eScience Applications on the SURFnet R&E Network

Cees de Laat

EU

SURFnet

NWO

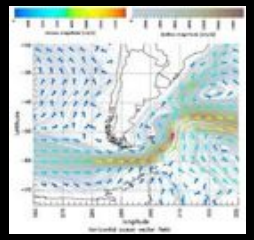
University of Amsterdam

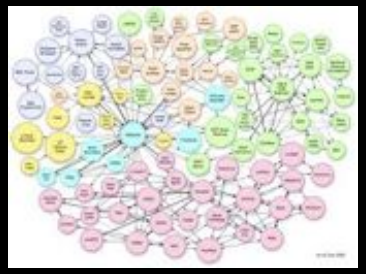
TNO

NCF

Internet developments

... more data!





... more realtime!

... more users!

Internet developments

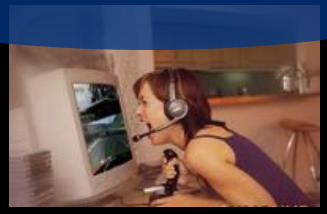
... more data!

Speed

Volume

Deterministic

Real-time

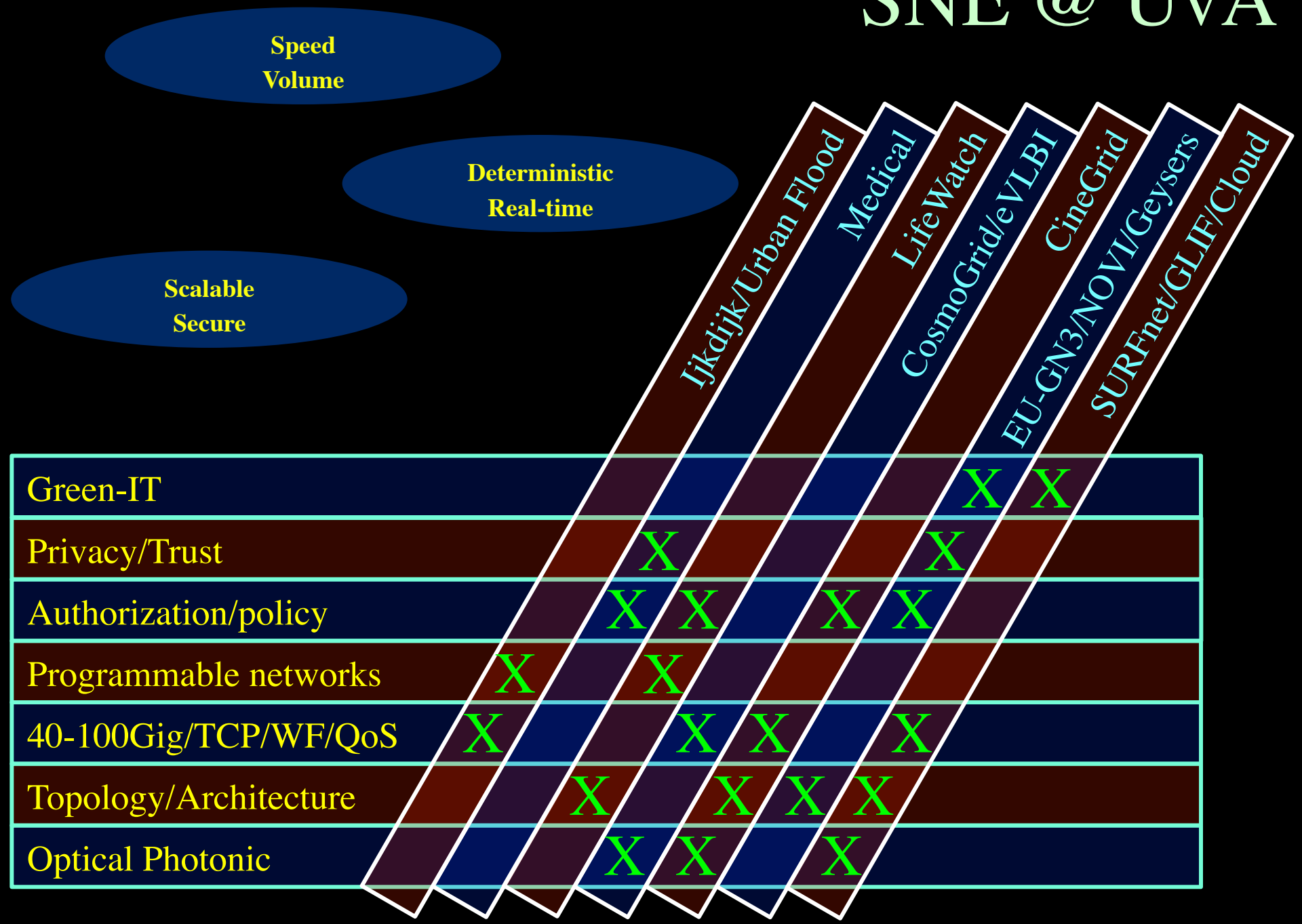


Scalable

Secure

... more users!

SNE @ UvA


Speed
Volume
Deterministic
Real-time
Scalable
Secure
Ijkdijk/Urban Flood
Medical
LifeWatch
CosmoGrid/eVLBI
CineGrid
EU-GN3/NOVI/Geysers
SURFnet/GLIF/Cloud
Green-IT
Privacy/Trust
Authorization/policy
Programmable networks
40-100Gig/TCP/WF/QoS
Topology/Architecture
Optical Photonic
X X
X X
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X X
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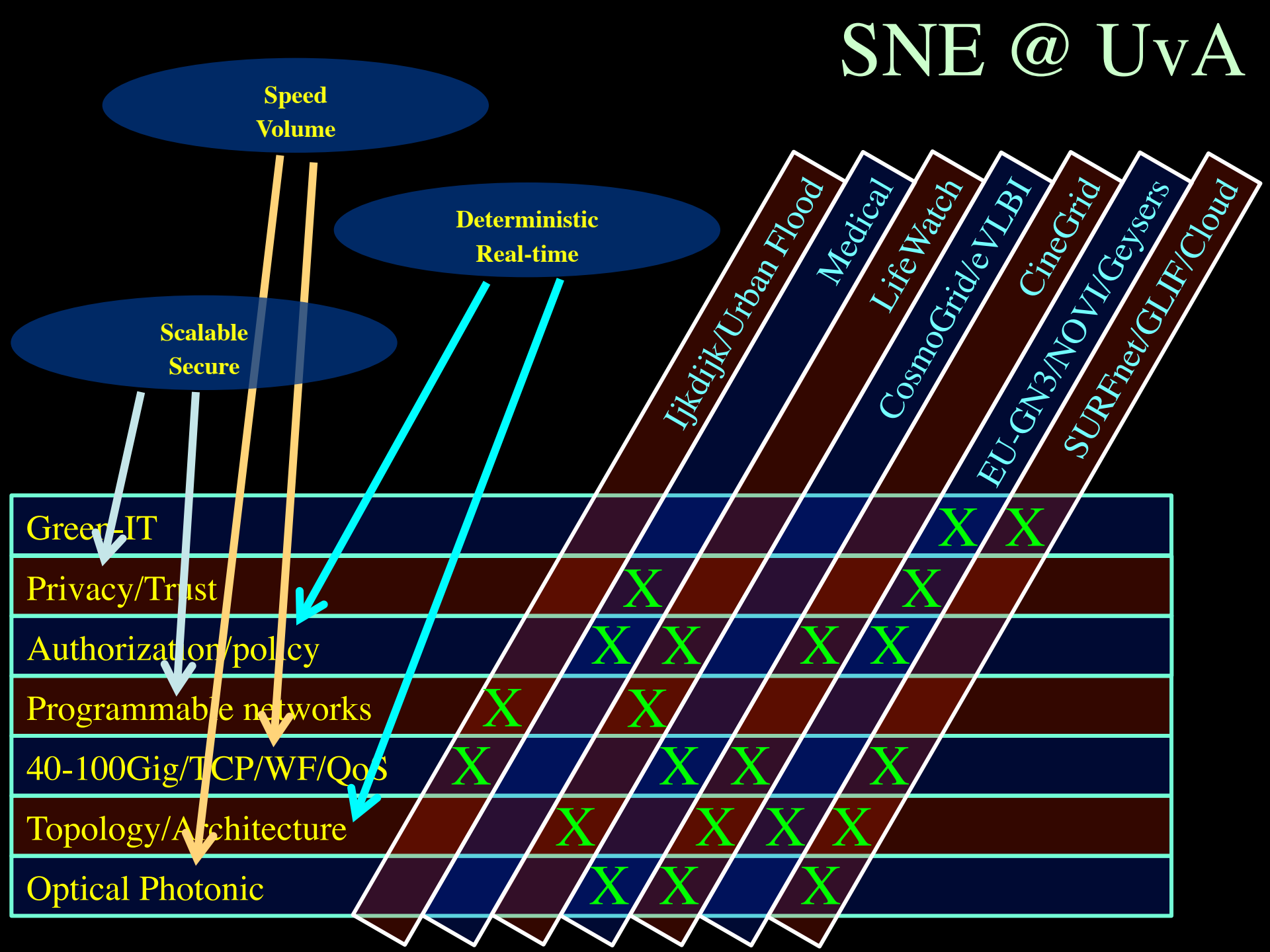
X X X

SNE @ UvA


Speed
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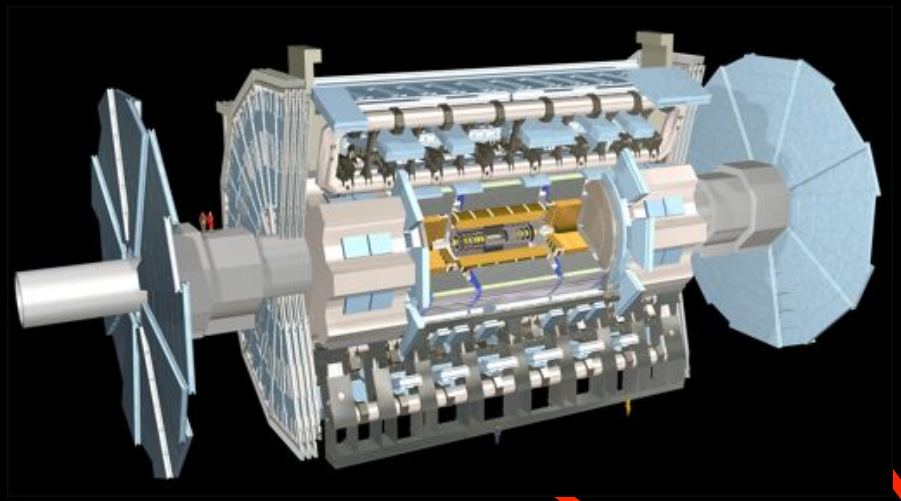
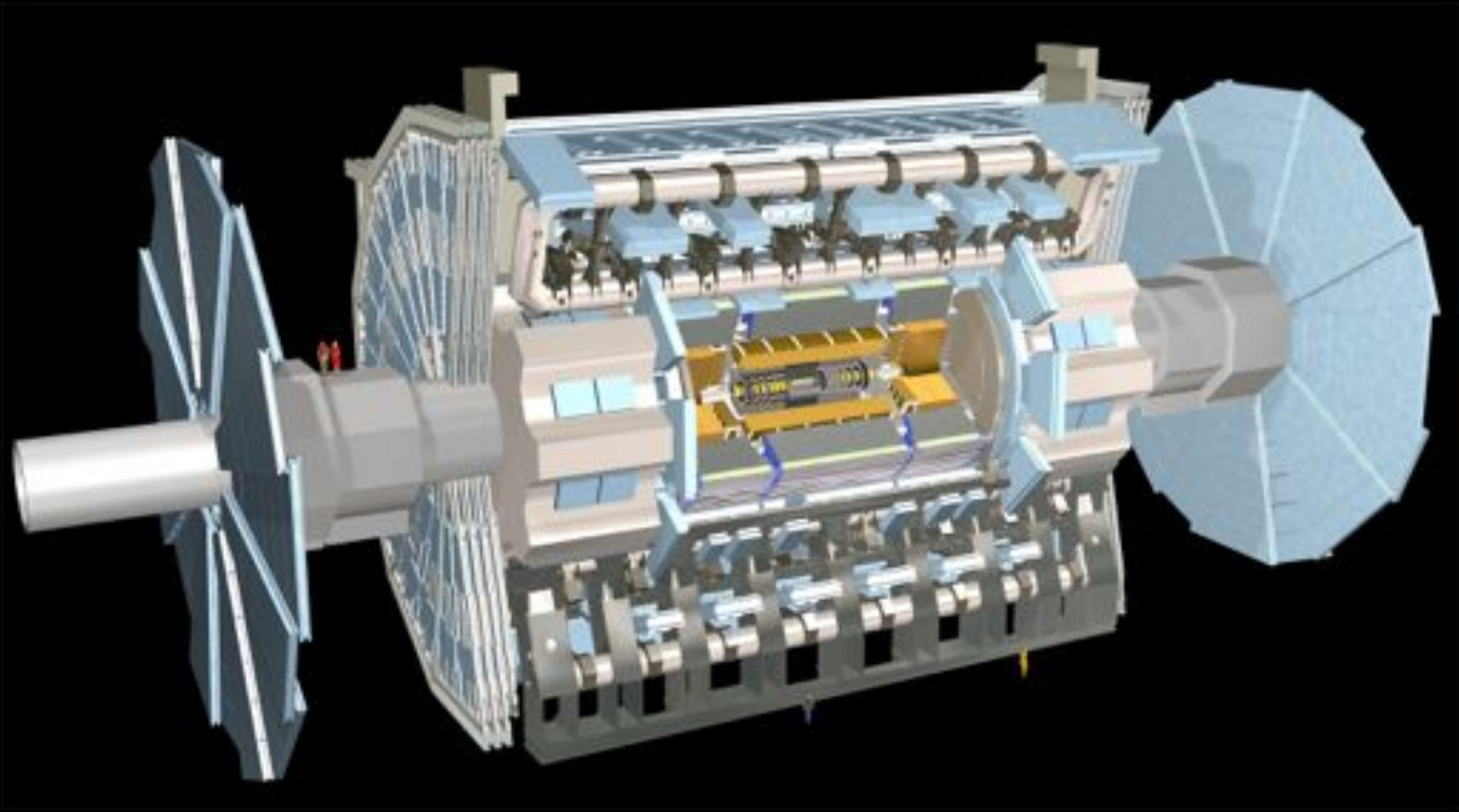
SNE @ UvA

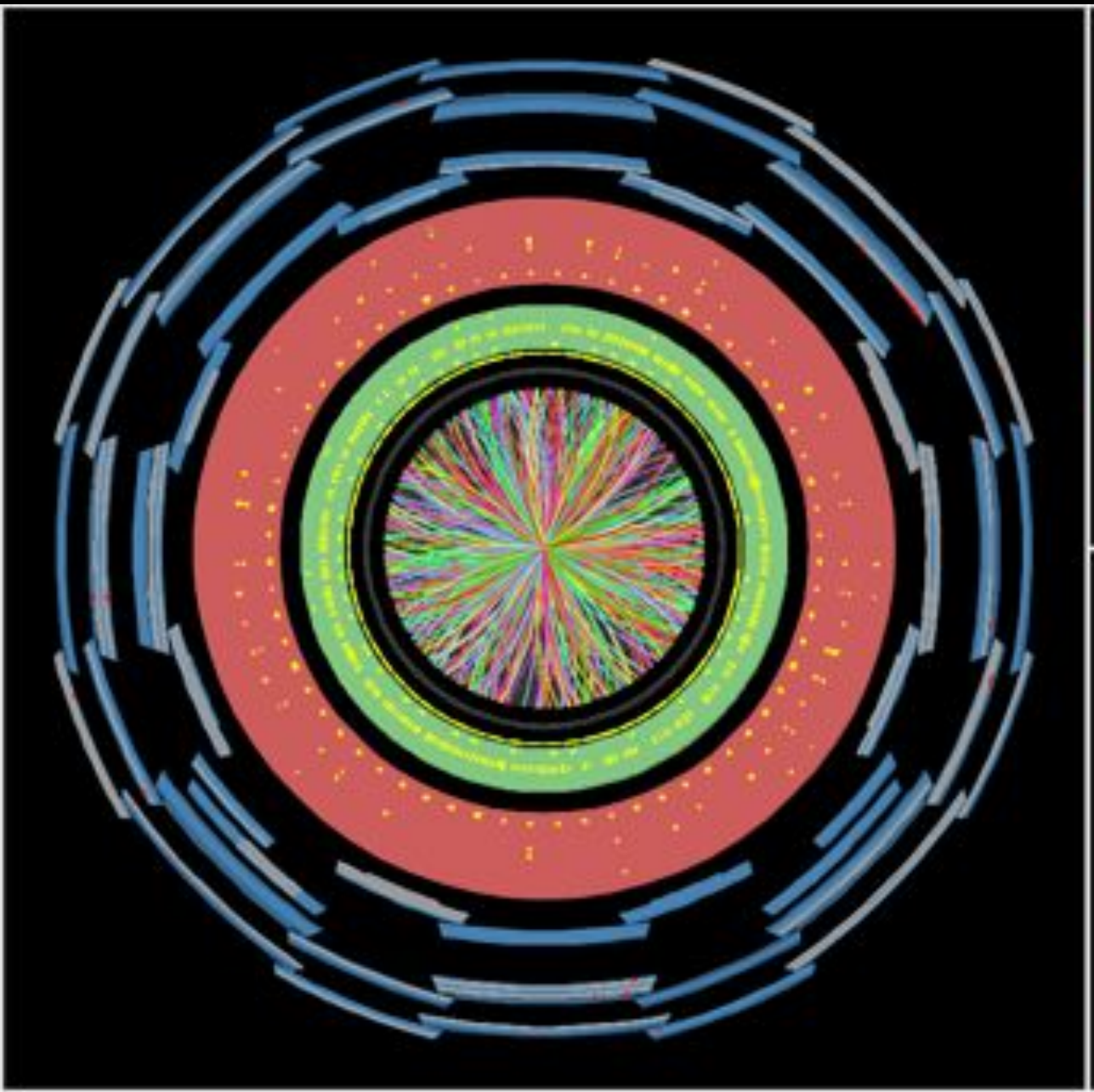


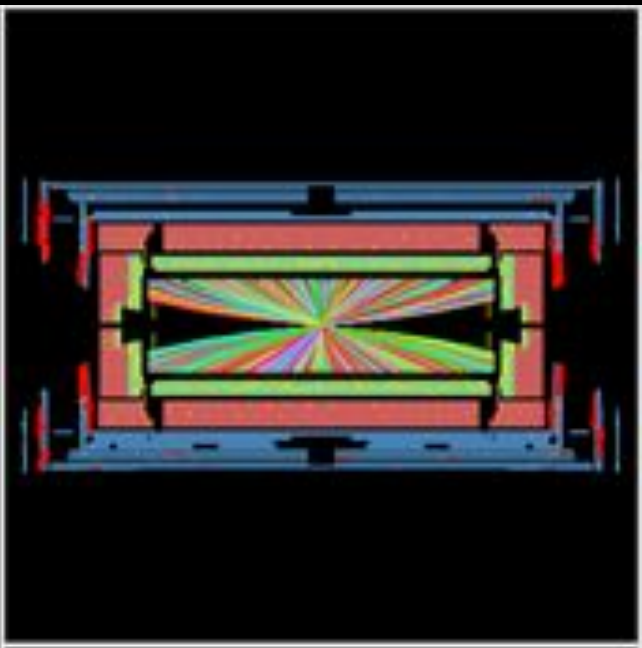
	Ijkdijk/Urban Flood	Medical	LifeWatch	CosmoGrid/eVLBI	CineGrid	EU-GN3/NOVI/Geysers	SURFnet/GLIF/Cloud
Green-IT						X	X
Privacy/Trust		X			X		
Authorization/policy		X	X		X	X	
Programmable networks	X		X				
40-100Gig/TCP/WF/QoS	X		X	X		X	
Topology/Architecture		X		X	X	X	
Optical Photonic		X	X		X		

ATLAS detector @ CERN Geneve



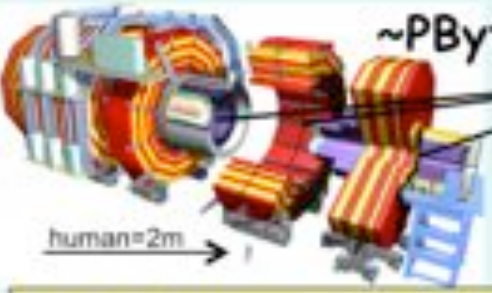
One Event in Atlas!





