST Studies, <http://terena.nl/publications/files/SERENATE-FINAL.pdf>
- A decade (+) of success in serving R&E needs of the Continent → Smoothing-out **“digital divides”** & enabling powerful education communities (educators, students, pupils?)
- NREN's as public utilities for the R&E communities – extending **“commons”** principle
- **Solidarity** – human networking of NREN community
- Stable **Governance**: NREN Policy Committee (NREN PC)

The NREN Policy Committee

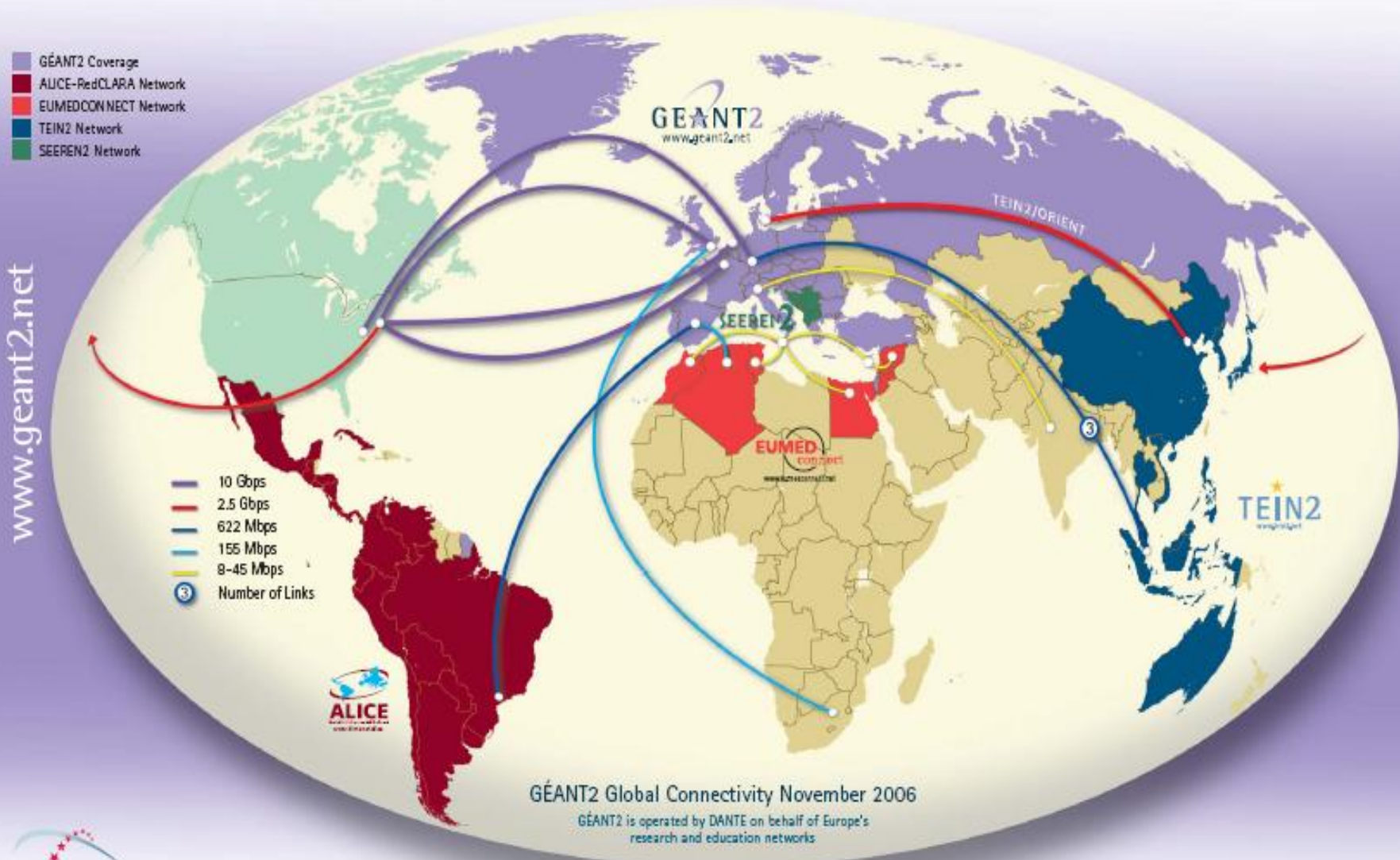
- | | |
|---|--|
| <ol style="list-style-type: none">1. Austria (ACOnet)2. Belgium (BELNET)3. Bulgaria (ISTF)4. Croatia (CARNet)5. Czech Republic (CESNET)6. Cyprus (CYNET)7. Germany (DFN)8. Estonia (EENet)9. France (RENATER)10. Greece (GRNET)11. Hungary (HUNGARNET)12. Ireland (HEANet)13. Israel (IUCC)14. Italy (GARR)15. Latvia (LATNET)16. Lithuania (LITNET)17. Luxembourg (RESTENA)18. Malta (UoM)19. Netherlands (SURFNET) | <ol style="list-style-type: none">20. Nordic Countries – Denmark, Finland, Iceland, Norway, Sweden (NORDUNET)21. Poland (PSNC)22. Portugal (FCCN)23. Romania (RoEduNet)24. Russia (JSCC)25. Slovakia (SANET)26. Slovenia (ARNES)27. Spain (RedIRIS)28. Switzerland (SWITCH)29. Turkey (ULAKBIM)30. United Kingdom (UKERNA) <p><u>PLUS NON-VOTING MEMBERS:</u>
Delivery of Advanced Network Technologies to Europe Ltd. (DANTE)
Trans-European Research & Education Networking Association (TERENA)</p> <p>PERMANENT OBSERVERS: CERN, AMRES, MARNET</p> |
|---|--|

