

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

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# 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

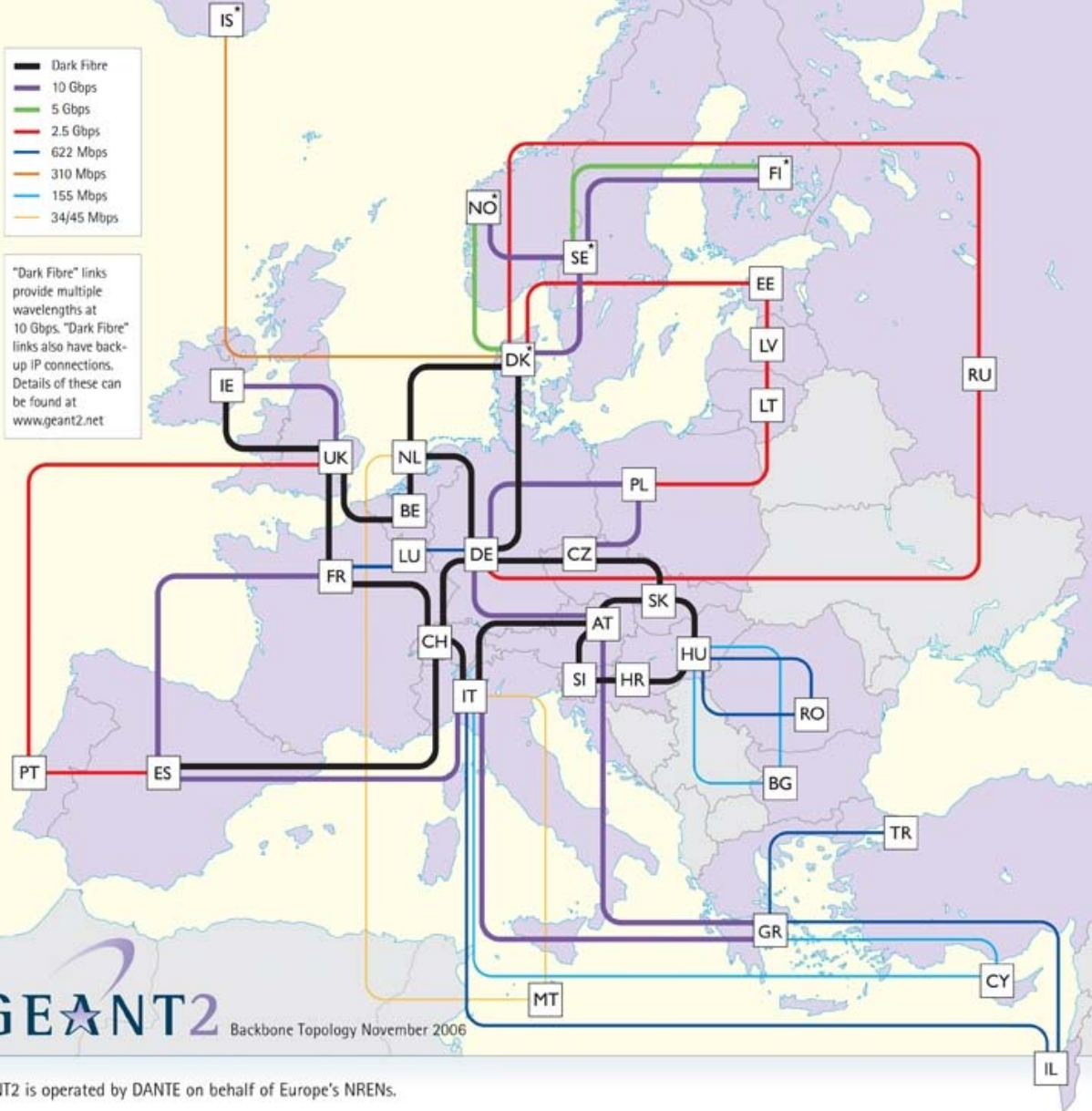
- Century old Telecom (+ 40 years ARPAnet - Internet) experience: Proven strong **“Network Externalities”** → Sharing tradition
- Industry needs for **Next Generation Network** proofs of concept, synergy with R&E community: The ARPAnet paradigm @ the US of America, inspiring the **“US of Europe”**
- **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

