Consortium GARR

***Frontier Science 2005***
***New Frontiers in Subnuclear Physics***

# GARR and the Research Networks


*Enzo Valente*
*INFN and GARR*


INFN Istituto Nazionale di Fisica Nucleare

# Challenges of Next Generation Science in the Information Age

*Petabytes of complex data explored and analyzed by 100s-1000s of globally dispersed scientists, in 10s-100s of teams*

- Flagship Applications
  - High Energy & Nuclear Physics, AstroPhysics Sky Surveys: TByte to PByte "block" transfers at 1-10+ Gbps
  - Fusion Energy: Time Critical Burst-Data Distribution; Distributed Plasma Simulations, Visualization, Analysis
  - eVLBI: Many (quasi-) real time data streams at 1-10 Gbps
  - BioInformatics, Clinical Imaging: GByte images on demand
- Advanced integrated Grid applications rely on reliable, high performance operation of our LANs and WANs
- *Analysis Challenge:* Provide results with rapid turnaround, over networks of varying capability in different world regions

# The Global Networks for Collaborative Science

- *National and International Networks, with sufficient (rapidly increasing) capacity and seamless end-to-end capability, are essential for*
  - *The daily conduct of collaborative work in both experiment and theory*
  - *Experiment development & construction on a global scale*
  - *Grid systems supporting analysis involving scientists in all world regions*
  - *The conception, design and implementation of next generation facilities as "global networks"*
- *"Collaborations on this scale would never have been attempted, if they could not rely on excellent networks"*

# NREN: the National Research and Education Networks

•3 million+ scientists and researchers in 34 countries in Europe

•Projects with ‘demanding’requirements
–International user groups
–High bandwidth requirements
–Specialised service requirements

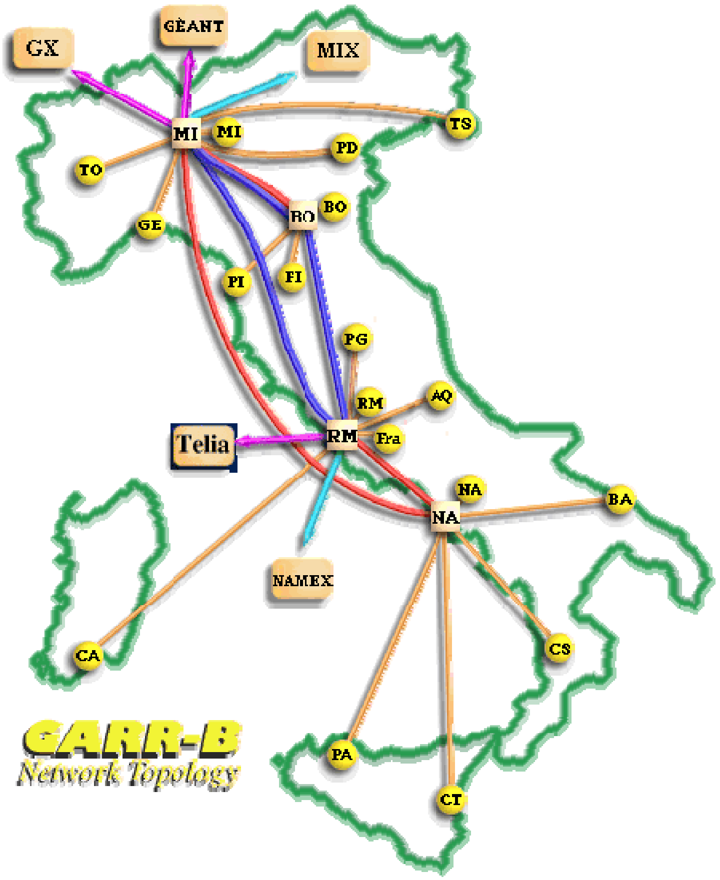
•Custom solutions for the particular user group
•To manage the lifecycle of the networking aspects of each user project
•Customer focused

# The GARR Network history

- GARR means:
  - **Harmonization and Synergy between Academy and Research**

- **1973-1990:** CNR, ENEA,INFN and Universities independent Networks
- **1989: GARR set up as virtual Consortium**
- **1990-1994: GARR-1**, first common network at 2Mbps
- **1994-1998**: **GARR-2**, GARR-1 evolution to 34Mbps
- **1998-2003**: **GARR-B** (Broadband) at 155Mbps
- **2001: Consortium GARR becomes a legal entity**
- **2003-2006: GARR-G** (Giganet) at 2.5-10Gbps

# GARR-B(roadband) (1998-2002)




Backbone at
2.5G and 155M

Accesses
up to 155M

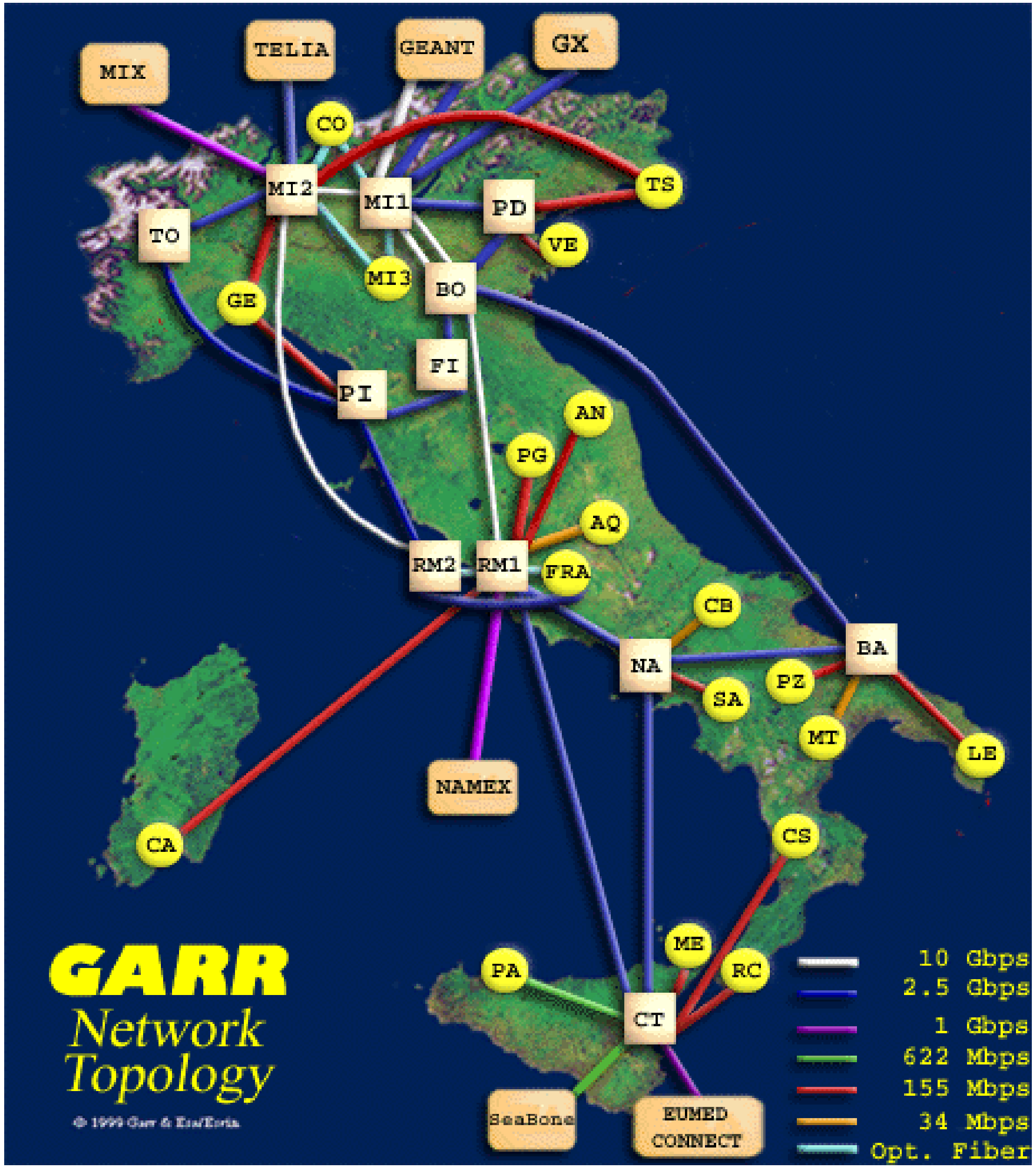
The GARR-G backbone

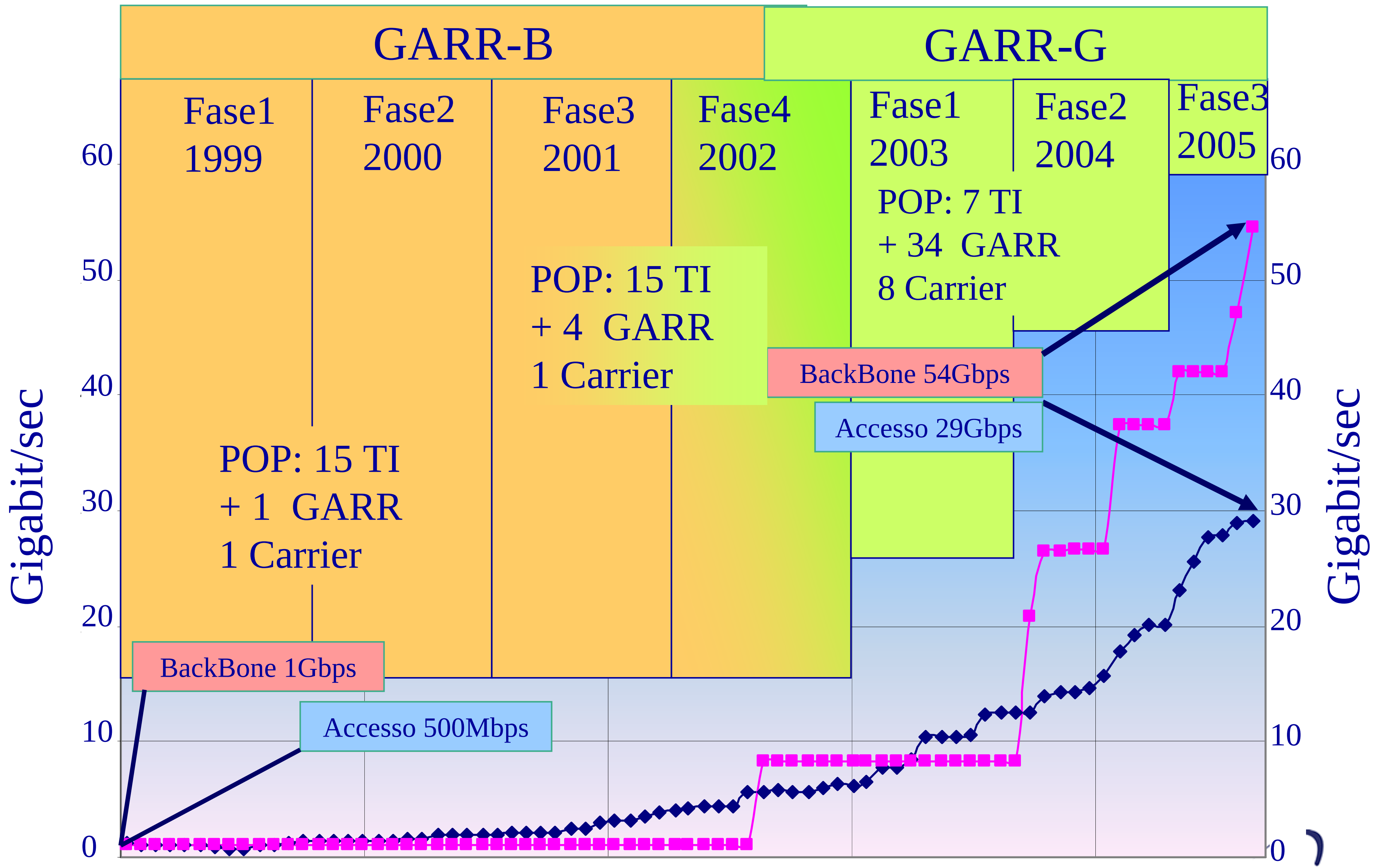
(Sep-Dec 2005)

Backbone at 2.5G and 10G

Wavelenghts and dark fibres

Accesses up to 1G



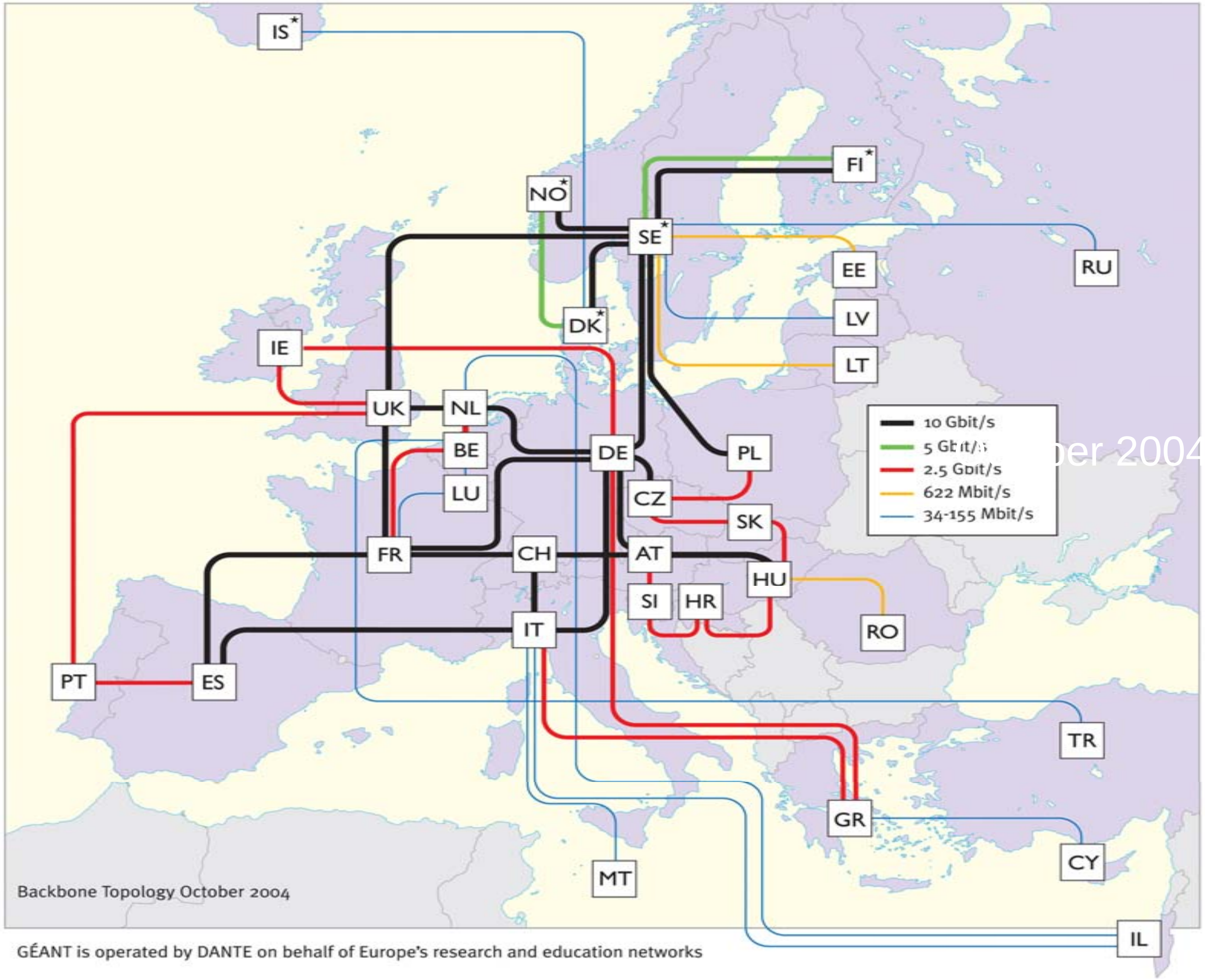

GARR-B
GARR-G
Fase1
1999
Fase2
2000
Fase3
2001
Fase4
2002
Fase1
2003
Fase2
2004
Fase3
2005
POP: 15 TI
+ 1 GARR
1 Carrier
POP: 15 TI
+ 4 GARR
1 Carrier
POP: 7 TI
+ 34 GARR
8 Carrier
BackBone 54Gbps
Accesso 29Gbps
BackBone 1Gbps
Accesso 500Mbps
Gigabit/sec
0
10
20
30
40
50
60

# International Collaborations on Networking

- DANTE, TERENA, Internet2

- European R&D and infrastructural Projects:
  - GEANT/GEANT2, EGEE/EGEE2 (Research Infrastructures)
  - EUMedconnect, ALICE, TEIN-2 , Orient (China)
  - EU-Med-Grid, EU-ChinaGrid, EU-India-Grid, EELA
  - MUPBed (GMPLS)

# GEANT Network in 2004



# Evolution of European Research Networks

Pan-European Research Network:

| | | | | |
|---|---|---|---|---|
| GEANT2 | 2004-2008 | 34 countries | dark fibre and wavelenghts | |
| GÉANT | 2001-2004 | 32 countries | 2.5-10 Gbps Backbone | IP |
| TEN-155 | 1998-2001 | 19 countries | 155-622 Mbps Backbone | IP, ATM |
| TEN-34 | 1997-1998 | 18 countries | 34 Mbps Backbone | IP, ATM |
| EuropaNET | 1993-1997 | 18 countries | 2 Mbps Backbone | IP, CDN |
| COSINE | 1986-1993 | 15 countries | 64 Kbps Backbone | IP, X25 |

- TEN-34 network emerged from the TEN-34 project in 1997. The accompanying Advanced ATM Testing programme was carried out by Task Force TEN (TF-TEN).
- The QUANTUM project produced the TEN-155 network in 1998; its accompanying testing programme is called QUANTUM Testing Programme (QTP), carried out by Task Force TANT (TF-TANT, Testing of Advanced Networking Technologies).
- In the case of GÉANT, the project and network will carry the same name. The Managed Bandwidth Service and the testing programme will be continued as part of GÉANT, the latter by TF-NGN (Task Force New Generation Networks) and by other projects like SEQUIN.

# GN1/GN2: A European Model

- 30 National Research & Education Networks-NRENs of the extended European Research Area (ERA)
- More than 3000 Research & Education Institutions
- Millions of end-users + *eScience* Projects (e.g. Grids) under *Accepted Usage Policy* (AUP) rules
- A 3-tier Federal Architecture, subsidized by National and EU Research & Education funds:
  - **The Campus Network (LAN/MAN)**
  - **The NREN (MAN/WAN)**
  - **The Pan-European Interconnection: TEN34 → TEN155 → GÉANT (GN1 in FP5) → GÉANT2 (GN2 in FP6)**

  **NREN Policy Committee, DANTE, TERENA**

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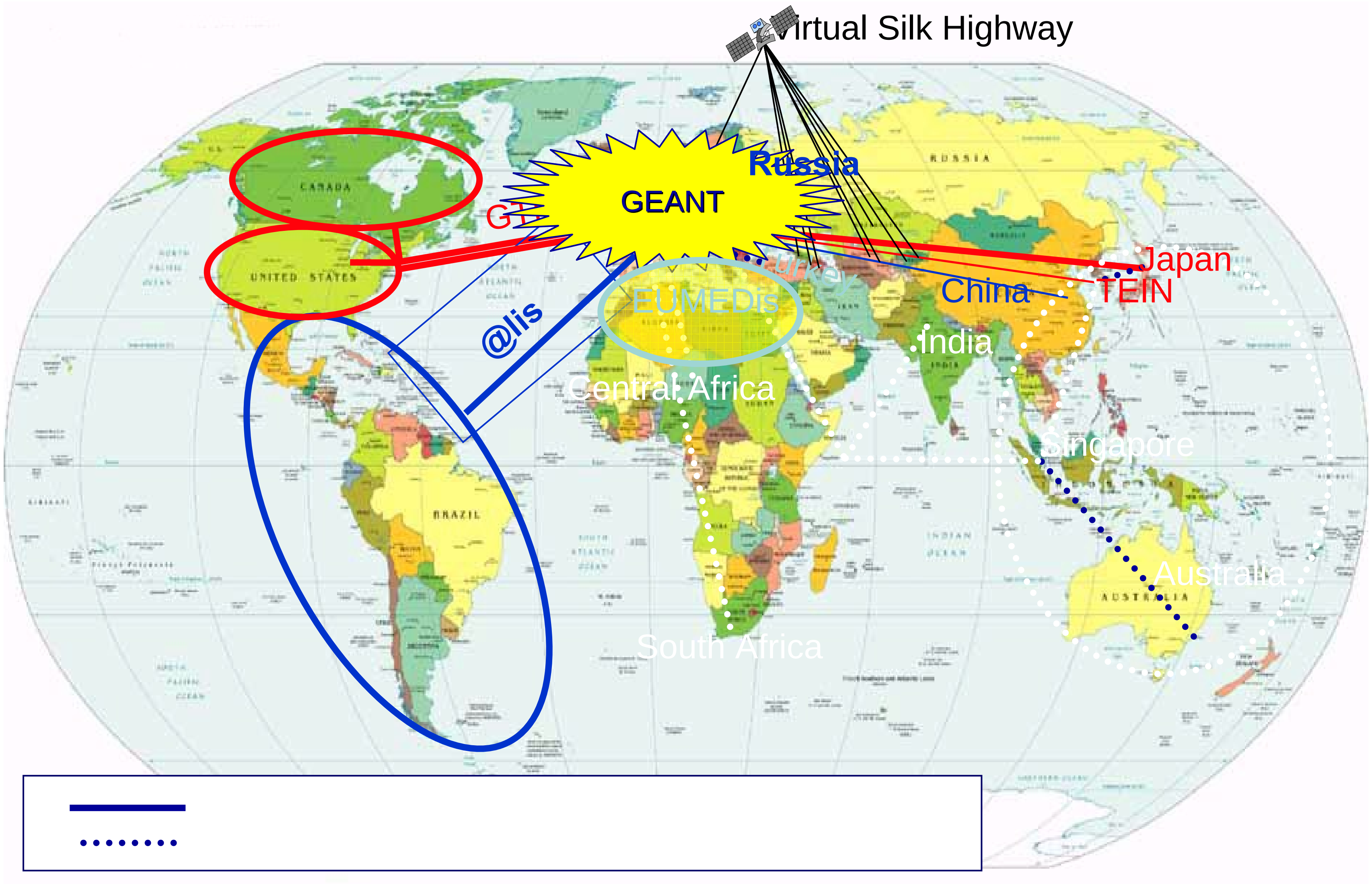
# The NREN PC

| | |
|---|---|
| Austria (ACOnet)<br>Belgium (BELNET)<br>Bulgaria (ISTF)<br>Croatia (CARNet)<br>Czech Republic (CESNET)<br>Cyprus (CYNET)<br>Germany (DFN)<br>Estonia (EENet)<br>Fance (RENATER)<br>Greece (GRNET)<br>Hungary (HUNGARNET)<br>Ireland (HEANet)<br>Israel (IUCC)<br>Italy (GARR)<br>Latvia (LATNET)<br>Lithuania (LITNET)<br>Luxembourg (RESTENA)<br>Malta (UoM) | Netherlands (SURFNET)<br>Nordic Countries – Denmark, Finland, Iceland, Norway, Sweden (NORDUNET)<br>Poland (PSNC)<br>Portugal (FCCN)<br>Romania (RoEduNet)<br>Russia (JSCC)<br>Slovakia (SANET)<br>Slovenia (ARNES)<br>Spain (RedIRIS)<br>Switzerland (SWITCH)<br>Turkey (ULAKBIM)<br>United Kingdom (UKERNA)<br>PLUS NON-VOTING MEMBERS:<br>Delivery of Advanced Network Technologies to Europe Ltd. (DANTE)<br>Trans-European Research & Education Networking Association (TERENA)<br>PERMANENT OBSERVERS: CERN, AMREJ, MARNET |