LHC Data Grid Hierarchy

CMS as example, Atlas is similar



~PByte/sec

Online System

~100 MBytes/sec

100000 flops/byte

10 Pflops/s

event simulation

Tier 0 +1

HPSS

event reconstruction

CMS detector: 15m X 15m X 22m

12,500 tons, $700M.

~2.5 Gbits/sec

Tier 1

Italian Regional Center

German Regional Center

NIKHEF Dutch Regional Center

FermiLab, USA Regional Center

...

~0.6-2.5 Gbps

analysis

Tier2 Center

Tier 2

~0.6-2.5 Gbps

Tier 3

Institute ~0.25TIPS

Physics data cache

100 - 1000 Mbits/sec

Tier 4

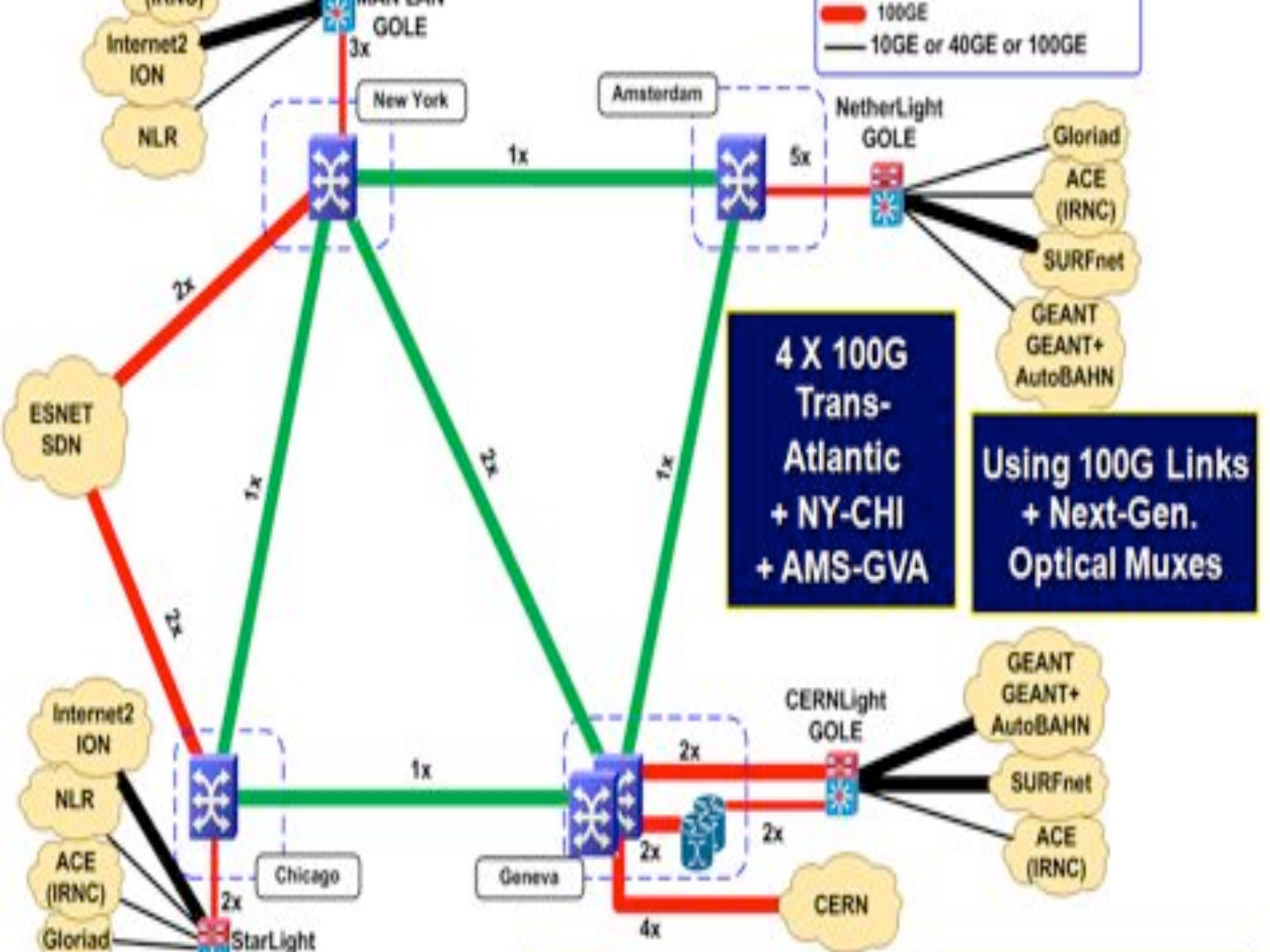
Workstations

Courtesy Harvey Newman, CalTech and CERN

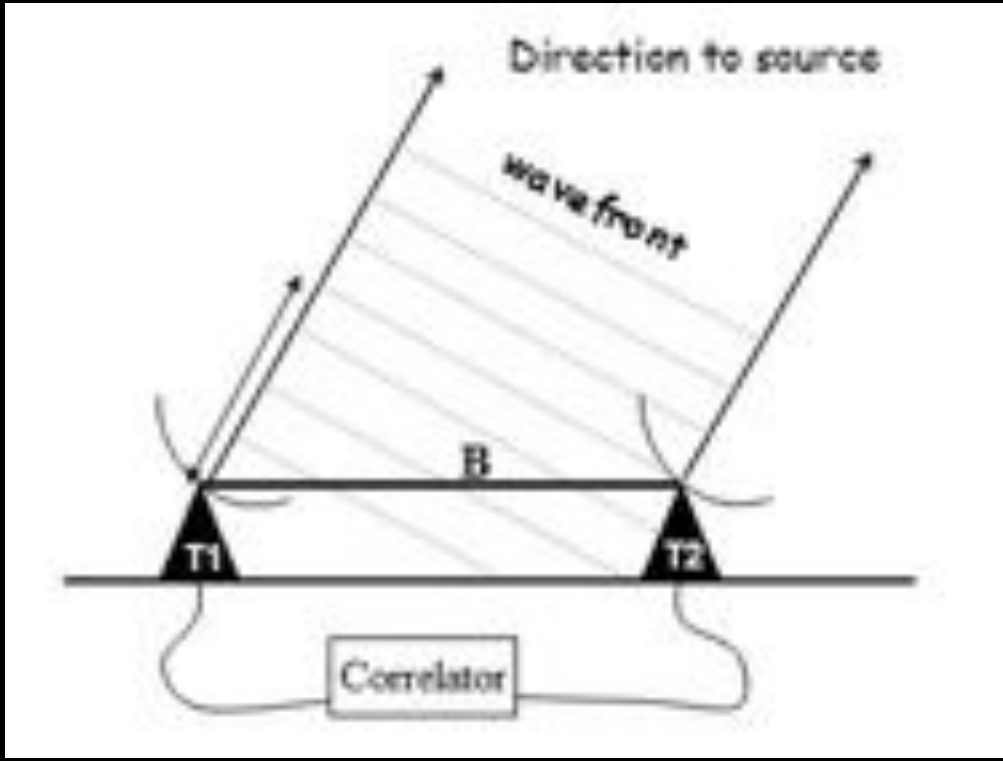
CERN/CMS data goes to 6-8 Tier 1 regional centers, and from each of these to 6-10 Tier 2 centers.

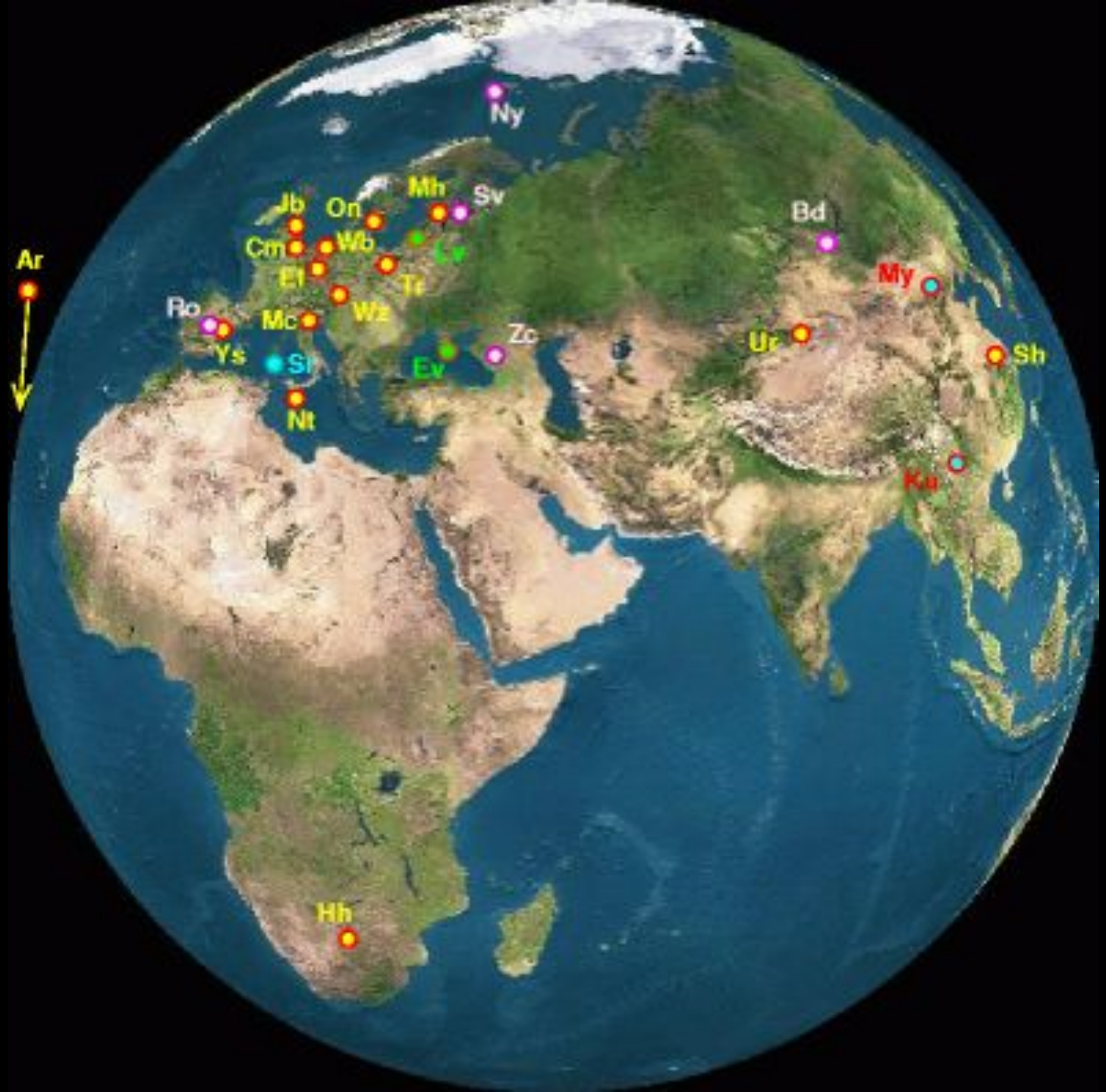
Physicists work on analysis "channels" at 135 institutes. Each institute has ~10 physicists working on one or more channels.

2000 physicists in 31 countries are involved in this 20-year experiment in which DOE is a major player.


100GE
10GE or 40GE or 100GE
Internet2 ION
NLR
MAN LAN
GOLE
3x
New York
Amsterdam
NetherLight GOLE
5x
1x
Gloriad
ACE (IRNC)
SURFnet
GEANT GEANT+ AutoBAHN
2x
ESNET SDN
4 X 100G Trans-Atlantic + NY-CHI + AMS-GVA
Using 100G Links + Next-Gen. Optical Muxes
Internet2 ION
NLR
ACE (IRNC)
Gloriad
Chicago
StarLight
Geneva
CERN
CERNLight GOLE
GEANT GEANT+ AutoBAHN
SURFnet
ACE (IRNC)

e -Very Large Base Interferometer




Ny
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Jb
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Cm
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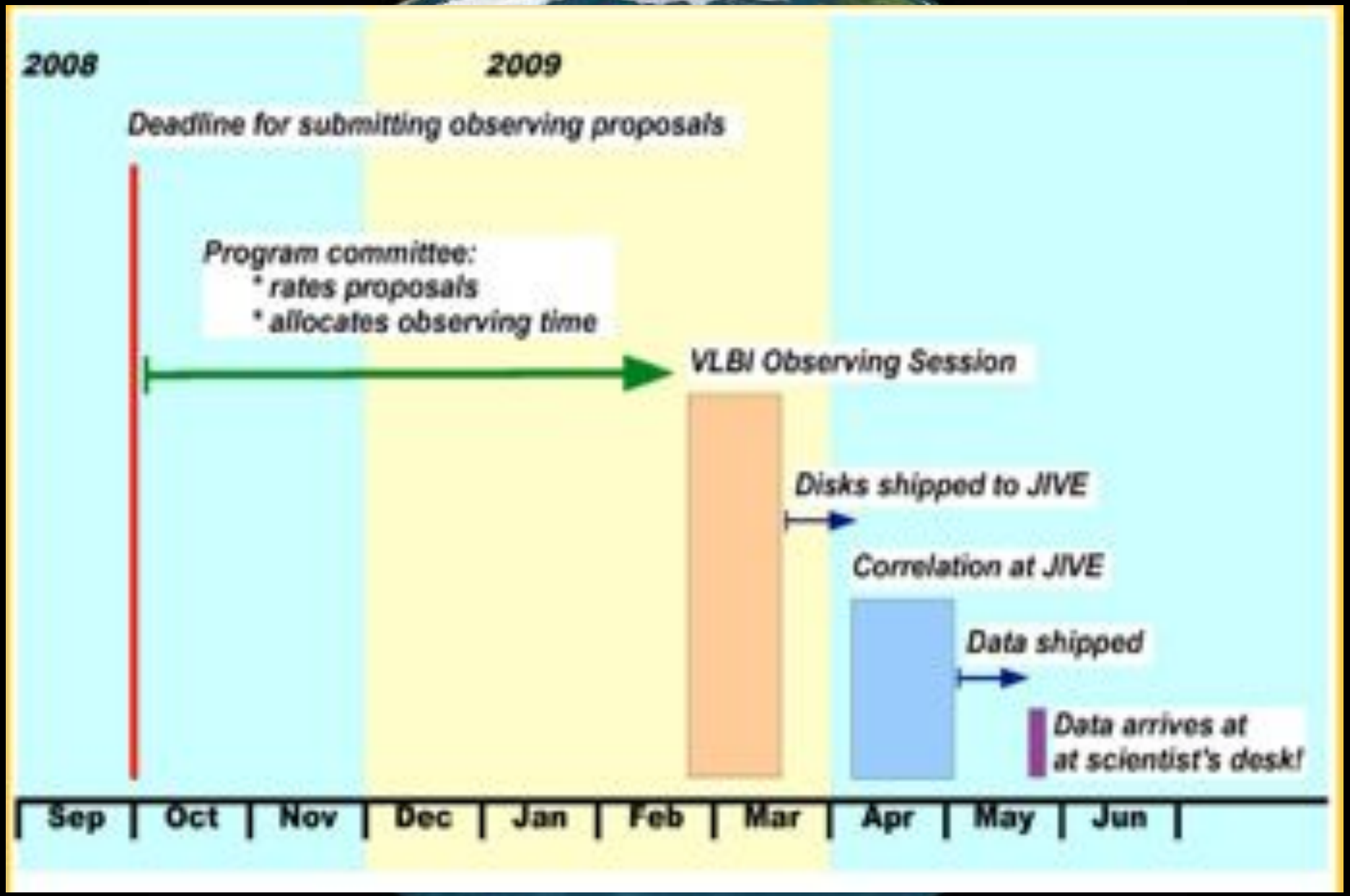
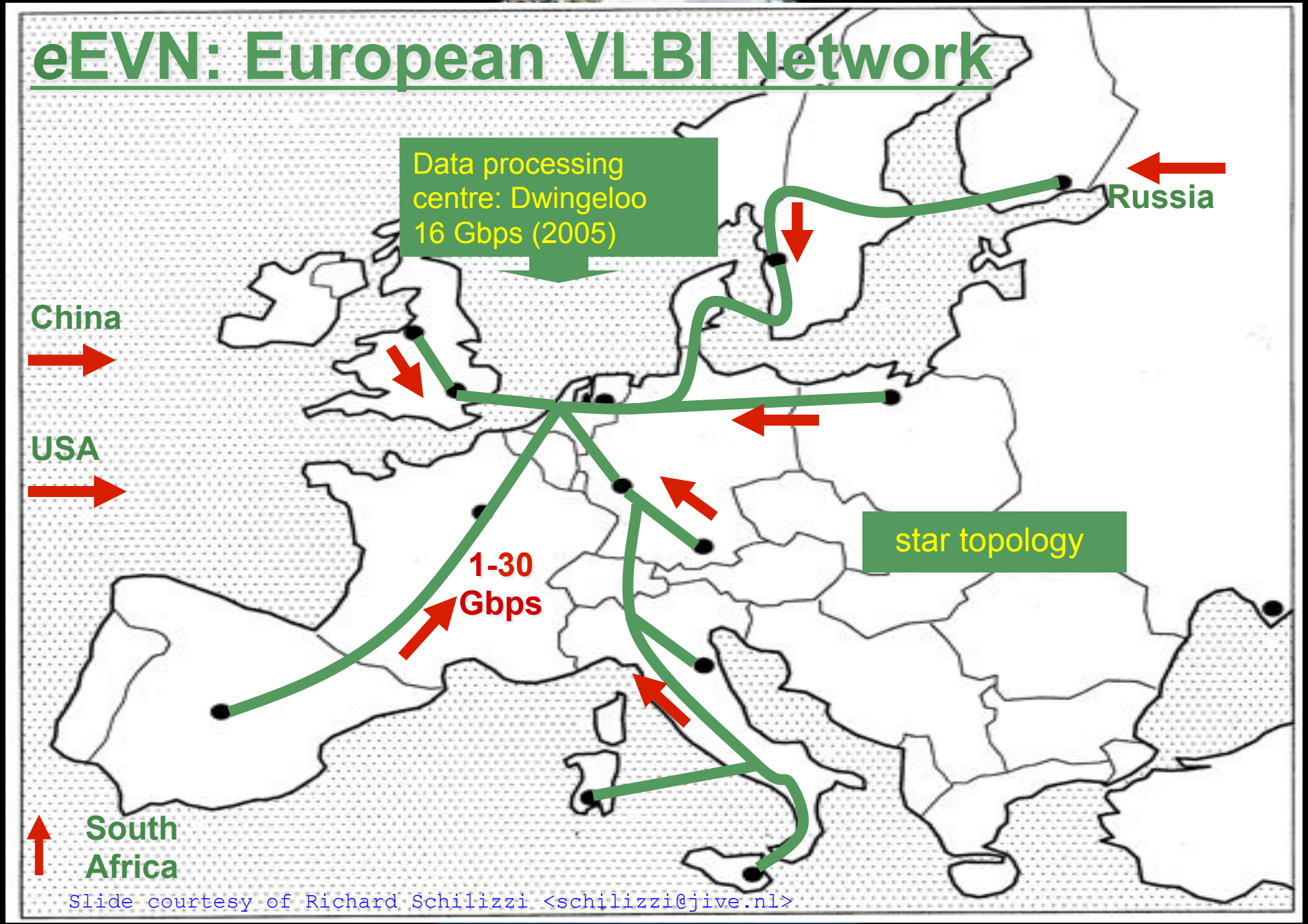
Ka
Hh