GÉANT2 Topology

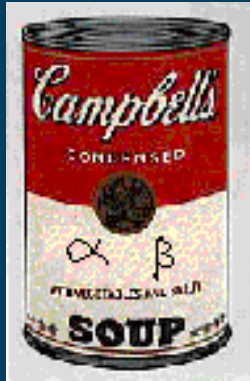
15+ NRENs
 interconnected
 within the Dark
 Fibre (DF) “cloud”
 Rest, via leased
 “lambda” and
 SDH circuits



GEANT2 At the Heart of Global Research Networking



The GÉANT2 $\alpha\beta$ Soup



AutoBAHN
JRA2
eduGAIN
GN2
JRA1
SA3
perfSONAR
AMPS
SA2
PERT
EARNEST
JRA3
cNIS
E2ECU
eduroam
NA4
JRA5
CBF
JRA4

The GN2 Project Structure (1/3)

Human **Networking Activities (NA's)**

- Project management – **NA1**
- Dissemination, publicity, events – **NA2, NA3 & NA7**
- NREN Compendium – **NA4**
- Support for NREN's – **NA4** (help to overcome digital divides)
- Foresight Study (EARNEST) – **NA5**
- Task Forces – **NA6**

The GN2 Project Structure (2/3)

Specific **Service Activities (SA's)**

- Procurement of the GÉANT2 network – **SA1**
- Rollout and operation – **SA2**
- Support for Multi-Domain Services – **SA3** (e.g. **AMPS**, **PERT** tools, **cNIS**)
- Global connections – **SA4**

The GN2 Project Structure (3/3)

Joint Research Activities (JRA's)

- Network performance monitoring – **JRA1** (e.g. **perfSONAR**)
- Network security – **JRA2** (e.g. federated **CERT's**, **Netflow Mon**)
- Bandwidth on demand – **JRA3** (multi-domain provisioning in hybrid heterogeneous networks, e.g. **AutoBAHN** architecture)
- Testbed and technology testing, including Cross Border Fiber / CBF – **JRA4** (e.g. GÉANT2 Testbed, **E2ECU** multi-domain monitoring tools)
- Roaming, authorization, mobility – **JRA5** (e.g. Networked Radius / 802.1X: **eduroam**, GID, Shibboleth cross-domain authentication, federated AAI: **eduGAIN**)
- Emphasis on transition to service: **From JRA's to SA's**

NREN's & GÉANT2: e-Science Enablers + Networking R&D Platforms

- NREN's - GÉANT2 provide cost effective **e2e switched & light path connectivity** within the Dark Fiber Cloud (DWDM footprint)
 - + Global **IPv4 – IPv6 coverage** and **Hybrid** networking services
 - + Network management, resiliency & support
- *e-Science* (GRID) Virtual Organizations obtain, production quality hybrid networking, beyond leasing individual circuits, wave-lengths or dark fibers
- *e-Infrastructures* as equalizers, reduce the **DIGITAL DIVIDES** in Europe & globally: **Big Science affordable via virtual e-Science**
- NRENs - GÉANT2 stimulate **Network Research** & enable novel concept evaluation - **emulations** in a global production environment via virtualization of facilities & services

Bandwidth Requirements per User

SERENATE Study Final Report, 2003

Cees De Laat, David Williams et. al.