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**)
  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**)
- PLUS NON-VOTING MEMBERS:**  
Delivery of Advanced Network Technologies to Europe Ltd. (**DANTE**)  
Trans-European Research & Education Networking Association (**TERENA**)
- PERMANENT OBSERVERS: CERN, AMRES, MARNET**

- Dark Fibre
- 10 Gbps
- 5 Gbps
- 2.5 Gbps
- 622 Mbps
- 310 Mbps
- 155 Mbps
- 34/45 Mbps

"Dark Fibre" links provide multiple wavelengths at 10 Gbps. "Dark Fibre" links also have backup IP connections. Details of these can be found at [www.geant2.net](http://www.geant2.net)



GEANT2 Backbone Topology November 2006

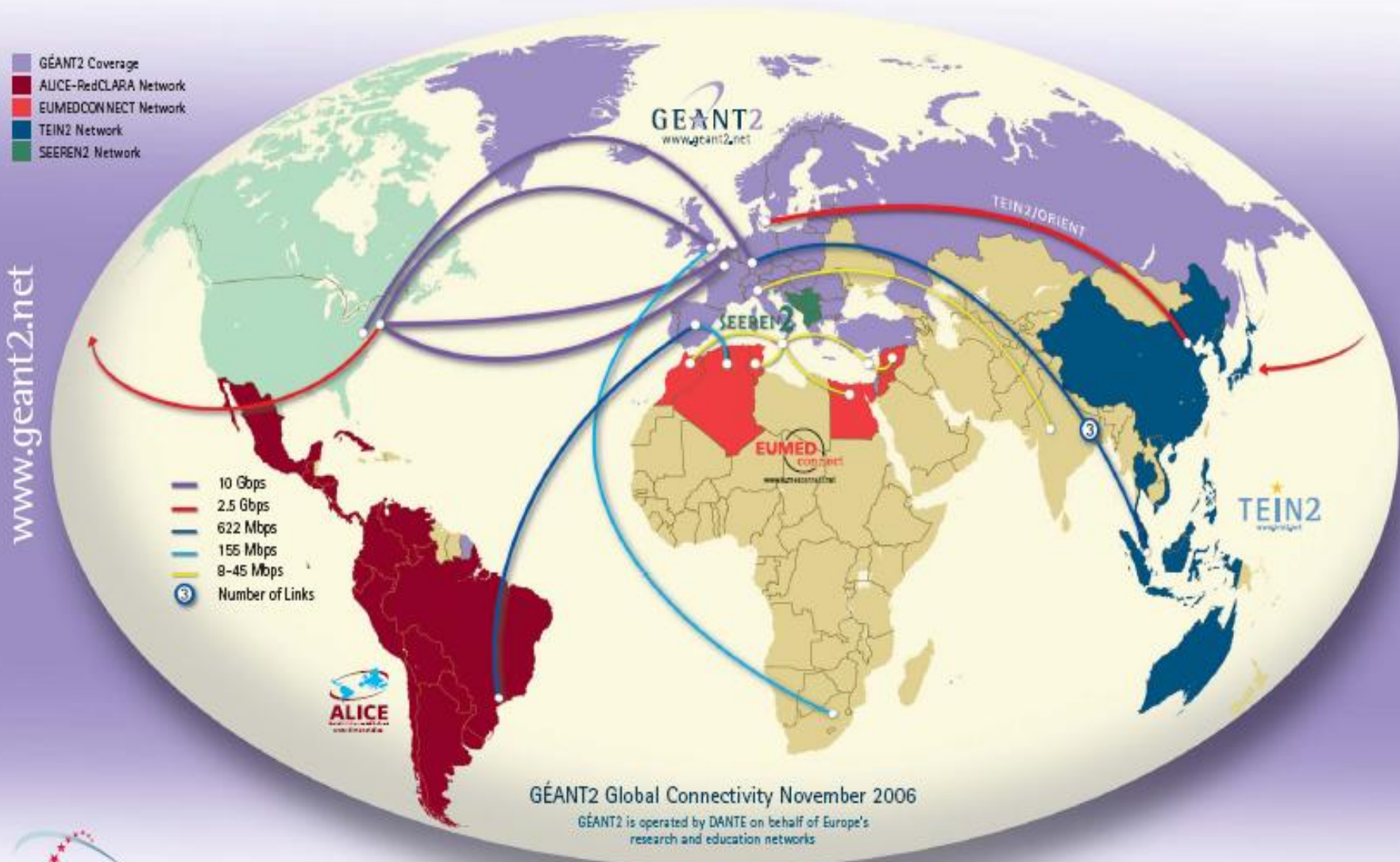
GEANT2 is operated by DANTE on behalf of Europe's NRENs.