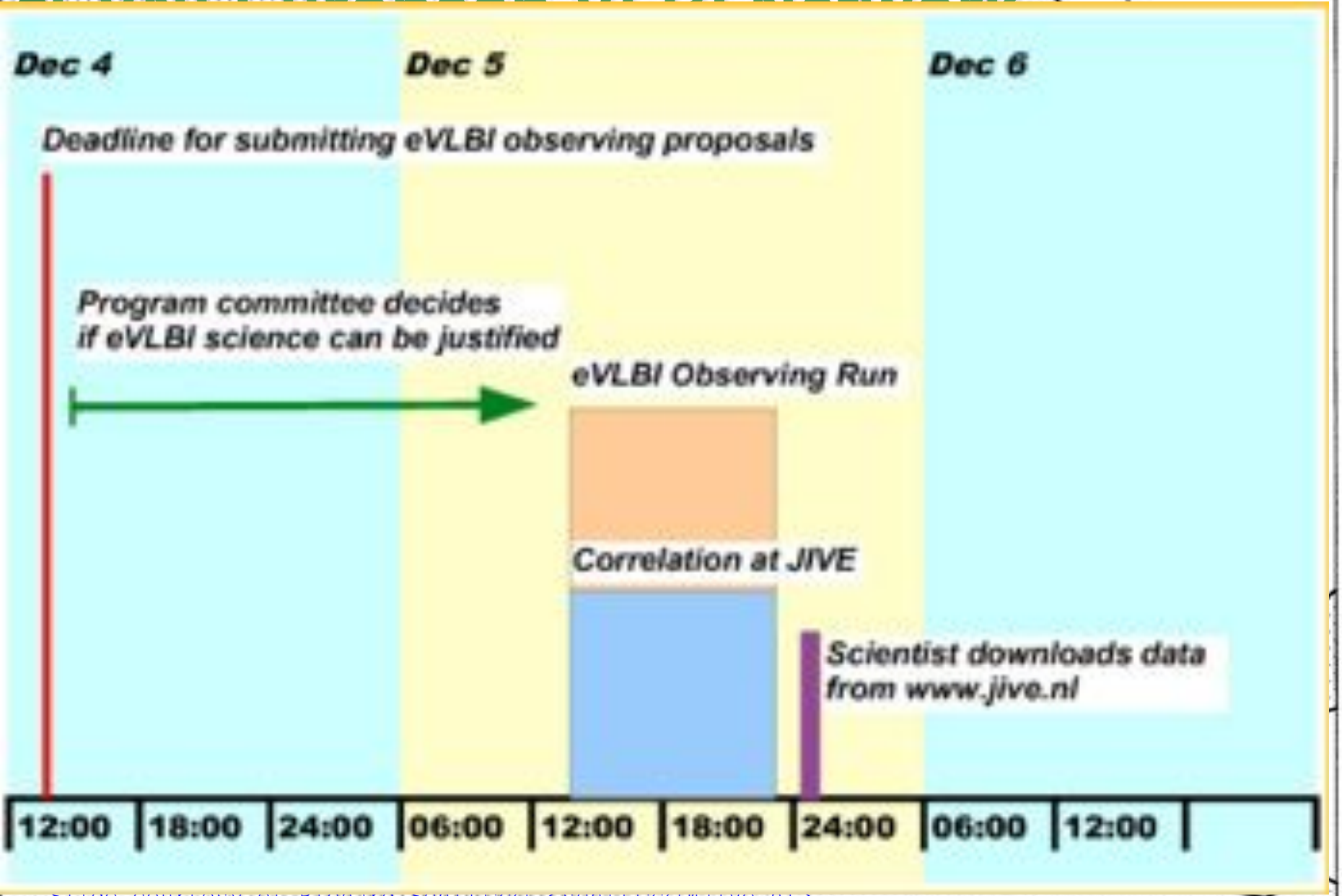

2008
2009
Deadline for submitting observing proposals
Program committee:
* rates proposals
* allocates observing time
VLBI Observing Session
Disks shipped to JIVE
Correlation at JIVE
Data shipped
Data arrives at
at scientist's desk!
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun

2008

2009


eEVN: European VLBI Network
Data processing centre: Dwingeloo
16 Gbps (2005)
Russia
China
USA
1-30 Gbps
star topology
South Africa
Slide courtesy of Richard Schilizzi <schilizzi@jive.nl>

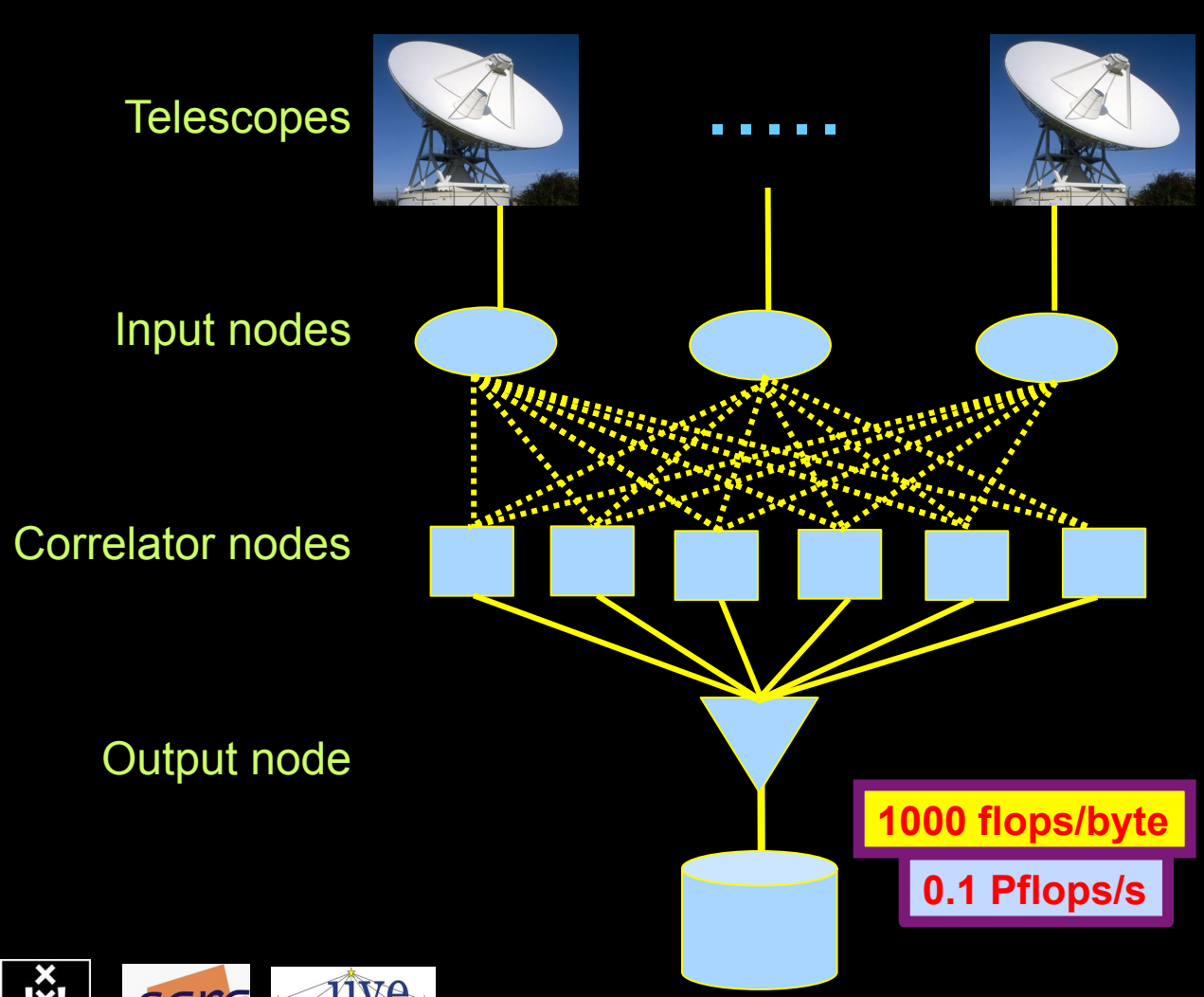
eEVN: European VLBI Network



Slide courtesy of Richard Schilizzi <schilizzi@jive.nl>

The SCARIe project

SCARIe: a research project to create a Software Correlator for e-VLBI.
VLBI Correlation: signal processing technique to get high precision image from spatially distributed radio-telescope.



16 Gbit/s - 2 Tflop ➔ THIS IS A DATA FLOW PROBLEM !!!

Research:

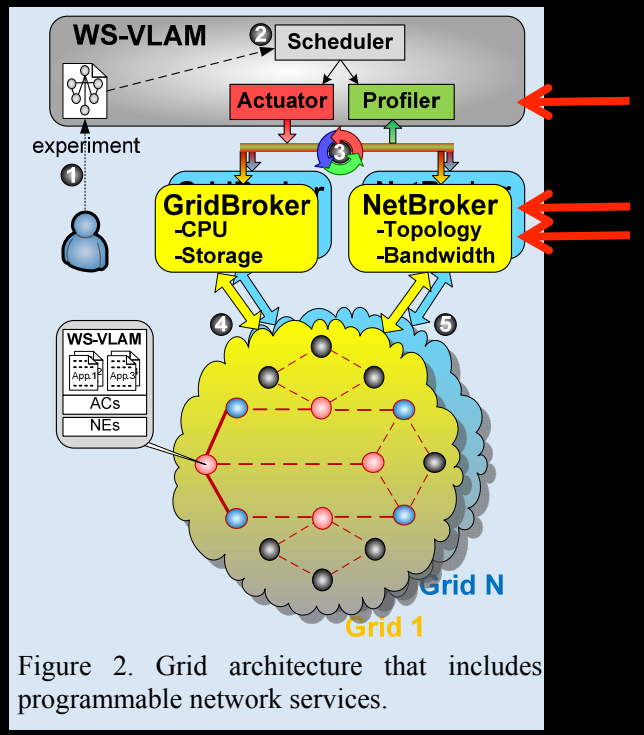
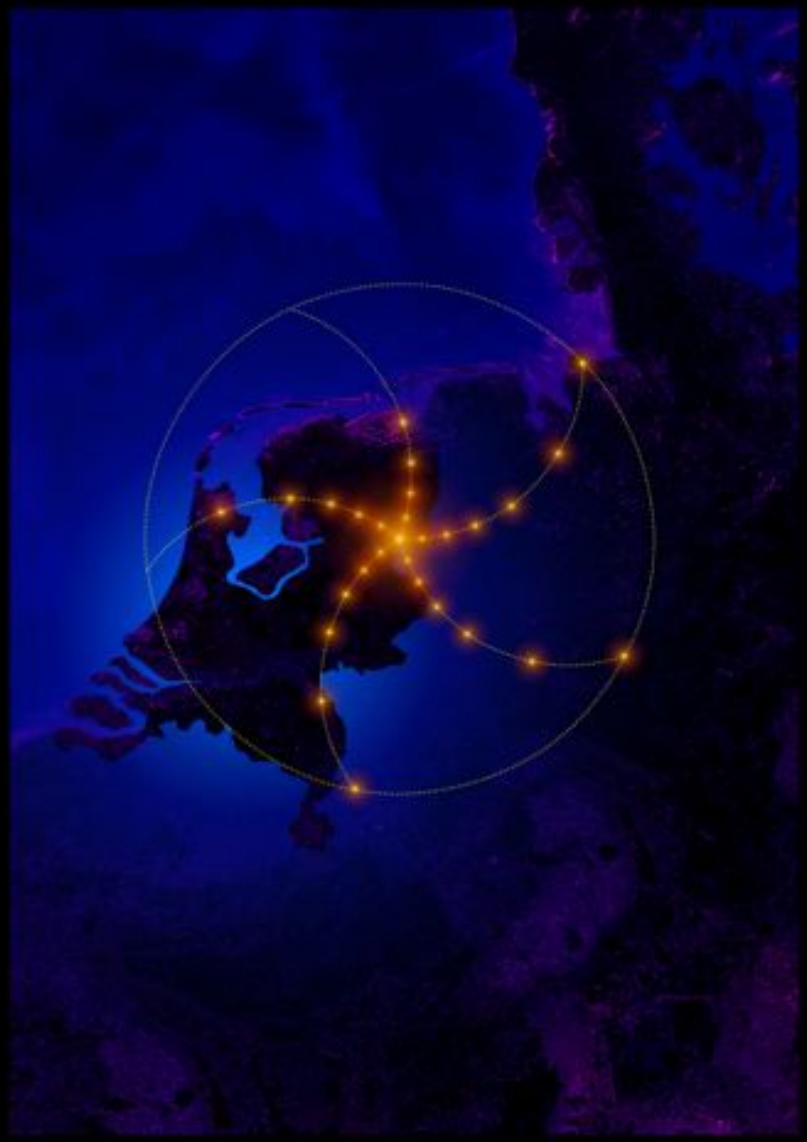


Figure 2. Grid architecture that includes programmable network services.

LOFAR as a Sensor Network

20 flops/byte

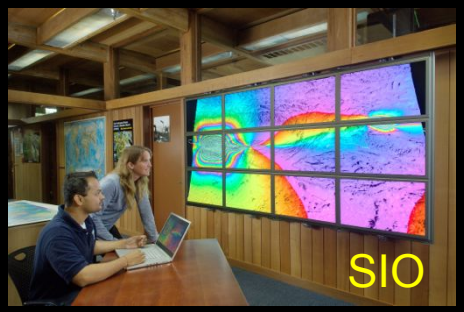


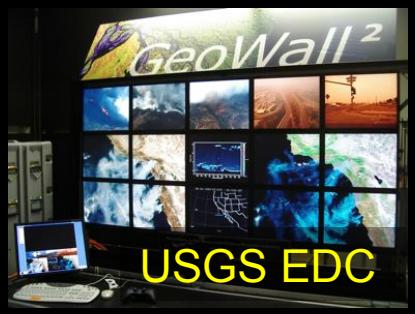
- LOFAR is a large distributed research infrastructure:

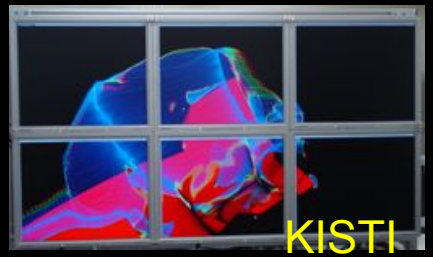
2 Tflops/s

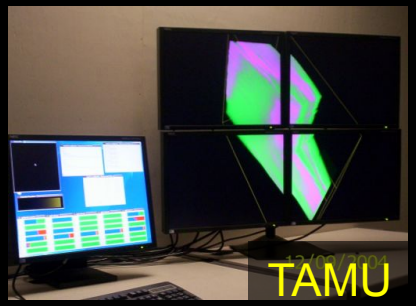
  - Astronomy:
    - >100 phased array stations
    - Combined in aperture synthesis array
    - 13,000 small “LF” antennas
    - 13,000 small “HF” tiles
  - Geophysics:
    - 18 vibration sensors per station
    - Infrasound detector per station
  - >20 Tbit/s generated digitally
  - >40 Tflop/s supercomputer
  - innovative software systems
    - new calibration approaches
    - full distributed control
    - VO and Grid integration
    - datamining and visualisation

US and International OptIPortal Sites









Real time, multiple 10 Gb/s

The “Dead Cat” demo

1 Mflops/byte

Real time issue

SC2004,
Pittsburgh,
Nov. 6 to 12, 2004
iGrid2005,
San Diego,
sept. 2005

Many thanks to:
AMC
SARA
GigaPort
UvA/AIR
Silicon Graphics, Inc.
Zoölogisch Museum

M. Scarpa, R.G. Belleman, P.M.A. Sloot and C.T.A.M. de Laat, "Highly Interactive Distributed Visualization", iGrid2005 special issue, Future Generation Computer Systems, volume 22 issue 8, pp. 896-900 (2006).

Where when will it happen?

IJKDIJK

300000 * 60 kb/s * 2 sensors (microphones) to cover all Dutch dikes

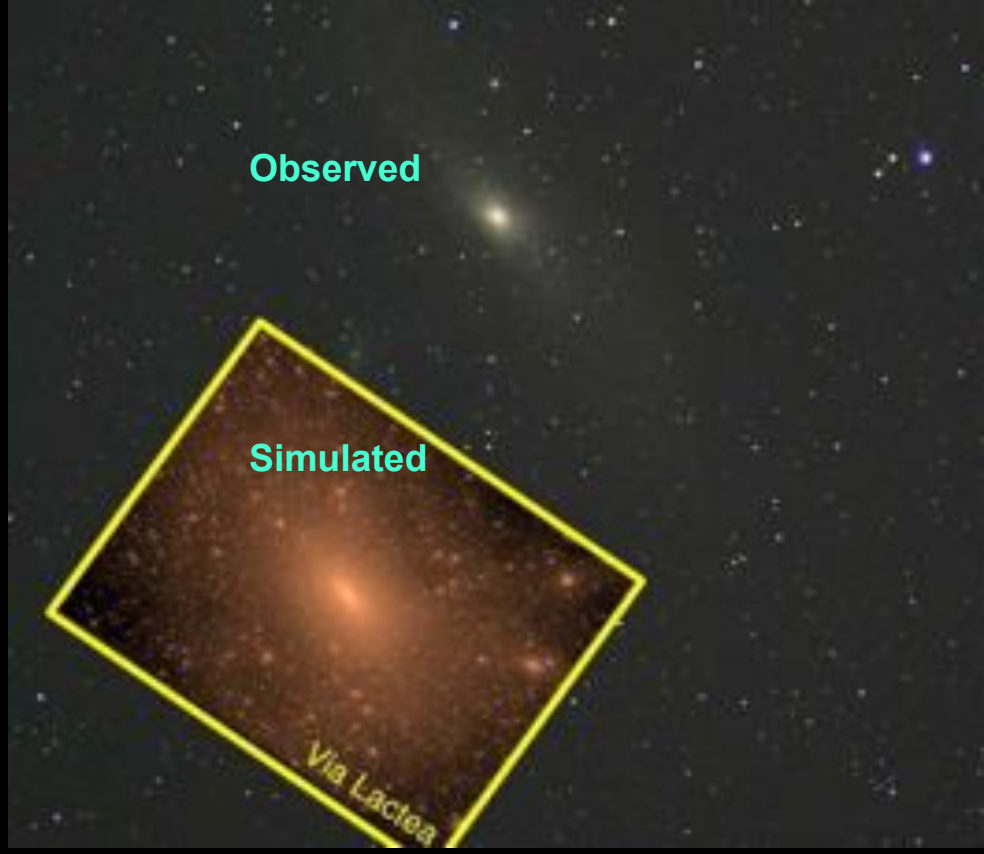
Sensor grid: instrument the dikes

First controlled breach occurred on sept 27th ‘08:

Many Pflops/s

Many small flows -> 36 Gb/s

CosmoGrid



- Motivation:
  previous simulations found >100 times more substructure than is observed!
- Simulate large structure formation in the Universe
  - Dark Energy (cosmological constant)
  - Dark Matter (particles)
- Method: Cosmological *N*-body code
- Computation: Intercontinental SuperComputer Grid

The hardware setup

10 Mflops/byte

1 Eflops/s

- 2 supercomputers :
  - 1 in Amsterdam (60Tflops Power6 @ SARA)
  - 1 in Tokyo (30Tflops Cray XD0-4 @ CFCA)
- Both computers are connected via an intercontinental optical 10 Gbit/s network

Why is more resolution is better?