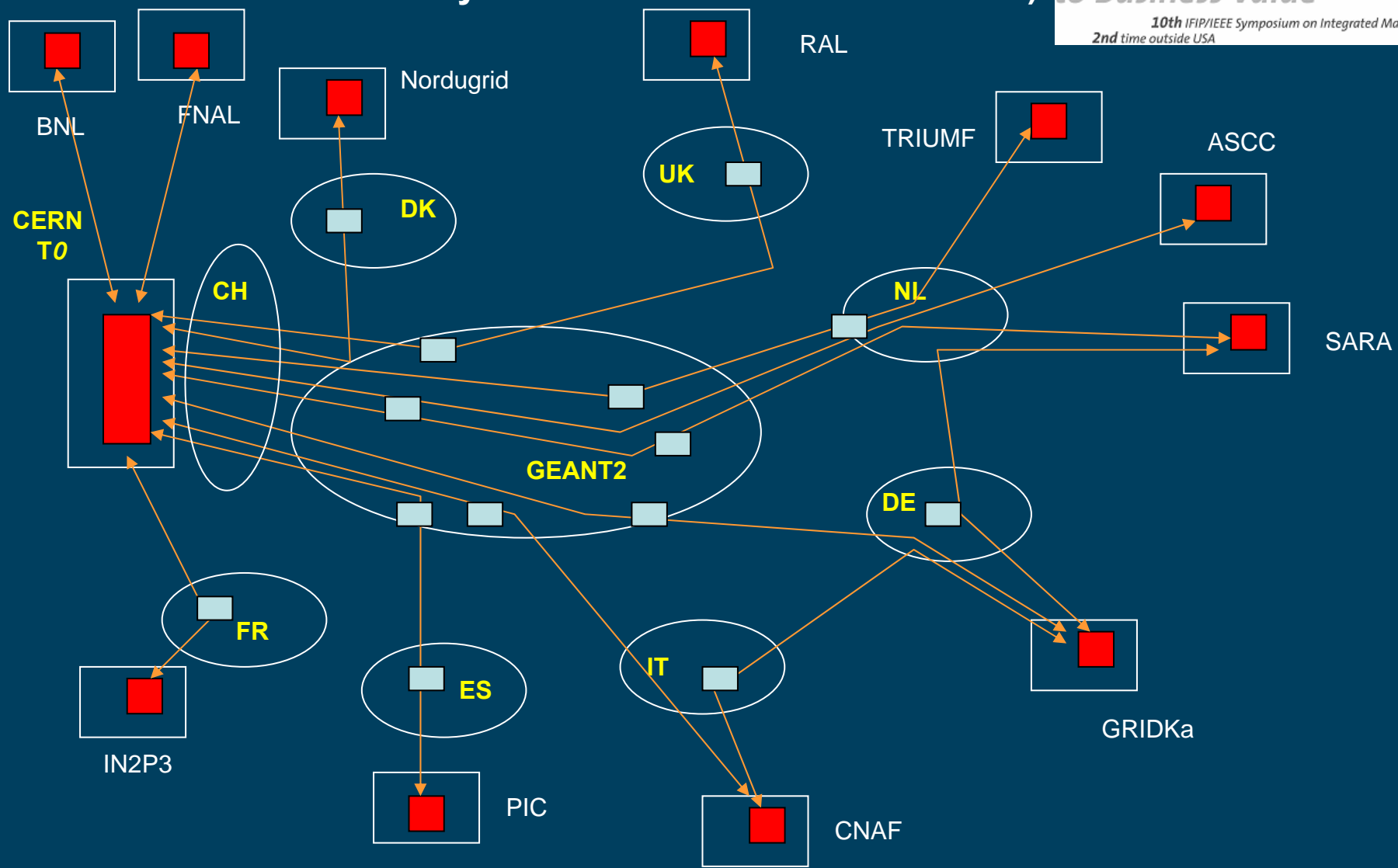
of users



ADSL

GigE

LHC TIER0 – TIER1 Optical Private Network - OPN, (Scenario based on work by **Roberto Sabatino** DANTE CTO)