# GEANT Global Connectivity

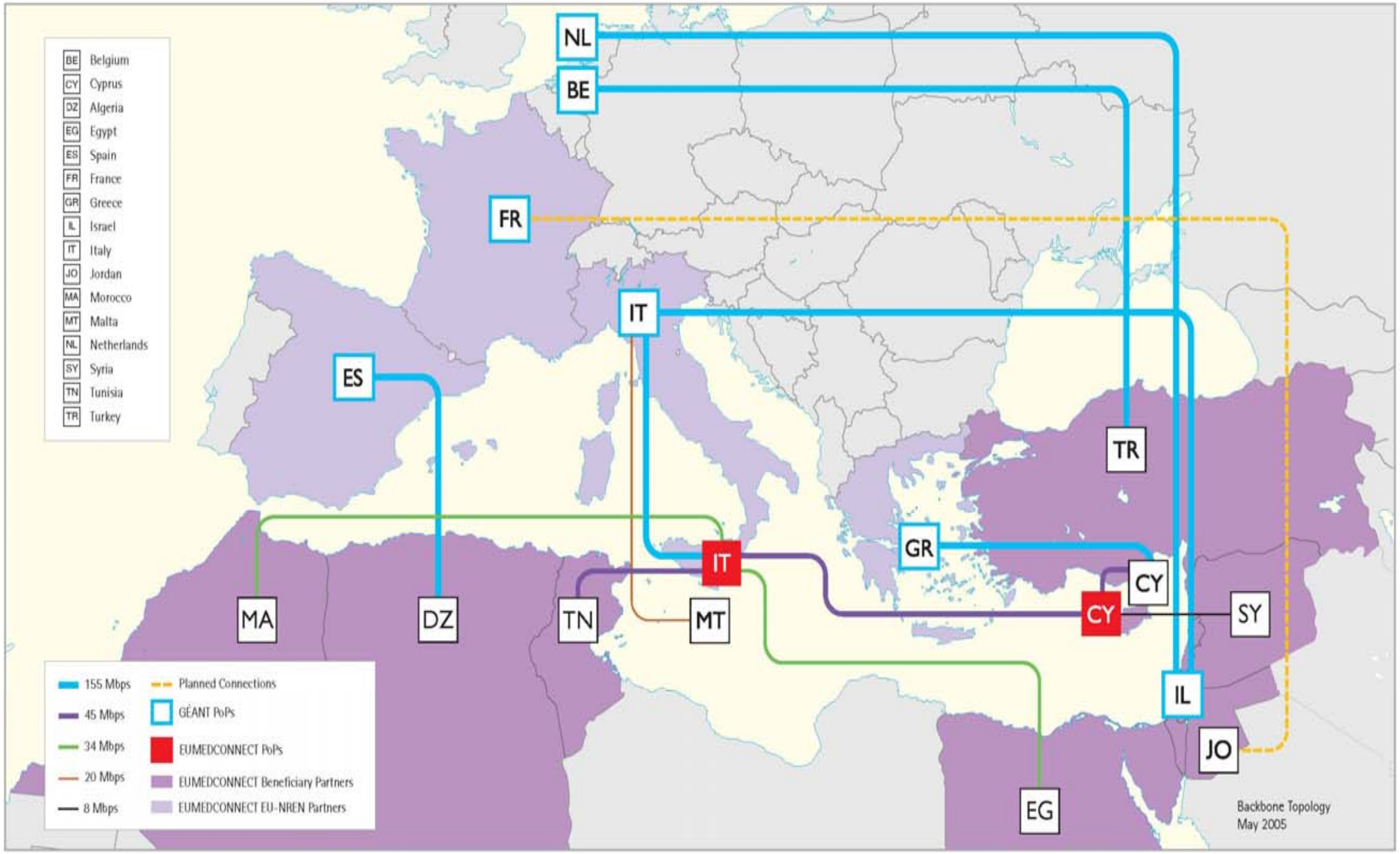


# GEANT Global Connectivity

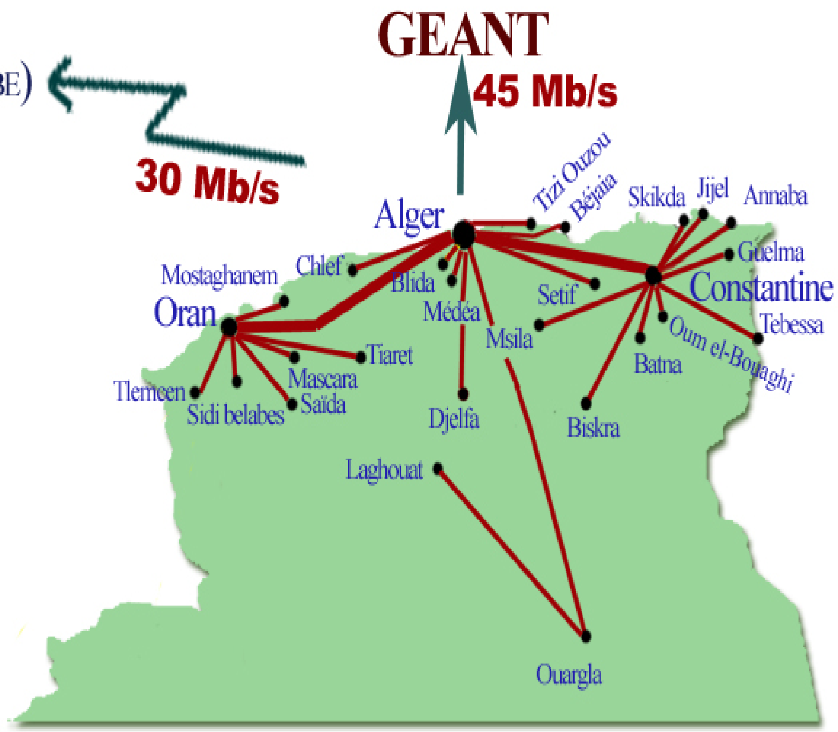
- 10 Gbps + 3x2.5 Gbps to North America
- 2.5 Gbps to Japan
- 622 Mbps to South America
- 622 Mbps to Mediterranean countries
- 155 Mbps to South Africa

Will be Improved in GEANT2

# GÉANT Global Connectivity


BE Belgium
CY Cyprus
DZ Algeria
EG Egypt
ES Spain
FR France
GR Greece
IL Israel
IT Italy
JO Jordan
MA Morocco
MT Malta
NL Netherlands
SY Syria
TN Tunisia
TR Turkey
NL
BE
FR
IT
ES
TR
GR
CY
CY
SY
IT
MA
DZ
TN
MT
IL
JO
EG
155 Mbps
45 Mbps
34 Mbps
20 Mbps
8 Mbps
Planned Connections
GÉANT PoPs
EUMEDCONNECT PoPs
EUMEDCONNECT Beneficiary Partners
EUMEDCONNECT EU-NREN Partners
Backbone Topology
May 2005

# MED NREN networks rapidly developing: e.g. 1 Algeria (ARN network)




**Alger**

| | |
|---|---|
| MESRS | Université d'Alger |
| USTHB | ENP |
| EPAU | INI |
| ENA | ENS-Kouba |
| CDTA | ENS-Bouzareah |
| ANDRU | ENTP |
| INA | CREAD |
| CDER | INC |
| CRAAG | UFC |
| ISMAL | INPS |
| ENV | CGS |

**Oran**

| | |
|---|---|
| USTO | Université Esenia |
| CRASC | ENSET |
| ANDRS | ITO |

**Constantine**

Université Emir AEK
Université de constantine
ENS Constantine

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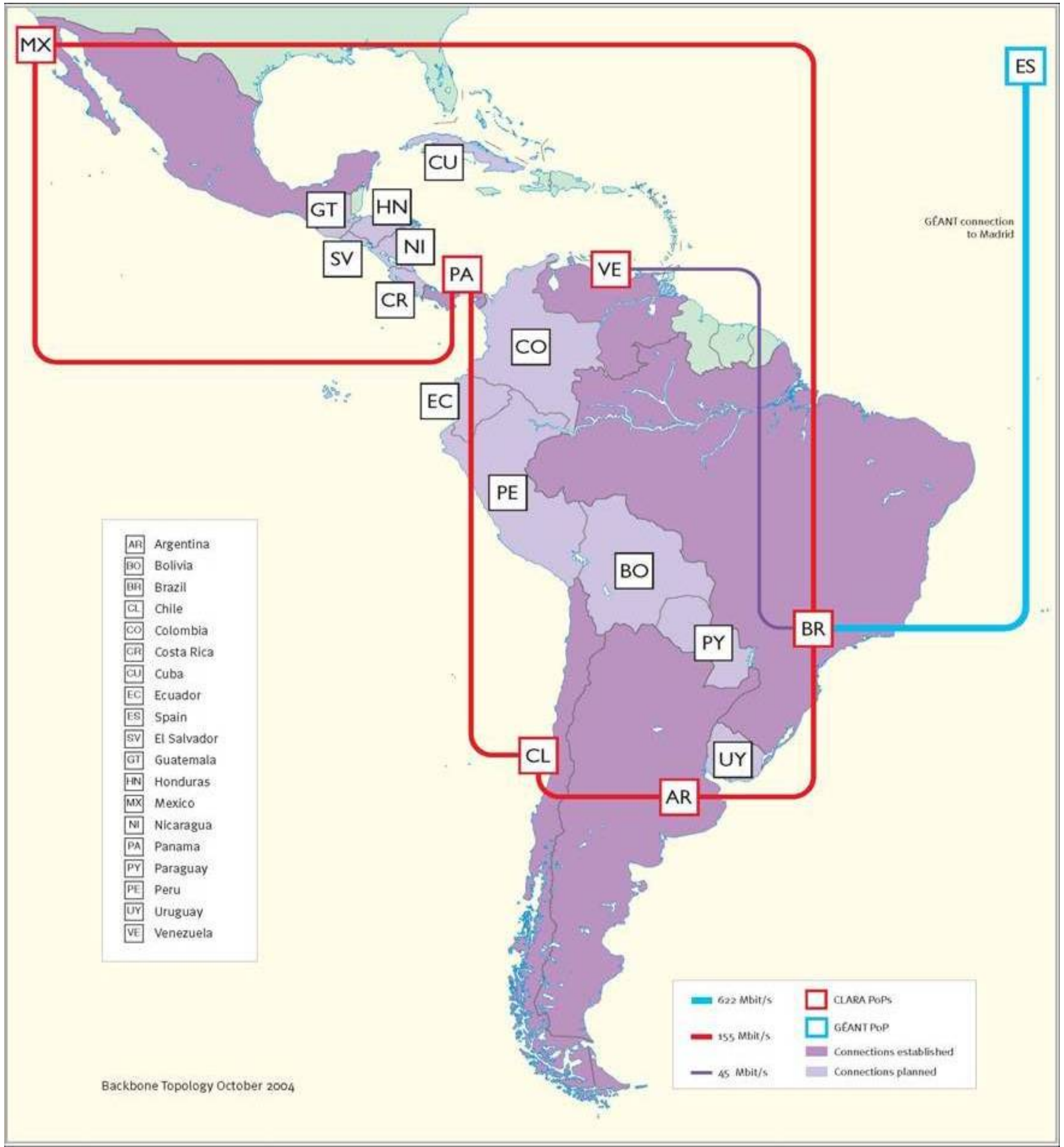
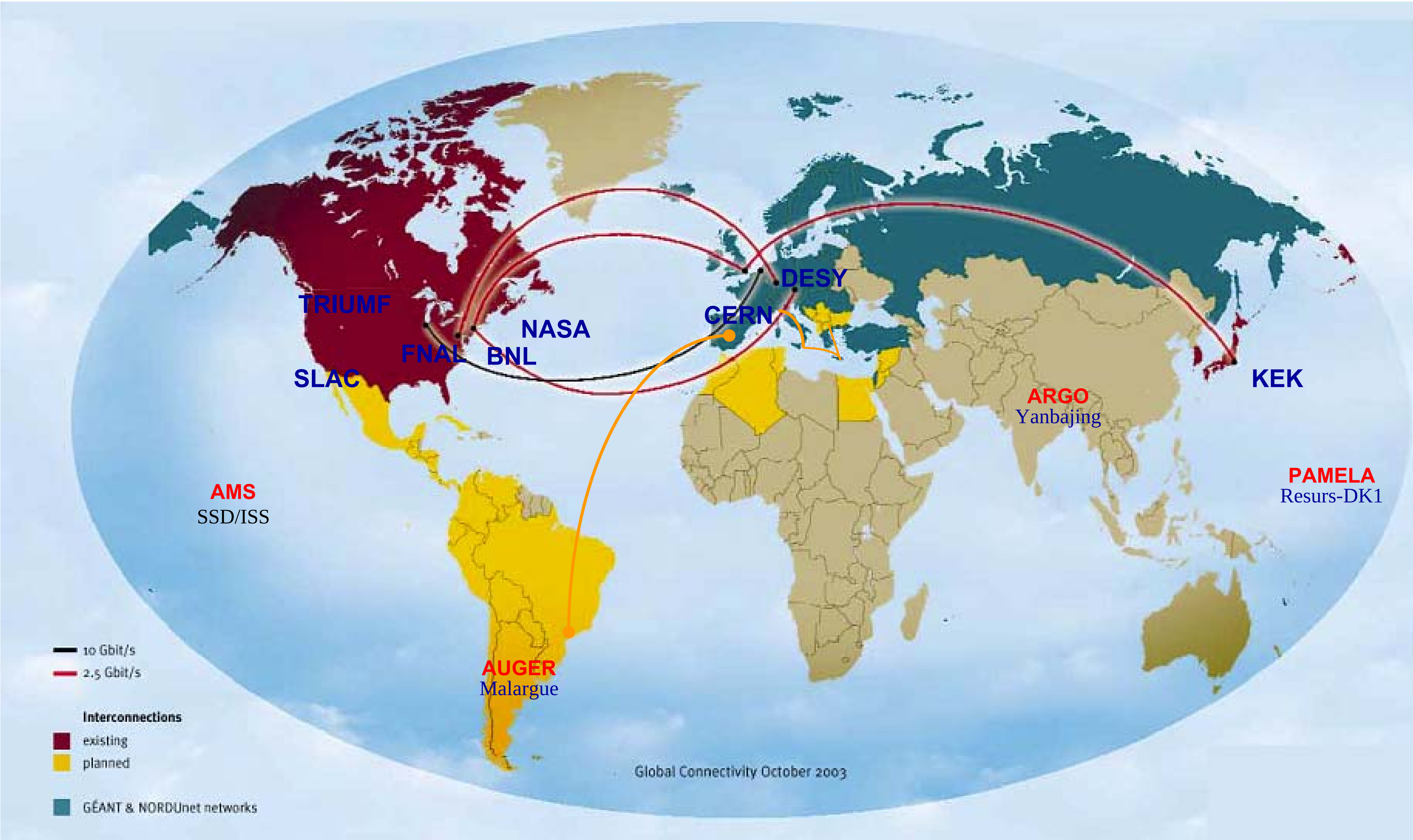



ALICE
America Latina Interconectada Con Europa

INFN
Istituto Nazionale di Fisica Nucleare

# Sites relevant to HEP



# GN2 project

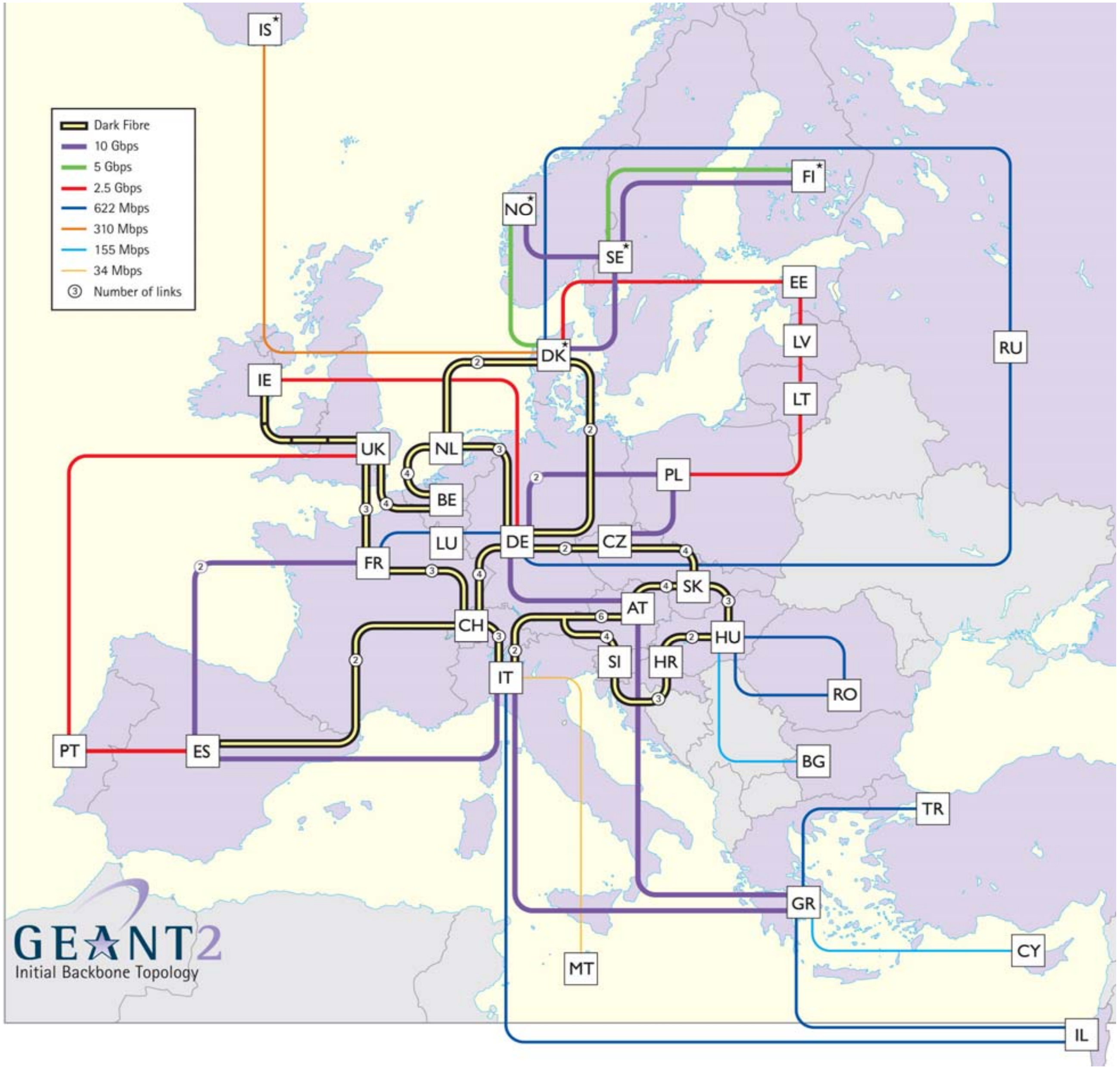
- Co-funded by the European Commission (EC) as an Integrated Infrastructure Initiative (6th Framework Program for RTD)
  - Combining in a single contract, several activities essential to reinforce research infrastructures and to provide an integrated service at the European level
    - Networking activities
    - Provision of access to transnational users
    - Joint Research Activities
- 32 partners
  - 30 NRENs + DANTE + TERENA
- Total budget: 178.643.730 €
- EC contribution: 93.000.000 €
- Duration: 4 years (Sep 2004 – Aug 2008)

The EU (GN2) subsidy covers < 1% of the total Research & Education Networking European Infrastructure:

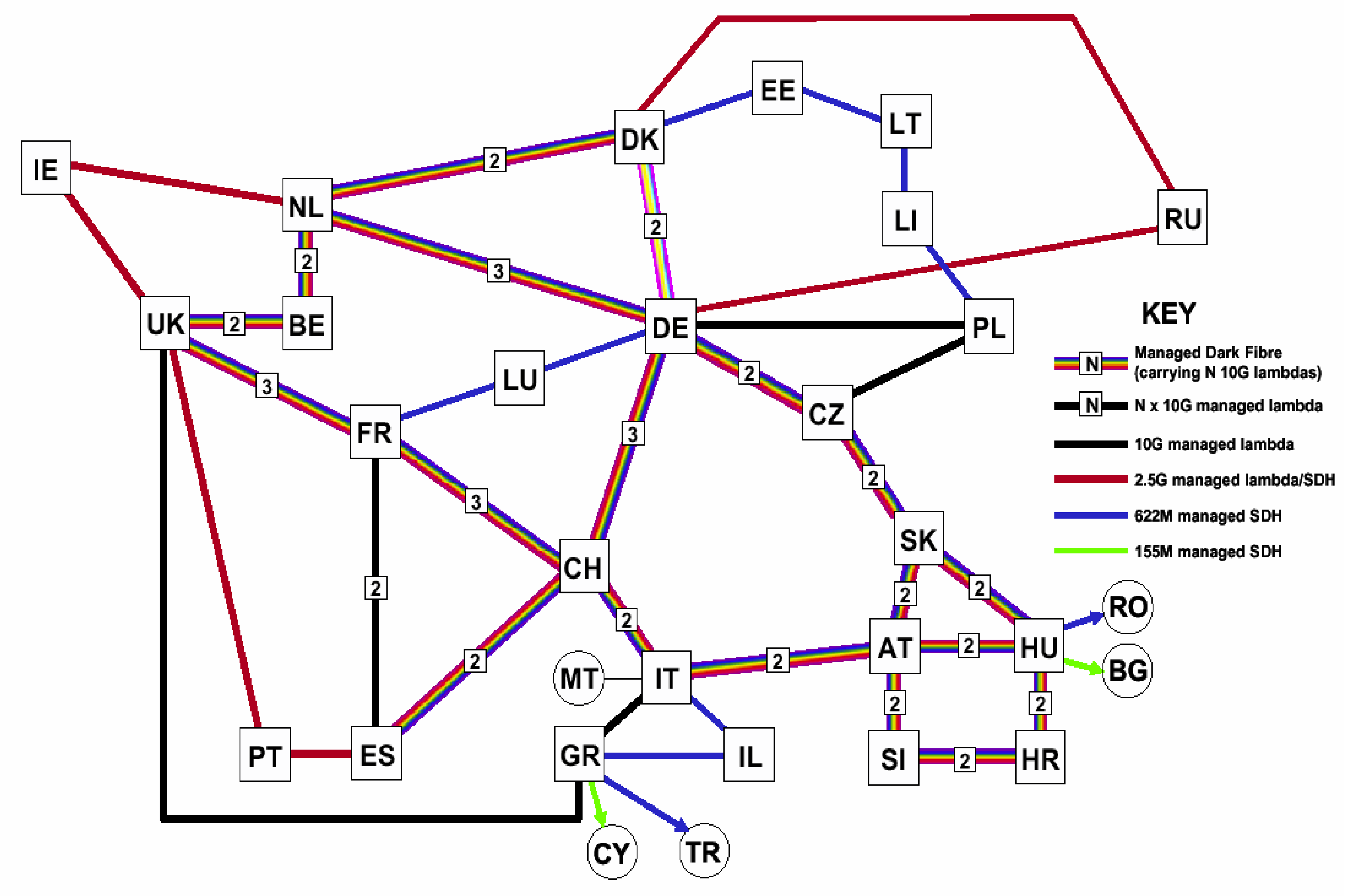
Campus LAN / MAN-WAN NREN / GÉANT-GÉANT2

***(Assuming Cost factoring 100 / 10 / 1)***

# GEANT2 2005


Dark Fibre
10 Gbps
5 Gbps
2.5 Gbps
622 Mbps
310 Mbps
155 Mbps
34 Mbps
Number of links
IS*
NO*
FI*
SE*
EE
LV
LT
RU
DK*
IE
UK
NL
BE
PL
LU
DE
CZ
FR
SK
AT
CH
HU
SI
HR
IT
RO
BG
PT
ES
TR
GR
CY
MT
IL
GEANT2
Initial Backbone Topology

# The GEANT2 network (GN2 Project)



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# Global Hybrid Networking

- The Internet enabled the ubiquitous global networking community based on IP services and the Web
- The Next Generation Hybrid Network will enable the global knowledge – based society by providing advanced collaborative platforms via hybrid IPv6 & Manageable Layer 1-2 (Ethernet & Light-path switching over Dark Fiber) Services
- GÉANT2 offers this new environment to European educators & researchers and paves the way for global, ubiquitous advanced networking services (cyber-services)
- The NREN - Grid /HPC communities test – develop - tailor and deploy network-based services & applications: Collaborative platforms, security, AAA, roaming…
- Key common issue: To integrate Hybrid Network control plane aspects within Grid Middle-ware (M/W)
- Grid (and HPCN) requirements motivated the design and deployment of GÉANT2 as a hybrid, dark-fiber network

Some open policy issues:

- Easing of *Digital Divides*
- Inclusion of wider user communities – Acceptable Usage Policies / AUPs – *Regulatory Status*
- Funding – sustainability - ownership - control of eInfrastructures: New *Business Models*
- Management & Control planes of hybrid networks: *Open Standards, Muli-domain, User access*
- Role of Open Source for Hybrid Networks and Grids: Towards an *Open HPCN Architecture?*