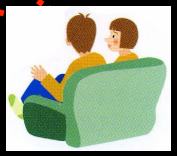
1. More Resolution Allows Closer Viewing of Larger Image
2. Closer Viewing of Larger Image Increases Viewing Angle
3. Increased Viewing Angle Produces Stronger Emotional Response

HDTV (2K)

1920

1080

30°



3.0 × Picture Height

UHDTV(8K)

24 Gb/s

7680

4320

0.75 × Picture Height

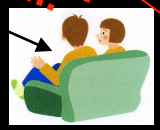
100°

SHD (4K)

3840

2160

7.6 Gb/s



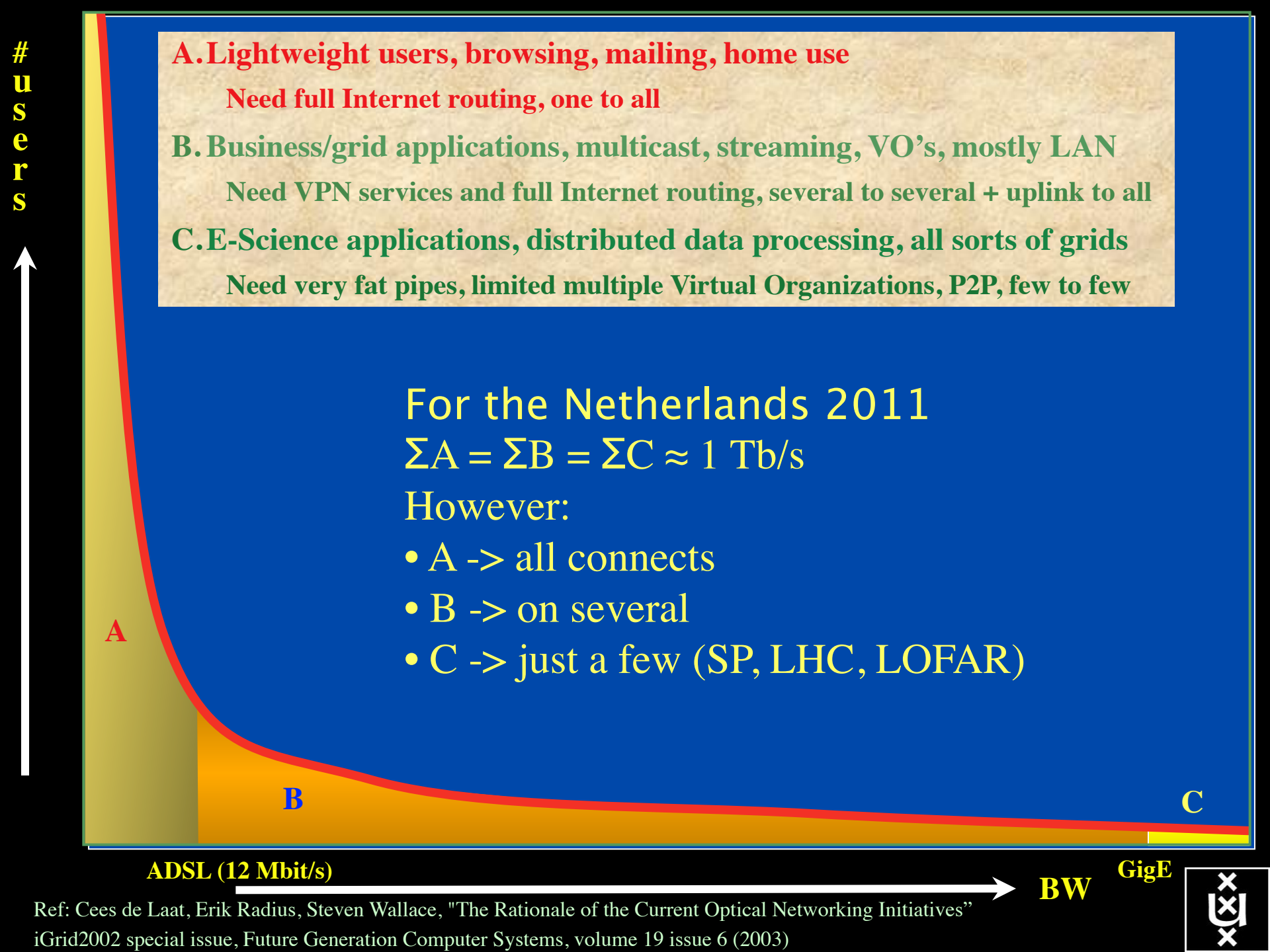
60°

1.5 × Picture Height

Yutaka TANAKA
SHARP CORPORATION
Advanced Image Research Laboratories


Red End
Robin Noorda & Bethany de Forest


Hey at all
We're almost done. Shhh..



Ref: Cees de Laat, Erik Radius, Steven Wallace, "The Rationale of the Current Optical Networking Initiatives" iGrid2002 special issue, Future Generation Computer Systems, volume 19 issue 6 (2003)

#users

A. Lightweight users, browsing, mailing, home use

Need full Internet routing, one to all

B. Business/grid applications, multicast, streaming, VO's, mostly LAN

Need VPN services and full Internet routing, several to several + uplink to all

B

C

ADSL (12 Mbit/s) → BW GigE

Ref: Cees de Laat, Erik Radius, Steven Wallace, "The Rationale of the Current Optical Networking Initiatives" iGrid2002 special issue, Future Generation Computer Systems, volume 19 issue 6 (2003)

Big and small flows don't go well together on the same wire!

Towards Hybrid Networking!

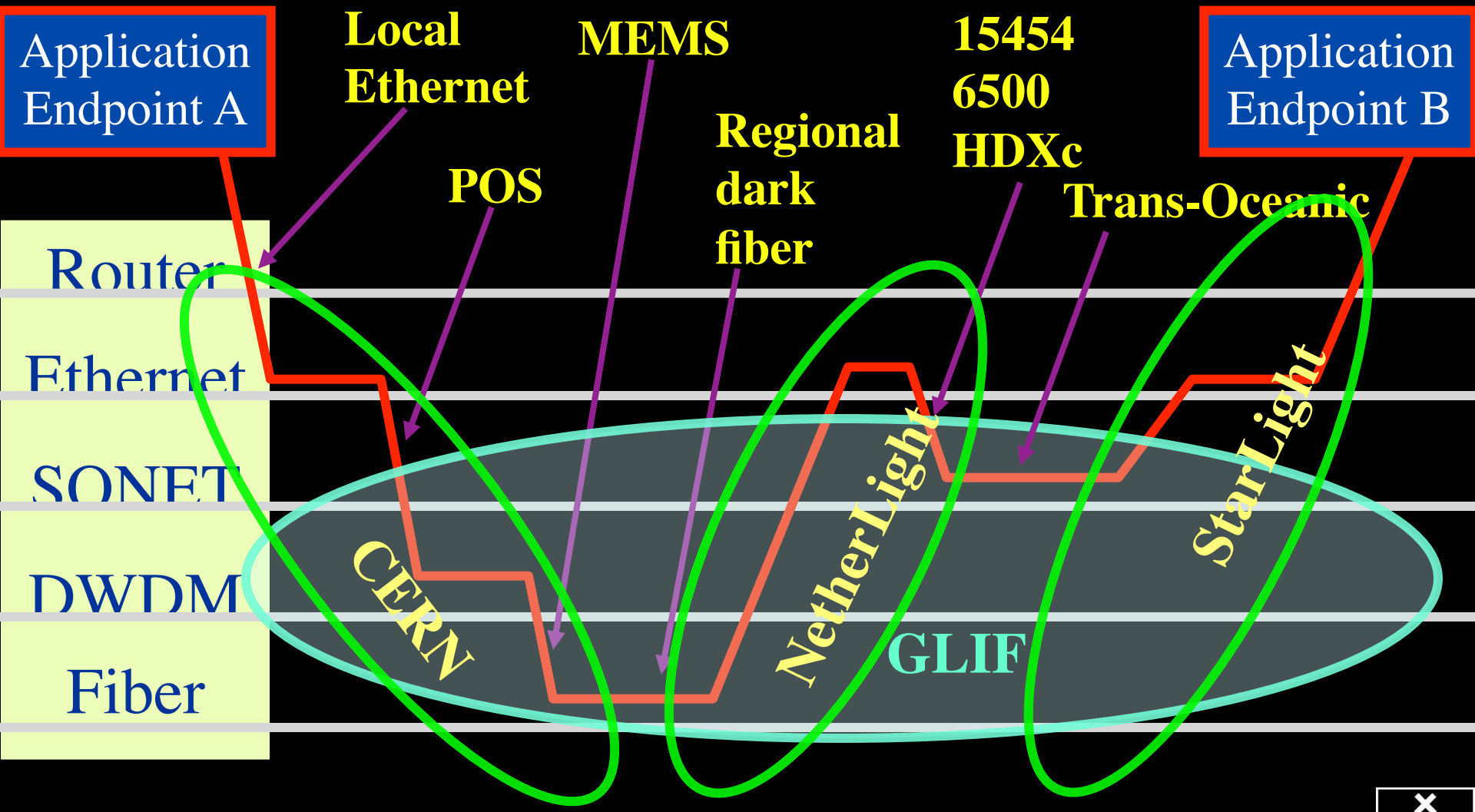
- Costs of photonic equipment 10% of switching 10 % of full routing
  - for same throughput!
  - Photonic vs Optical (optical used for SONET, etc, 10-50 k$/port)
  - DWDM lasers for long reach expensive, 10-50 k$
- Bottom line: look for a hybrid architecture which serves all classes in a cost effective way
  - map A -> L3 , B -> L2 , C -> L1 and L2
- Give each packet in the network the service it needs, but no more !

L1 ≈ 2-3 k$/port

L2 ≈ 5-8 k$/port

L3 ≈ 75+ k$/port

How low can you go?



Hybrid computing

Routers ⇐ ⇒ Supercomputers

Ethernet switches ⇐ ⇒ Grid & Cloud

Photonic transport ⇐ ⇒ GPU's

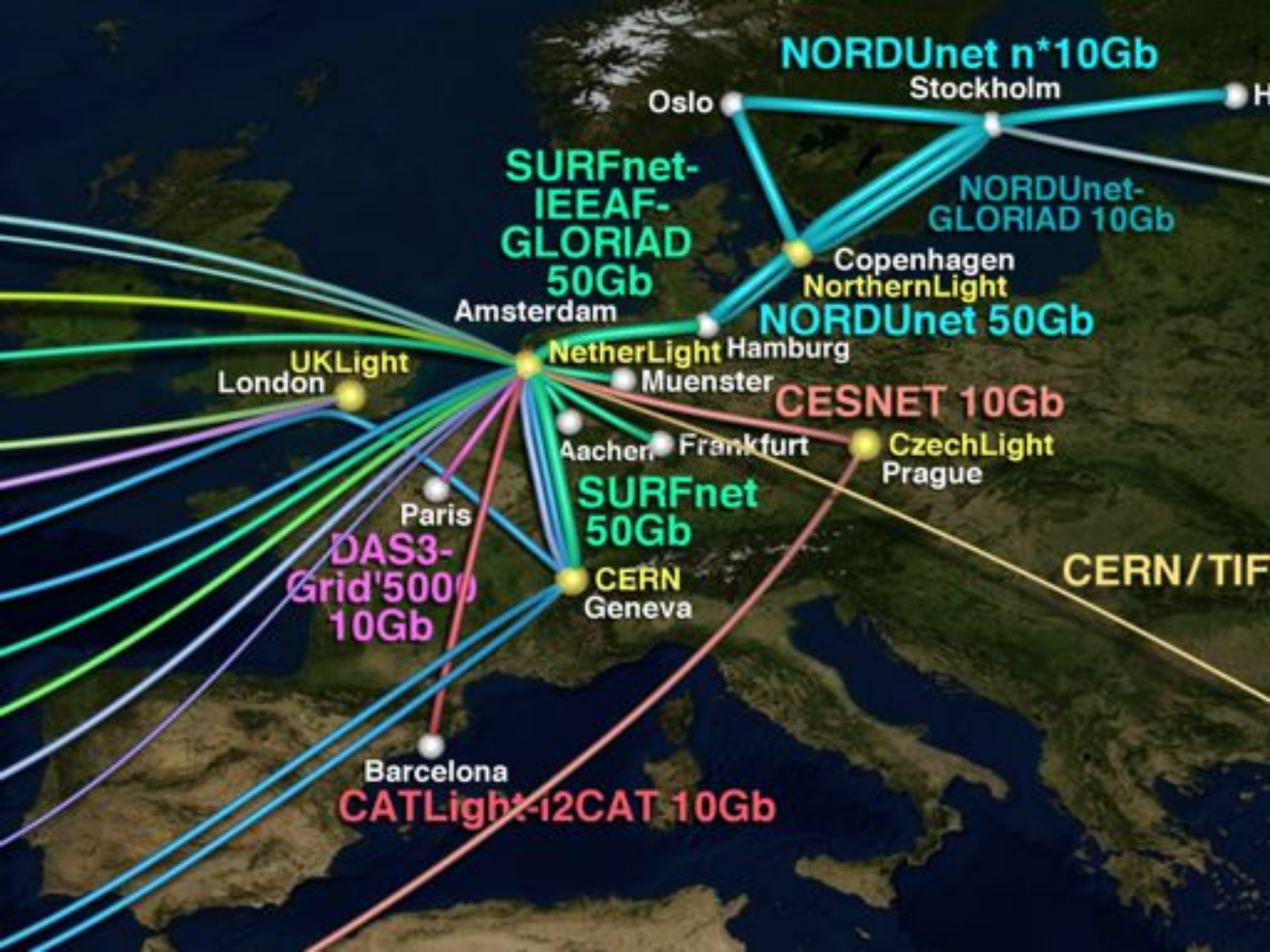
What matters:

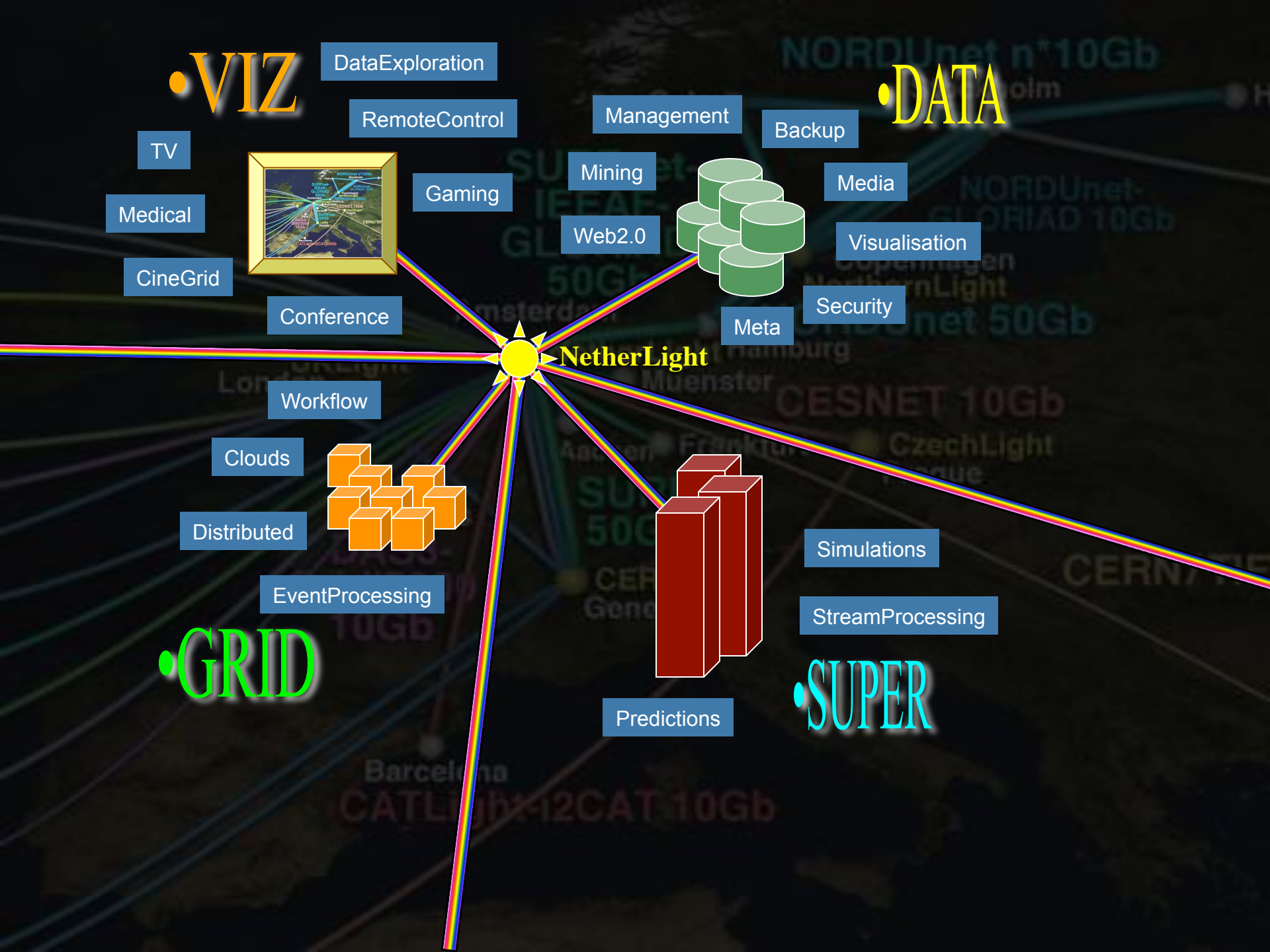
Energy consumption/multiplication

Energy consumption/bit transported

GLIF 2008

Visualization courtesy of Bob Patterson, NCSA
Data collection by Maxine Brown.


NORDUnet n*10Gb
Oslo
Stockholm
SURFnet-
IEEAF-
GLORIAD
50Gb
NORDUnet-
GLORIAD 10Gb
Copenhagen
NorthernLight
NORDUnet 50Gb
Amsterdam
NetherLight
Hamburg
UKLight
London
Muenster
CESNET 10Gb
Aachen
Frankfurt
CzechLight
Prague
SURFnet
50Gb
Paris
DAS3-
Grid'5000
10Gb
CERN
Geneva
CERN/TIF
Barcelona
CATLight-i2CAT 10Gb


•VIZ
DataExploration
RemoteControl
TV
Medical
CineGrid
Gaming
Conference
•DATA
Management
Backup
Mining
Media
Web2.0
Visualisation
Security
Meta
NetherLight
Workflow
Clouds
Distributed
EventProcessing
•GRID
Simulations
StreamProcessing
Predictions
•SUPER

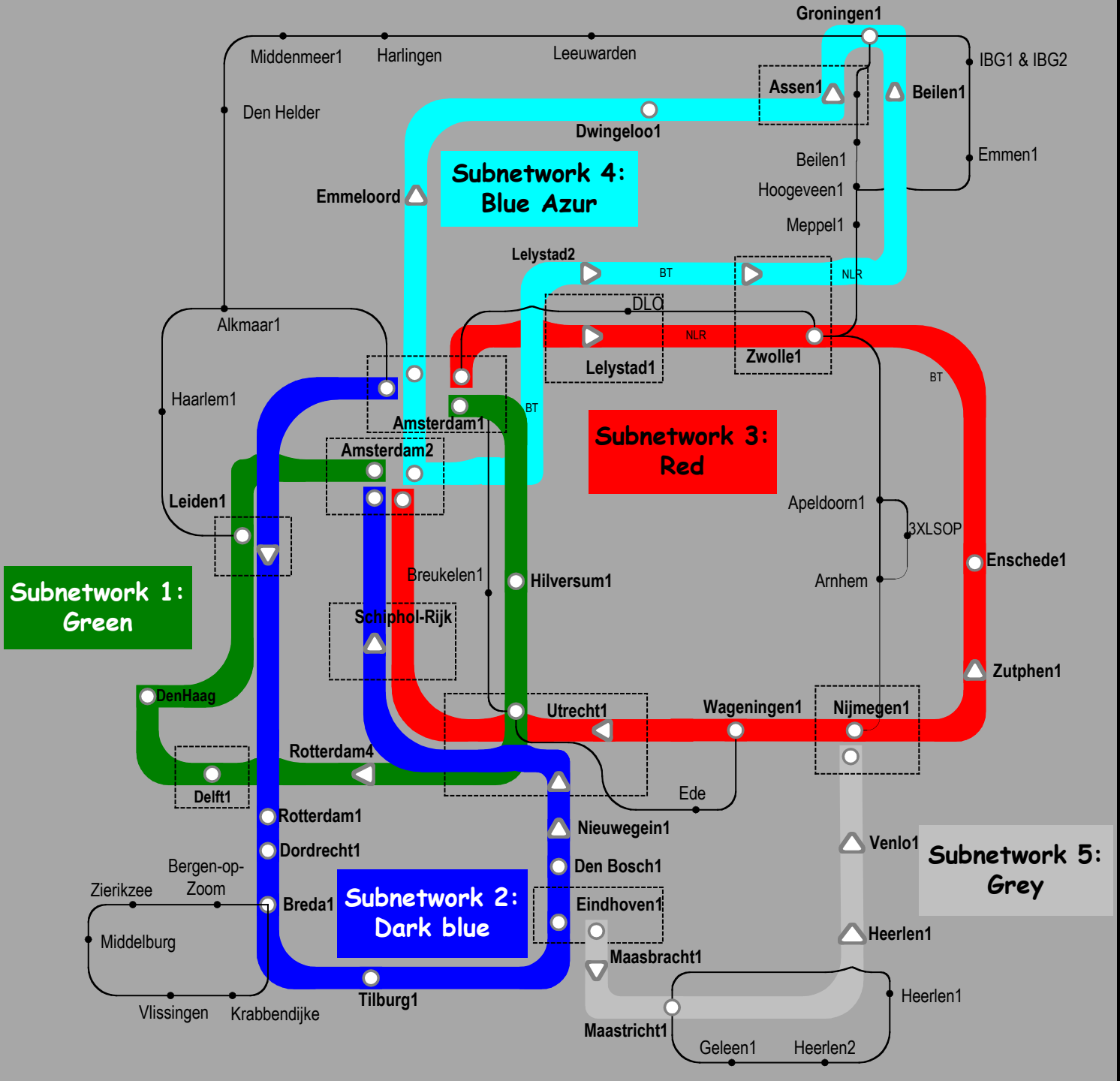
In The Netherlands SURFnet connects between 180:

- universities;
- academic hospitals;
- most polytechnics;
- research centers.

with an indirect ~750K user base

~ 8860 km

scale comparable to railway system



Common Photonic Layer (CPL) in SURFnet6

supports up to 72 Lambda's of 10 / 40 / 100 G

Alien light From idea to realisation!