GÉANT2 NOC Functionality

- IP NOC
- Transmission NOC
- Switching NOC
- E2ECU (end-to-end co-ordination unit)

e2e circuits typically span campuses, NREN's and GÉANT **multiple domains** of heterogeneous data & control planes (e.g. GigE's, SDH/GFP, 10 Gig LAN/WAN PHY)

LHC OPN T0-T1 Schema

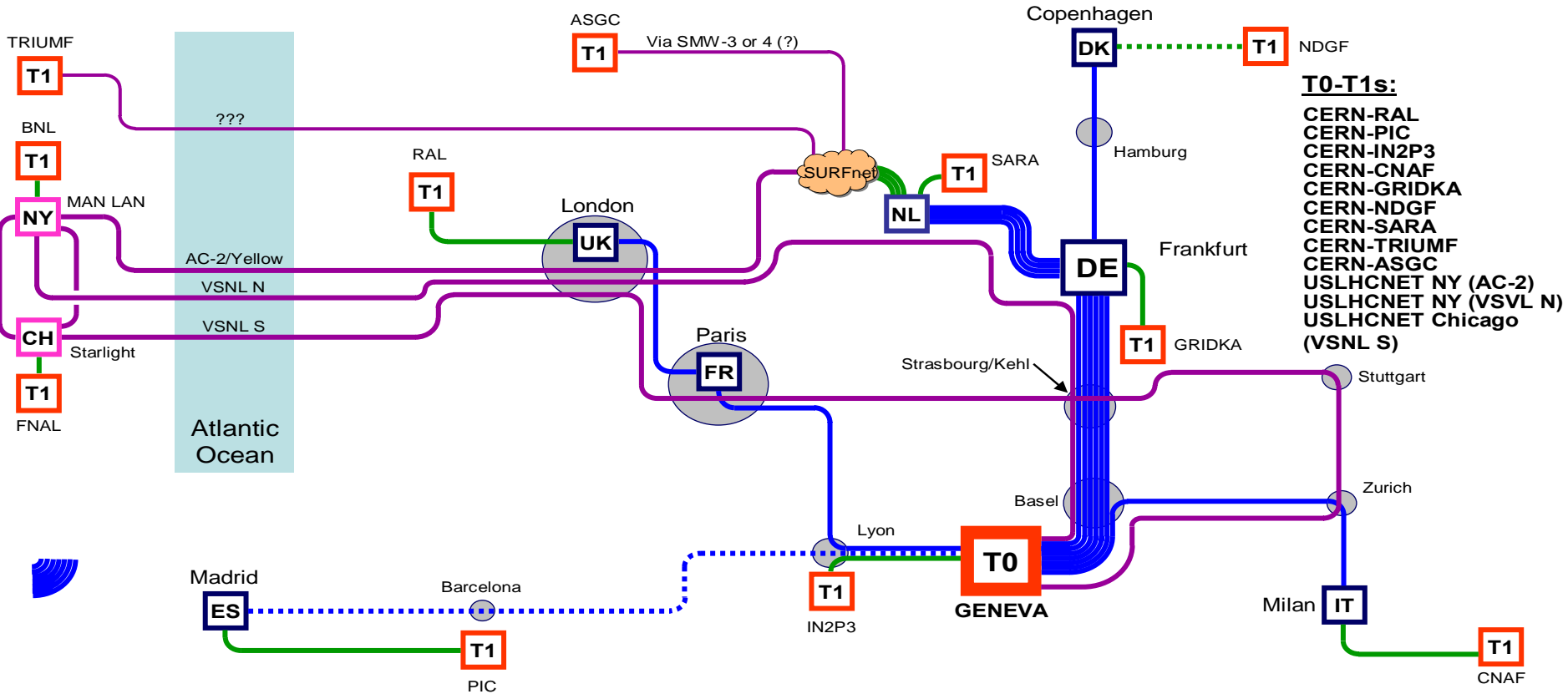
as presented by **Hans Döbbling**, DANTE GM
 (Based on material by **Michael Enrico**, DANTE &
 GN2/JRA4 Activity Leader)



T0-T1 Lambda routing (schematic) [v6]