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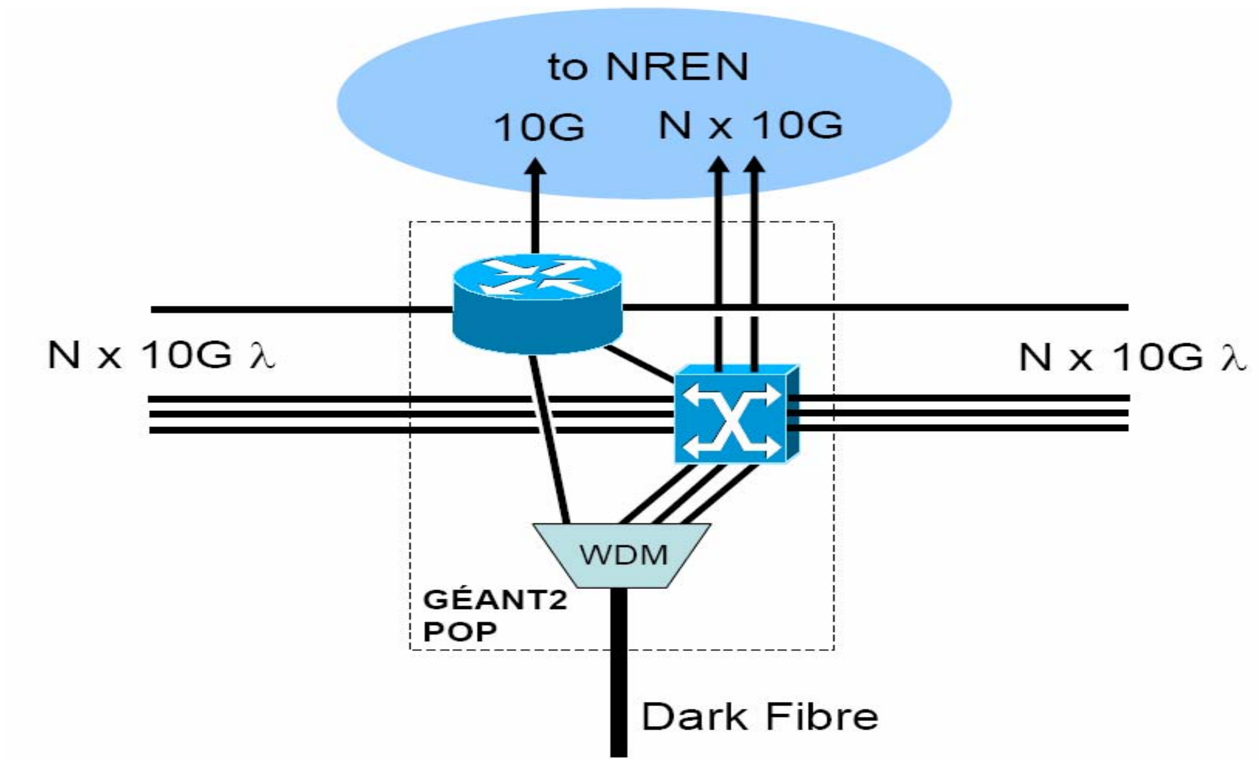
# GEANT2 Hybrid Architecture




- Implementation on dark fiber, IRU Asset, Transmission & Switching Equipment
  - Layer 1 & 2 switching, “the Light Path”
  - Point to Point (E2E) WL services

# GN2 – NREN
## hot potatoes

- Assess NREN – GÉANT requirements & technology trends over the next 10 years (*foresight*)
- Test & deploy "bleeding edge" technologies (e.g. nx40 Gbps over DF) and adopt novel business models (e.g. DF ownership & *cross-border fiber provisioning* by neighboring NRENs)
- Coordinate between Next Generation Networking & High Performance Computing towards a *Global HPCN*
- Test & deploy GÉANT - wide *Security & Monitoring* (prerequisite for eScience / Grids, eSchools, Digital Libraries, eGovernment, eHealth …)
- Establish *virtual collaborative environments* (e.g. VRVS, Access Grid)
- Enhance *global connectivity* (USA, Canada, China, Japan, Korea, Africa, Mediterranean area, Balkans, Latin America, India)
- Help easing the *digital divides*
- Promote NRENs – GÉANT – GÉANT2 as a *European success story*

while at the same time

- *Keep-up the good work and meet new challenges in the GTREN – eScience world (deploy optical technologies, provide e2e L1/L2 connectivity, update cost sharing models, test new business models …)*

*Not a mission impossible!*

# Some User Group applications and bandwidth requirements

- DEISA (HPC cluster):
  - 9 sites at 1G in 2004/2005 and 10G in 2006

- eVLBI: European VLBI Network (EVN)
  - 16+ Radio Telescope Observatories at 1G+ each (2006)
  - JIVE (Dwingeloo, NL) at >10G

- EGEE (Scientific Grids)
  - ‘really many’ grid sites

- LHC (HEP):
  - 11*Tier1 (2*10G/each)
  - T0 at CERN (n*10G) (2006)
  - ‘many’ Tier2 at 1G (at least) (2006-2007)

## *EGEE*

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# Grids and Networks for Global e-Science

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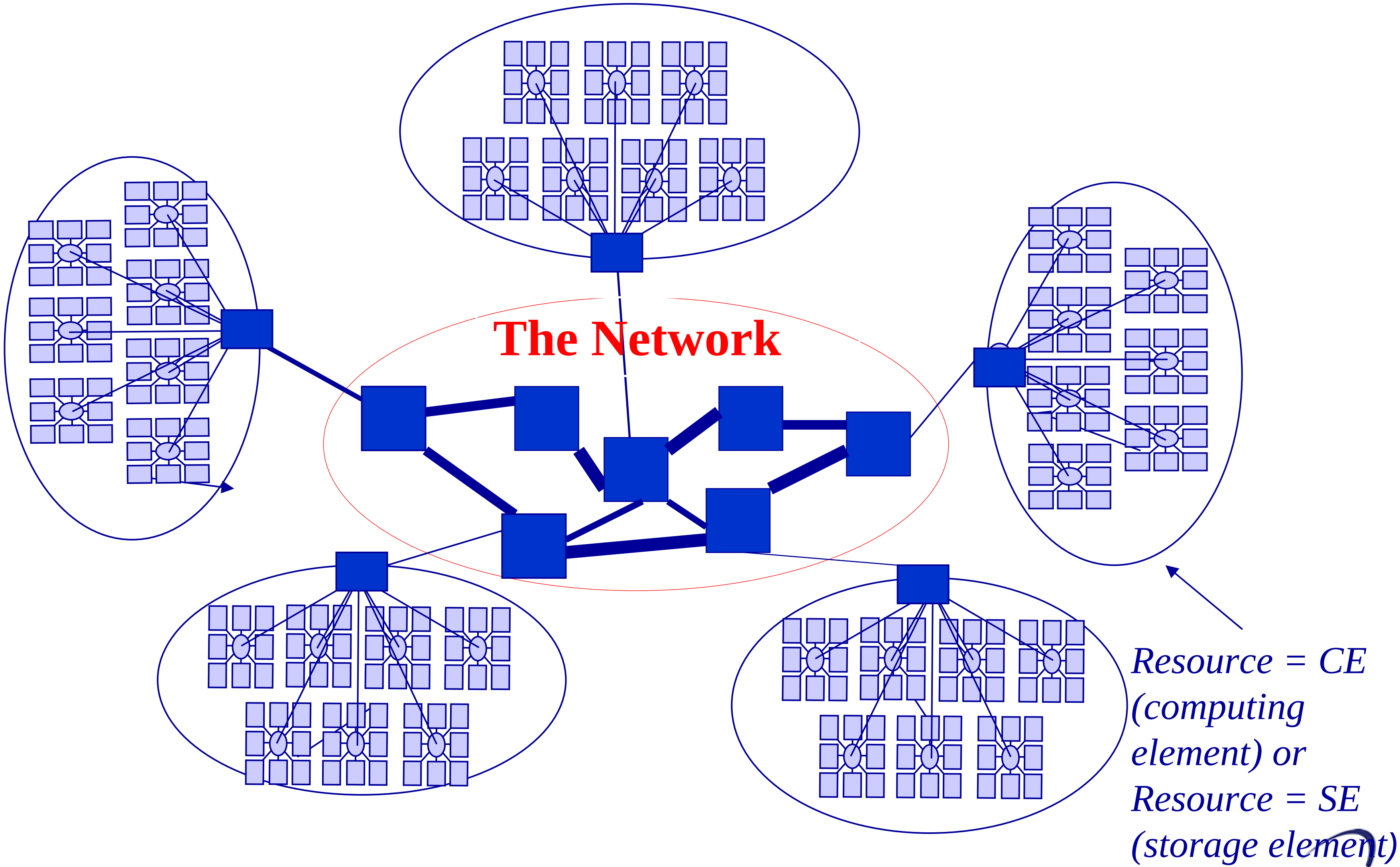
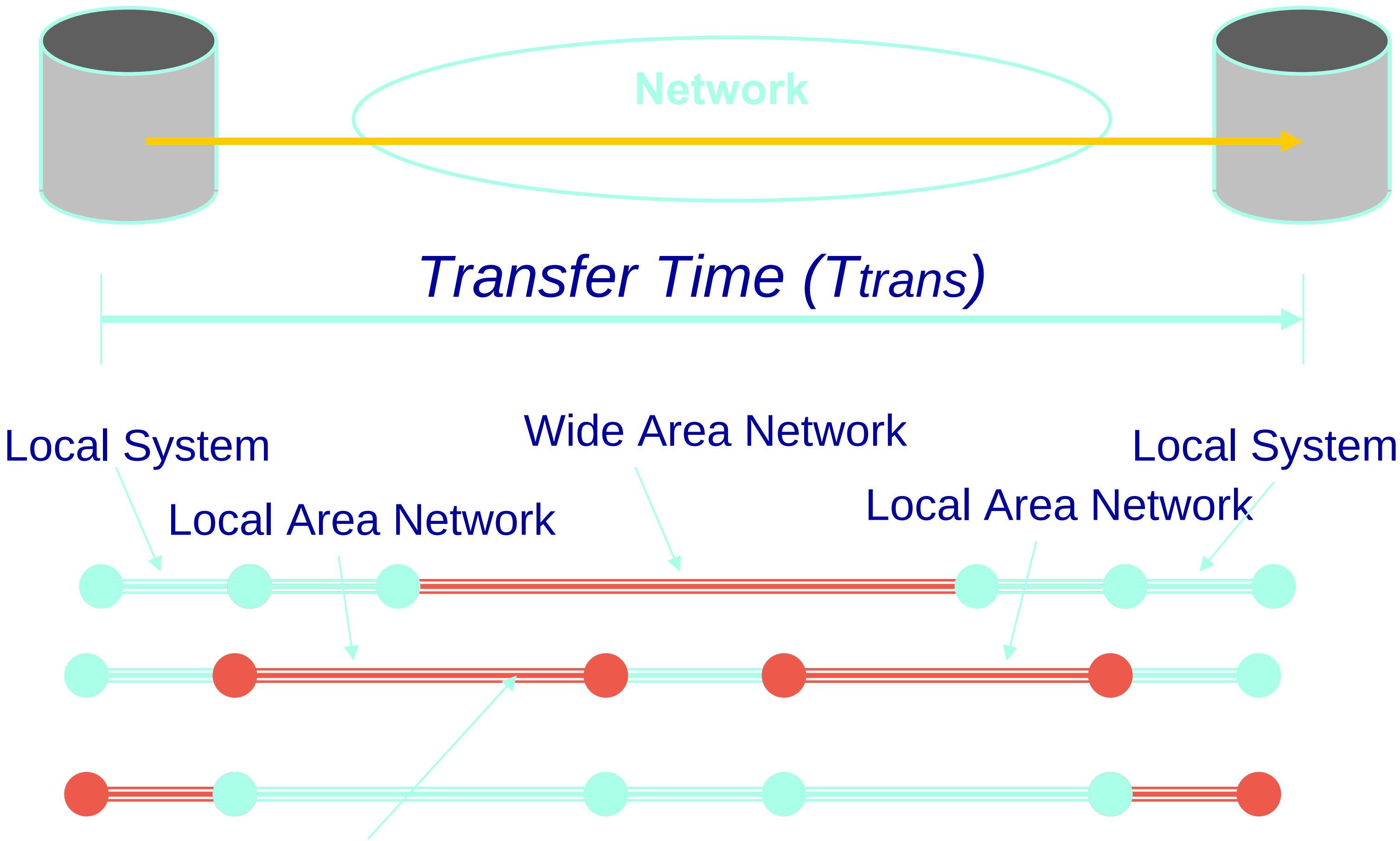
# Grid Network Element Concept



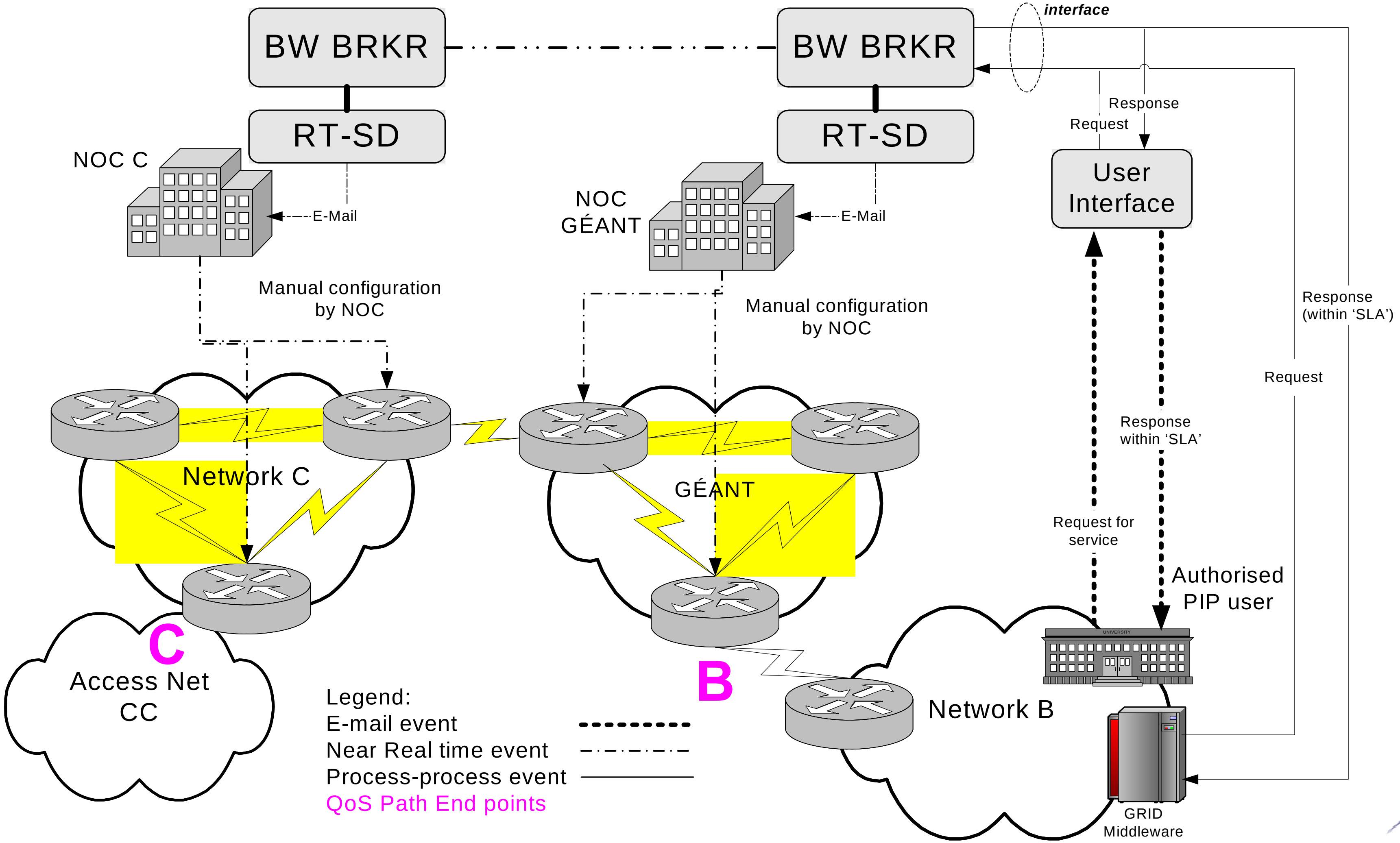

The Network is a key Element of a Grid infrastructure

# Grids: Where is the bottleneck?



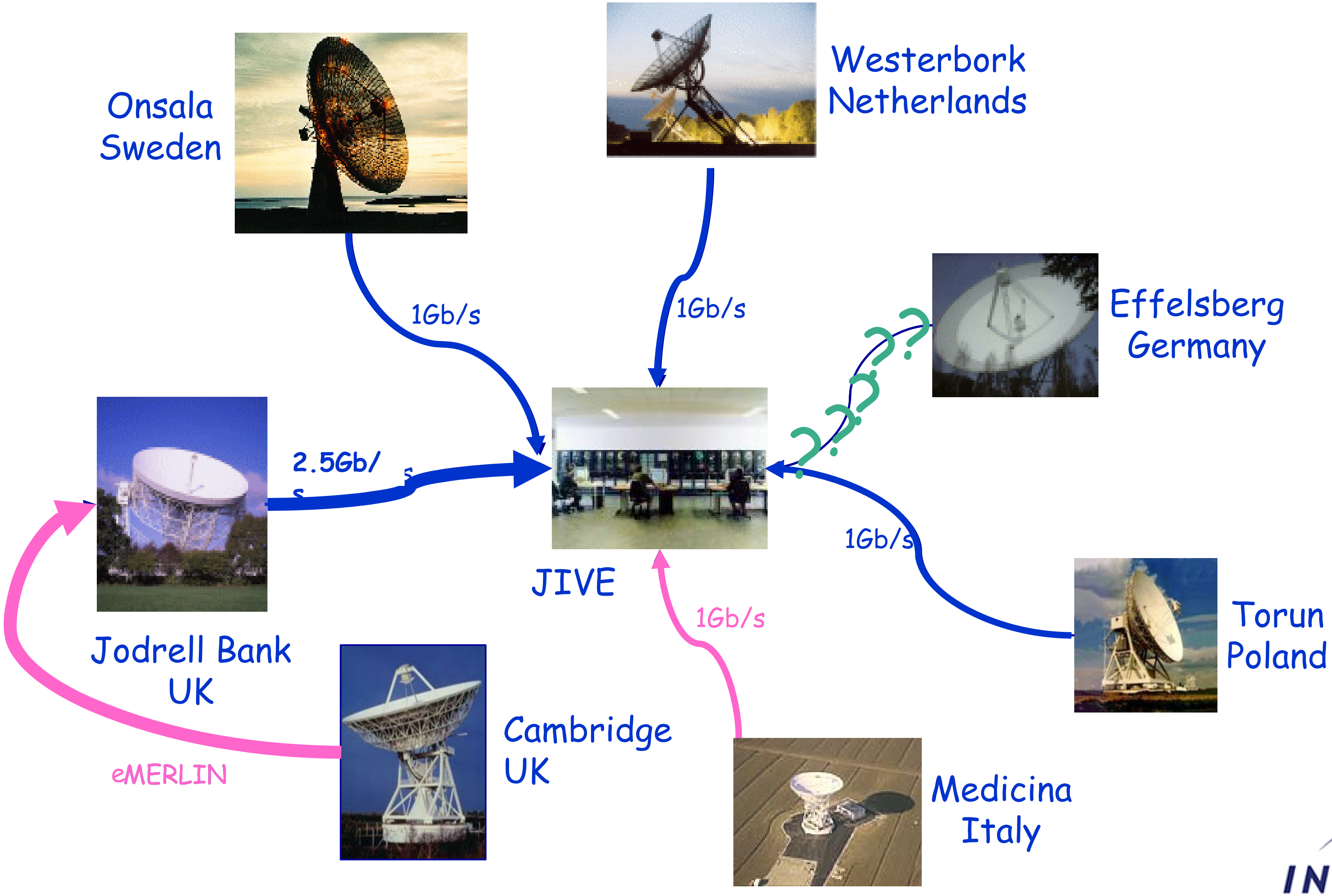
# EGEE and Grids:
# A more detailed architecture...

GN2 Inter-domain Manual PS (EGEE compliant):

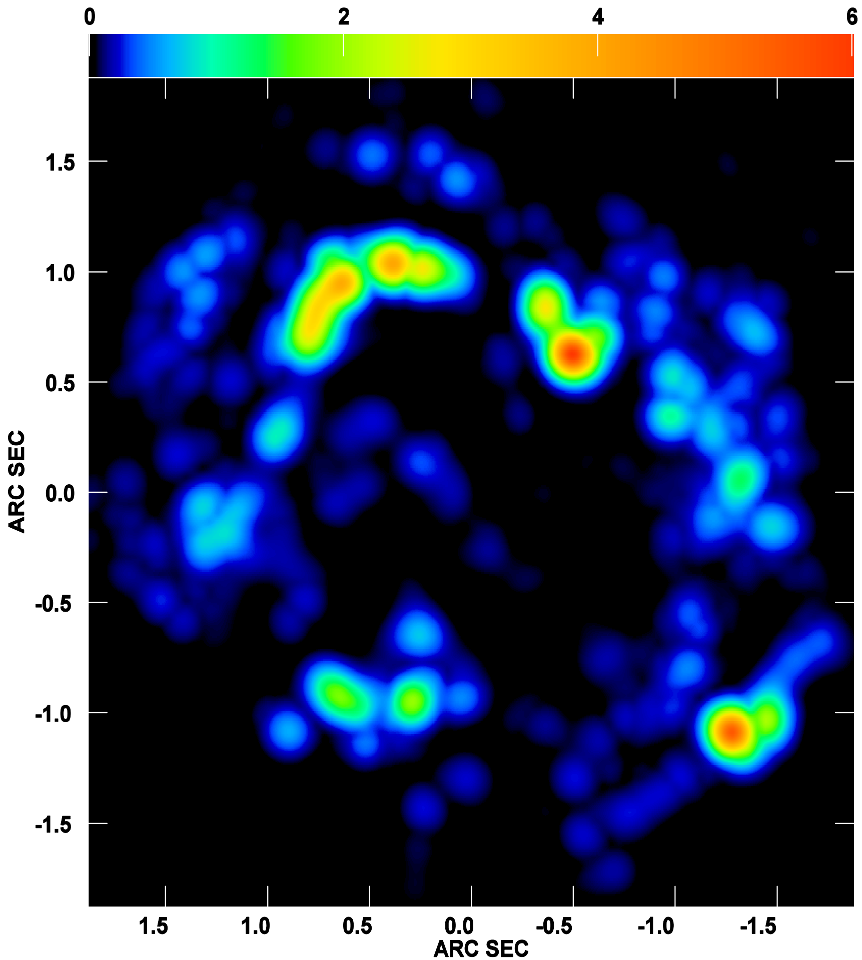


## *eVLBI*

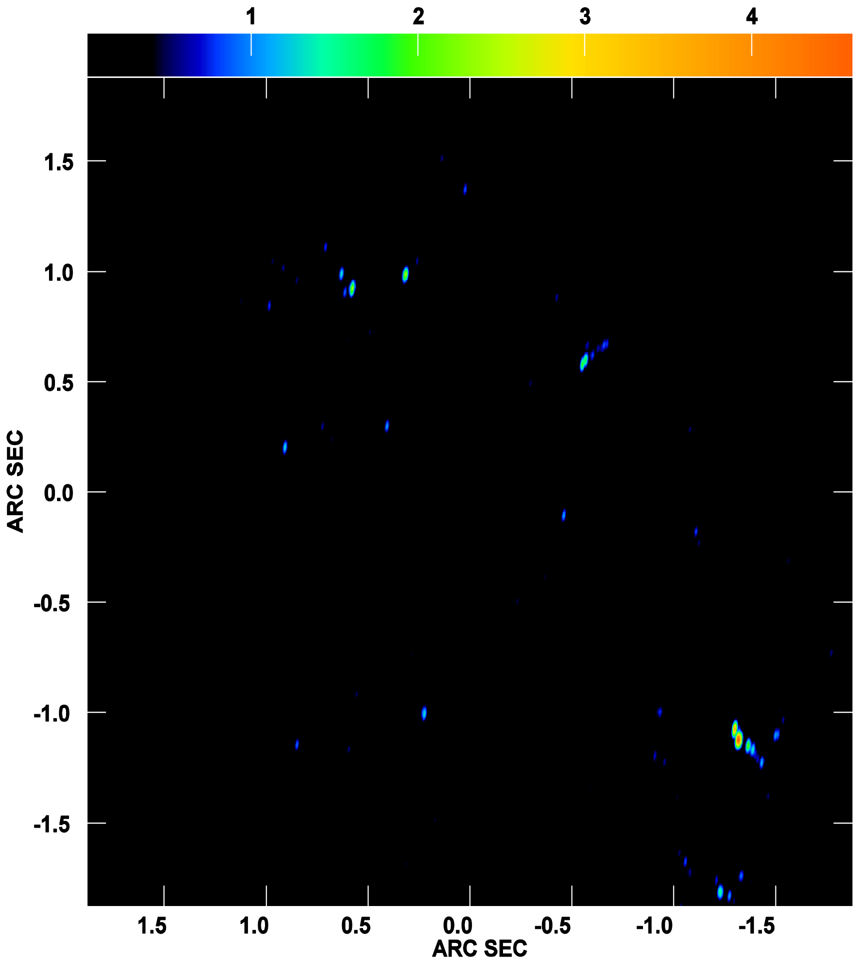
# Telescopes connections



# IRC+10420




MERLIN, March 2002



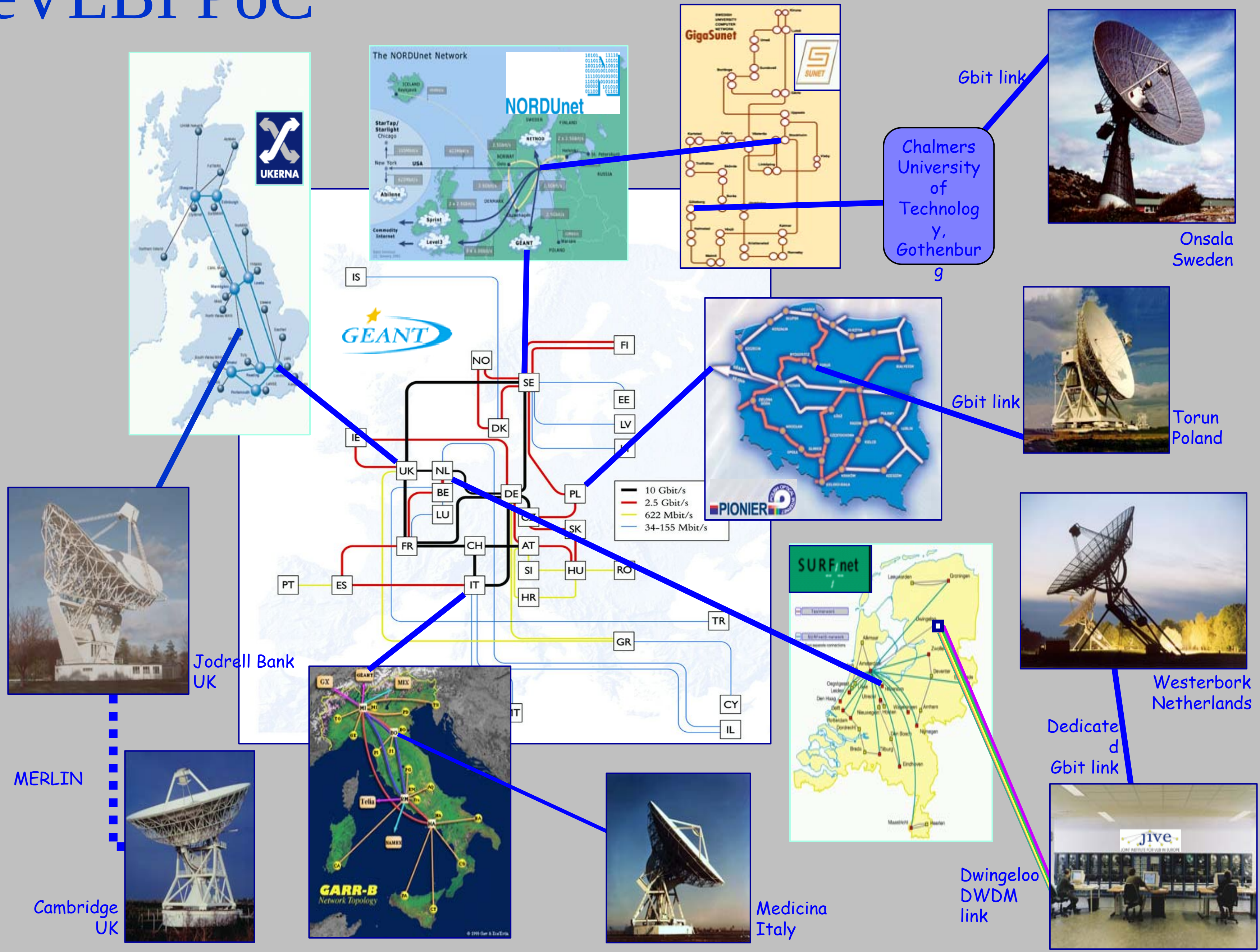

eVLBI, September 2004

# eVLBI Proof of Concept (PoC) targets:

- for the EVN and JIVE
  - Feasibility of eVLBI:- Costs, timescales, logistics.
  - Standards:- Protocols, parameter tuning, procedures at telescope and correlator.
  - New Capabilities:- Higher data rates, improved reliability, quicker response.