# GEANT2 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



GEANT2 Global Connectivity November 2006  
 GEANT2 is operated by DANTE on behalf of Europe's research and education networks

# The GÉANT2 $\alpha\beta$ Soup



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

# 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.*

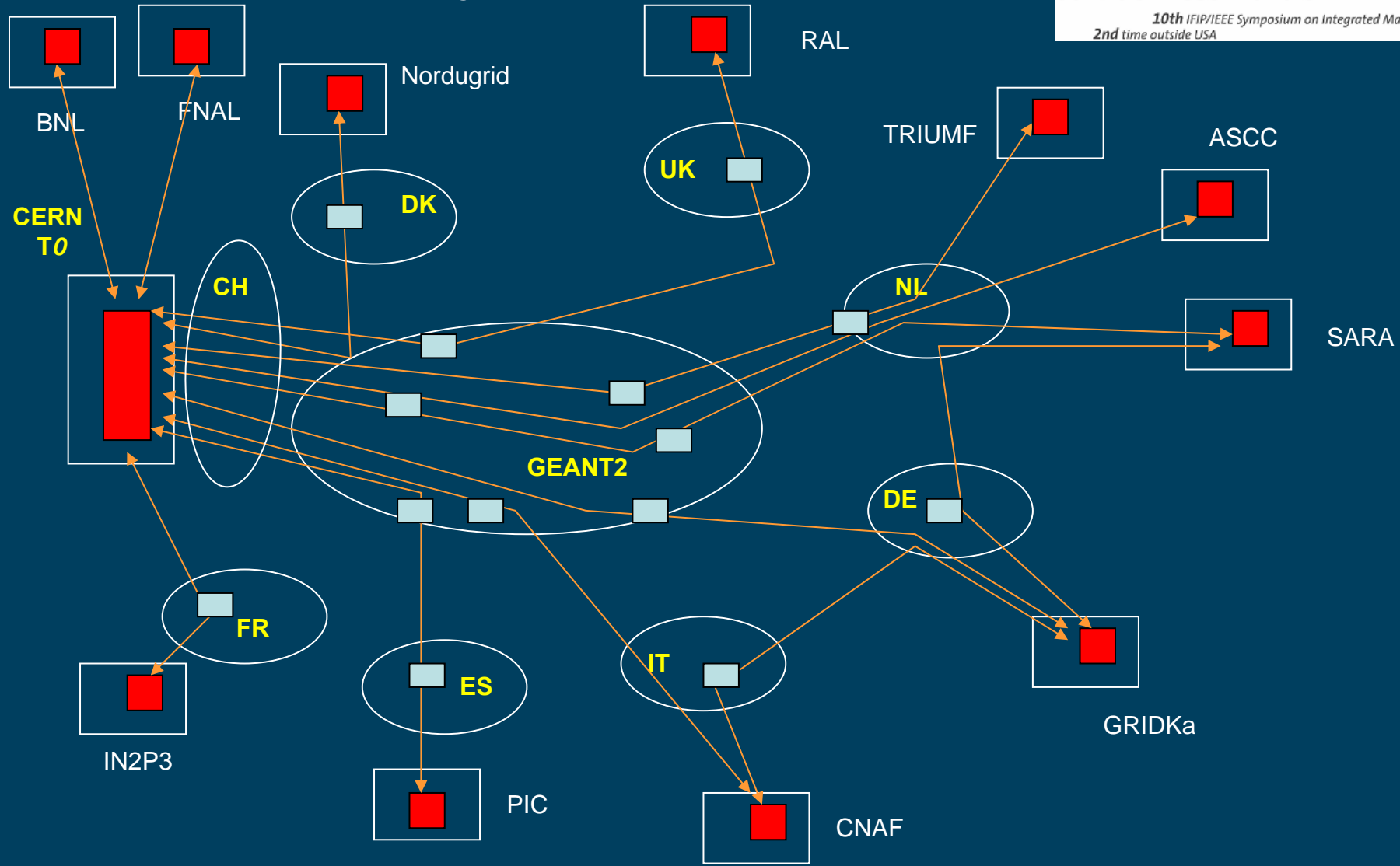
# of users



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

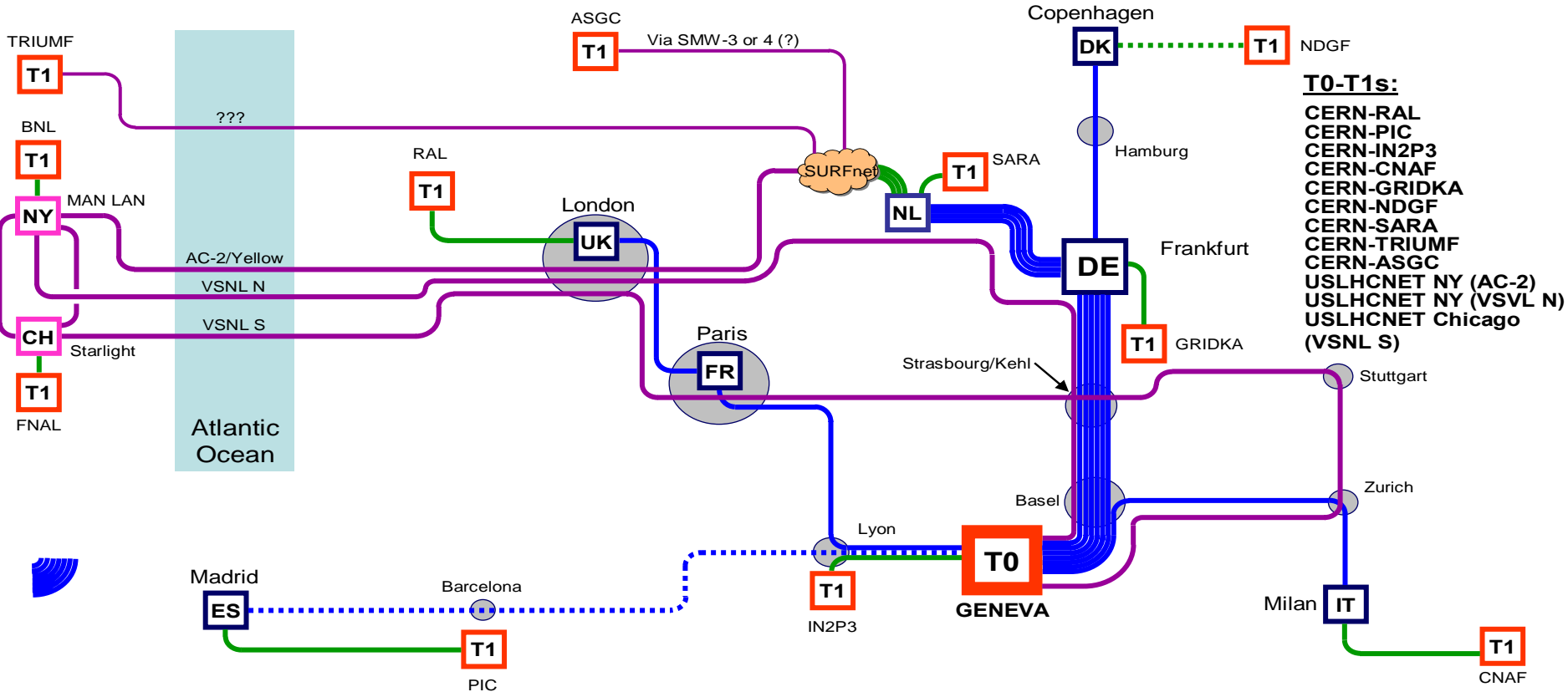
as presented by **Hans Döbbling**, DANTE GM  
 (Based on material by **Michael Enrico**, DANTE &  
 GN2/JRA4 Activity Leader)