Connect. Communicate. Collaborate



LHC OPN T1-T1 Schema

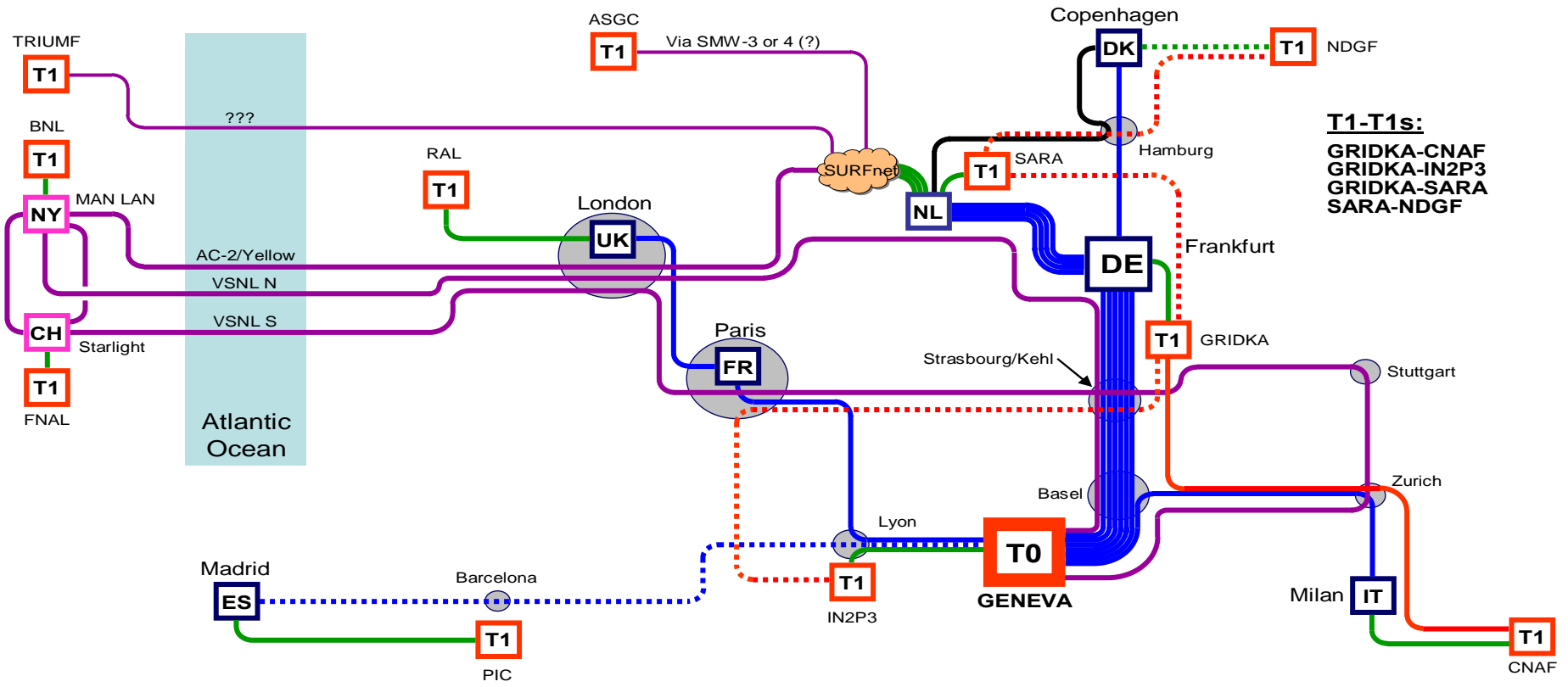
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T1-T1 Lambda routing (schematic) [v6]



Connect. Communicate. Collaborate



- T1-T1s:**
- GRIDKA-CNAF
 - GRIDKA-IN2P3
 - GRIDKA-SARA
 - SARA-NDGF

e2e Monitoring

- **perfSONAR** tools, mainly developed within **GN2/JRA1** + US (Internet2, ESNet...) + NREN's (DFN, CESNET...) + Academic Research Groups (Munich Network Management Team...)
 - Passive & active monitoring probes
 - Packet Switched IP measurements: Fault, Performance...
 - 10 Gig OPN's, E2EMON (**GN2/JRA4**)
 - Plan to add monitoring of Layer 2 GigE, SDH...
 - e2e Coordination Unit (E2ECU); include end-system (Grid) attributes?
 - Web services at North-bound interfaces
 - Visualization tools
- **Example: Multi-Domain Monitoring** for the LHC Optical Private Network