40Gb/s alien wavelength transmission via a multi-vendor 10Gb/s DWDM infrastructure

NCF

Alien wavelength advantages

- Direct connection of customer equipment[1] → cost savings
- Avoid OEO regeneration → power savings
- Faster time to service[2] → time savings
- Support of different modulation formats[3] → extend network lifetime

Alien wavelength challenges

- Complex end-to-end optical path engineering in terms of linear (i.e. OSNR, dispersion) and non-linear (FWM, SPM, XPM, Raman) transmission effects for different modulation formats.
- Complex interoperability testing.
- End-to-end monitoring, fault isolation and resolution.
- End-to-end service activation.

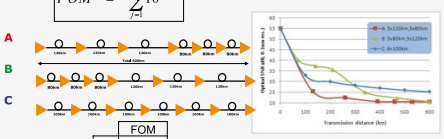
In this demonstration we will investigate the performance of a 40Gb/s PM-QPSK alien wavelength installed on a 10Gb/s DWDM infrastructure.

New method to present fiber link quality, FoM (Figure of Merit)

In order to quantify optical link grade, we propose a new method of representing system quality: the FOM (Figure of Merit) for concatenated fiber spans.

$$FOM = \sum_{j=1}^{N} 10^{\left(\frac{L_j}{10}\right)}$$

Lj, span losses in dB
N, number of spans

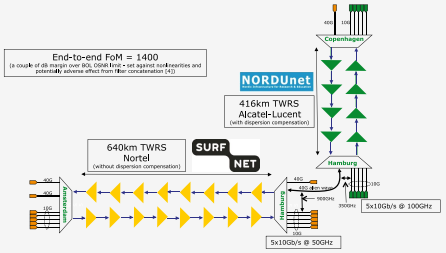


	FOM
A	5504
B	5504
C	1897

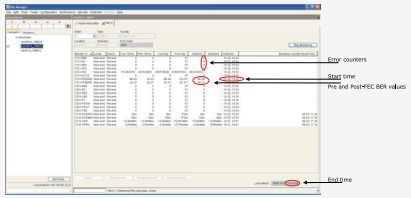
Easy-to-use formula that accurately quantifies transmission system performance

Transmission system setup

JOINT SURFnet/NORDUnet 40Gb/s PM-QPSK alien wavelength DEMONSTRATION.



Test results



Error-free transmission for 23 hours, 17 minutes → BER < 3.0 10^{-16}

Conclusions

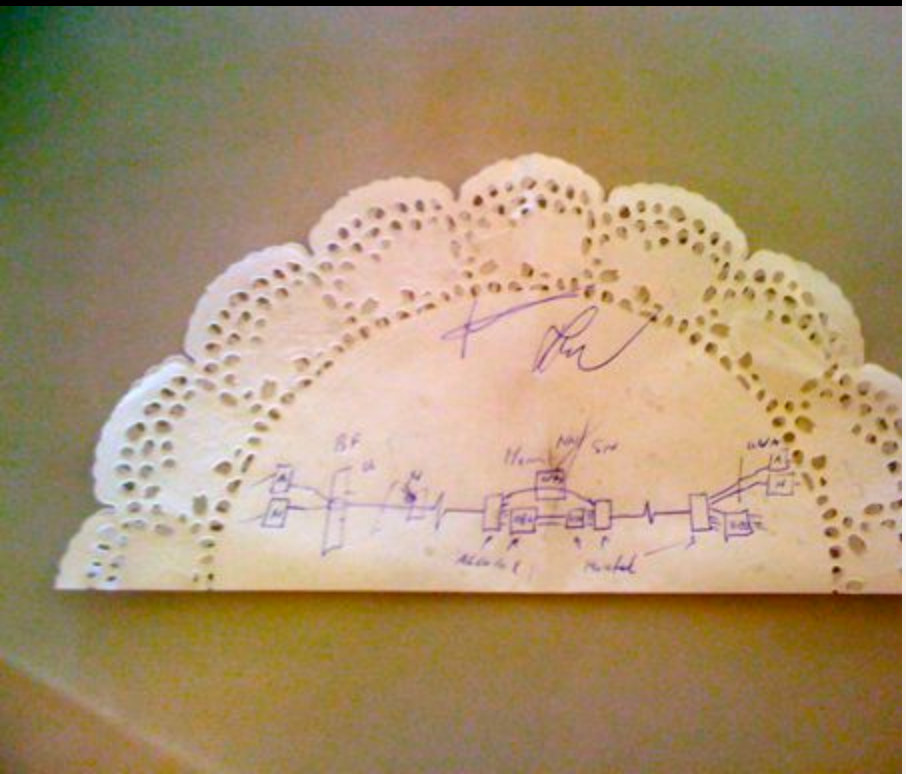
- We have investigated experimentally the all-optical transmission of a 40Gb/s PM-QPSK alien wavelength via a concatenated native and third party DWDM system that both were carrying live 10Gb/s wavelengths.
- The end-to-end transmission system consisted of 1056 km of TWRS (TrueWave Reduced Slope) transmission fiber.
- We demonstrated error-free transmission (i.e. BER below 10-15) during a 23 hour period.
- More detailed system performance analysis will be presented in an upcoming paper.

NORTEL NORDUnet telindus together with ISIT SURFNET

REFERENCES [1] "OPERATIONAL SOLUTIONS FOR AN OPEN DWDM LAYER", O. GERSTEL ET AL, OFC'2009 | [2] "AT&T OPTICAL TRANSPORT SERVICES", BARBARA E. SMITH, OFC'09
[3] "OPEX SAVINGS OF ALL-OPTICAL CORE NETWORKS", ANDREW LORD AND CARL ENGINEER, ECOC2009 | [4] NORTEL/SURFNET INTERNAL COMMUNICATION

ACKNOWLEDGEMENTS WE ARE GRATEFUL TO NORDUNET FOR PROVIDING US WITH BANDWIDTH ON THEIR DWDM LINK FOR THIS EXPERIMENT AND ALSO FOR THEIR SUPPORT AND ASSISTANCE DURING THE EXPERIMENTS. WE ALSO ACKNOWLEDGE TELINDUS AND NORTEL FOR THEIR INTEGRATION WORK AND SIMULATION SUPPORT

Alien light From idea to realisation!



40Gb/s alien wavelength transmission via a multi-vendor 10Gb/s DWDM infrastructure

NCF

Alien wavelength advantages

- Direct connection of customer equipment[1] → cost savings
- Avoid OEO regeneration → power savings
- Faster time to service[2] → time savings
- Support of different modulation formats[3] → extend network lifetime

Alien wavelength challenges

- Complex end-to-end optical path engineering in terms of linear (i.e. OSNR, dispersion) and non-linear (FWM, SPM, XPM, Raman) transmission effects for different modulation formats.
- Complex interoperability testing.
- End-to-end monitoring, fault isolation and resolution.
- End-to-end service activation.

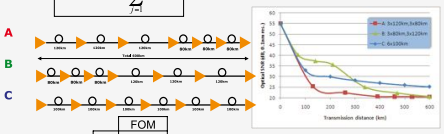
In this demonstration we will investigate the performance of a 40Gb/s PM-QPSK alien wavelength installed on a 10Gb/s DWDM infrastructure.

New method to present fiber link quality, FoM (Figure of Merit)

In order to quantify optical link grade, we propose a new method of representing system quality: the FOM (Figure of Merit) for concatenated fiber spans.

$$FOM = \sum_{j=1}^{N} 10^{\left(\frac{L_j}{10}\right)}$$

Lj, span losses in dB
N, number of spans

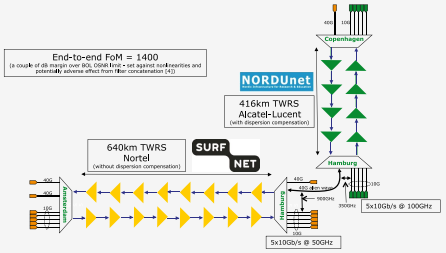


	FOM
A	5504
B	5504
C	1897

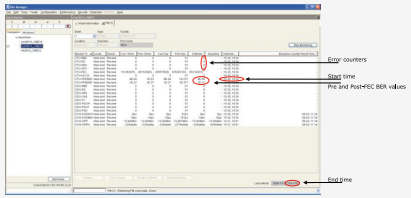
Easy-to-use formula that accurately quantifies transmission system performance

Transmission system setup

JOINT SURFnet/NORDUnet 40Gb/s PM-QPSK alien wavelength DEMONSTRATION.



Test results



Error-free transmission for 23 hours, 17 minutes → BER < 3.0 10^{-16}

Conclusions

- We have investigated experimentally the all-optical transmission of a 40Gb/s PM-QPSK alien wavelength via a concatenated native and third party DWDM system that both were carrying live 10Gb/s wavelengths.
- The end-to-end transmission system consisted of 1056 km of TWRS (TrueWave Reduced Slope) transmission fiber.
- We demonstrated error-free transmission (i.e. BER below 10-15) during a 23 hour period.
- More detailed system performance analysis will be presented in an upcoming paper.

NORTEL NORDUnet telindus together with ISIT SURF NET

REFERENCES [1] "OPERATIONAL SOLUTIONS FOR AN OPEN DWDM LAYER", O. GERSTEL ET AL, OFC'2009 | [2] "AT&T OPTICAL TRANSPORT SERVICES", BARBARA E. SMITH, OFC'09 [3] "OPEX SAVINGS OF ALL-OPTICAL CORE NETWORKS", ANDREW LORD AND CARL ENGINEER, ECOC2009 | [4] NORTEL/SURFNET INTERNAL COMMUNICATION

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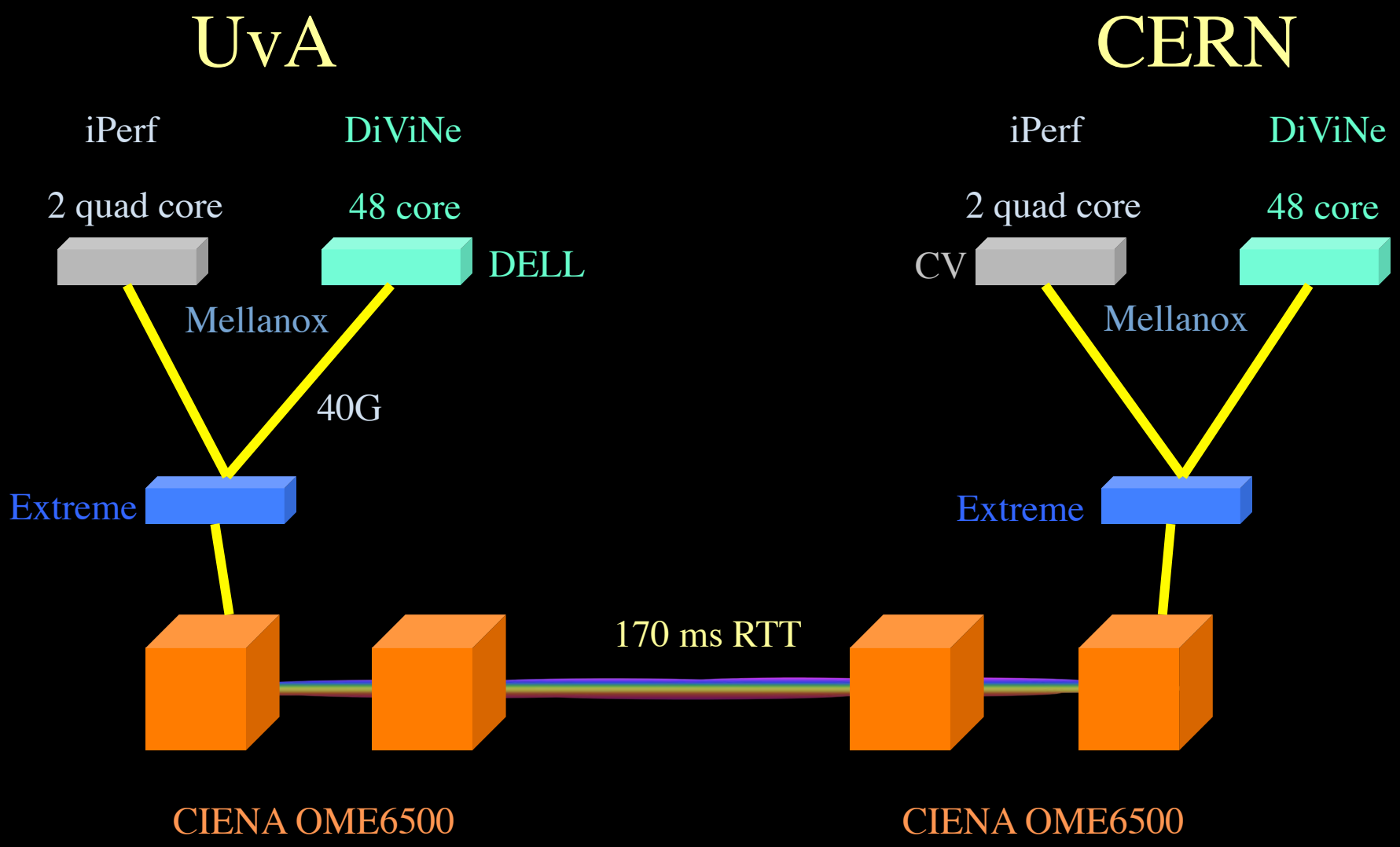
Setup



Amsterdam – Geneva (CERN) – 1650KM (~1000Miles)

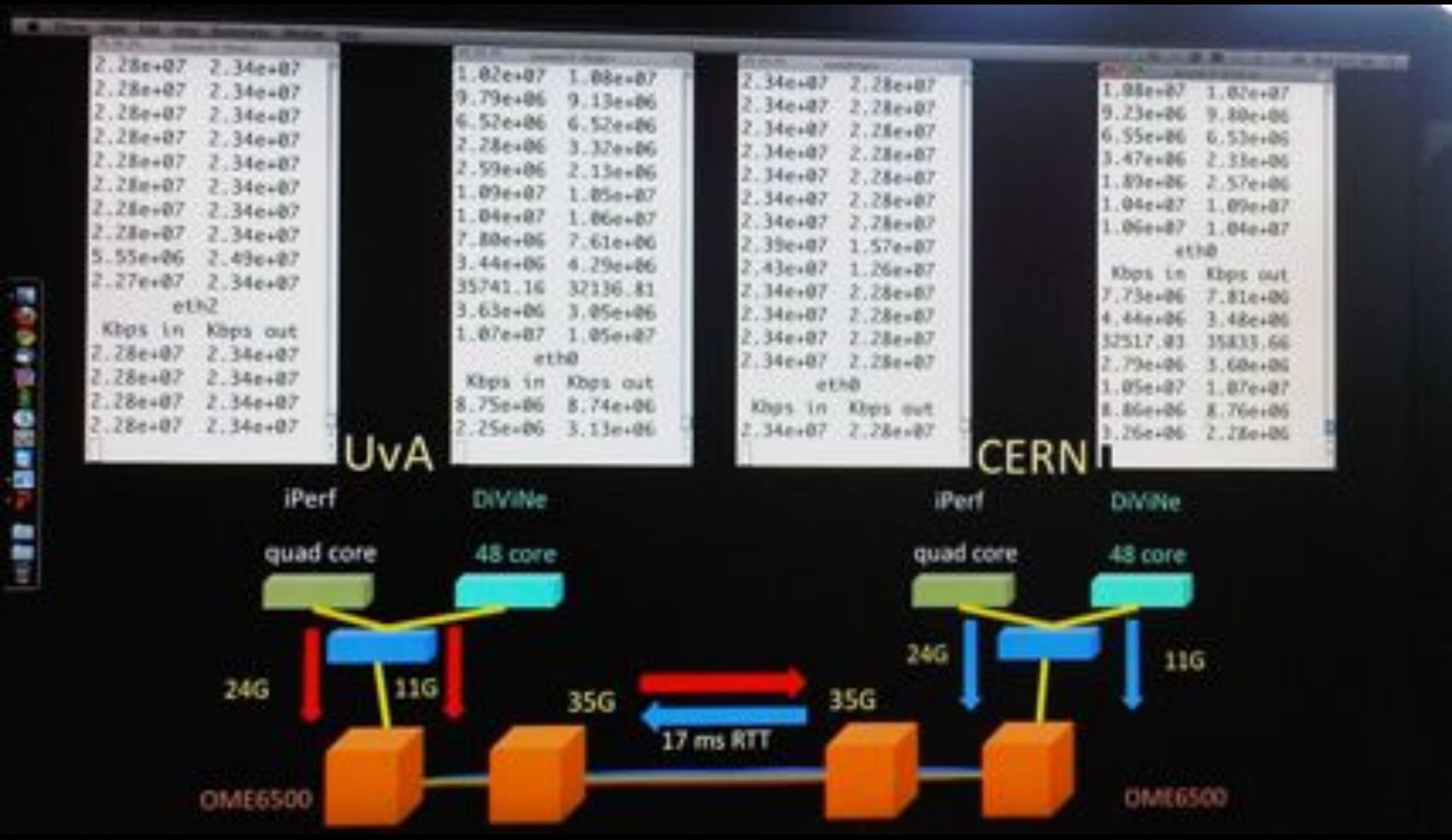
Demo setup codename: FlightCees

Ciena ActiveFlex(OME) 6500

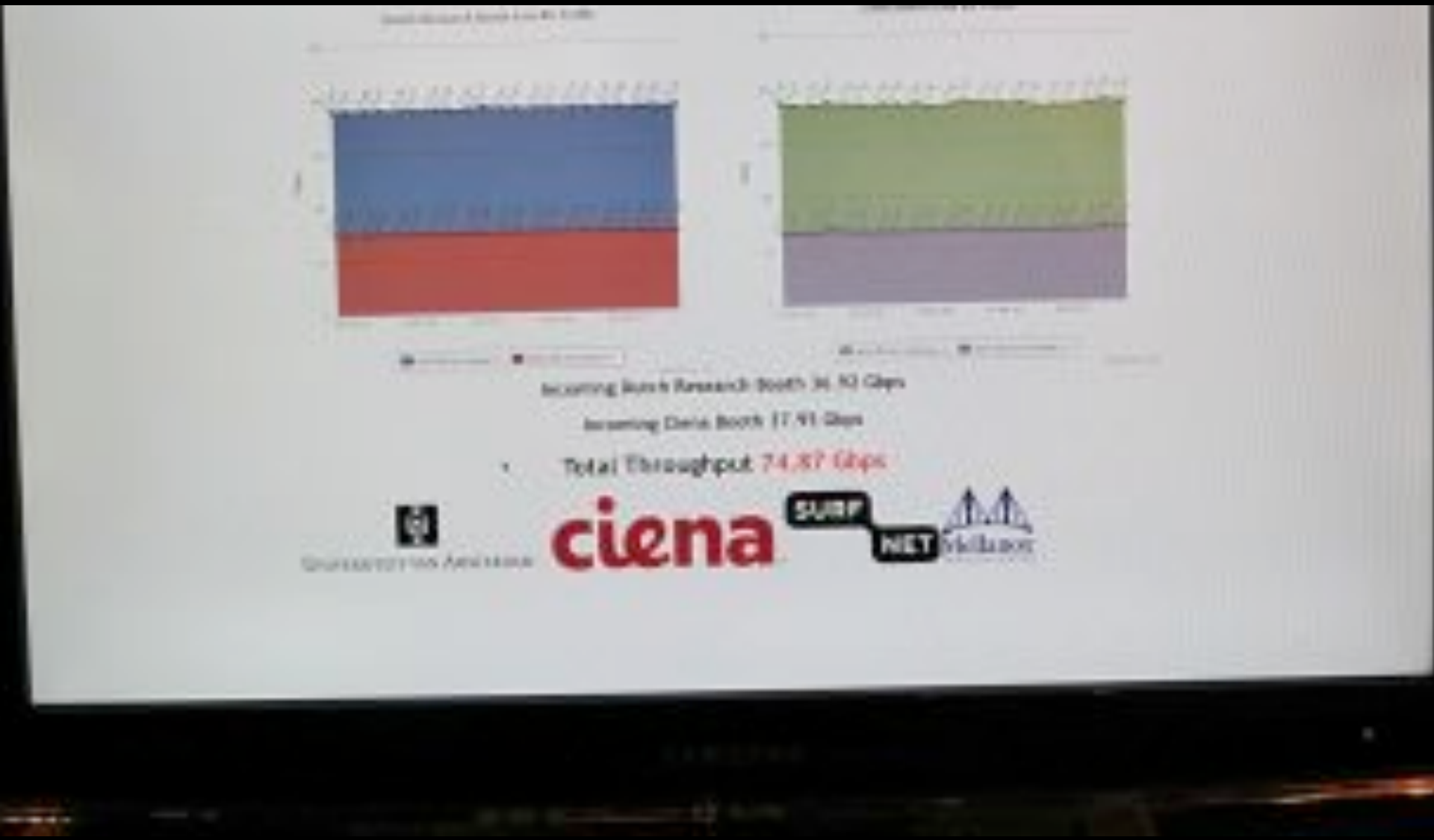
Broadcom 40GE 18 port L2 Ethernet Switch