- for GÉANT and the NRENs
  - To see significant network usage with multiple Gbit streams converging on JIVE.
  - Minimum is three telescopes
  - Must be seen to enable new science and not just solve an existing data-transport problem
  - Real-time operation is seen as the ultimate aim, buffered operation accepted as a development stage.

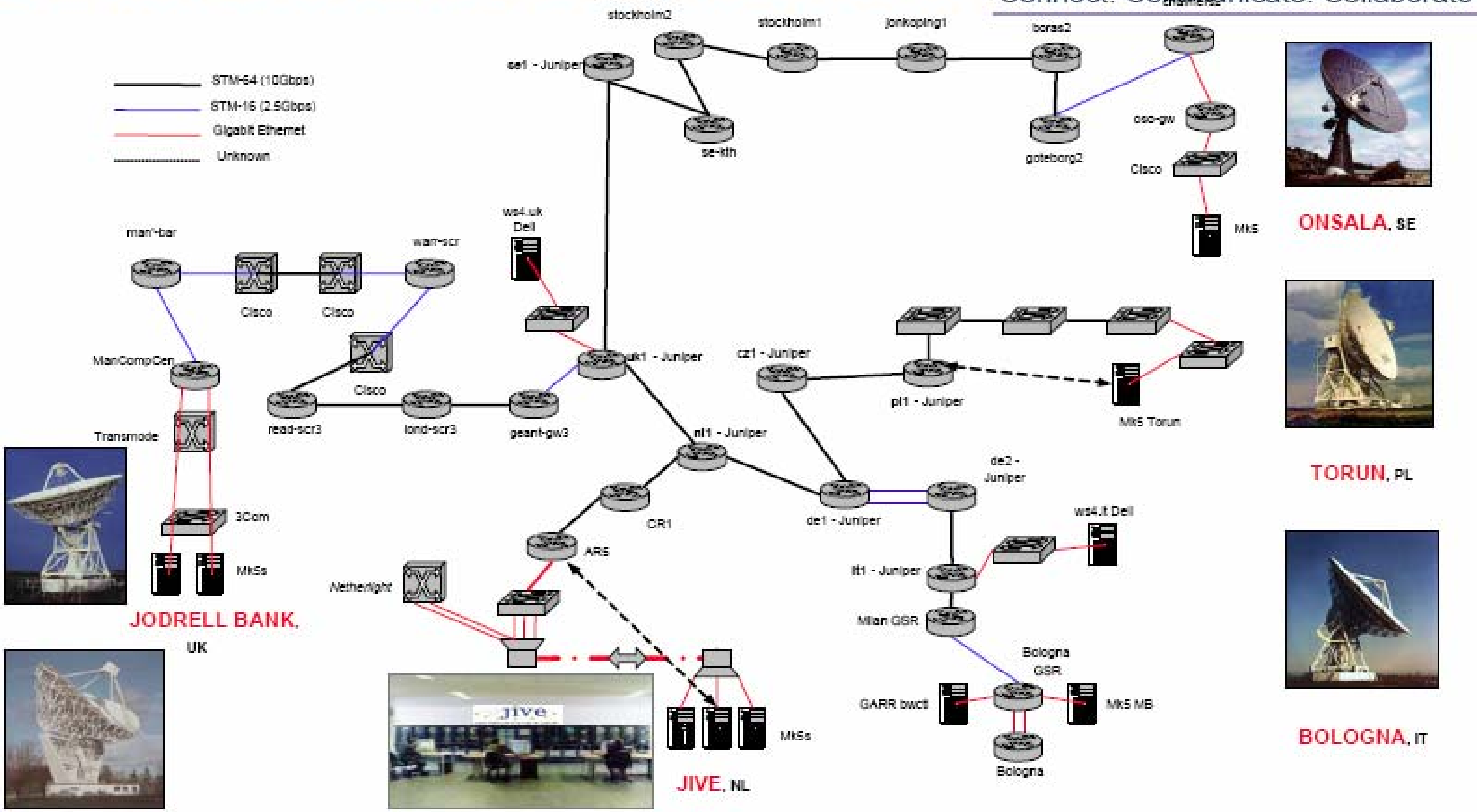
# eVLBI PoC



Gbit link
Chalmers University of Technology, Gothenburg
Onsala Sweden
Gbit link
Torun Poland
Westerbork Netherlands
Dedicated Gbit link
Dwingeloo DWDM link
Medicina Italy
Jodrell Bank UK
MERLIN
Cambridge UK
The NORDUnet Network
NORDUnet
GigaSunet
SUNET
UKERNA
GEANT
PIONIER
SURFnet
GARR-B
Network Topology
10 Gbit/s
2.5 Gbit/s
622 Mbit/s
34-155 Mbit/s
IS
FI
NO
SE
EE
LV
DK
IE
UK
NL
DE
PL
BE
LU
SK
FR
CH
AT
PT
ES
IT
SI
HU
RO
HR
TR
GR
CY
IL

# GÉANT2/NREN eVLBI Network

Connect. Communicate. Collaborate




GÉANT2

EUROPEAN vlbi NETWORK

DANTE

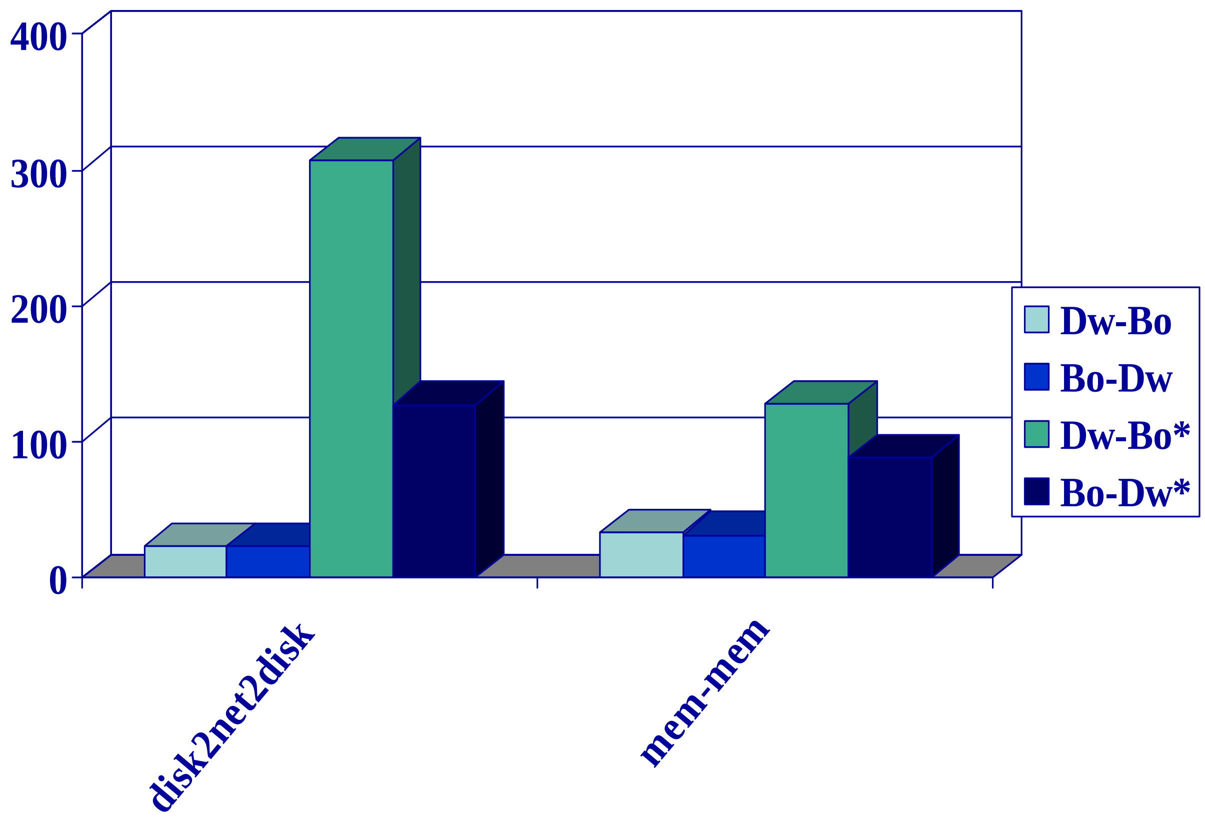
# eVLBI: Proof of Concept (PoC)

- October 7-8, 2003
- Mark5 connected to GARR-G router in Bologna
- 1GE channel available from Bologna to Dwingeloo

| | Dwingeloo ->Bologna (Mb/s) | Bologna -> Dwingeloo (Mb/s) |
|---|---|---|
| Net2disk <-> Disk2net | 125 to 307 | 107 to 127 |
| Memory <-> Memory | 128 | 88 |
| UDPmon | 500 | 670 |

- ⇨ TCP window tweaking
- ⇨ No network optimization/debugging performed (possible packet loss)
- ⇨ Possible influence of different Mark5 hardware
- ⇨ New tests scheduled soon

# Disk2net-net2disk Dwingeloo-Bologna



# eVLBI PoC Test results

| | Memory-memory | | Disk2net-net2disk | | In2net-net2disk | In2net-net2out |
|---|---|---|---|---|---|---|
| | UDP | TCP | UDP | TCP | TCP | TCP |
| Bench via patch | | 930 | 250 | | | 256 |
| Bench via Amsterdam | 500 | 360 | | | | 256 |
| Westerbork-JIVE | 867 | 680 | | | 256 | 256 |
| Bologna-JIVE | 670 | 128 | | 307 | | |
| Jodrell-JIVE | 50 | 70 | | | 64 | 256 |
| Torun-JIVE | 800 | 260 | | | | 256 |
| Onsala-JIVE | | | | 177 | 256 | 256 |
| JIVE-Haystack | 612 | | | 71 | | |

## Huygens Space Probe Lands on Titan – Monitored by 17 telescopes in Au, Jp, CN, US

- In October 1997, the Cassini spacecraft left Earth to travel to Saturn
- On Christmas day 2004, the Huygens probe separated from Cassini
- On 14 January 2005 it started it's descent through the dense (methane, nitrogen) atmosphere of Titan (speculated to be similar to that of Earth billions of years ago)

  [**Courtesy G. McLaughlin]** ➲
- The signals sent back from Huygens to Cassini were monitored by 17 telescopes in Australia, China, Japan and the US to accurately position the probe to within a kilometre (Titan is ~1.5 billion kilometres from Earth)

# Australian eVLBI data sent over high speed links to the Netherlands

- The data from two of the Australian telescopes were transferred to the Netherlands over high-speed links and were the first to be received by JIVE (Joint Institute for VLBI in Europe), the correlator site
- The data was transferred at an average rate of 400Mbps (note: 1Gbps was available)
- The data from these two telescopes were reformatted and correlated within hours of the end of the landing
- This early correlation allowed calibration of the data processor at JIVE, ready for the data from other telescopes to be added
- Significant international collaborative effort

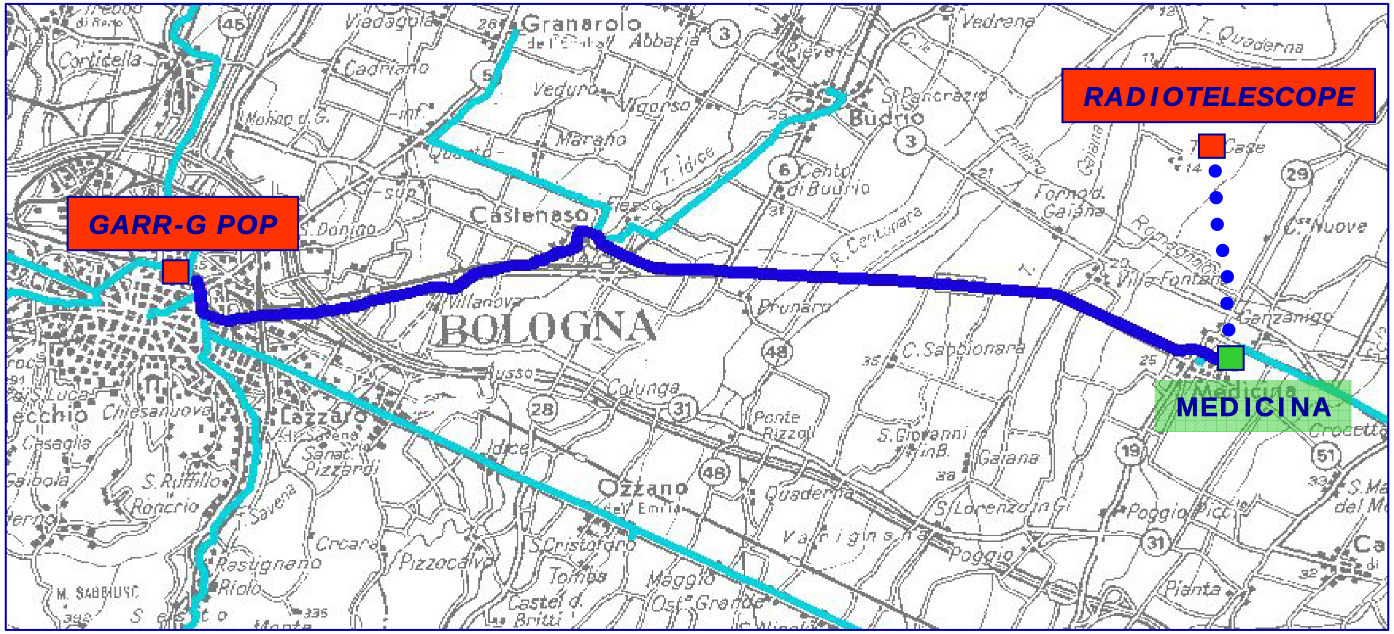
# eVLBI PoC lesson learned

- Mark5 not very well suited for eVLBI
  - Hardware limitations (interrupt conflicts, outdated motherboards, proprietary hardware)
  - Software limitation (stuck to kernel 2.4 because of Jungo drivers, proprietary software)
- Next platform?
  - support for 4Gbps, PCI Xpres?
  - as much off-the-shelf as possible
  - as simple as possible (no disks!)
- Networks were performing rather well
- Dedicated lightpaths…

## *Wavelenghts and Dark Fibres*

# eVLBI - Medicina RadioTelescope

- operational
- ~ 30Km fibers already in place
- ~ 5.5 Km still to be covered to be dug along the street and fields (end 2005)



# eVLBI – SRT, the Sardinian Radio Telescope

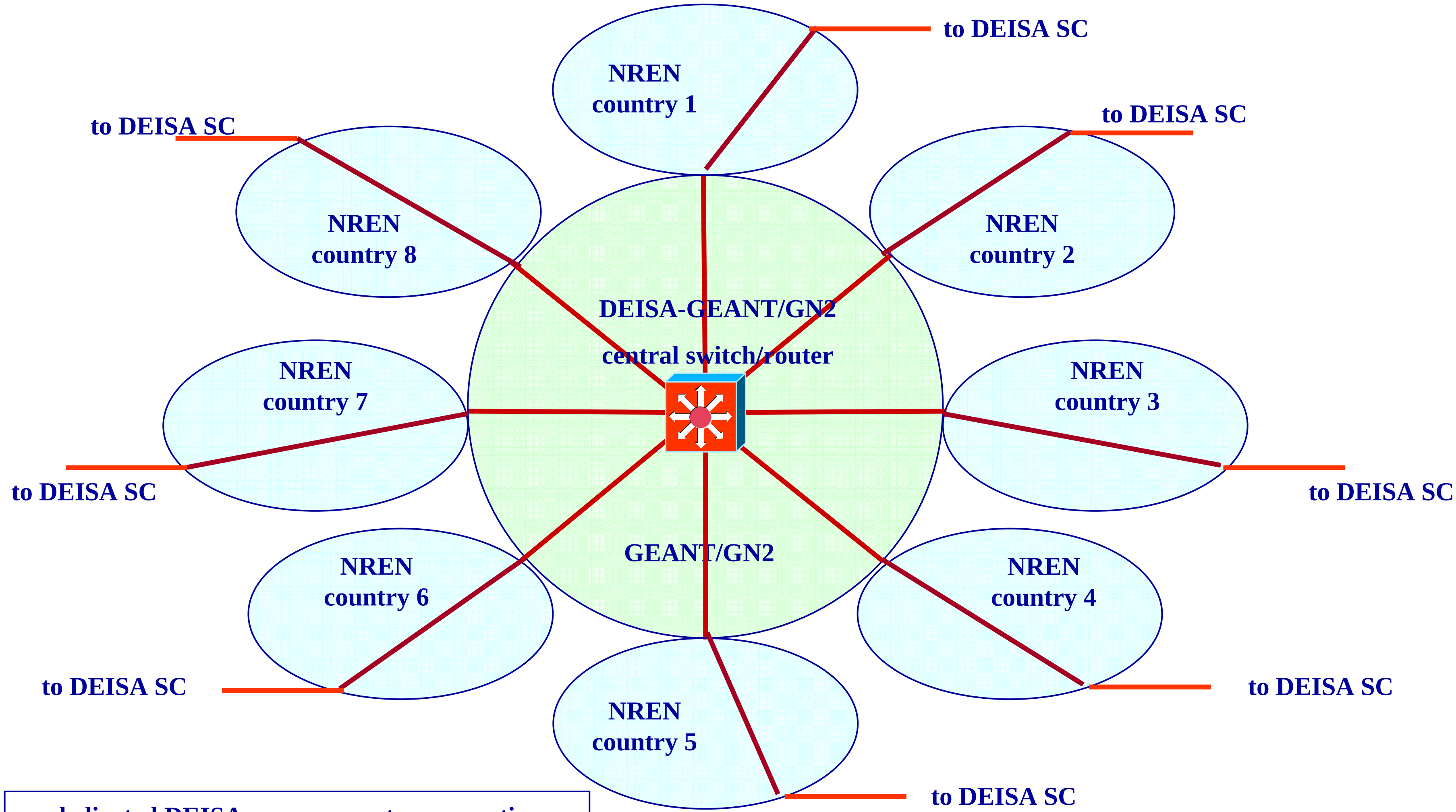
- Expected to be operational end 2006
- 35Km distance from GARR-G PoP
- no fiber in place
- Fiber ducts already planned till next village

# eVLBI - Noto Radio Telescope

- operational
- ~ 68Km distance between Noto and GARR-G PoP in Catania
- GARR, INFN and INAF initiative

## *DEISA*

# Logical view of DEISA network



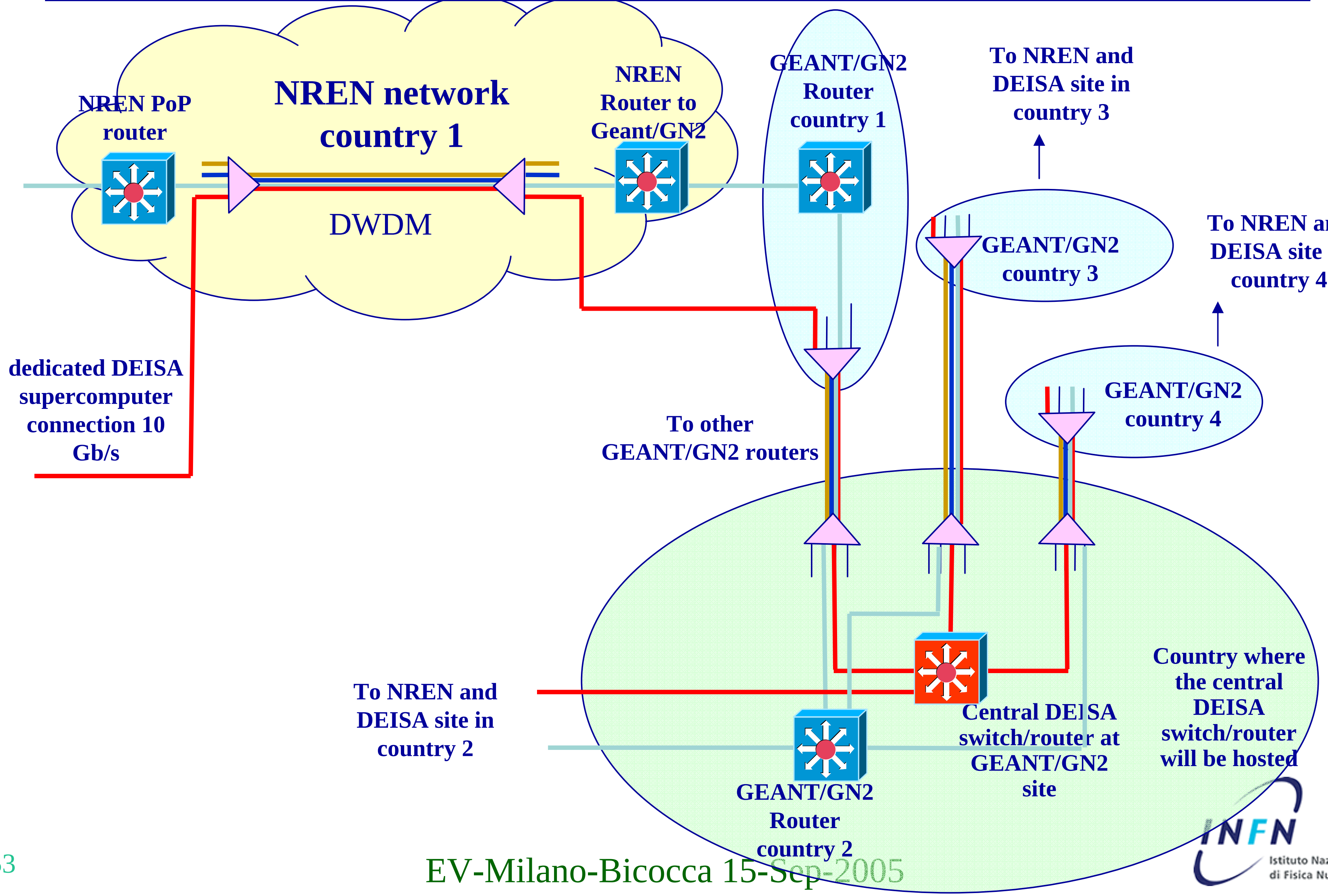

dedicated DEISA supercomputer connection

red lines (site local) = 1Gb/s / 10 Gb/s
red lines (NREN) = 1Gb/s / 10 Gb/s
red lines GEANT/GN2) = 1Gb/s / 10 Gb/s