Experience in Multi-Domain Service Support in GÉANT2

(Based on material by **Toby Rodwell**, DANTE & GN2/SA3 Activity Leader)

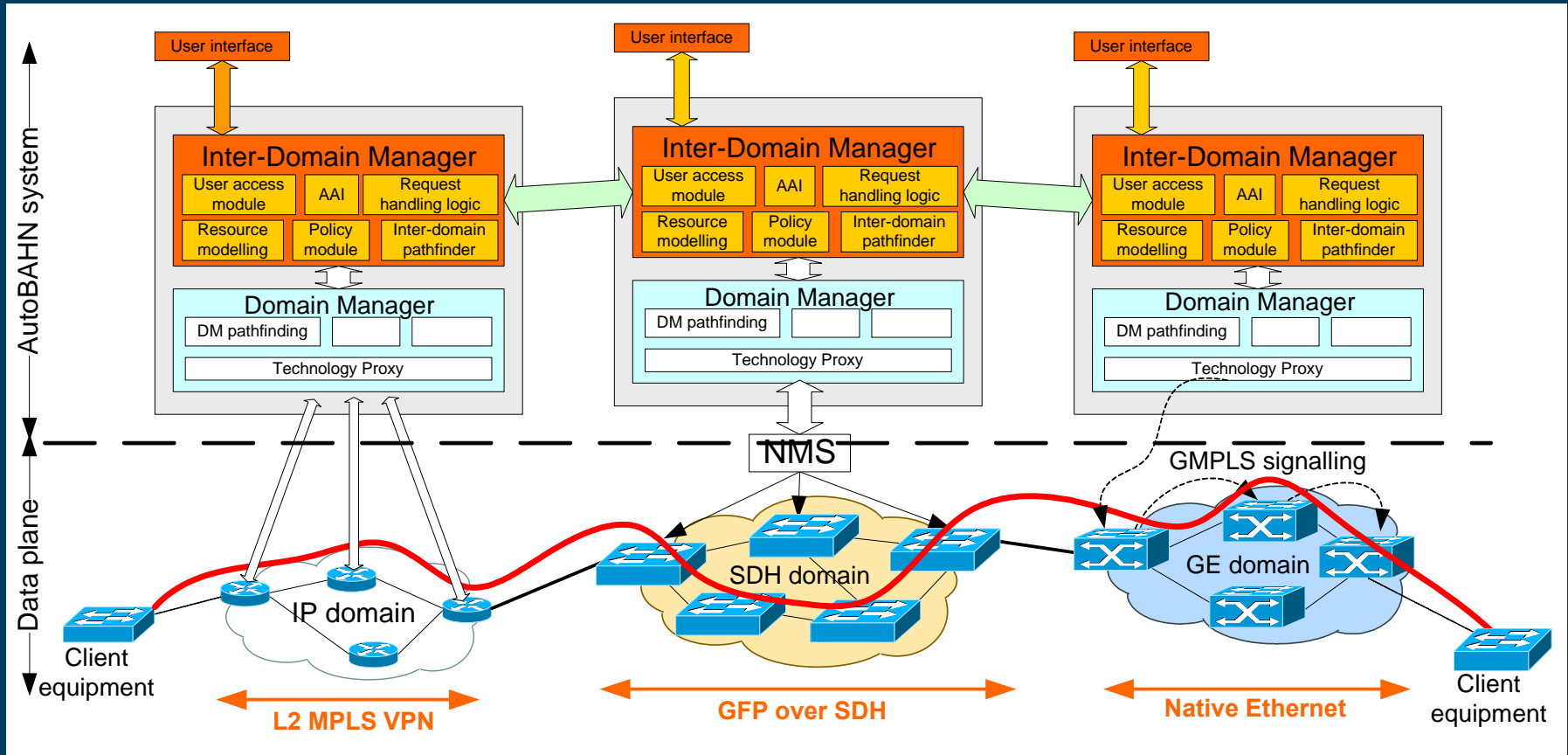
- Performance Enhancement & Response Team (**PERT**)
- Premium IP and Advance Multi-domain Provisioning System (**AMPS**)
 - AMPS installed in NREN's (5 in pilot phase, 15 underway)
 - Includes topology discovery module to simplify deployment
 - LSP extensions
- Network Performance - QoS Measurement Point (**MP**) network
 - Currently more than 10 HADES/BWCTL MP's deployed, plan to cover all GÉANT2 PoP's
- Common Network Information Service (**cNIS**)
 - A single & common schema of network topology information for use by all GÉANT2 applications (and others)
 - Packet-switched and circuit-switched topologies (as required)