## T0-T1 Lambda routing (schematic) [v6]



Connect. Communicate. Collaborate



# LHC OPN T1-T1 Schema

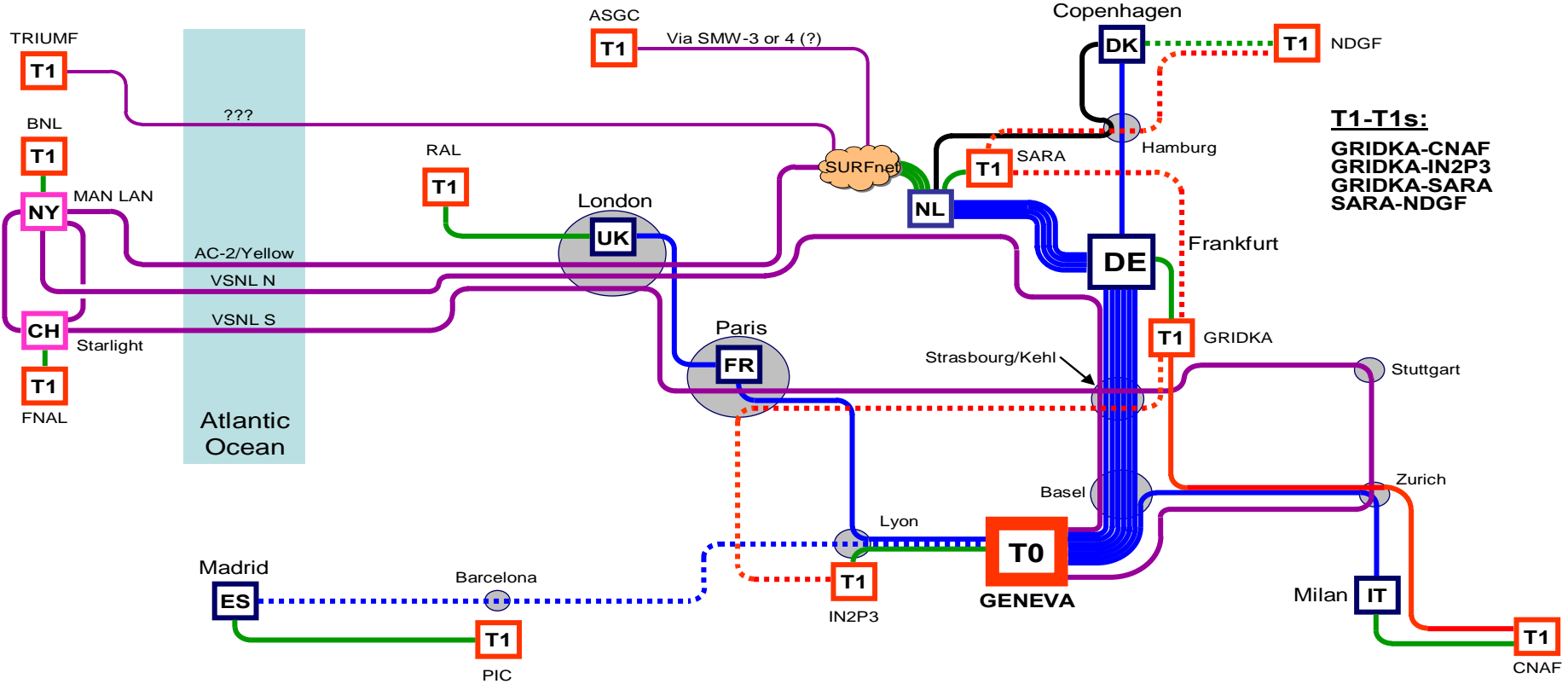
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## T1-T1 Lambda routing (schematic) [v6]