# “DEISA Virtual Private Network”

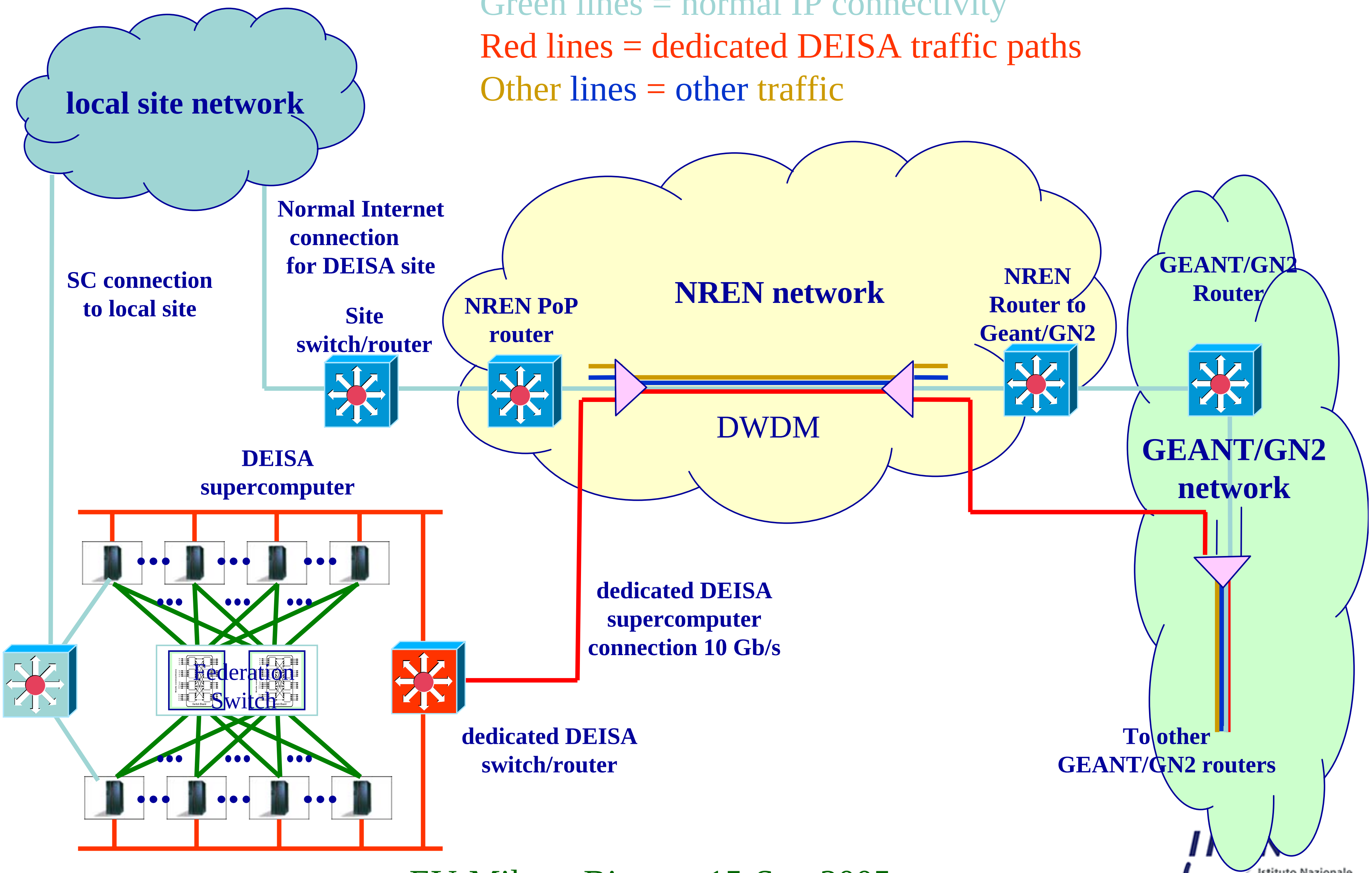
- DEISA supercomputers are connected to each other via a star like network (VPN)
- A central switch/router within GEANT infrastructure forwards traffic to other sites
- Connection to this switch preferable 1-10 Gb/s wavelength (point-to-point from DEISA site to central DEISA switch/router).
- Other possibilities are PremiumIP, TDM, …
- Management issues

# DEISA network and normal IP connect

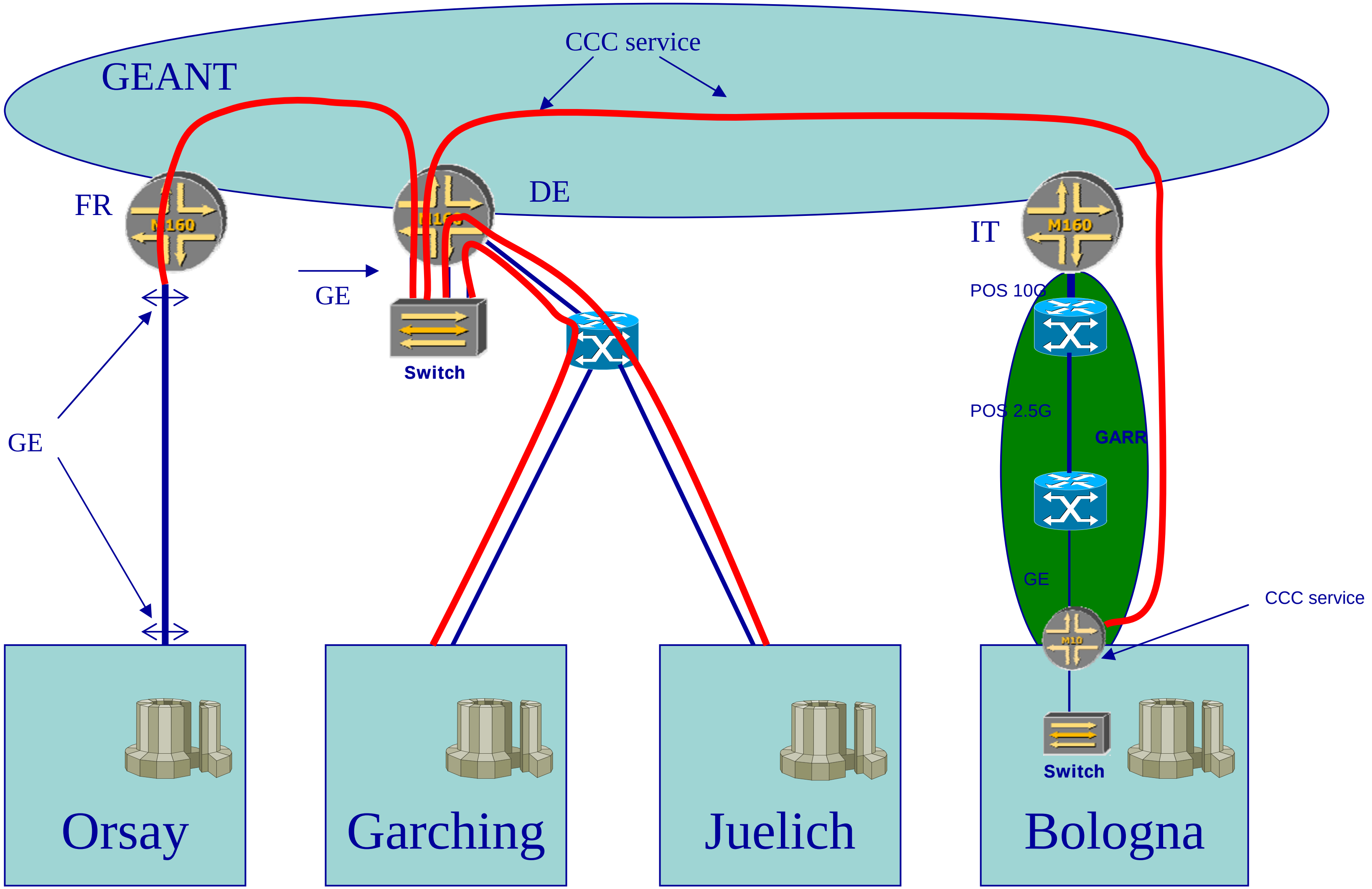


# DEISA supercomputer and normal site connect

Green lines = normal IP connectivity
Red lines = dedicated DEISA traffic paths
Other lines = other traffic

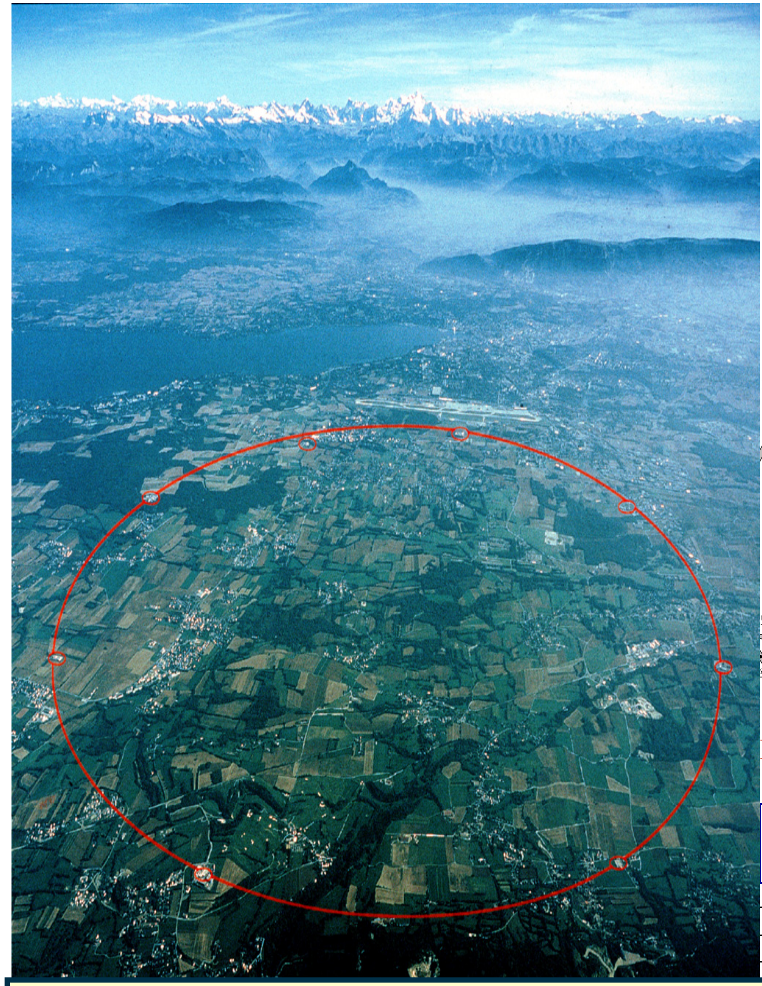


# DEISA : GEANT + NREN Proof of Concept

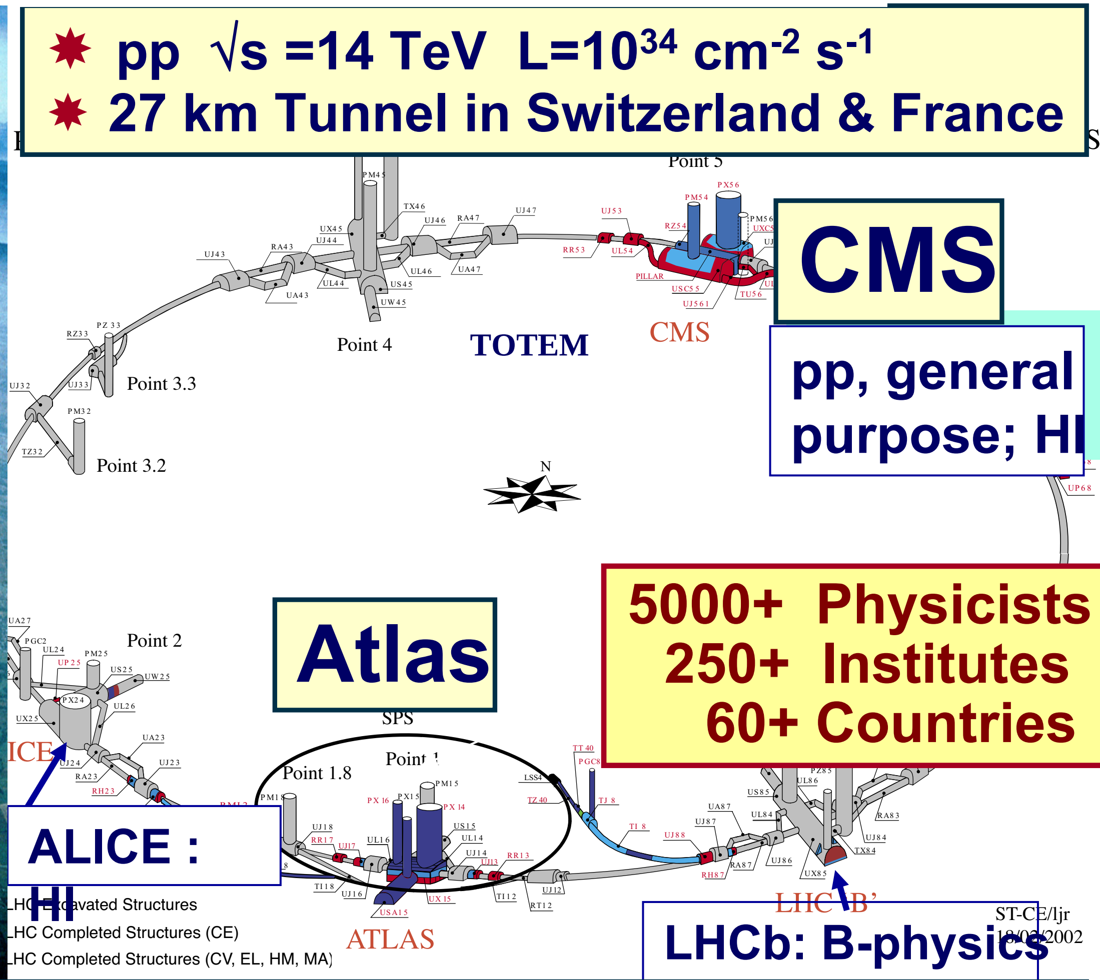


## *LHC*

# Large Hadron Collider CERN, Geneva: 2007 Start



- pp $\sqrt{s}$ =14 TeV L=$10^{34}$ $cm^{-2}$ $s^{-1}$
- 27 km Tunnel in Switzerland & France




**CMS**

pp, general purpose; HI

**Atlas**

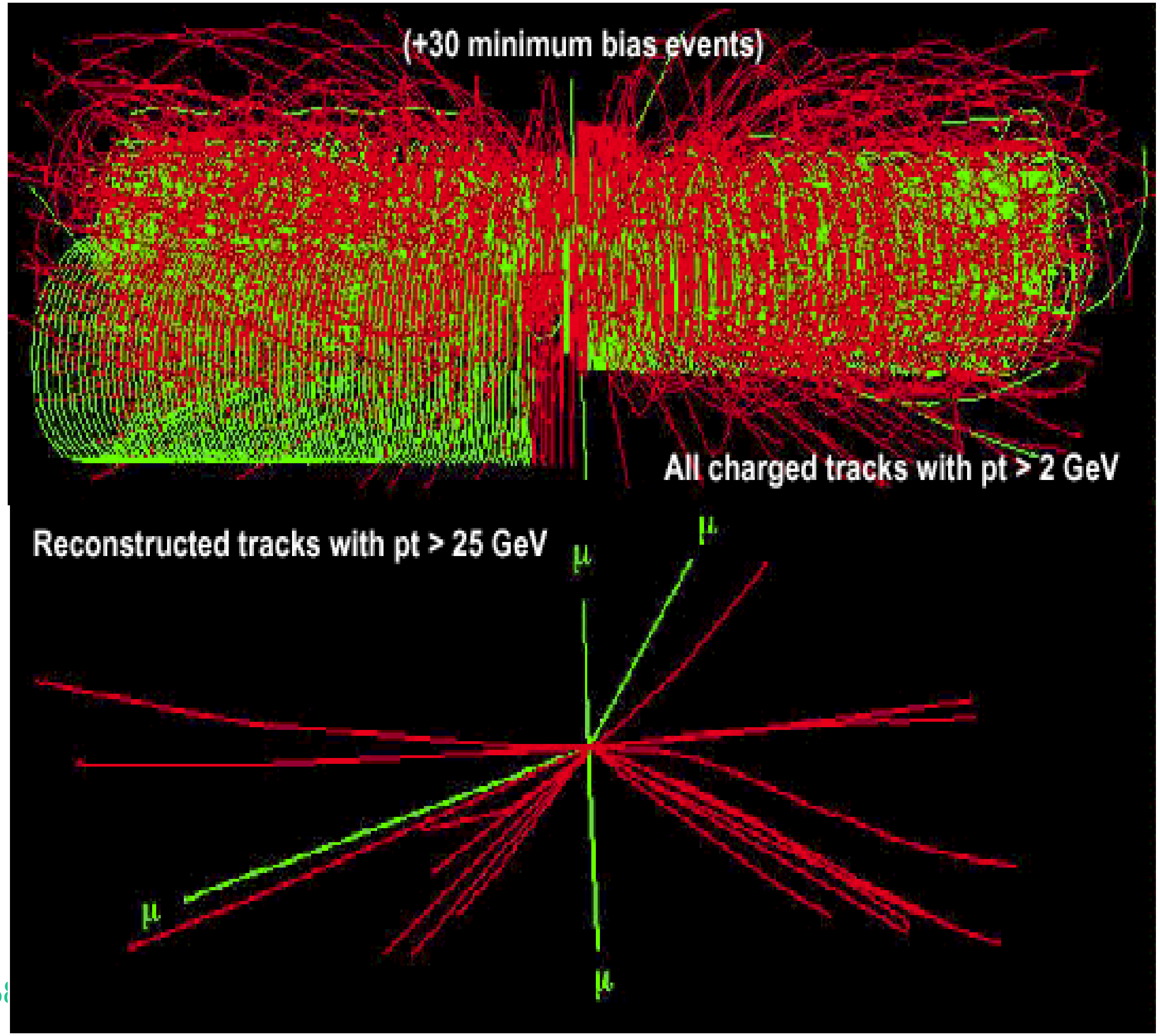
ALICE : HI

5000+ Physicists
250+ Institutes
60+ Countries

LHCb: B-physics

Higgs, SUSY, Extra Dimensions, CP Violation, QG Plasma, … *the Unexpected*

# LHC: Many Petabytes/Yr of Complex Data
# Unprecedented Instruments, IT Challenges

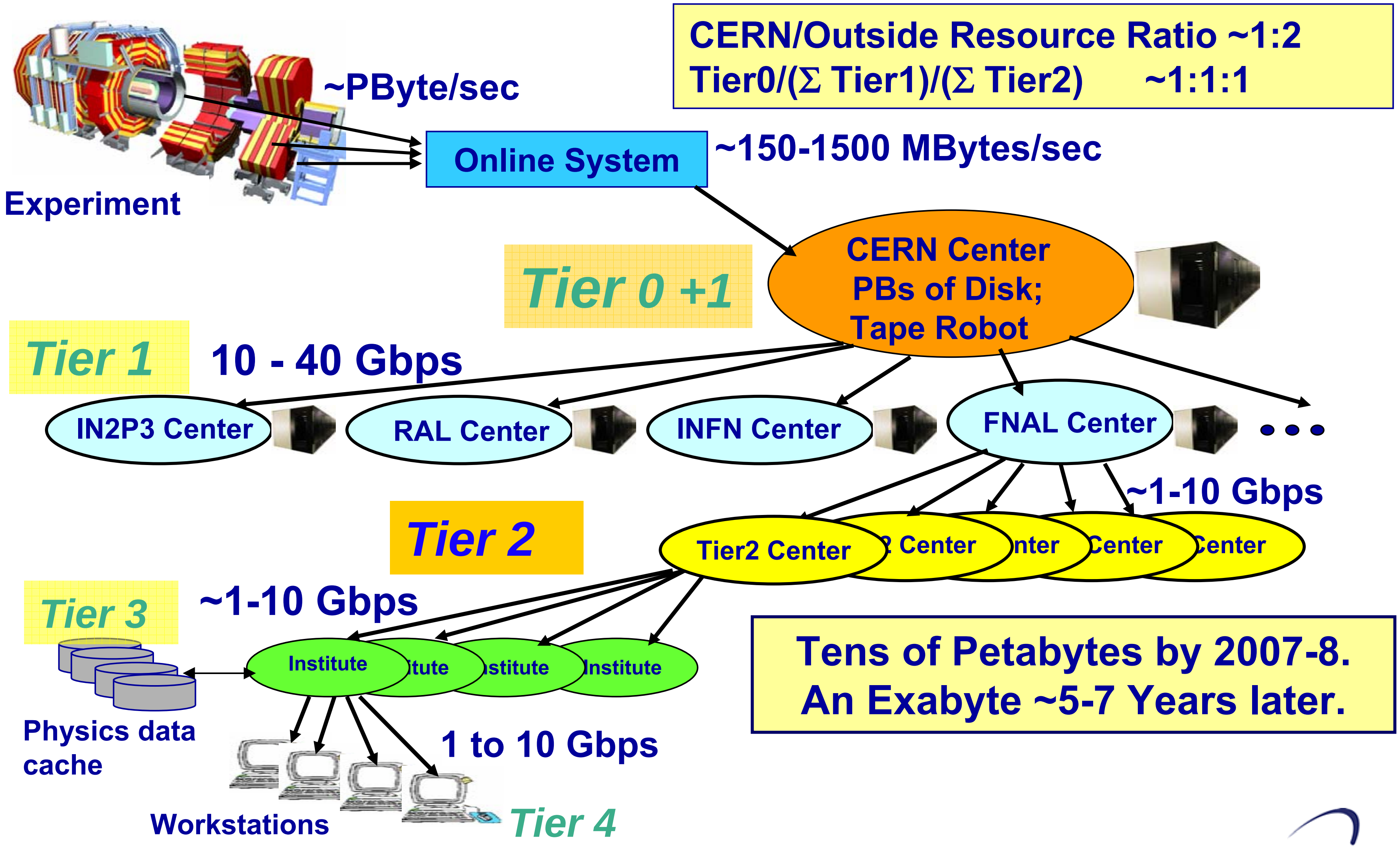



**At $10^{34}$ Luminosity**
**A Bunch Crossing**
**Every 25 nsec**
**(40 MHz)**

**~20 Events from**
**Known Physics**
**Superimposed**
**Per Crossing:**
**$10^9$ Interactions/s**

**Instruments**
**E.g. CMS**
**Tracker:**
**223 Sq-meters of**
**Silicon Sensors**

# LHC Data Grid Hierarchy (developed at Caltech, HN)




**Emerging Vision: A Richly Structured, Global Dynamic System**

# LHC: bandwidth needed to transfer data T0 to T1

## Bandwidth requirements

| | ***LHC-T0*** | ***T0-T1*** | ***T1-T0*** | ***T1-T1*** | ***T1-T2*** | ***T2-T1*** | ***T0-T2*** | ***T2-T1*** |
|---|---|---|---|---|---|---|---|---|
| ***ATLAS*** | | 3.5G | | 2.5G | 750M | | | |
| ***ALICE*** | | 1-5G | 1.6G | 0.3G | 0.1G | | | |
| ***CMS*** | | 2.5G | | | | | | |
| ***LHCb*** | 0.8G | 3.6G | | | 2G | | | |

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# LHC Tier0/Tier1/Tier2 Overview

- 1 Tier0 at CERN
- 7 Tier1 sites in Europe (ES,FR,UK,DE,IT,NL,SE)
- 1 Tier1 in Asia Pacific (Taiwan)
- 3 Tier1 in North America (FNAL, BNL,TRIUMF)

- All currently have 1-10 Gbps IP connections to CERN

- 10Gbps lightpath available on timescales ranging from immediately to Autumn 2006

- Number, location and bandwidth requirements of Tier2 sites unclear to many NRENs and HEP institutions





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# LHC high-level network architecture