Supermicro Intel Server

Dell R815 Server


2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
5.55e+06 2.49e+07
2.27e+07 2.34e+07
eth2
Kbps in Kbps out
2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
2.28e+07 2.34e+07
1.02e+07 1.08e+07
9.79e+06 9.13e+06
6.52e+06 6.52e+06
2.28e+06 3.32e+06
2.59e+06 2.13e+06
1.09e+07 1.05e+07
1.04e+07 1.06e+07
7.80e+06 7.61e+06
3.44e+06 4.29e+06
35741.16 32136.81
3.63e+06 3.05e+06
1.07e+07 1.05e+07
eth0
Kbps in Kbps out
8.75e+06 8.74e+06
2.25e+06 3.13e+06
UvA
iPerf
DiViNe
quad core
48 core
24G
11G
35G
35G
17 ms RTT
OME6500
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.35e+07 1.57e+07
2.43e+07 1.26e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
2.34e+07 2.28e+07
eth0
Kbps in Kbps out
2.34e+07 2.28e+07
1.08e+07 1.02e+07
9.23e+06 9.80e+06
6.55e+06 6.53e+06
3.47e+06 2.33e+06
1.89e+06 2.57e+06
1.04e+07 1.09e+07
1.06e+07 1.04e+07
eth0
Kbps in Kbps out
7.73e+06 7.81e+06
4.44e+06 3.48e+06
32517.03 35833.66
2.79e+06 3.60e+06
1.05e+07 1.07e+07
8.86e+06 8.76e+06
3.26e+06 2.28e+06
CERN
iPerf
DiViNe
quad core
48 core
24G
11G
OME6500

Live stats - Supercomputing 2010



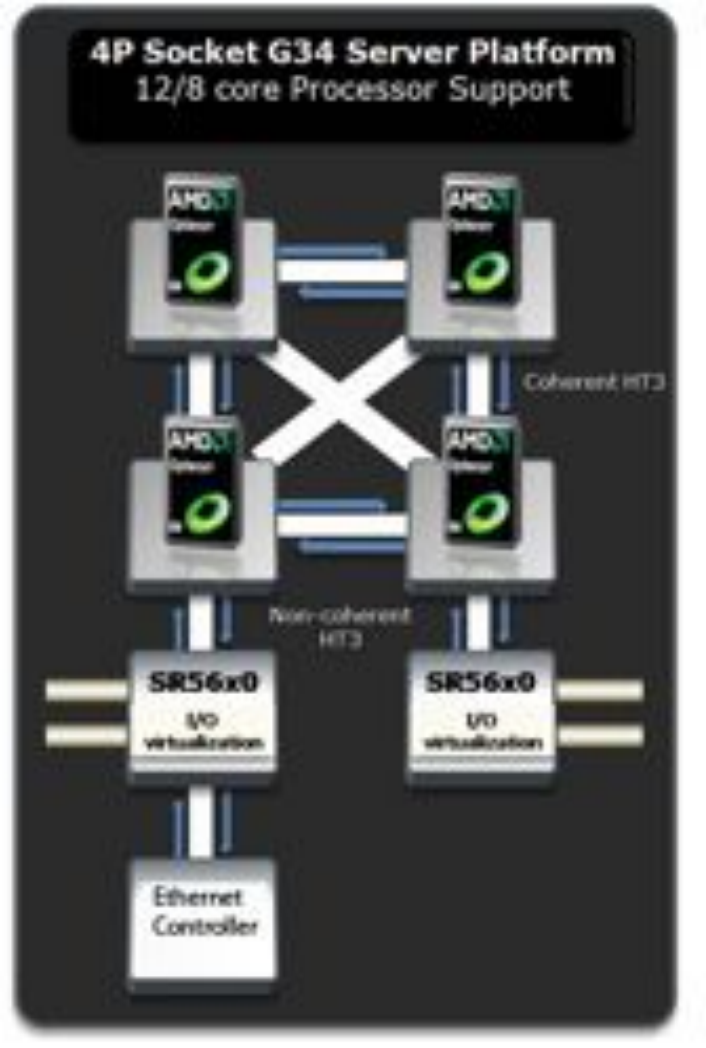
Results (rtt = 17 ms)

- Single flow iPerf 1 core -> 21 Gbps
- Single flow iPerf 1 core <> -> 15+15 Gbps
- Multi flow iPerf 2 cores -> 25 Gbps
- Multi flow iPerf 2 cores <> -> 23+23 Gbps
- DiViNe <> -> 11 Gbps
- Multi flow iPerf + DiVine -> 35 Gbps
- Multi flow iPerf + DiVine <> -> 35 + 35 Gbps

Performance Explained

- Mellanox 40GE card is PCI-E 2.0 8x (5GT/s)
- 40Gbit/s raw throughput but ….
- PCI-E is a network-like protocol
  - 8/10 bit encoding -> 25% overhead -> 32Gbit/s maximum data throughput
  - Routing information
- Extra overhead from IP/Ethernet framing
- Server architecture matters!
  - 4P system performed worse in multithreaded iperf

Server Architecture



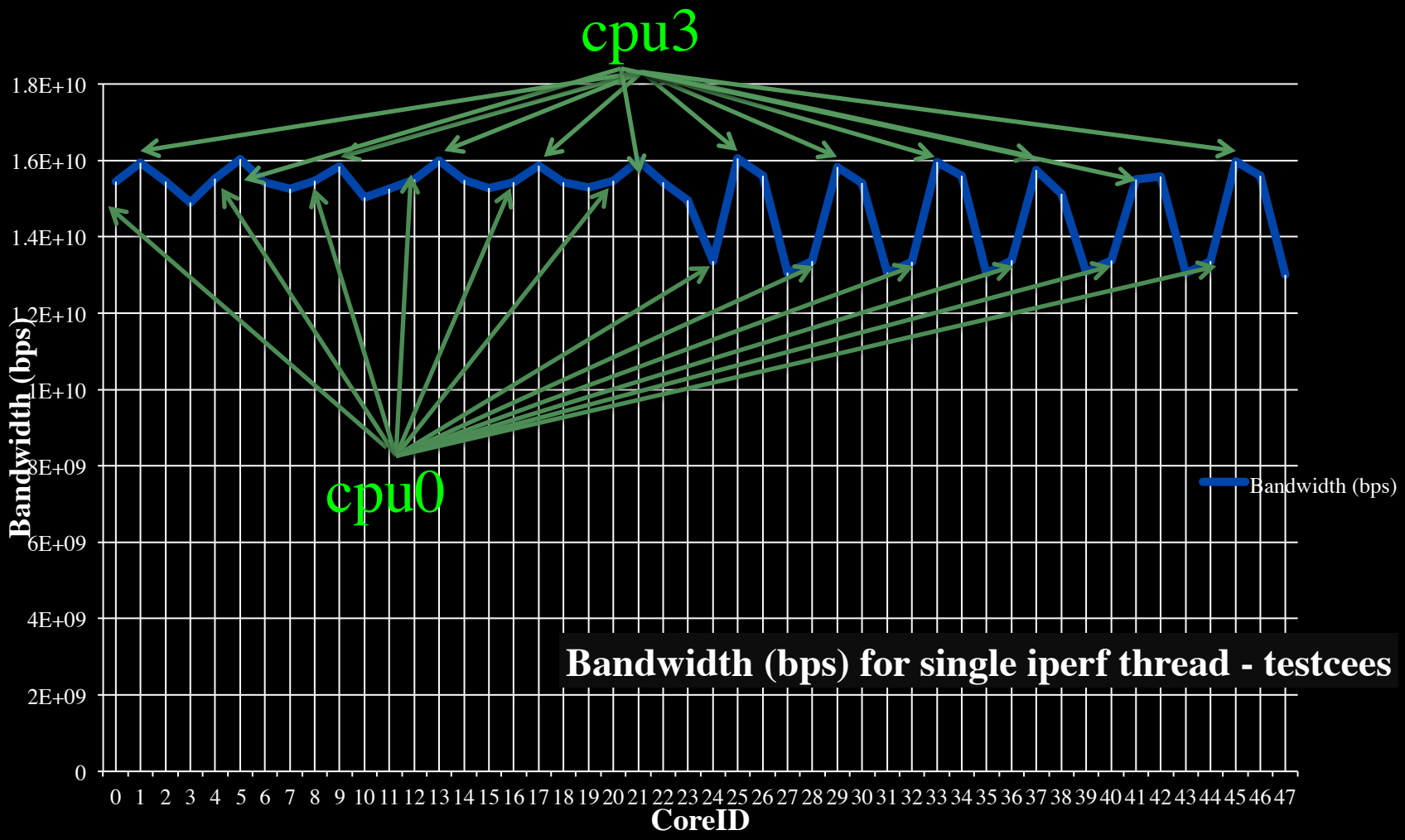
DELL R815

4 x AMD Opteron 6100

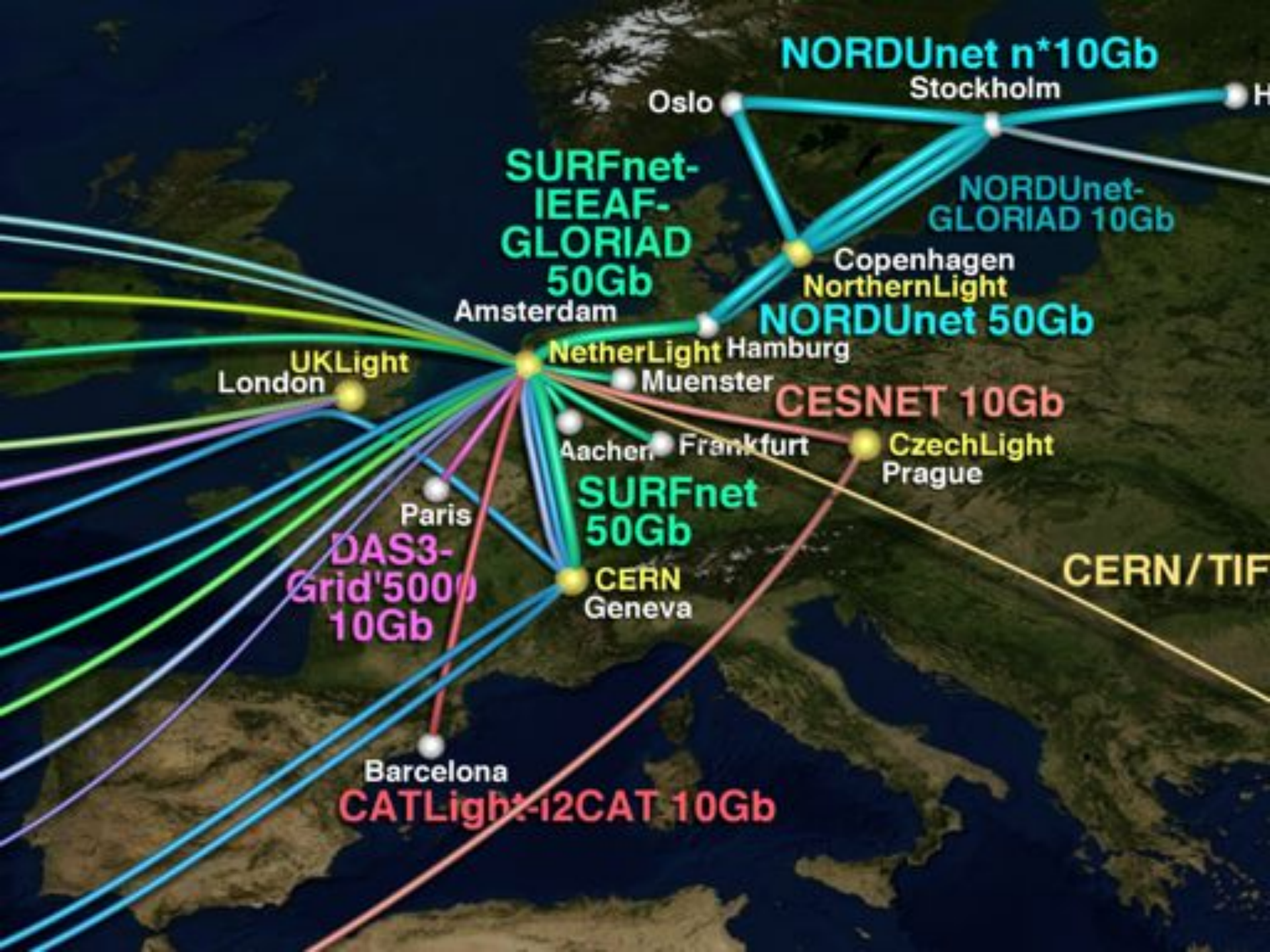
Supermicro X8DTT-HIBQF

2 x Intel Xeon

CPU Topology benchmark



We used numactl to bind iperf to cores


NORDUnet n*10Gb
Oslo
Stockholm
SURFnet-
IEEAF-
GLORIAD
50Gb
NORDUnet-
GLORIAD 10Gb
Copenhagen
NorthernLight
NORDUnet 50Gb
Amsterdam
NetherLight
Hamburg
UKLight
London
Muenster
CESNET 10Gb
Aachen
Frankfurt
CzechLight
Prague
SURFnet
50Gb
Paris
DAS3-
Grid'5000
10Gb
CERN
Geneva
CERN/TIF
Barcelona
CATLight-i2CAT 10Gb

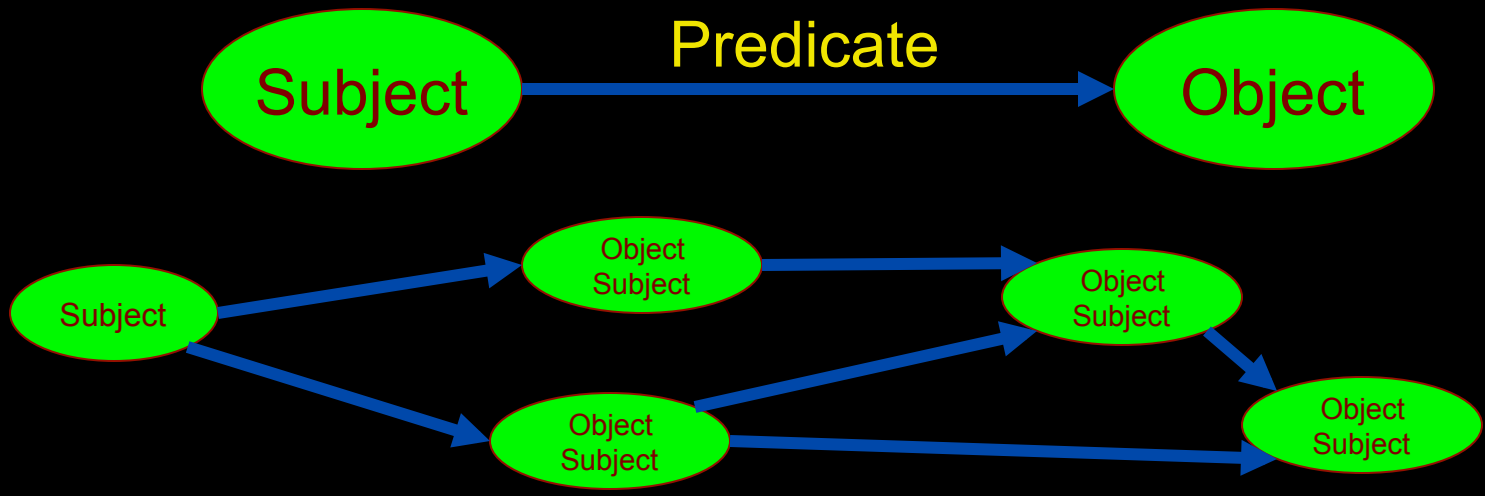
GLIF 2008

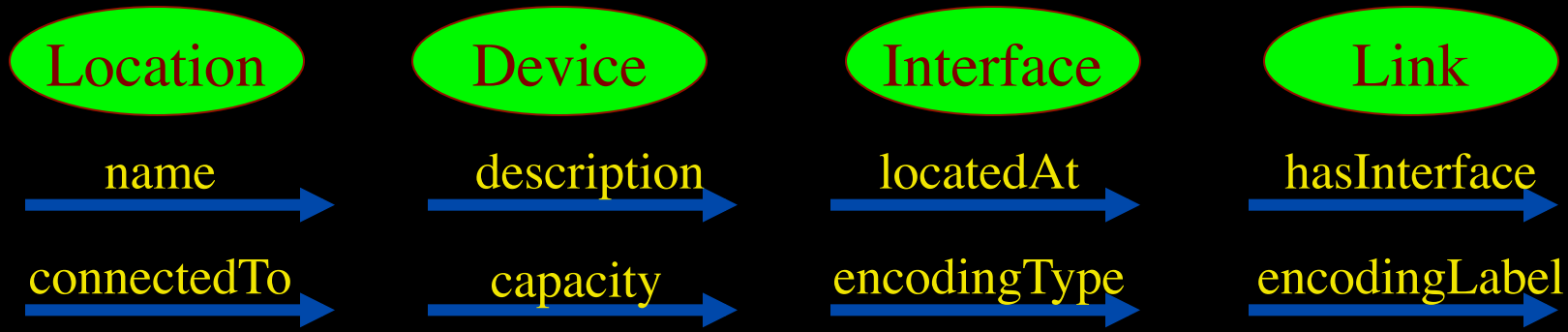
Visualization courtesy of Bob Patterson, NCSA
Data collection by Maxine Brown.

We zoeken: TOMTOM voor complexe netwerken!