Connect. Communicate. Collaborate



# 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)

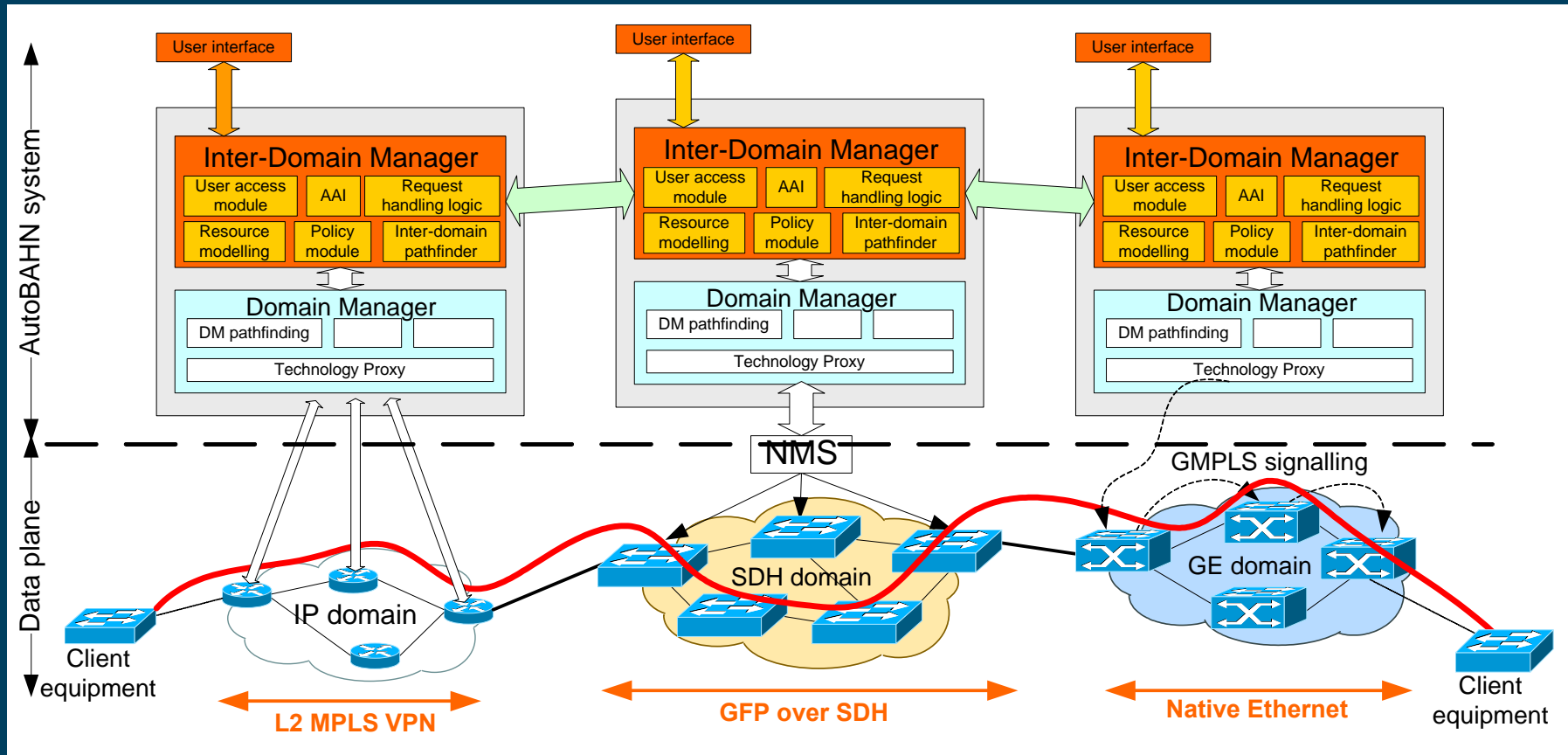
- Performance Enhancement & Response Team (**PERT**)
- Premium IP and Advance Multi-domain Provisioning System (**AMPS**)
  - AMPS installed in NREN's (5 in pilot phase, 15 underway)
  - Includes topology discovery module to simplify deployment
  - LSP extensions
- Network Performance - QoS Measurement 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](http://www.geant2.net)
- [www.dante.net](http://www.dante.net)
- For latest news and fact-sheets  
<http://www.geant2.net/media>
- For research activities  
<http://www.geant2.net/research>