**LHC network traffic:**

- 10 Gbit/s lambda per T1-T0 link
- A lightpath is

(i) a point to point circuit based on WDM technology

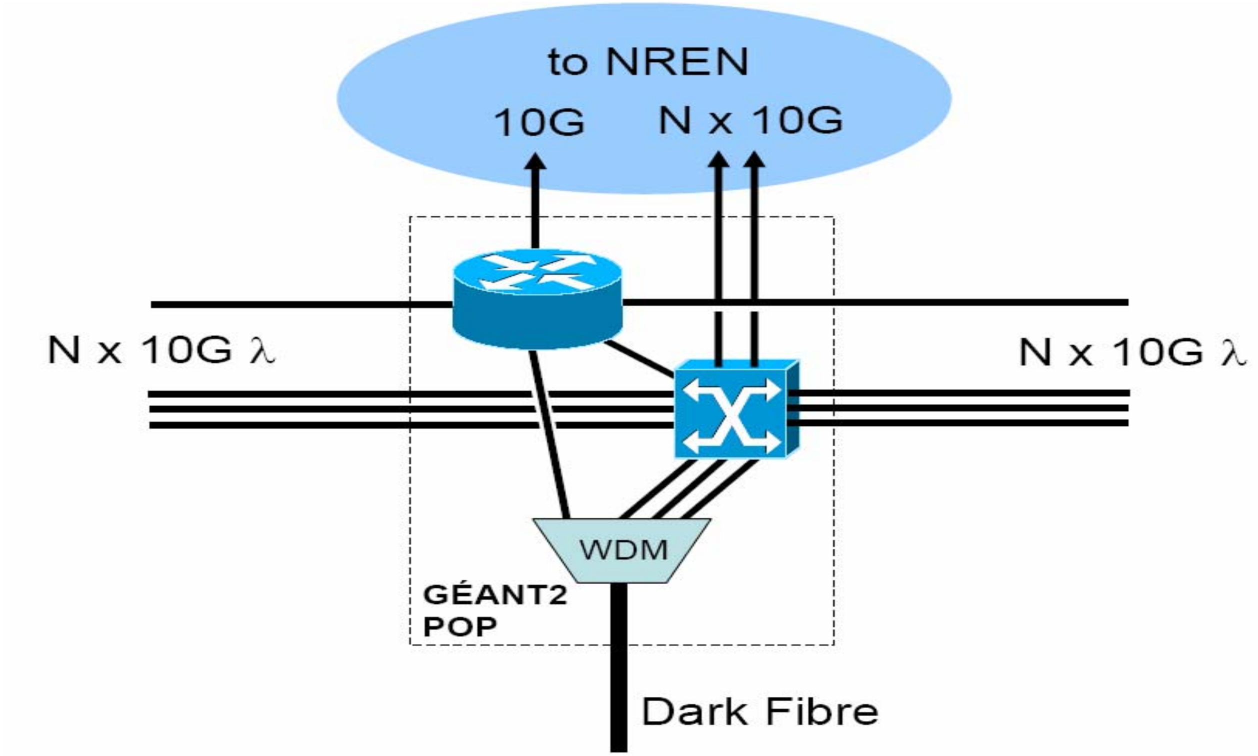
- STM-64 circuit
- 10GE LAN PHY circuit

(ii) a circuit-switched channel between two end points with deterministic behaviour based on TDM technology

- a GE or 10GE channel carried over an SDH/SONET infrastructure with GFP-F encapsulation
- an STM-64/OC-192 channel between two points carried over an SDH/SONET infrastructure

(iii) concatenations of (i) and (ii)

# GEANT2 Hybrid Architecture




- Implementation on dark fiber, IRU Asset, Transmission & Switching Equipment
  - Layer 1 & 2 switching, “the Light Path”
  - Point to Point (E2E) WL services

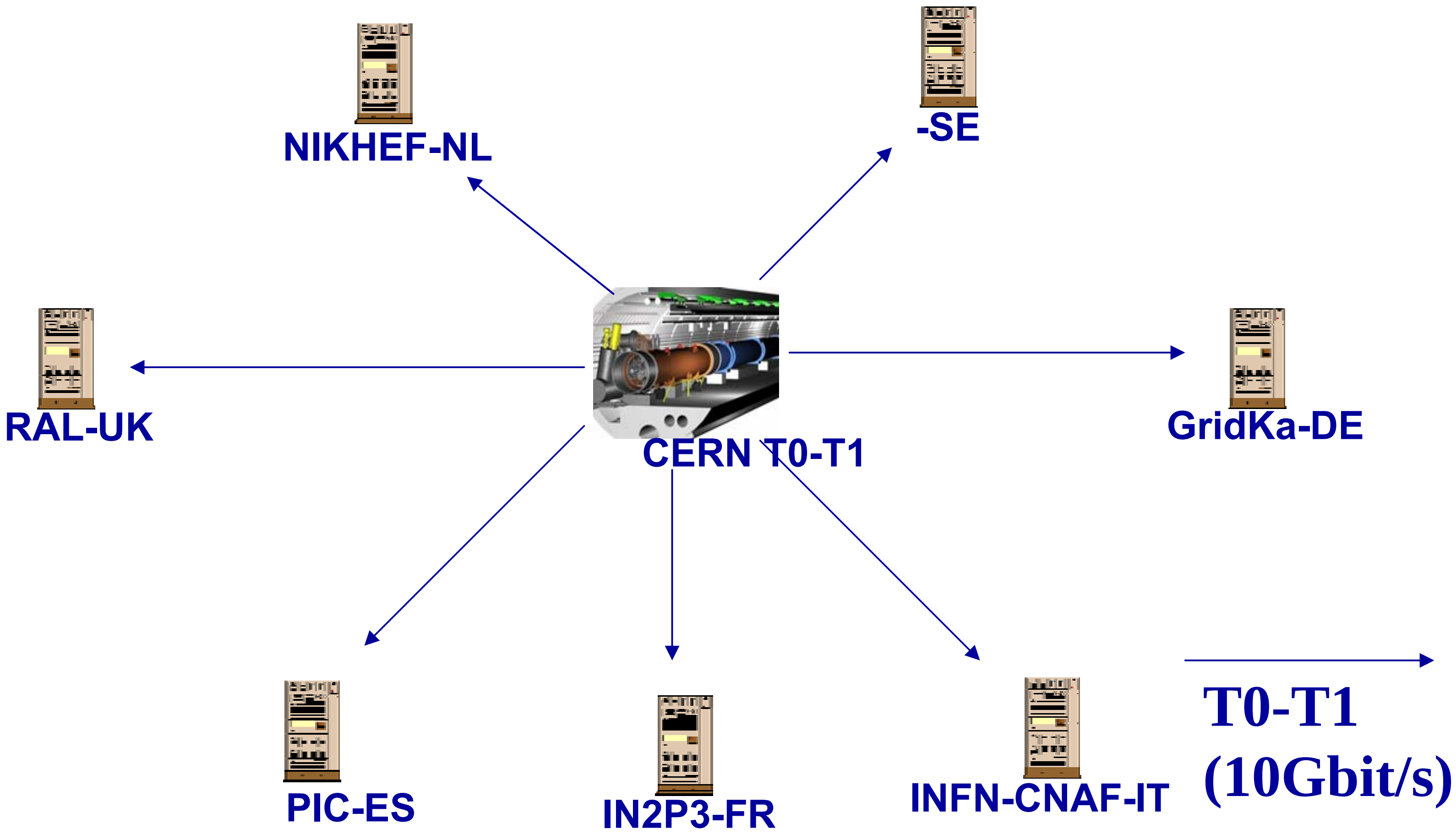
Consortium GARR

# LHC high-level network architecture

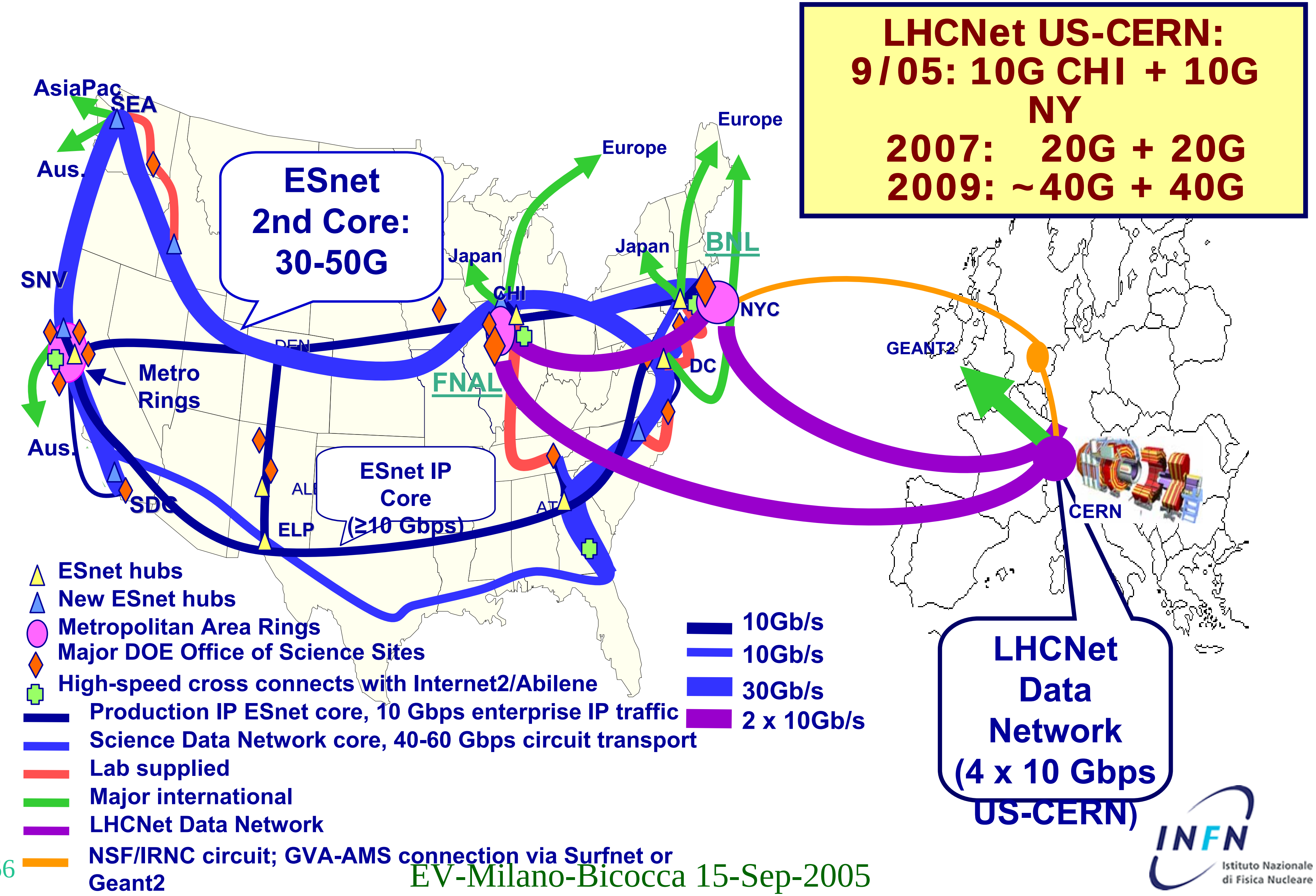
## List of LHC Tier1

| *T1* | *Location* | | *NRENs involved* |
|---|---|---|---|
| ASCC | Taipei - Taiwan | | ASnet |
| Brookhaven | Upton – NY- USA | | ESnet – LHCnet |
| CERN | Geneva - Switzerland | | |
| CNAF | Bologna - Italy | | Geant2 - GARR |
| Fermilab | Batavia - Ill - USA | | ESnet – LHCnet |
| IN2P3 | Lyon - France | | Renater |
| GridKa | Karlsruhe – Germany | | Geant2 - DFN |
| SARA | Amsterdam - NL | | Geant2 - SURFnet |
| NorduGrid | Scandinavia | | Geant2 - Nordunet |
| PIC | Barcelona - Spain | | Geant2 - RedIRIS |
| RAL | Didcot - UK | | Geant2 – Ukerna |
| TRIUMF | Vancouver - Canada | | CA*Net4 |

# LHC: T0-T1 in Europe



## LHCNet , ESnet Plan 2007/2008: 40Gbps US-CERN, ESnet MANs, IRNC



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# LHC high-level network architecture

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(iii)concatenations of (i) and (ii)



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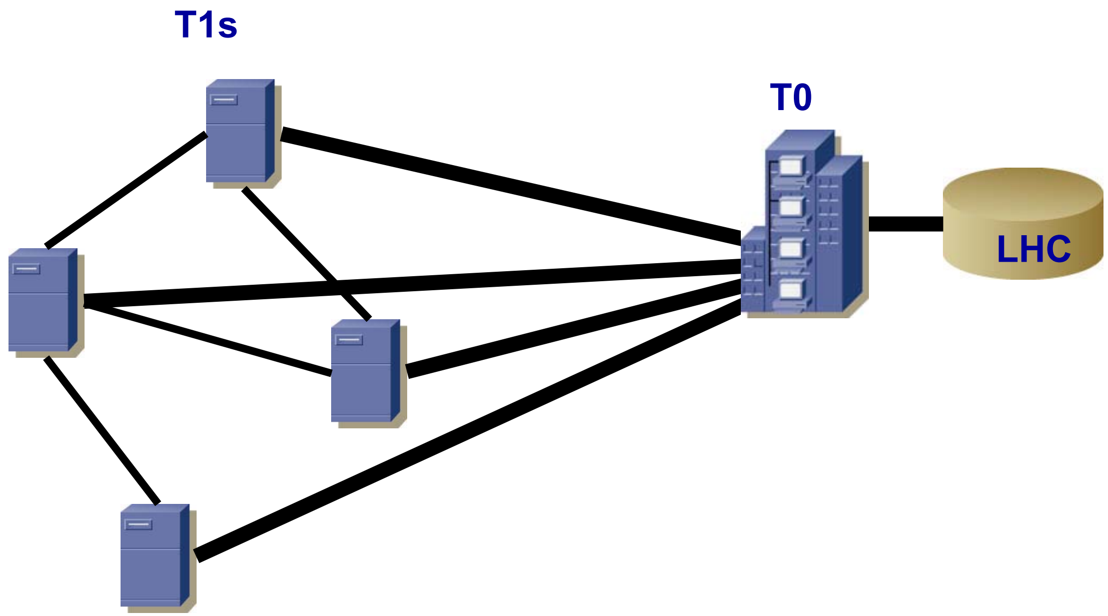
T1s
T0
LHC

# LHC high-level network architecture

## Provisioning :

- Every T1 responsible for connectivity from T1 to T0
- Every T1 will make available the termination point of the T1-T0 line on the T1 side
- T0 will provide the interfaces to each T1 link at CERN
- CERN is available to host T1's equipment for T0-T1 link termination at CERN
- **T1s are encouraged to provision direct T1-T1 connectivity**
- **T1s are encouraged to provision backup T0-T1 links on alternate physical routes**

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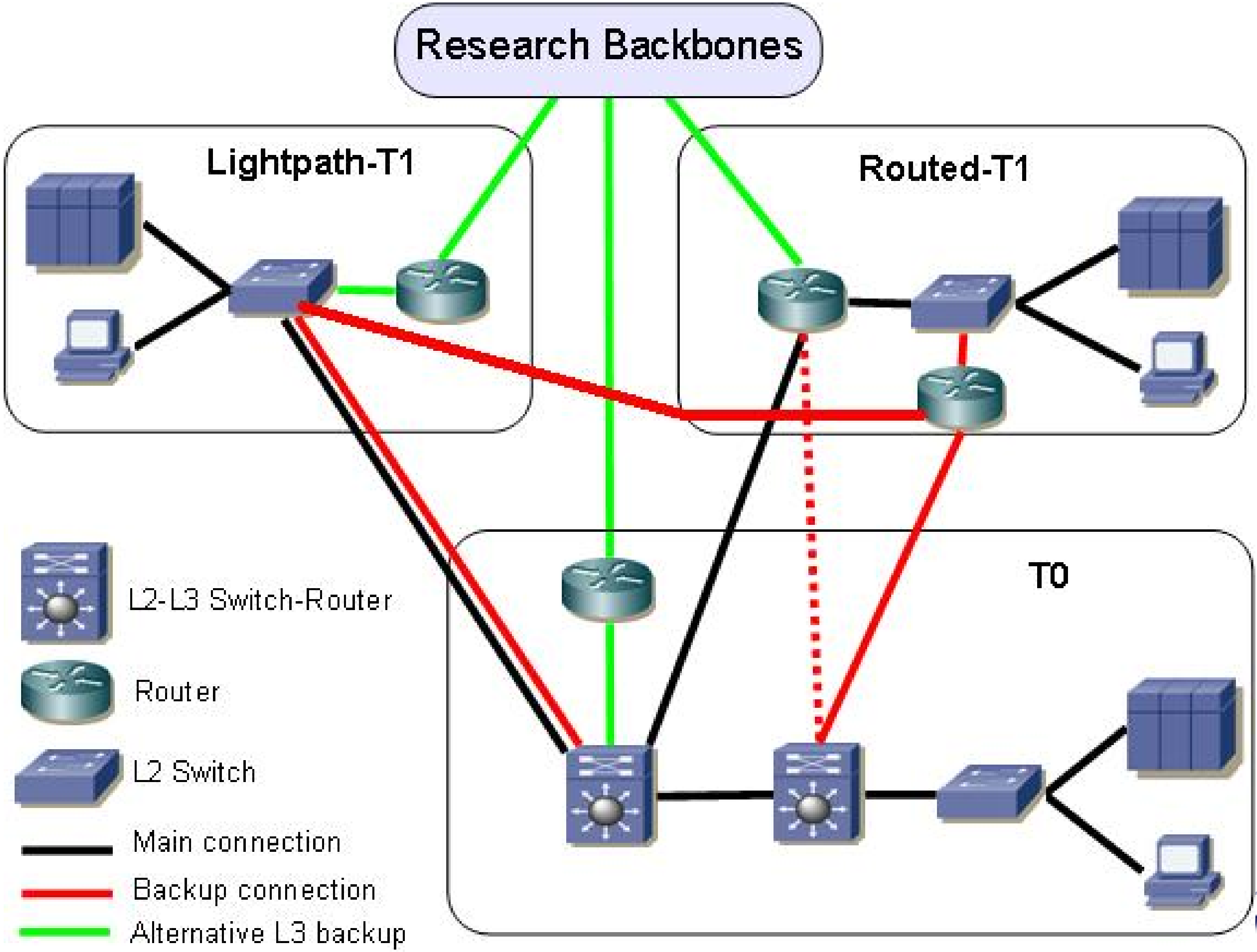
# LHC high-level network architecture



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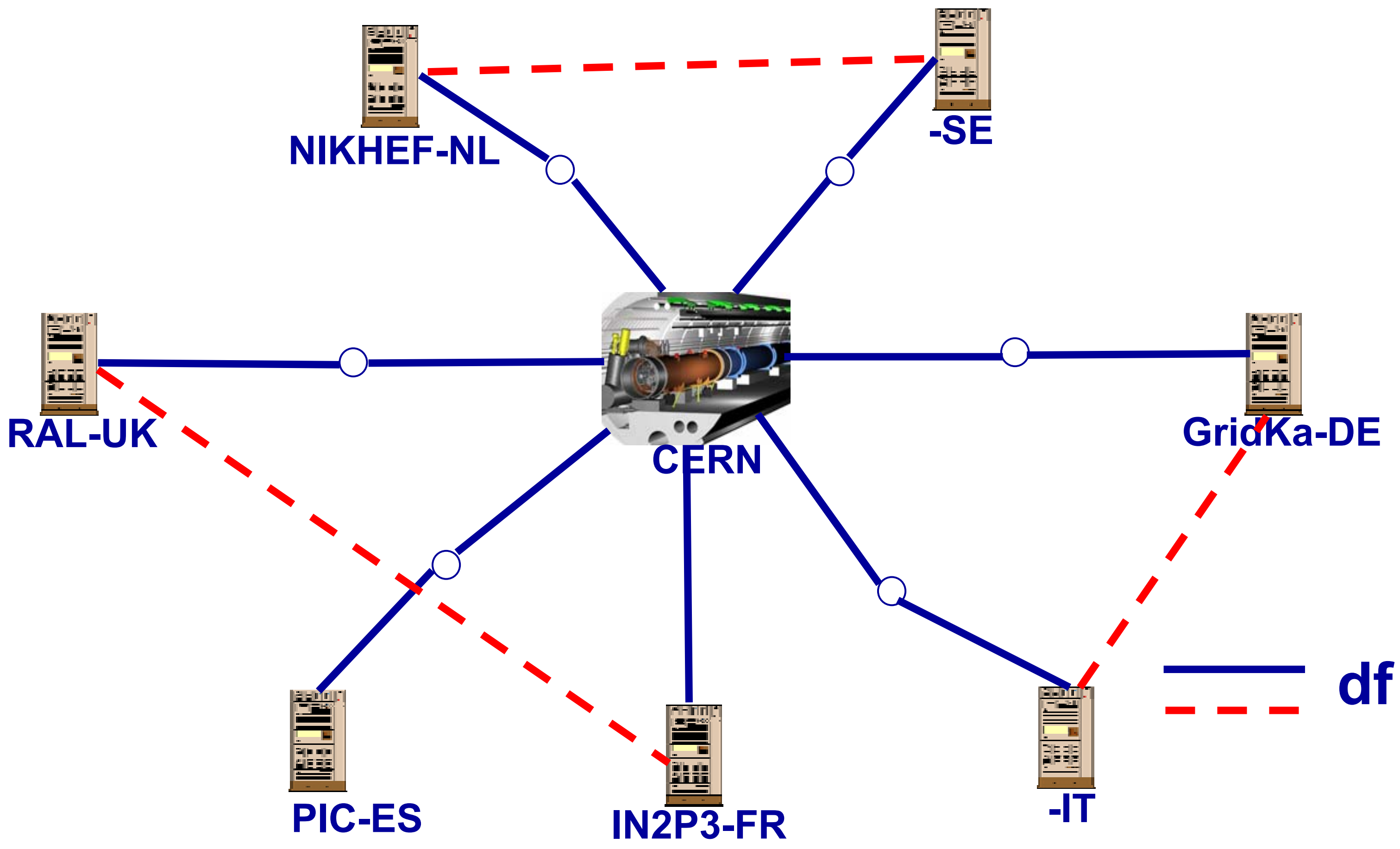
# Backup connectivity

- Backup paths are necessary in case of failure of the primary links.
- Recommended solution is to have two physically distinct paths using different interfaces on the T0-T1 equipment
- Backup connectivity can be also provided at Layer 3 via NRNs and  Research Backbones (potential impact on non-LHC production traffic)

# LHC: Cross Border dark Fibre complement



# LHC-RedIRIS (Spain)

- Connecting the PIC Tier 1 site in Barcelona
- Traffic crosses 3 domains prior to reaching GÉANT2:
  - PIC network
  - Anella Cientifica (Catalan Regional Network)
  - RedIRIS
- Currently 1Gbps VPN is supported
- Upgrade planned for RedIRIS connection to Catalan Network, date TBD
- 7 Tier 2 sites are known in Spain
- Bandwidth requirement of Tier 2 sites unknown
- Tier 2 sites connectivity varies from GE to STM-4

# LHC-DFN (Germany)

- DFN connects the Tier 1 site at Karlsruhe to CERN via GÉANT2
- Presently 10G Lambda is available, Karlsruhe-to-DFN-to-GÉANT-to-CERN
- Testing is already taking place and high-datarate transfers have been shown Karlsruhe to CERN
- Tier2 centres are not yet known so provision is unclear

# LHC-UKERNA (UK)

- UKERNA will connect the RAL Tier1 site to CERN via GÉANT2
- 1Gbps RAL-CERN via UKLight possible now
- 10G lambda to RAL expected by Autumn 2005
- 10G lambda RAL-UKLight (switched port)-GÉANT2 by end 2006
- Four distributed Tier 2 sites: NorthGrid, SouthGrid, ScotGrid, LondonGrid: bandwidth requirements unknown

# LHC-SURFnet (Netherlands)

- SURFnet will connect the Tier1 site at SARA, Amsterdam
- SURFnet6 provides a 10G lambda to SARA since July 2005
- Initially 10G Lambda to CERN will be provided by SURFnet, later by GÉANT2 when available
- Tier2 sites in the Netherlands will be connected via 10G lambdas by January 2006
- 1G lightpaths will be provided over Netherlight and/or GÉANT from Dutch Tier2s to non-Dutch Tier1s

# LHC-RENATER (France)

- RENATER will connect the IN2P3 (Lyon) Tier1 site *directly* to CERN (not via GÉANT2)
- RENATER will procure dark fibre between Paris, Lyon and CERN
- 10G lightpath will be provided Lyon-CERN
- Traffic to/from the 3 French Tier 2 sites will pass over the RENATER network

# LHC-NORDUnet (Nordic Countries)

- NORDUnet will connect the 'distributed' Tier1 site in the Nordic countries
- Connectivity via lambdas can be provided by mid-2006 for all the sites concerned

# LHC-GARR (Italy)

- GARR connects the Bologna Tier1 site to CERN via GÉANT2
- 10Gbps ring provided by GARR, connecting INFN-CNAF (Tier 1) and GÉANT2 PoP in Milan will be operational by the end of September 2005
- Presently available: 2*1G Lambda (CNAF-GARR-GEANT-CERN)
- By the end of 2005, multiple lambdas will be available from this site to GÉANT2, allowing as many 10Gbps connections as required
- Up to 12 Italian Tier2 candidates, all with DF to GARR backbone. TBD
- 8 Tier2 sites already have 1Gbps connection. All will have 1Gbps connectivity by end of September 2005