Multi-Domain Provisioning: The *AutoBAHN* Concept (1/2)

(Based on material by *Afrodite Sevasti*, GRNET & GN2/JRA3 Activity Leader)

- Automated Bandwidth Allocation across Heterogeneous Networks: Bandwidth on Demand services for the NREN community
- The environment:
 - Multi-domain
 - Multiple technologies
 - Requirements for:
 - end-to-end non-contended capacity
 - a standardized interface for service requests at end-points
 - service level indication to end-users
 - advance reservation (scheduled)
- Integrating data and control plane functionality under a common business layer

Multi-Domain Provisioning: The AutoBAHN Concept (2/2)



Multi-Domain Hybrid Networks: The NREN/GÉANT Community Experience



- End-to-end (e2e) provisioning: Technically accomplished for **homogeneous** (Premium IP/DiffServ or MPLS/TE) domains
- Need to establish trust/coordination across domains:
 - Federated AAI (**JRA5 - eduGAIN**)
 - Coordination of Anomaly/Intrusion Detection & CERT's (**JRA 2**)
 - Monitoring (active/passive measurements, **JRA1 - perfSONAR**)
 - Bandwidth allocation/scheduling for IP networks (**SA3 - AMPS**)

Some Multi-Domain Challenges (1/2)

- Interoperability - stitching of data & control plane domains: GMPLS, ASON...
CAUTION: Multi-Domain MPLS failure – yet
- Multi-domain extensions of **cNIS (SA3, JRA4, JRA3 – cNIS)**
 - Support use of “on demand” GigE circuits
 - Integrate Cross Border Fibre links
 - Support for Multi-domain Monitoring
 - Failure Analysis
 - Error message correlation
 - Scheduled Maintenance Analysis

Some Multi-Domain Challenges (2/2)

- Investigation - prototyping of monitoring & provisioning across *heterogeneous* data & control plane domains at multiple protocol layers (**JRA1 – perfSONAR, JRA3 – autoBAHN**)
 - Integrate business layer for hierarchical (tier) & cross-border fiber (peer) topologies
 - Decide on addressing of Layer 1 & 2 Network Elements at the Control Plane (**IPv6?**)
 - Deploy passive – active MP's (including end-user campuses)
 - Infer simple topology models & evaluate e2e paths (e.g. extend BGP routing and TE/QoS provisioning for Layers 2-3?)

Some Multi-Domain Challenges: Disruptive Network Research via Virtualization

- **NRENs & GÉANT2** to support **disruptive** experiments within but in isolation to **production** IPv4/v6 & Circuit Switched services via virtualized/sliced R&D Lab interconnections
- Virtual Infrastructure Planning, Deployment and Operations
 - Topology planning, geared towards FP7 **Network of the Future** Projects: Need for a novel **business model virtual service provisioning**
 - Slicing of **production** NREN/GEANT substrate → **disruptive** virtualized environment
 - WDM 10 GigE Optical Private Networks, GigE - SDH slicing
 - MPLS, Premium IP VPNs
 - Installation of virtualized Open Source – logical Programmable Routers & Multi-Protocol Service Switches, isolated from production facilities in selected **core NREN & GÉANT PoP's**
- Collaboration with US Network of the Future initiatives (**NSF GENI**)
- **Need to strengthen multi-stakeholder cooperation in Europe (NREN's, Users, Academic & Industrial Networking R&D Labs, Related Vendors & Service Providers)**

ICT e-Infrastructures: A CONCERTED EUROPEAN EFFORT

Research Networking & HPC/GRID communities common mission:

Provision of leading edge *e-Infrastructures* for
Research & Advancement of HPCN technologies as
European added value

Related Links

- www.geant2.net
- www.dante.net
- For latest news and fact-sheets
<http://www.geant2.net/media>
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<http://www.geant2.net/research>