# LHC-Tier1 SUMMARY

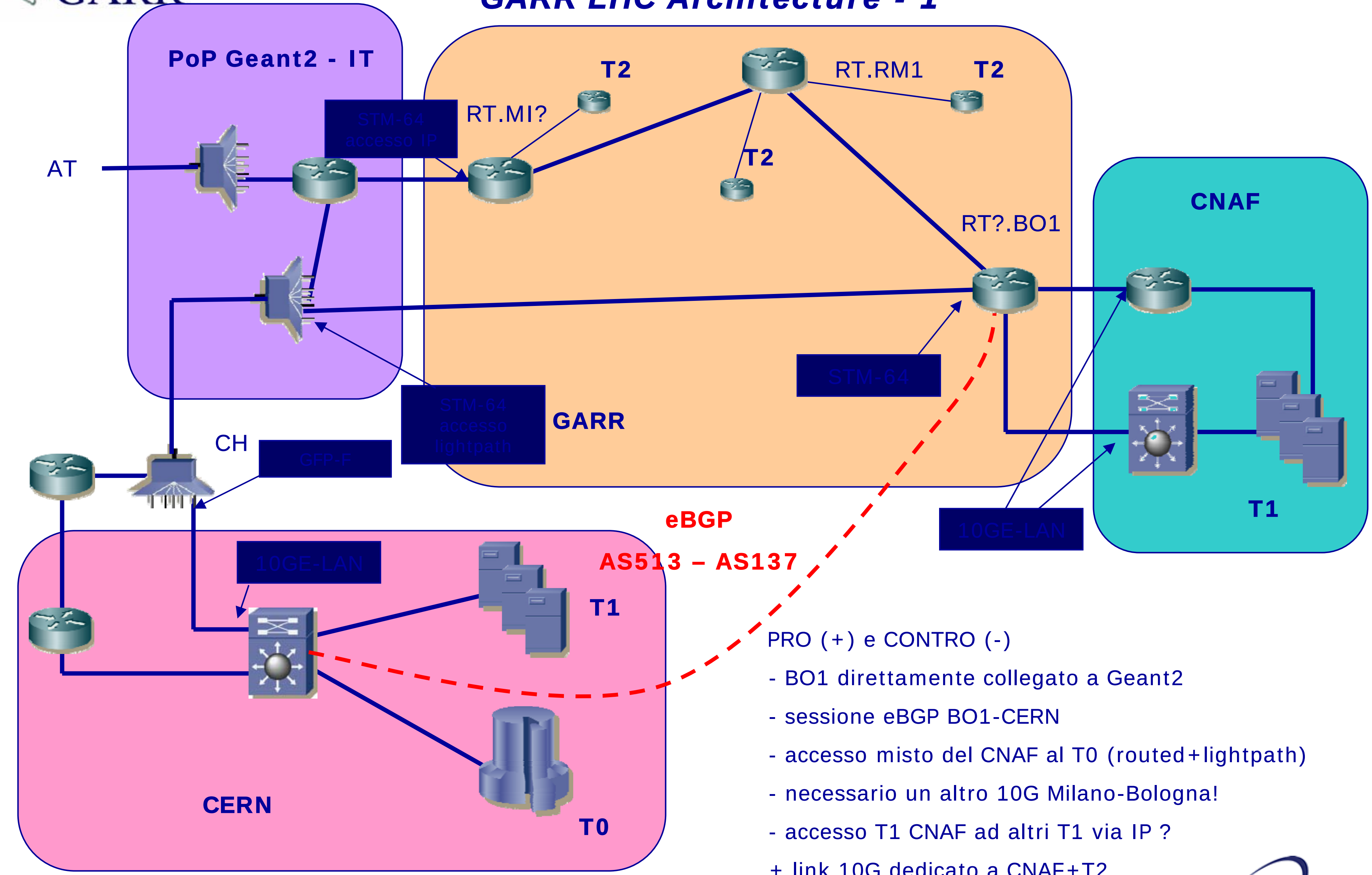
- Next Service challenge in March 2006

- 10G from Bologna to CERN, from Karlsruhe to CERN and between Karlsruhe and Bologna
  – available from December 2005
- Amsterdam will use Netherlight link to CERN until GÉANT2 paths are available
- Testing of Barcelona link at 10G from October 2005
- RAL and Nordic distributed facility restricted to 1G until late-2006 when 10G available

# LHC: INFN connectivity

- CNAF-T1 to CERN-T0
  - primary lightpath at 10G over CNAF-GARR-GEANT2-CERN
  - backup via IP
- CNAF-T1 to other T1's
  - lightpath at 10G CNAF-GARR-another T1 over CBF
  - 2 accesses at 10GE to GARR
- INFN-T2 to T0 is forbidden (allowed to CERN-T1...)
- INFN-T2 to CNAF-T1 and to other-T1/2
  - Access at (at least) 1G and via IP (resiliency)

# GARR LHC Architecture - 1




PRO (+) e CONTRO (-)

- BO1 direttamente collegato a Geant2
- sessione eBGP BO1-CERN
- accesso misto del CNAF al T0 (routed+lightpath)
- necessario un altro 10G Milano-Bologna!
- accesso T1 CNAF ad altri T1 via IP ?

+ link 10G dedicato a CNAF+T2

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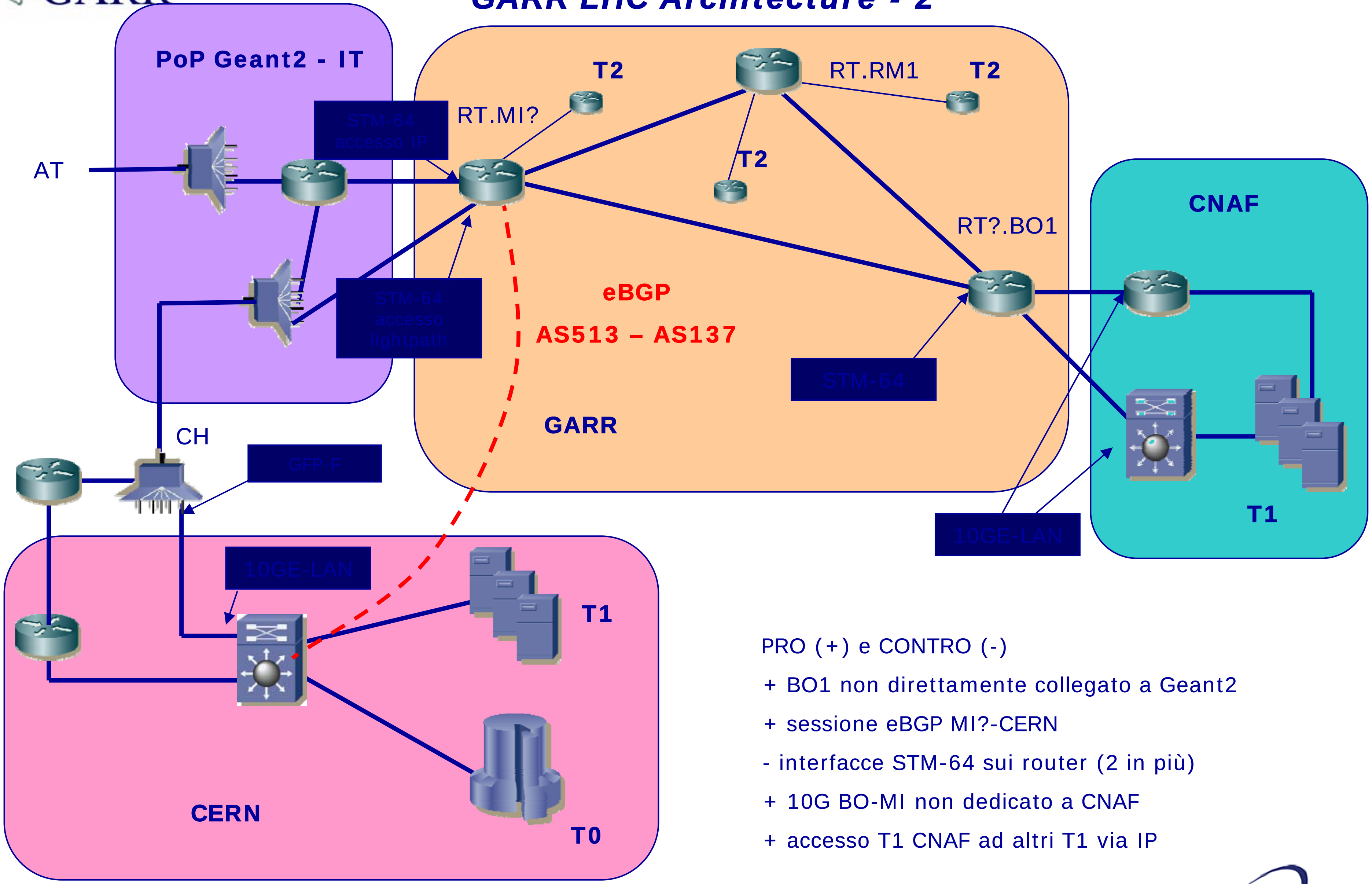
## *GARR LHC Architecture - 2*




PRO (+) e CONTRO (-)

+ BO1 non direttamente collegato a Geant2

+ sessione eBGP MI?-CERN

- interfacce STM-64 sui router (2 in più)

+ 10G BO-MI non dedicato a CNAF

+ accesso T1 CNAF ad altri T1 via IP

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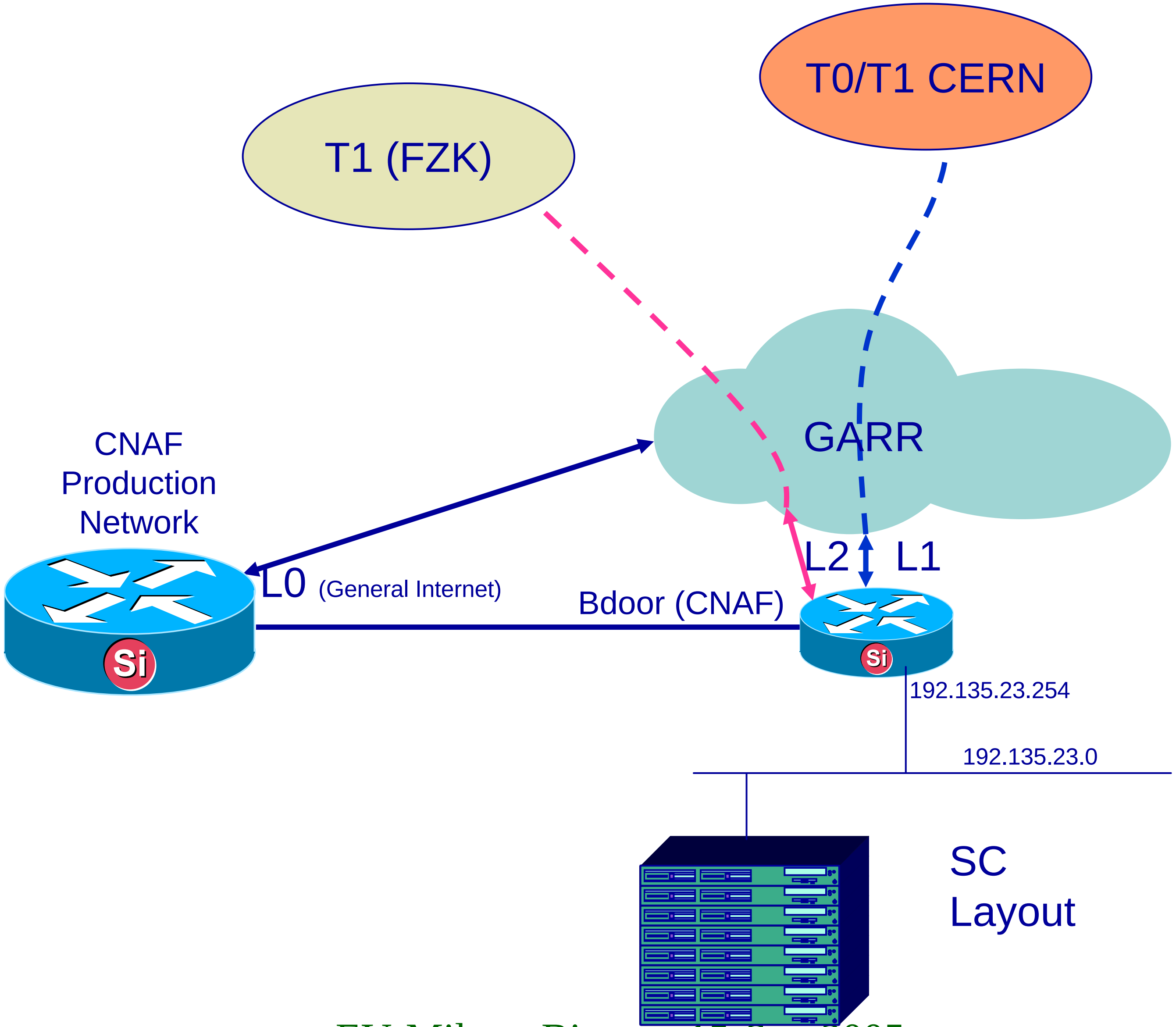
# LHC: CNAF Service Challenge Phase 1





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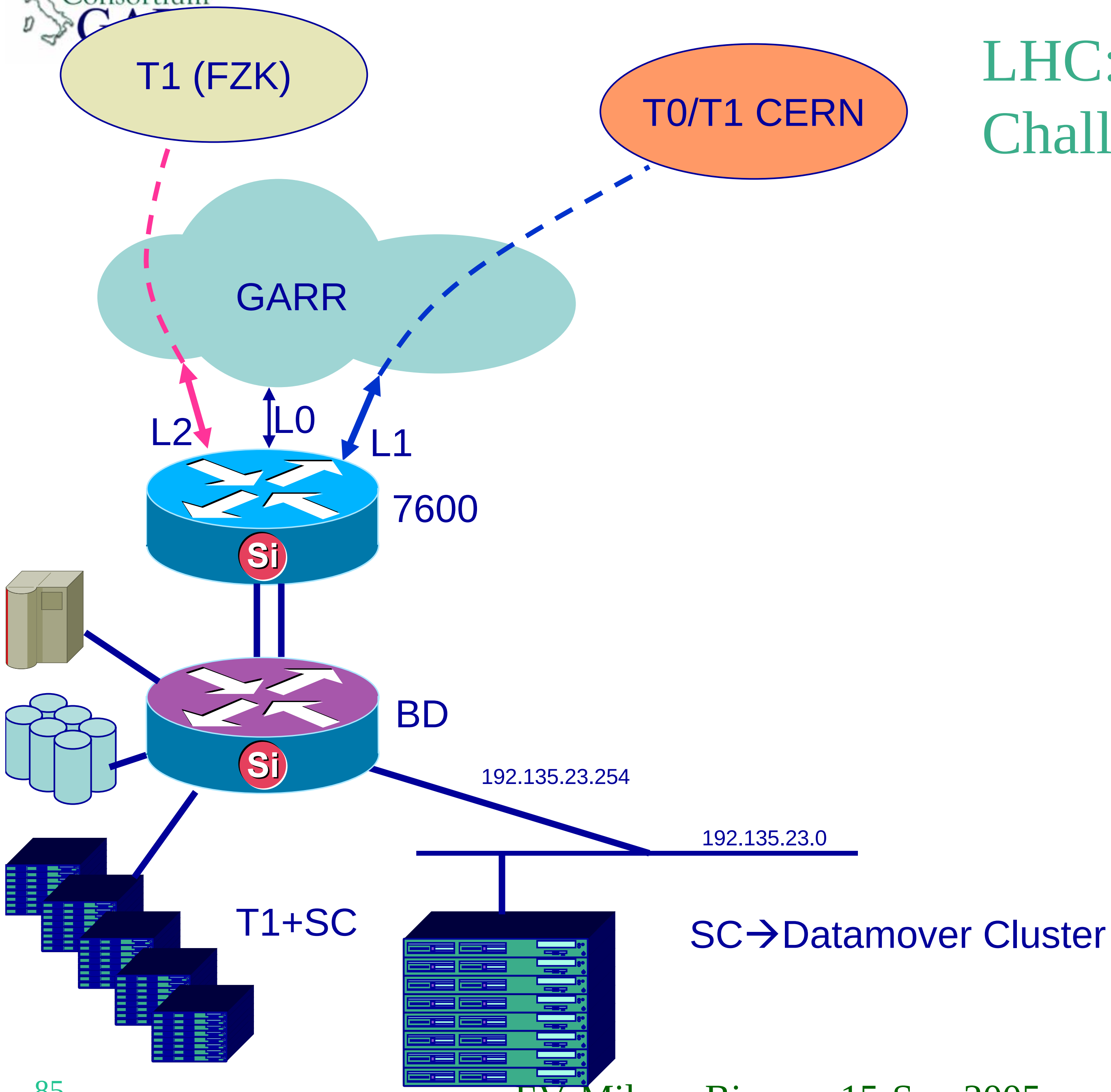
# LHC: CNAF Service Challenge Phase 2



# LHC: INFN and GARR

- 1 Tier1 (2*10Gbps) at INFN-CNAF (dic 2005)
- INFN Tier-2 candidates (1Gbps) among:
  - Bari, Catania, LNF, LNL, Milano, Napoli, Pisa, Roma, Torino

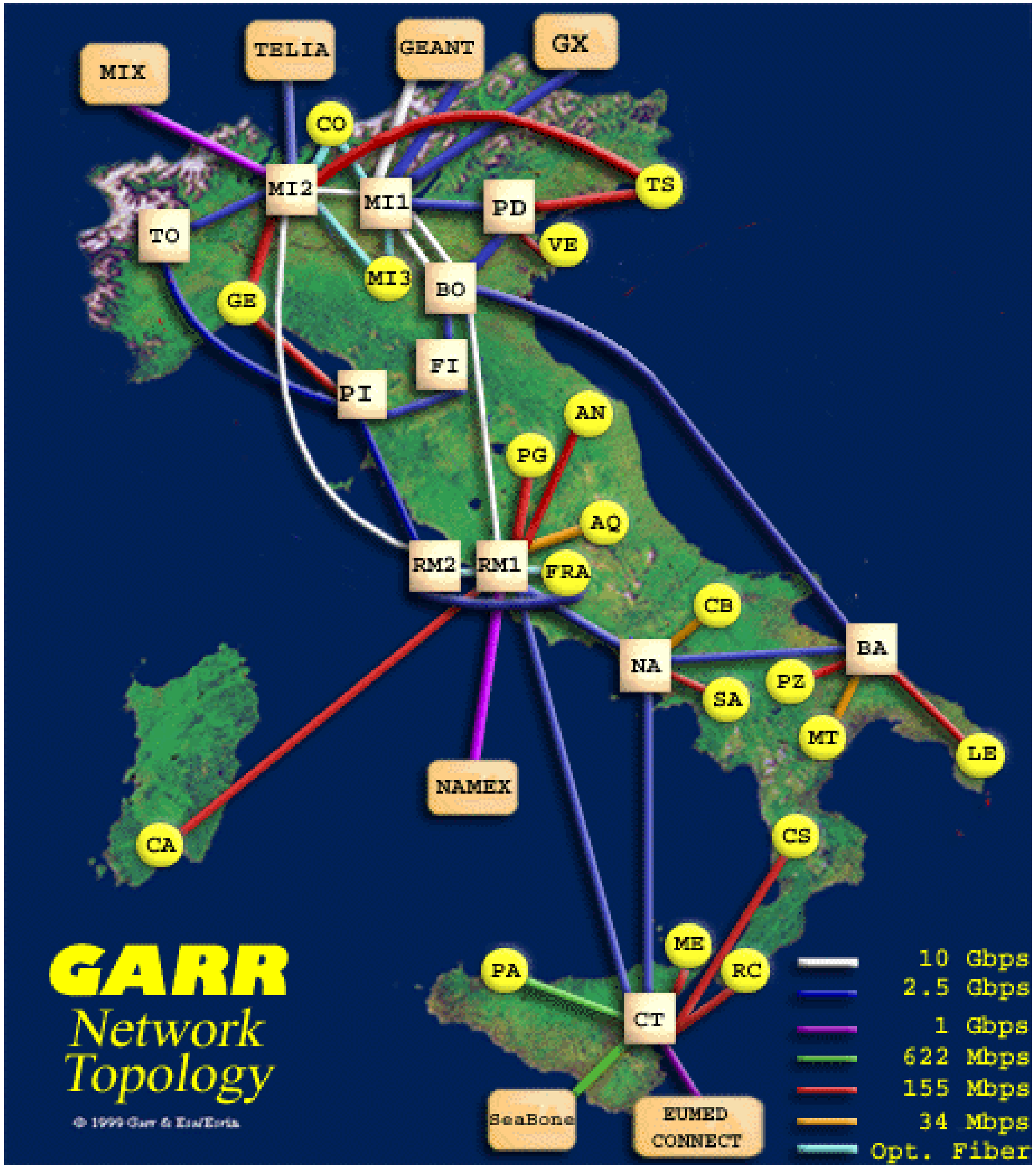
| | Sede | PoP | BGA | BEA | link | Data Attivazione | Disponibilità fibre | Necessità lato Sezione | ALICE | LHCb | CMS | ATLAS | Sede |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | INFN - Bari | BA1 | 16.384 | 46.080 | 100M-FE | 20050101 | Si | Porta 1Gbps | X | | X | | INFN - Bari |
| 2 | INFN - Bologna | BO1 | 25.600 | 158.720 | 1G-GE | 20050101 | Si | | | | | | INFN - Bologna |
| 3 | INFN - Catania-Cittadella | CT1 | 30.720 | 100.000 | 100M-FE | 20050114 | Si | | X | | | | INFN - Catania-Cittadella |
| 4 | INFN - Catania-GRID | CT1 | 0 | 1.000.000 | 1G-GE | 20040728 | Si | | | | | | INFN - Catania-GRID |
| 5 | INFN - CNAF - Bologna | BO1 | 200.000 | 1.000.000 | 1G-GE | 20050101 | Si | | | X | | | INFN - CNAF - Bologna |
| 6 | INFN - Firenze-Sesto | FI1 | 8.192 | 32.768 | 1G-GE | 20050101 | Si | | | | | | INFN - Firenze-Sesto |
| 7 | INFN - LNF - Frascati | Fra | 32.768 | 98.304 | 155M-ATM | 20050222 | Si | Porta 1Gbps | | | | X | INFN - LNF - Frascati |
| 8 | INFN - LNL - Legnaro (PD) | PD1 | 98.304 | 1.000.000 | 1G-GE | 20050101 | Si | | X | | X | | INFN - LNL - Legnaro (PD) |
| 9 | INFN - Milano | MI3 | 32.768 | 130.000 | 155M-ATM | 20050101 | Si | | | | | X | INFN - Milano |
| 10 | INFN - Napoli | NA1 | 32.768 | 65.536 | 100M-FE | 20050101 | Si | Porta 1Gbps | | | | X | INFN - Napoli |
| 11 | INFN - Padova | PD1 | 160.000 | 1.000.000 | 1G-GE | 20050101 | Si | | | | | | INFN - Padova |
| 12 | INFN - Pisa - Fibonacci | PI1 | 32.768 | 1.000.000 | 1G-GE | 20050427 | Si | | | | X | | INFN - Pisa - Fibonacci |
| 13 | INFN - Roma1 | RM1 | 40.960 | 100.000 | 1G-GE | 20050101 | Si | | | | X | X | INFN - Roma1 |
| 14 | INFN - Torino | TO1 | 51.200 | 1.000.000 | 1G-GE | 20050101 | Si | | X | | | | INFN - Torino |

# INFN sites and labs connected to GARR

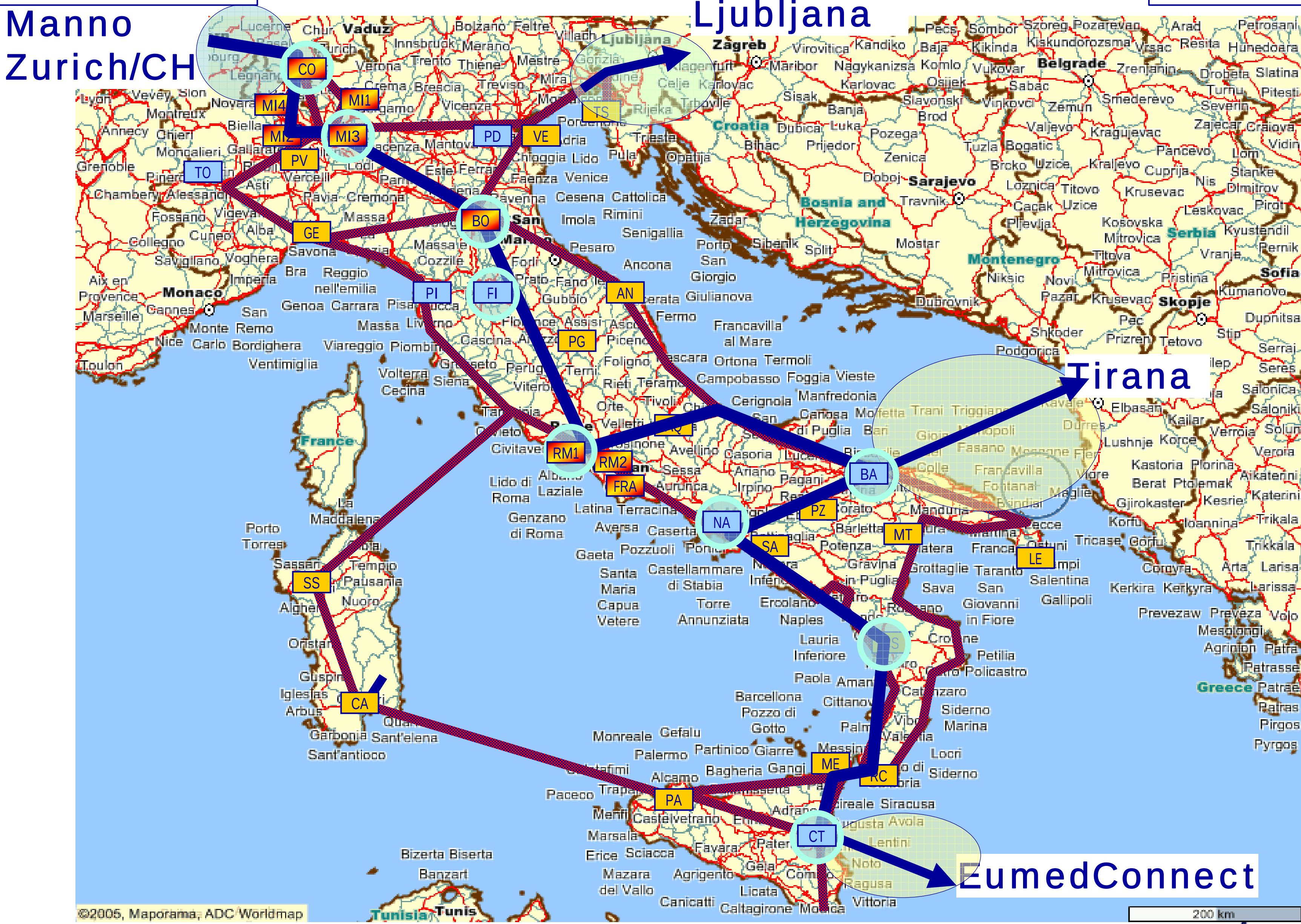
| Sede | Descrizione | Citta | PoP di accesso | Router di Trasporto | BGA | BEA | Velocita del link |
|---|---|---|---|---|---|---|---|
| INFN - AC - Frascati | INFN - Sede Amministrativa Centrale | 00044 Frascati (RM) | PoP-Fra | RC-Fra | 0 | 0 | I-LNF 100M-FE |
| INFN - Bari | INFN - Sezione di Bari | 70126 Bari | PoP-BA1 | RT-BA1 | 16.384 | 46.080 | 100M-FE |
| INFN - Bologna | INFN - Sezione di Bologna | 40127 Bologna | PoP-BO1 | RT1-BO1 | 25.600 | 158.720 | 1G-GE |
| INFN - Cagliari | INFN - Sezione di Cagliari | 09042 Monserrato (CA) | CA | RM | 16.384 | 30.720 | 34M-ATM |
| INFN - Catania-Cittadella | INFN - Sezione di Catania | 95125 Catania | PoP-CT1 | RT-CT1 | 30.720 | 100.000 | 100M-FE |
| INFN - Catania-GRID | INFN-GRID Sezione di Catania | 95125 Catania | PoP-CT1 | RT-CT1 | 0 | 1.000.000 | 1G-GE |
| INFN - CNAF - Bologna | INFN - CNAF | 40127 Bologna | PoP-BO1 | RT1-BO1 | 200.000 | 1.000.000 | 1G-GE |
| INFN - CNAF-LCG Bologna | INFN - CNAF | 40127 Bologna | PoP-BO1 | RT1-BO1 | 0 | 1.000.000 | 1G-GE |
| INFN - Cosenza | INFN - Gruppo Coll.. di Cosenza | 87036 Arcavacata di Rende (CS) | PoP-CS | RC-CS | 8.192 | 16.384 | 100M-FE |
| INFN - Ferrara | INFN - Sezione di Ferrara | 44100 Ferrara | PoP-BO1 | RT-BO1 | 15.360 | 24.576 | 155M-ATM |
| INFN - Firenze-Sesto | INFN - Sezione di Firenze | 50019 Sesto Fiorentino (FI) | PoP-FI1 | RT-FI1 | 8.192 | 32.768 | 1G-GE |
| INFN - Genova | INFN - Sezione di Genova | 16146 Genova | PoP-GE1 | RC-GE | 12.288 | 32.768 | 100M-FE |
| INFN - L'Aquila | INFN- Gruppo Coll. dell'Aquila | 67010 L'Aquila | AQ | RM | 8.192 | 8.192 | 4*2M |
| INFN - Lecce | INFN - Sezione di Lecce | 73100 Lecce | PoP-BA | RC-BA | 8.192 | 12.288 | U-LE 155M-ATM |
| INFN - LNF - Frascati | INFN - Laboratori Nazionali di Frascati | 00044 Frascati (RM) | PoP-Fra | RC-Fra | 32.768 | 98.304 | 155M-ATM |
| INFN - LNGS - Assergi (AQ) | INFN - Laboratori Nazionali del Gran Sasso | 67010 Assergi (AQ) | PoP-AQ | RC-AQ | 16.384 | 30.720 | 34M-ATM |
| INFN - LNL - Legnaro (PD) | INFN - Laboratori Nazionali di Legnaro | 35020 Legnaro (PD) | PoP-PD1 | RT-PD1 | 98.304 | 1.000.000 | 1G-GE |
| INFN - LNS - Catania | INFN - Laboratori Nazionali del Sud | 95123 Catania | PoP-CT1 | RT-CT1 | 10.240 | 30.720 | 100M-FE |
| INFN - Messina | INFN - Gruppo col. di Messina | 98166 Vill. S.Agata (ME) | NA | NA | 1.024 | 1.024 | 2M |
| INFN - Milano | INFN - Sezione di Milano | 20133 Milano | PoP-MI3 | RT-MI3 | 32.768 | 130.000 | 155M-ATM |
| INFN - Milano - Bicocca | INFN Milano II Bicocca | 20126 Milano | PoP-MI | RC-MI | 12.288 | 30.720 | 34M-ATM |
| INFN - Napoli | INFN - Sezione di Napoli | 80126 Napoli | PoP-NA1 | RT-NA1 | 32.768 | 65.536 | 100M-FE |
| INFN - Padova | INFN - Sezione di Padova | 35131 Padova | PoP-PD1 | RT-PD1 | 160.000 | 1.000.000 | 1G-GE |
| INFN - Parma | INFN - Gruppo col. di Parma | 43100 Parma | PoP-BO1 | RC-BO1 | 4.096 | 16.384 | U-PR 100M-FE |
| INFN - Pavia | INFN - Sezione di Pavia | 27100 Pavia | PoP-MI3 | RC-MI3 | 10.240 | 30.720 | 155M-ATM |
| INFN - Perugia | INFN - Sezione di Perugia | 06100 Perugia | PG | RM | 12.288 | 12.288 | 155M-ATM |
| INFN - Pisa - Fibonacci | INFN - Sezione di Pisa | 56127 Pisa | PoP-PI1 | RT-PI1 | 32.768 | 1.000.000 | 1G-GE |
| INFN - Pisa - S.Piero | INFN - Sezione di Pisa | 56010 San Piero a Grado (PI) | PoP-PI | RC-PI | 2.048 | 4.096 | 34M-ATM |
| INFN - Presidenza - Roma | INFN - Uffici di Presidenza | 00186 Roma | (vedi INFN-Roma1) | (vedi INFN-Roma1) | 0 | 0 | I-RM1 |
| INFN - Roma1 | INFN - Sezione di Roma1 | 00185 Roma | PoP-RM1 | RT-RM1 | 40.960 | 100.000 | 1G-GE |
| INFN - Roma2 | INFN - Sezione di Roma2 | 00133 Roma | PoP-RM1 | RT-RM1 | 10.240 | 71.680 | 155M-ATM |
| INFN - Roma3 | INFN - Sezione di Roma3 | 00146 Roma | PoP-RM2 | RT-RM2 | 8.192 | 32.768 | 100M-FE |
| INFN - Salerno | INFN - Gruppo col. di Salerno | 84081 Baronissi (SA) | PoP-SA | RC-SA | 4.096 | 16.384 | 100M-FE |
| INFN - Sanita' - Roma | INFN - Gruppo col. di Roma1 | 00161 Roma | (vedi INFN-Roma1) | (vedi INFN-Roma1) | 0 | 0 | I-RM1 |
| INFN - Torino | INFN - Sezione di Torino | 10125 Torino | PoP-TO1 | RT-TO1 | 51.200 | 1.000.000 | 1G-GE |
| INFN - Trento | INFN - Gruppo collegato di Trento | 38050 Povo (TN) | MI | MI | 1.024 | 1.024 | 2M |
| INFN - Trieste - Miramare | INFN - Trieste - Miramare | 34100 Trieste | TS | MI | 2.048 | 4.098 | U-SISSA 100M-FE |
| INFN - Trieste - Padriciano | INFN - Sezione di Trieste | 34012 Trieste | PoP-TS | RC-TS | 24.576 | 30.720 | 34M-ATM |
| INFN - Udine | INFN - Gruppo col. Udine | 33100 Udine | PoP-PD1 | RT-PD1 | 4.096 | 8.192 | U-UD 100M-FE |

The GARR-G backbone

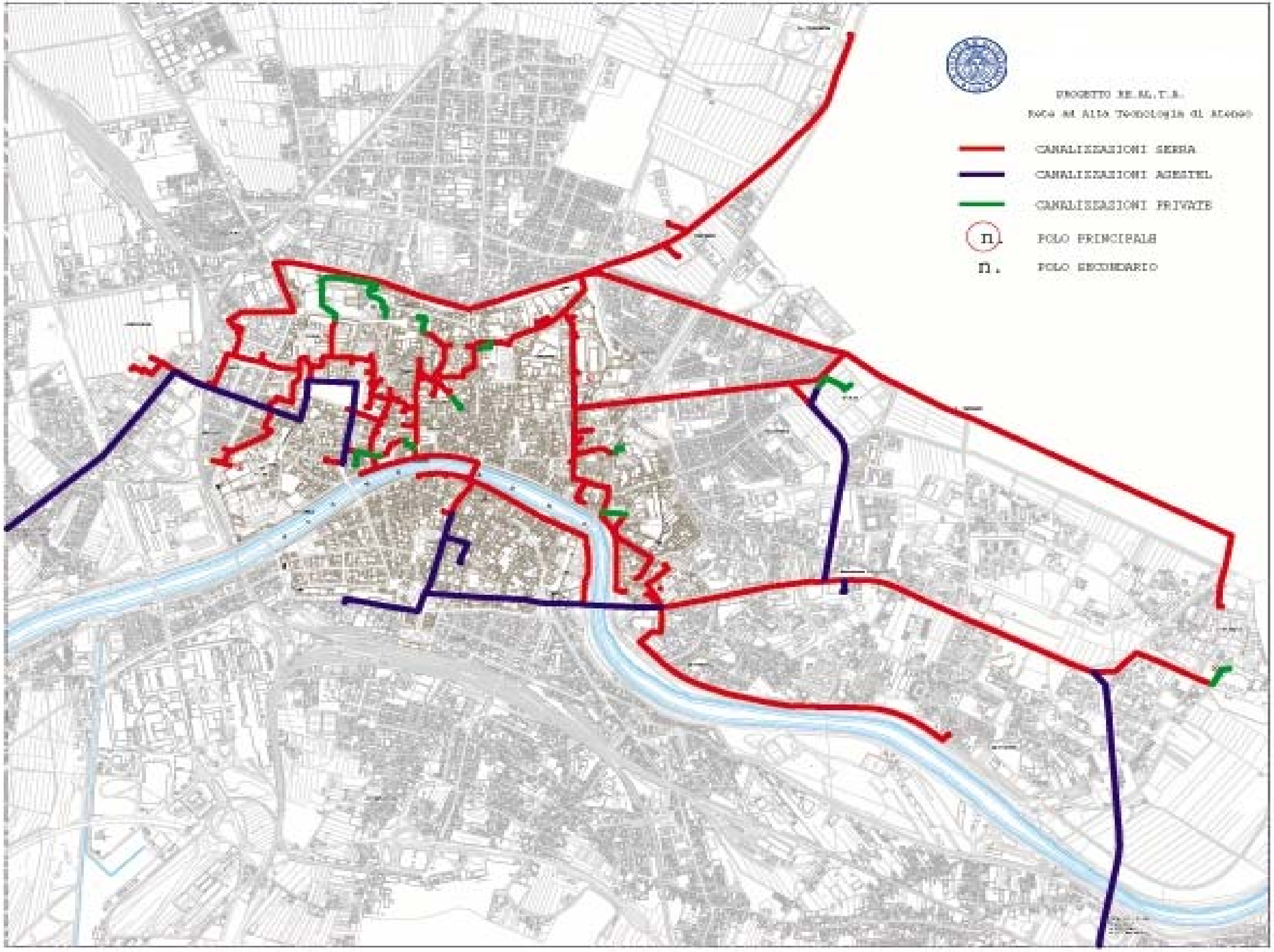
(Sep-Dec 2005)



# GARR-X Backbone and CBF



# SerRA: La rete metropolitana di Pisa



Consortium GARR

# BARI Città

Scala

0 1000 m

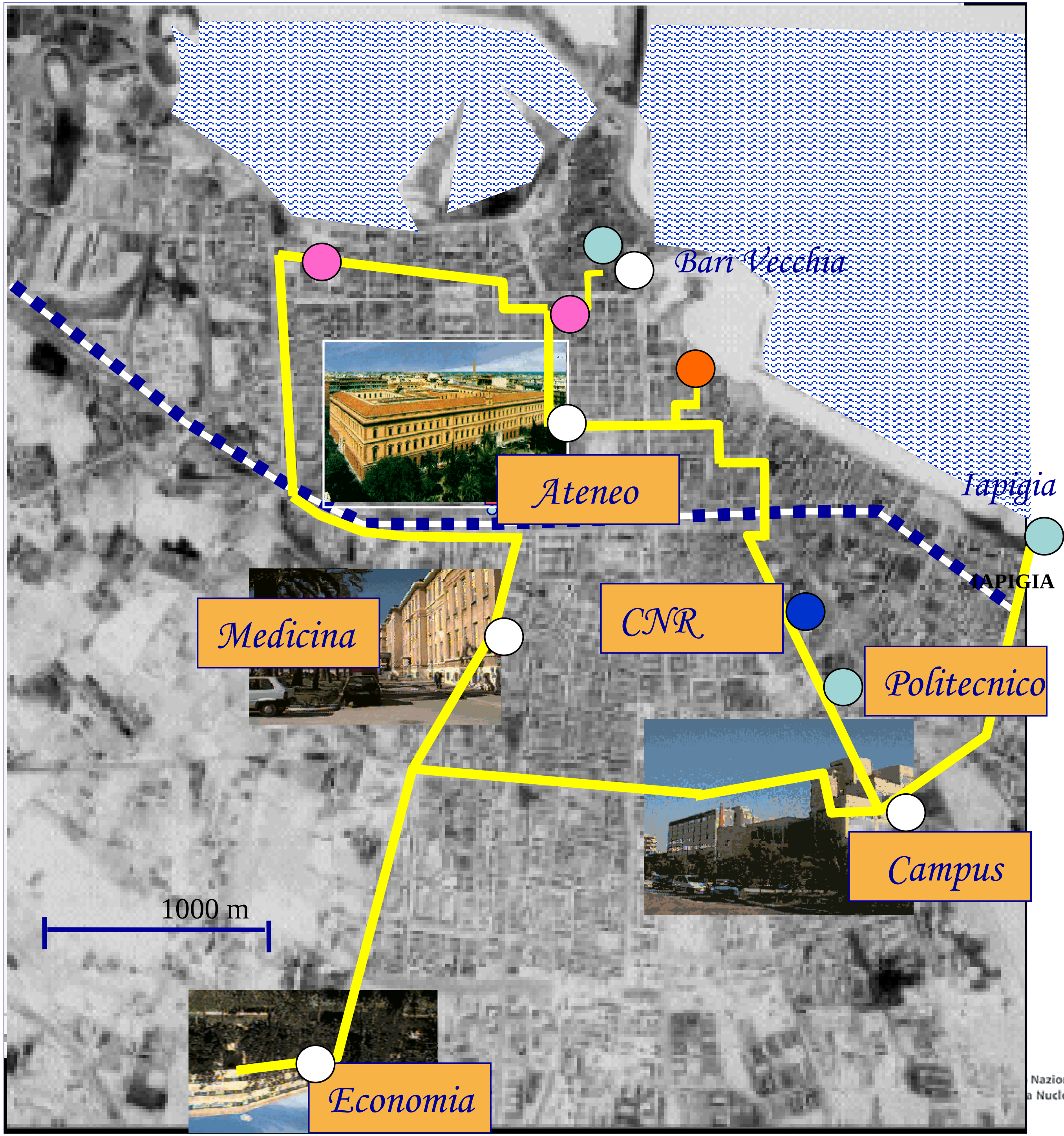
## Rete

## Accademica

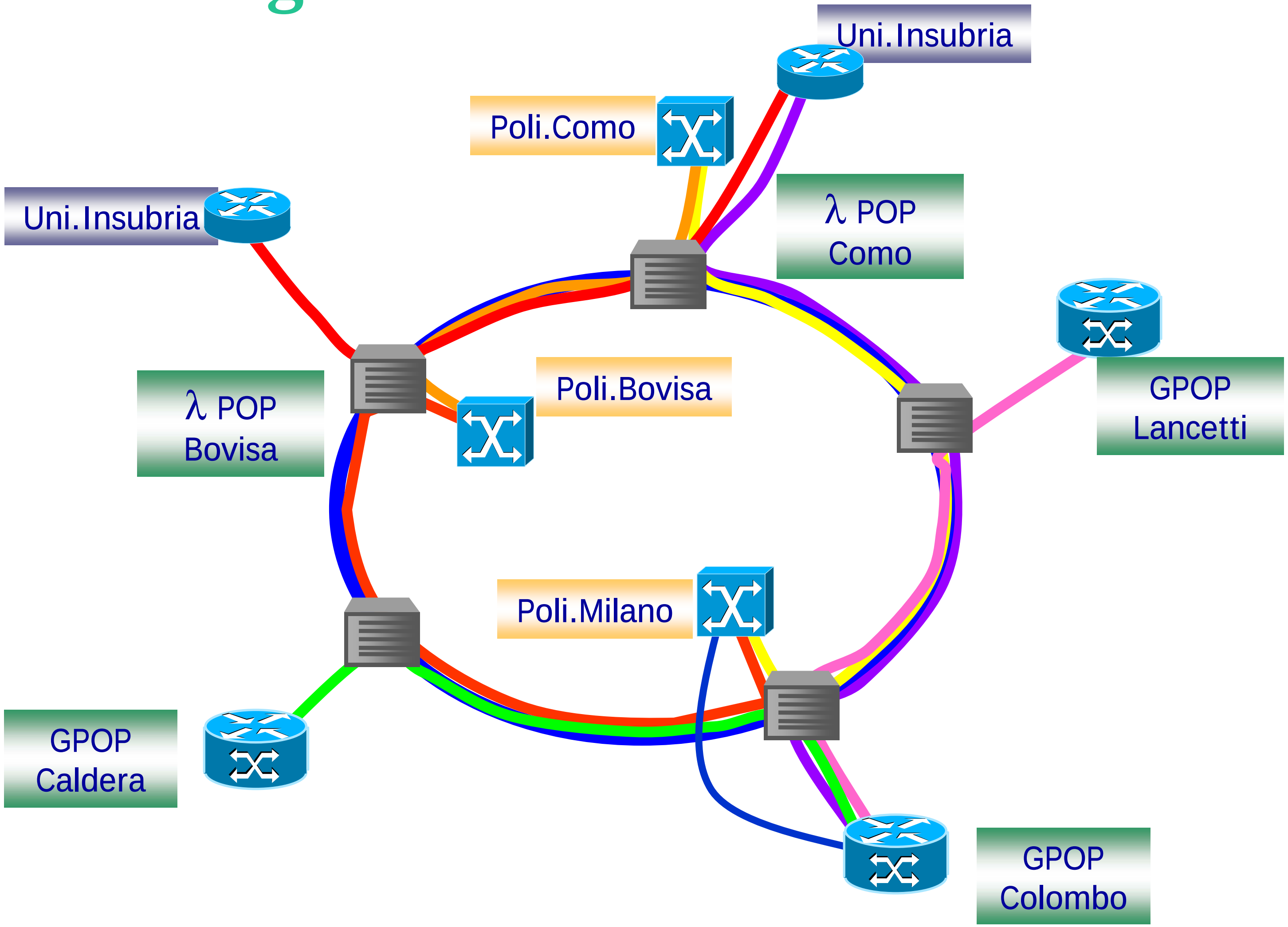
## Metropolitana

- Università
- Politecnico
- CNR
- Comune
- Acquedotto

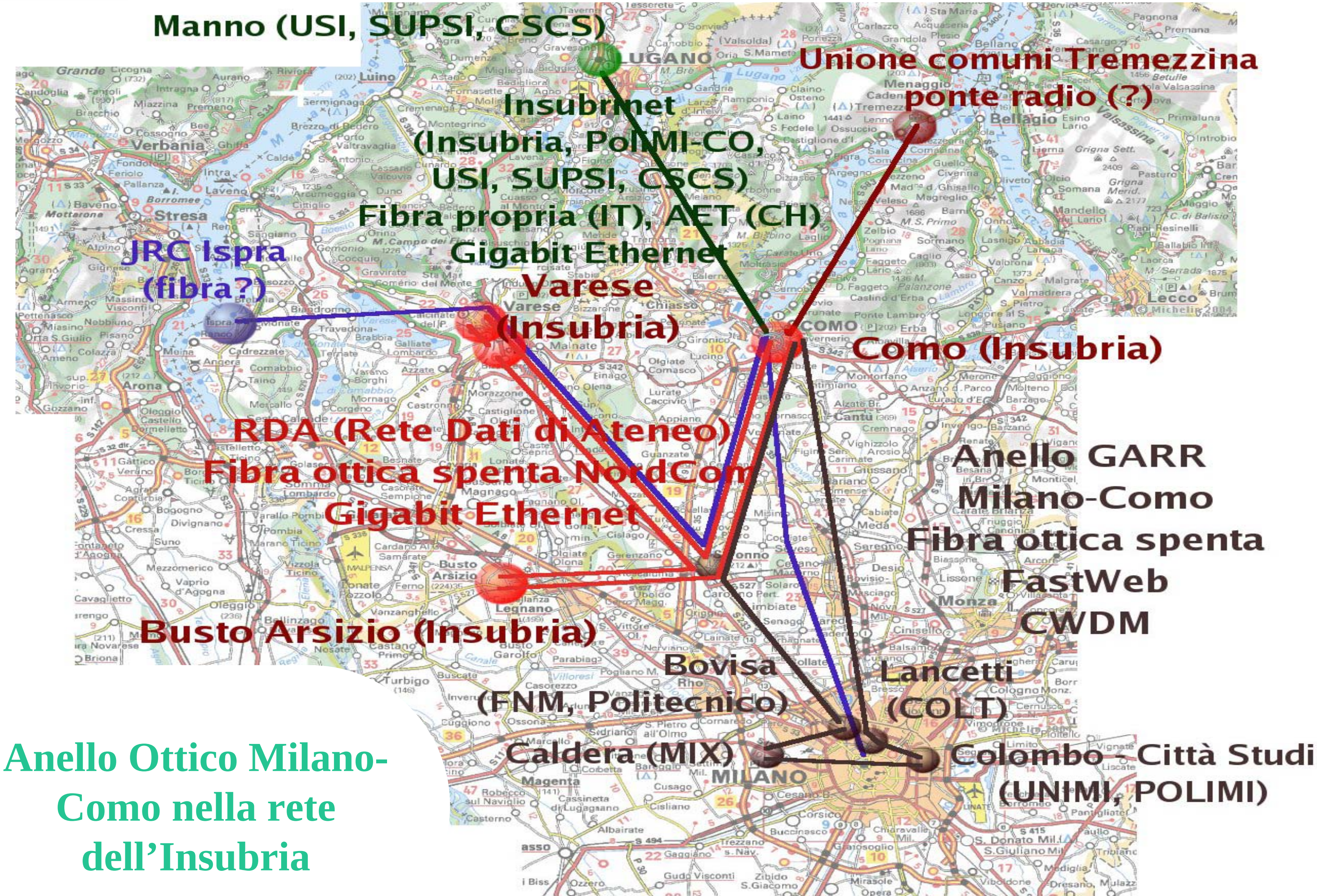
22 Km di cavo
a 24 fibre.



# Anello Ottico Milano Como nella Rete regionale dell'Insubria



Consortium GARR




**Anello Ottico Milano-Como nella rete dell'Insubria**



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