Network Description Language

- From semantic Web / Resource Description Framework.
- The RDF uses XML as an interchange syntax.
- Data is described by triplets:

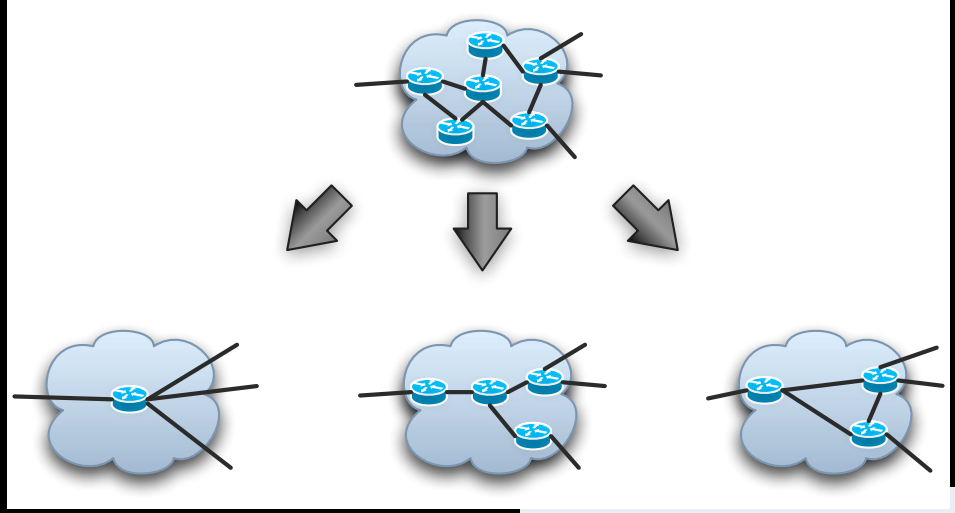




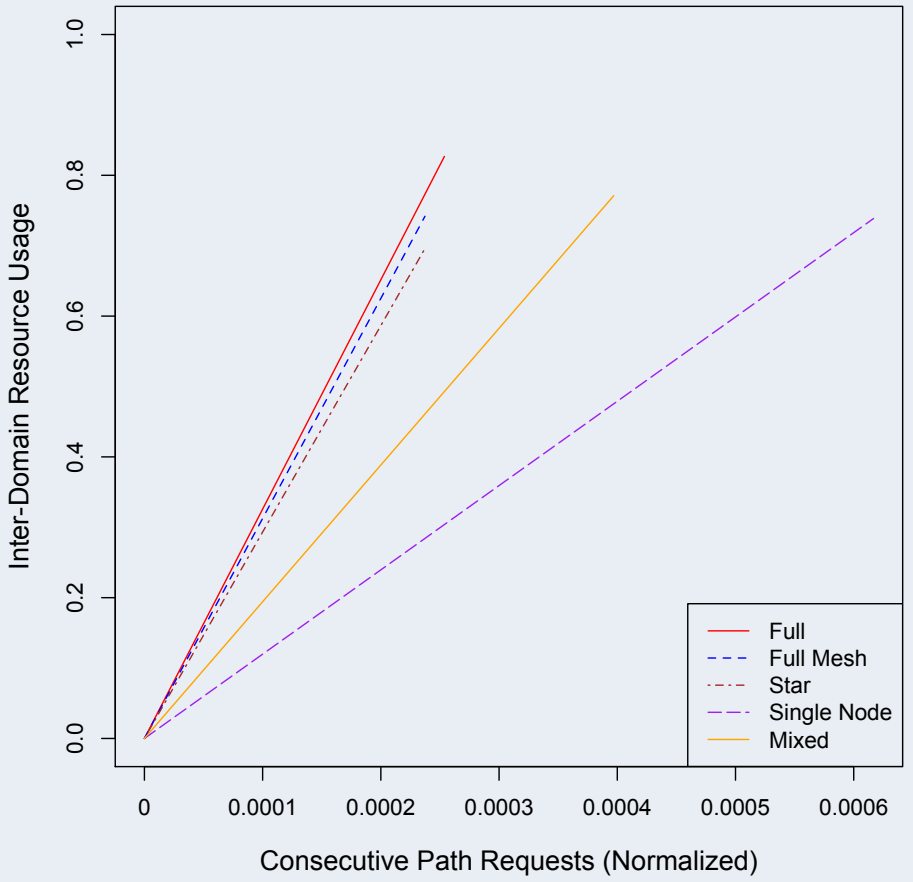
NetherLight in RDF

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:ndl="http://www.science.uva.nl/research/air/ndl#">
<!-- Description of Netherlight -->
<ndl:Location rdf:about="#Netherlight">
      <ndl:name>Netherlight Optical Exchange</ndl:name>
</ndl:Location>
<!-- TDM3.amsterdam1.netherlight.net -->
<ndl:Device rdf:about="#tdm3.amsterdam1.netherlight.net">
      <ndl:name>tdm3.amsterdam1.netherlight.net</ndl:name>
      <ndl:locatedAt rdf:resource="#amsterdam1.netherlight.net"/>
      <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:501/1"/>
      <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:501/3"/>
      <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:501/4"/>
      <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:503/1"/>
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
```

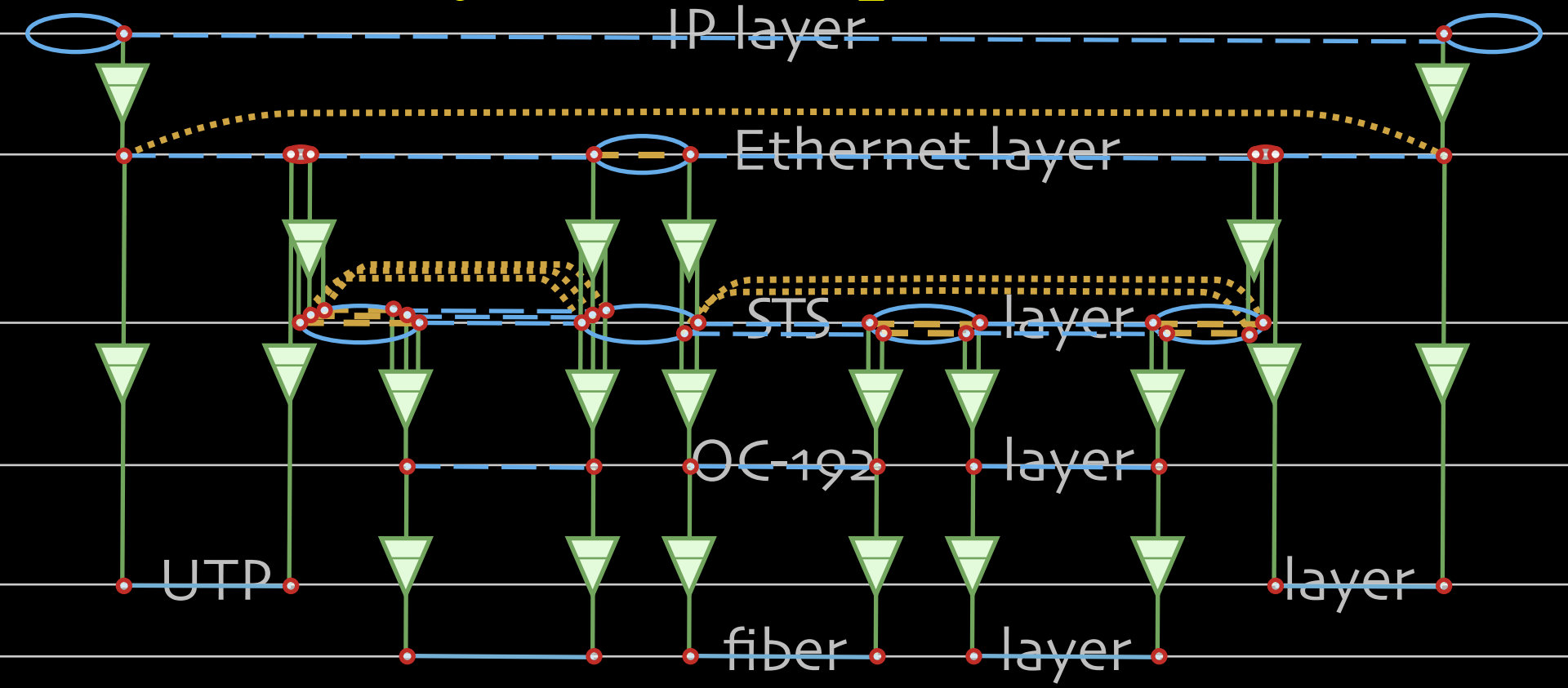
```
<!-- all the interfaces of TDM3.amsterdam1.netherlight.net -->

<ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:501/1">
            <ndl:name>tdm3.amsterdam1.netherlight.net:POS501/1</ndl:name>
            <ndl:connectedTo rdf:resource="#tdm4.amsterdam1.netherlight.net:5/1"/>
 </ndl:Interface>
<ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:501/2">
            <ndl:name>tdm3.amsterdam1.netherlight.net:POS501/2</ndl:name>
            <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:12/1"/>
</ndl:Interface>
```

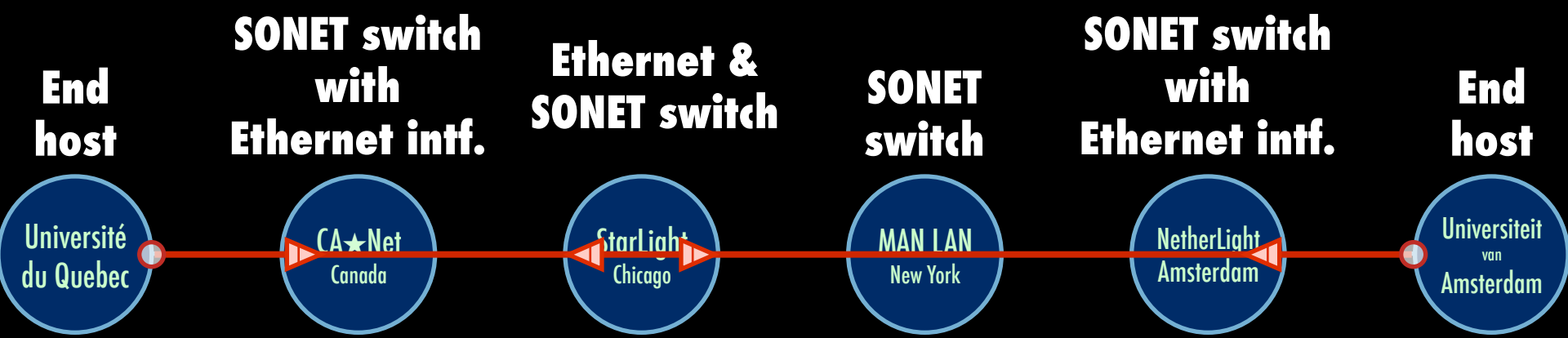


Topology Aggregation

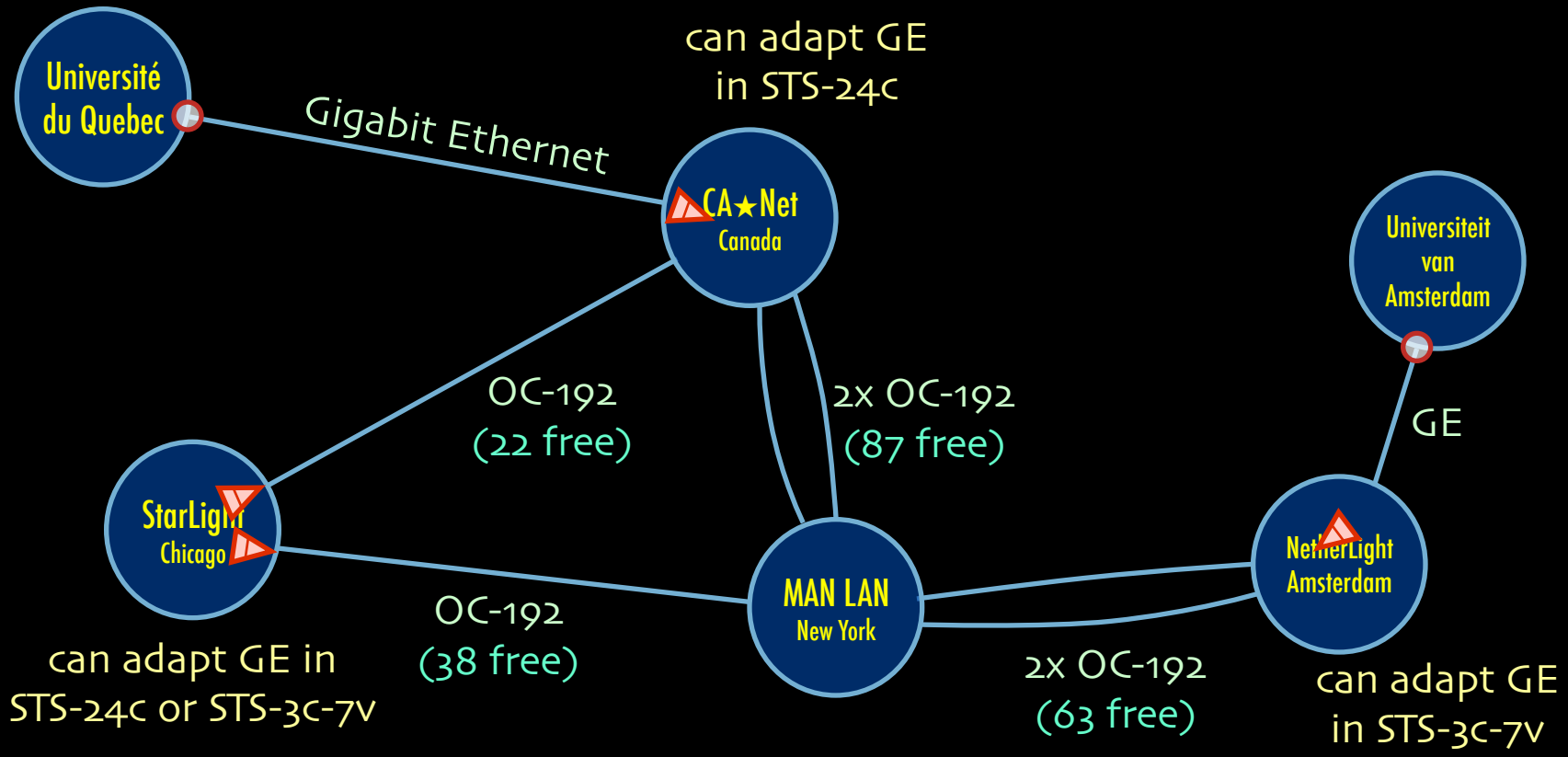


Multi-layer descriptions in NDL



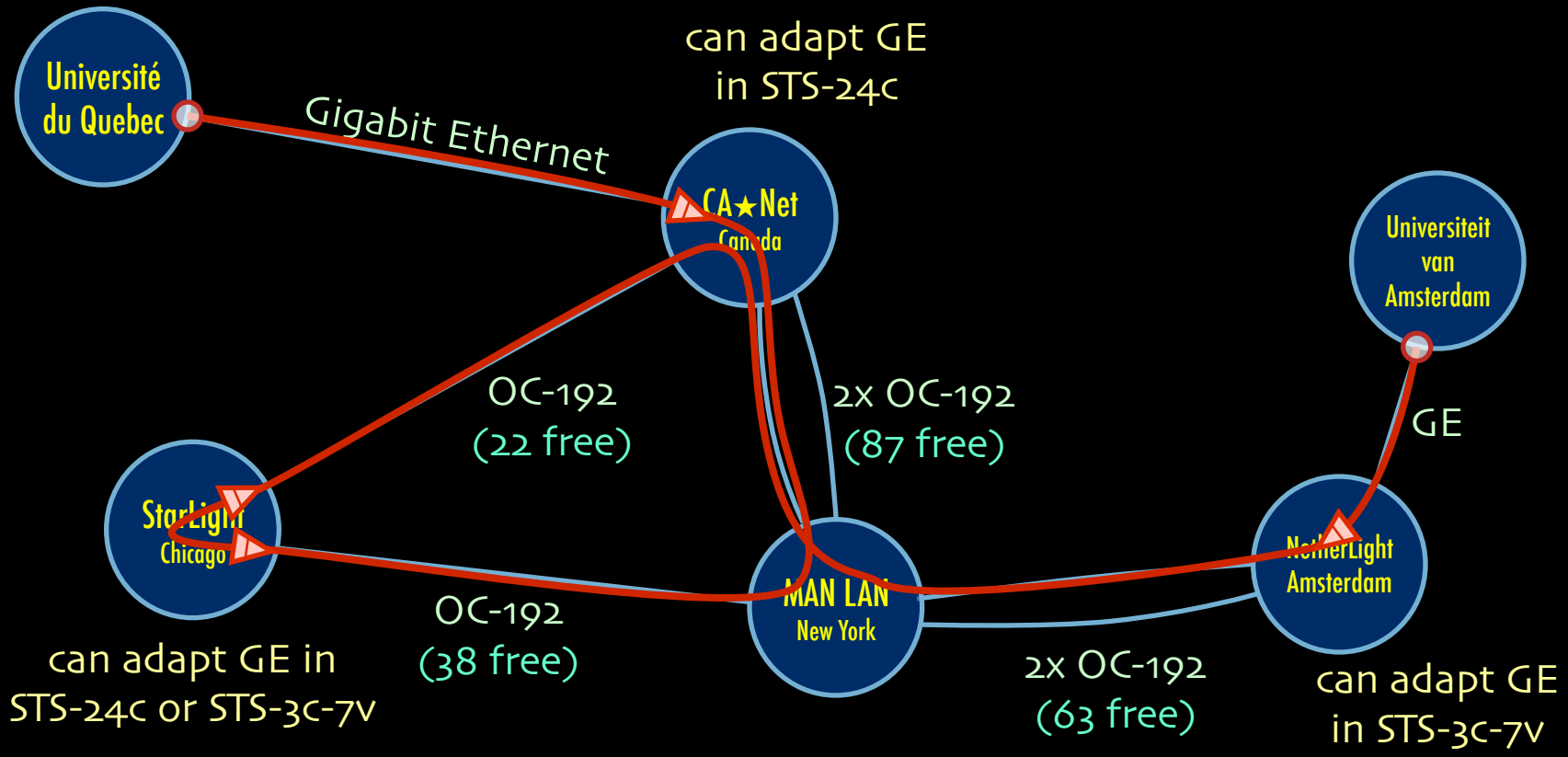


A weird example



Thanks to Freek Dijkstra & team

A weird example



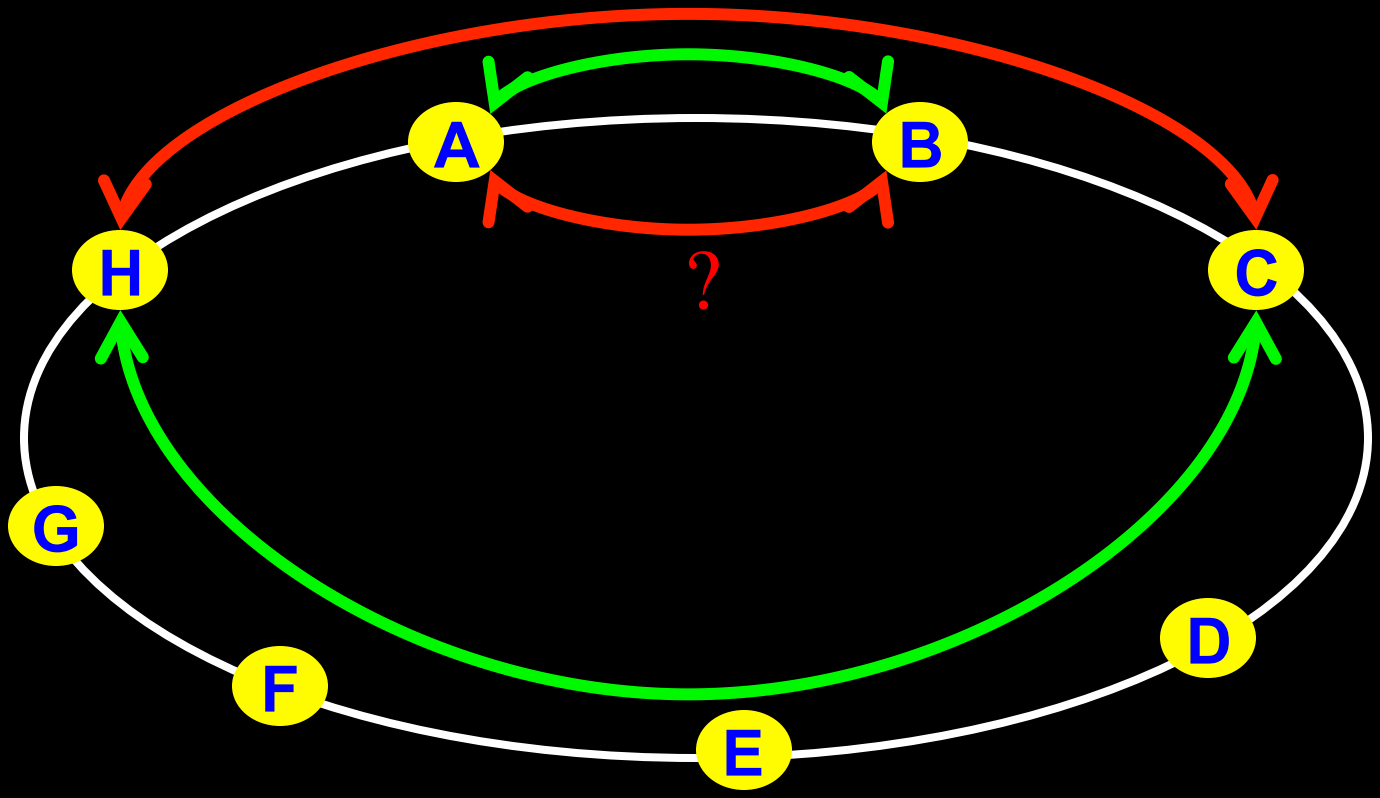
Thanks to Freek Dijkstra & team

The Problem

I want HC and AB

Success depends on the order

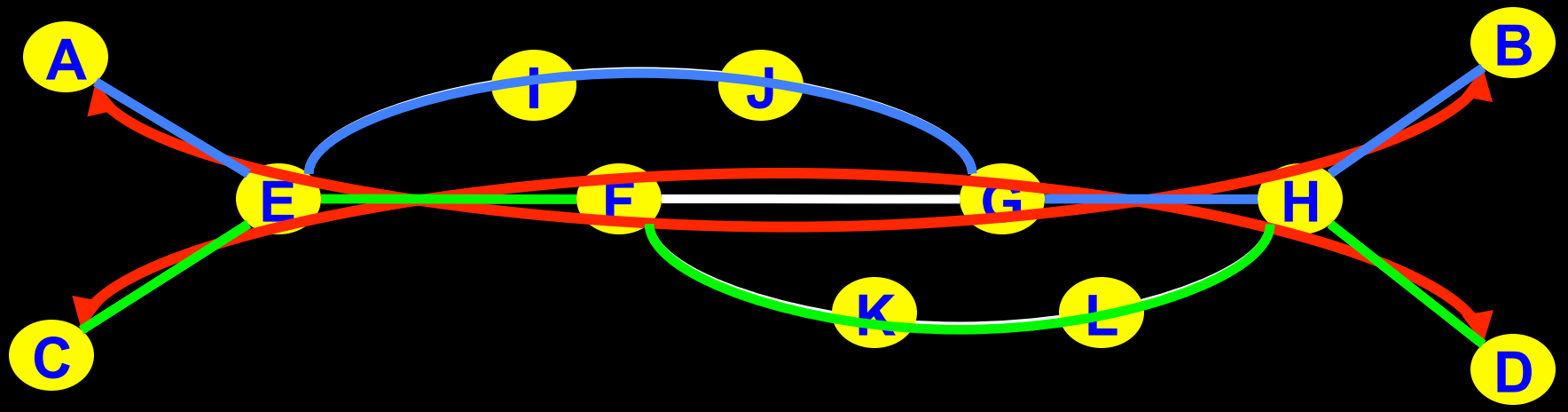
Wouldn't it be nice if I could request [HC, AB, ...]



Another one ☺

I want AB and CD

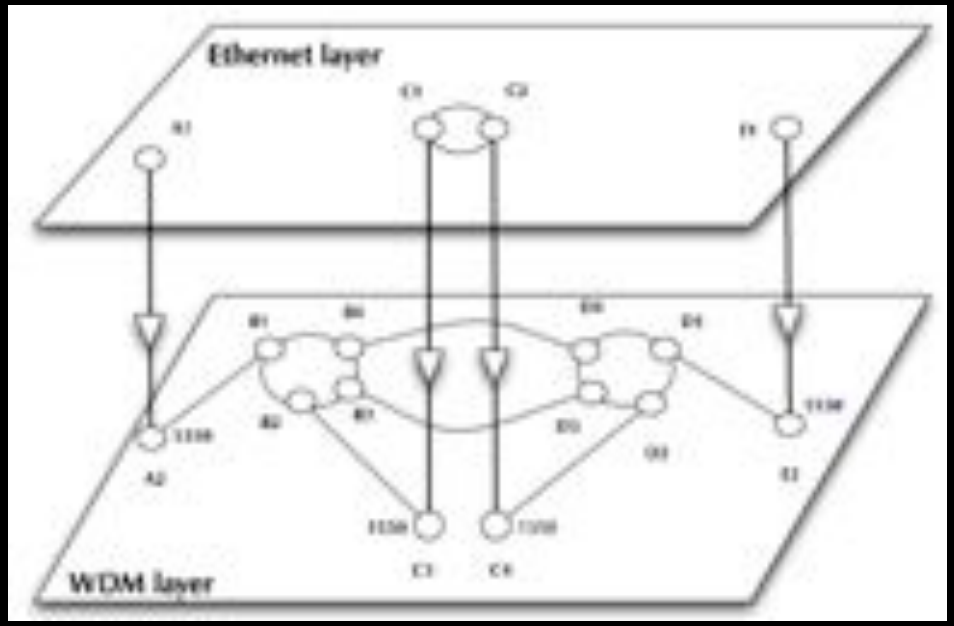
Success does not even depend on the order!!!

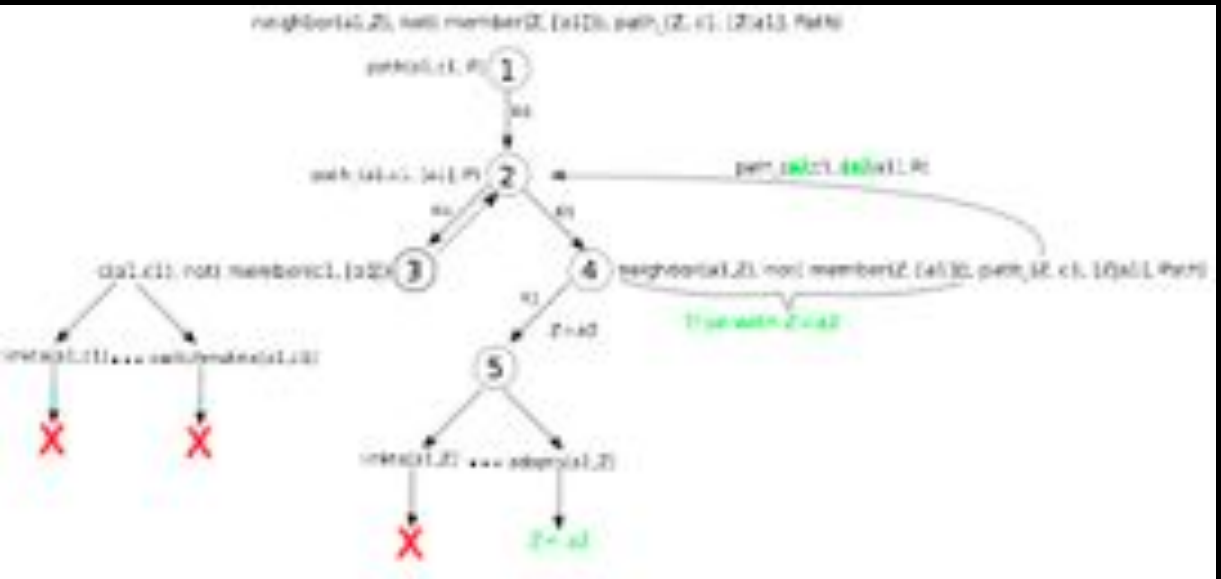


NDL + PROLOG

Research Questions:

- order of requests
- complex requests
- usable leftovers





- Reason about graphs
- Find sub-graphs that comply with rules

Multi-domain 2-layer networks

How do multi-domain 2-layer networks look like?

Guess: Projection algorithm (2-layer: Ethernet /WDM)

Steps:

1. Generate a multi-domain graph by BA-algorithm
2. Generate a graph for each domain by BA-algorithm
3. For each domain graph project random nodes onto WDM layer
4. Connect the domains at each layer according to the multi-domain graph
5. Assign random wavelengths to the adaptation links

Advantage:

- Number of adaptations determined by the degree of the projected nodes
- Multi-domain Ethernet-layer as well as the multi-domain WDM-layer graph are not necessarily connected.

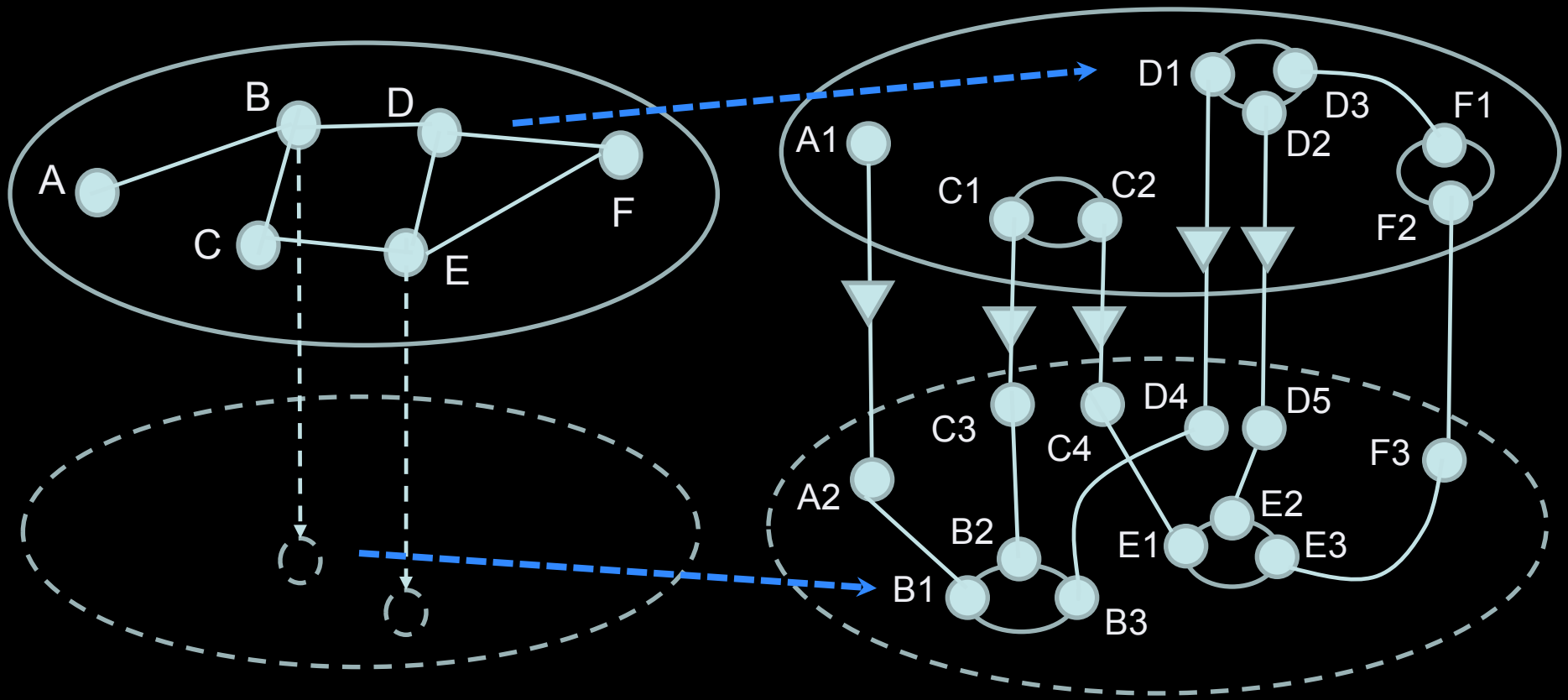
Input parameters:

- Number domains, number of nodes(devices) per domain
- Ratio of Ethernet-devices over WDM-devices per domain
- Distribution of wavelength

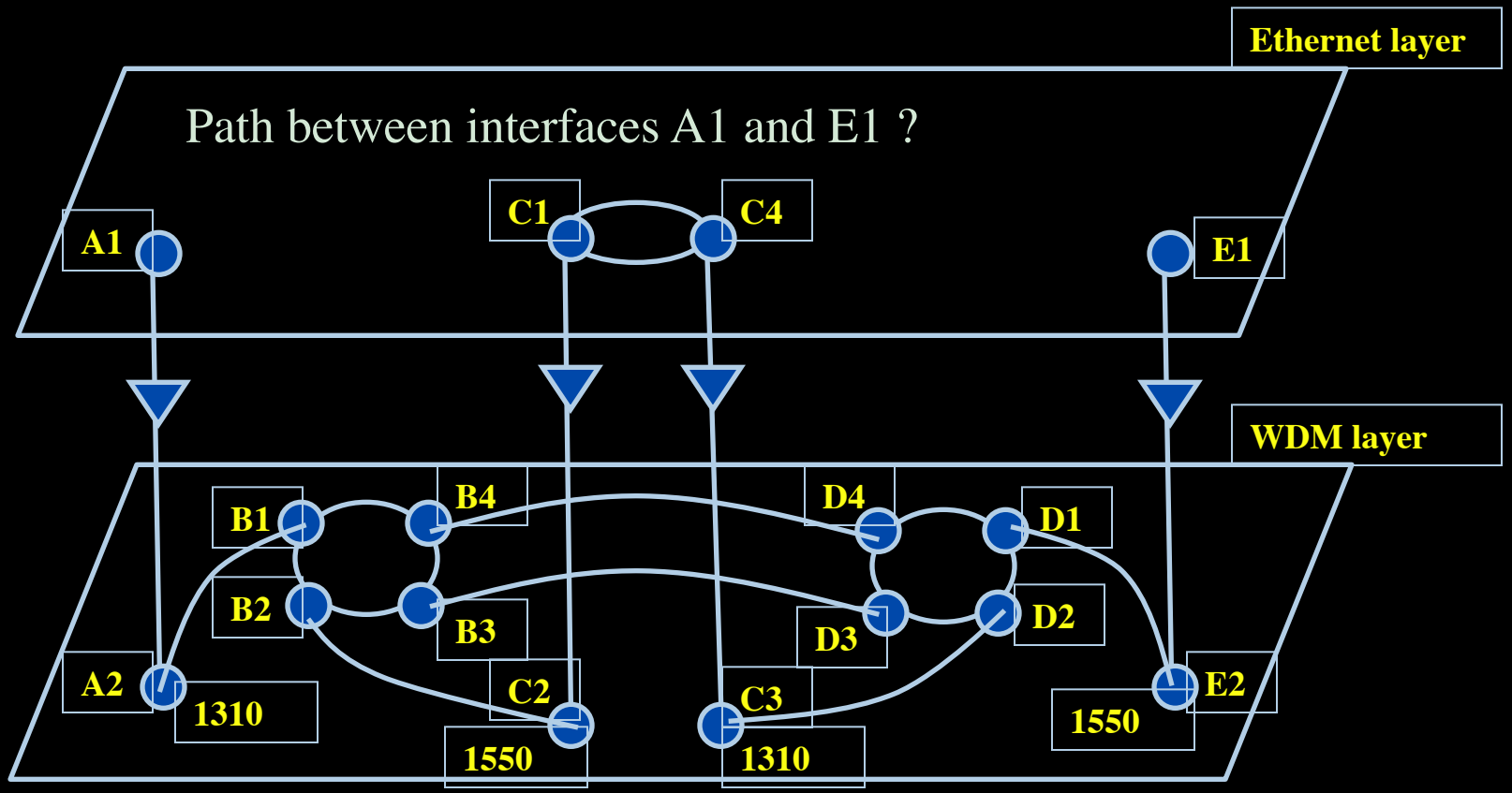
Multi-domain 2-layer networks

Projection algorithm

BA-algorithm to generate a graph for each domain
Project random nodes onto WDM layer



Multi-layer Network PathFinding



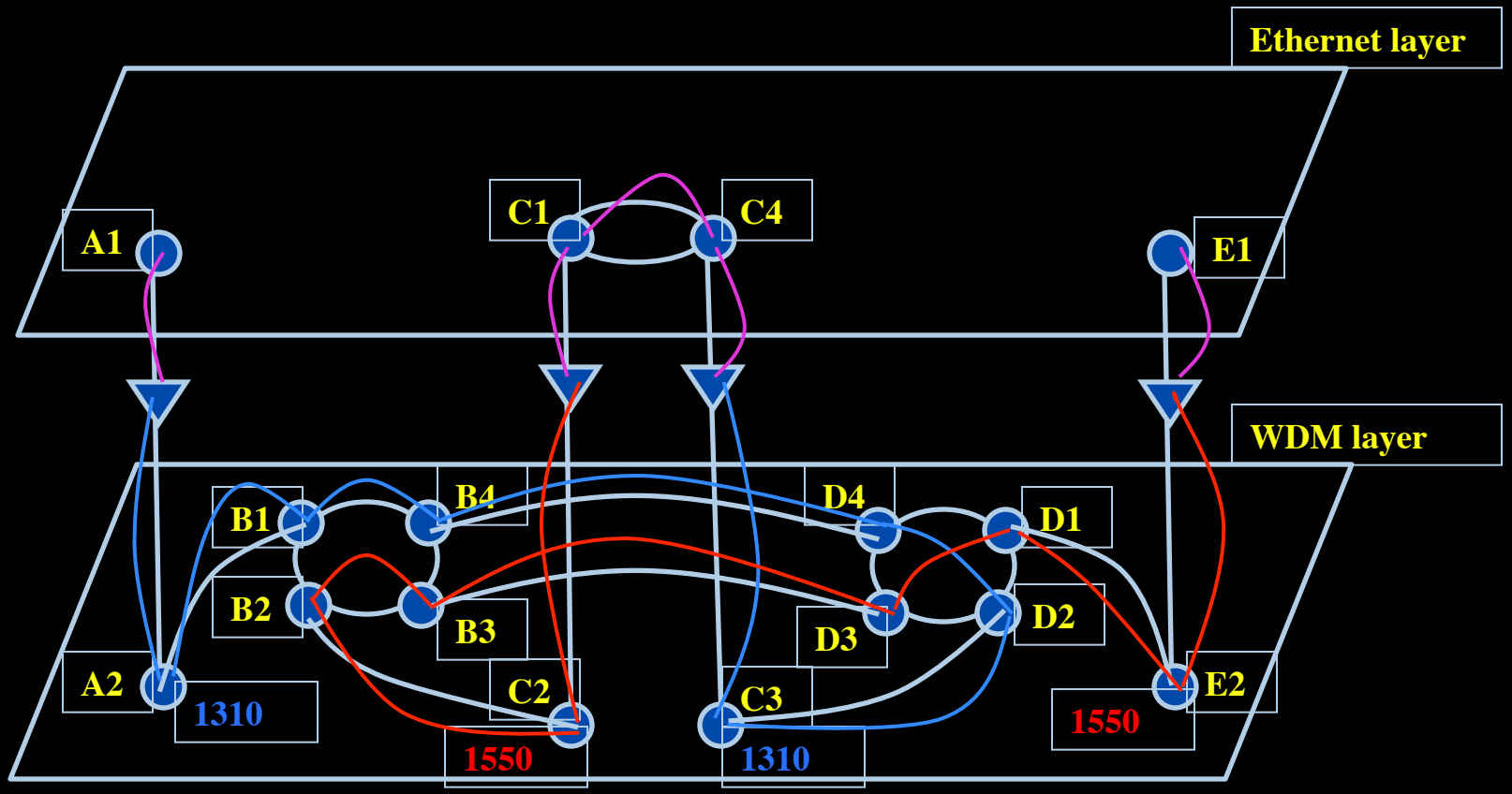
Prolog rule:

```
linkedto( Intf1, Intf2, CurrWav ):-                 %-- is there a link between  Intf1 and Intf2 for wavelength CurrWav ?
    rdf_db:rdf( Intf1, ndl:'layer', Layer ),        %-- get layer of interface Intf1 → Layer
    Layer == 'wdm#LambdaNetworkElement',            %-- are we at the WDM-layer ?
    rdf_db:rdf( Intf1, ndl:'linkedTo', Intf2 ),     %-- is Intf1 linked to Intf2 in the RDF file?
    rdf_db:rdf( Intf2, wdm:'wavelength', W2 ),      %-- get wavelength of Intf2 → W2
    compatible_wavelengths( CurrWav, W2 ).          %-- is CurrWav compatible with W2 ?
```

linkedto(B4, D4, CurrWav) is true for any value of CurrWav

linkedto(D2, C3, CurrWav) is true if CurrWav == 1310

Multi-layer Network PathFinding



Path between interfaces A1 and E1:

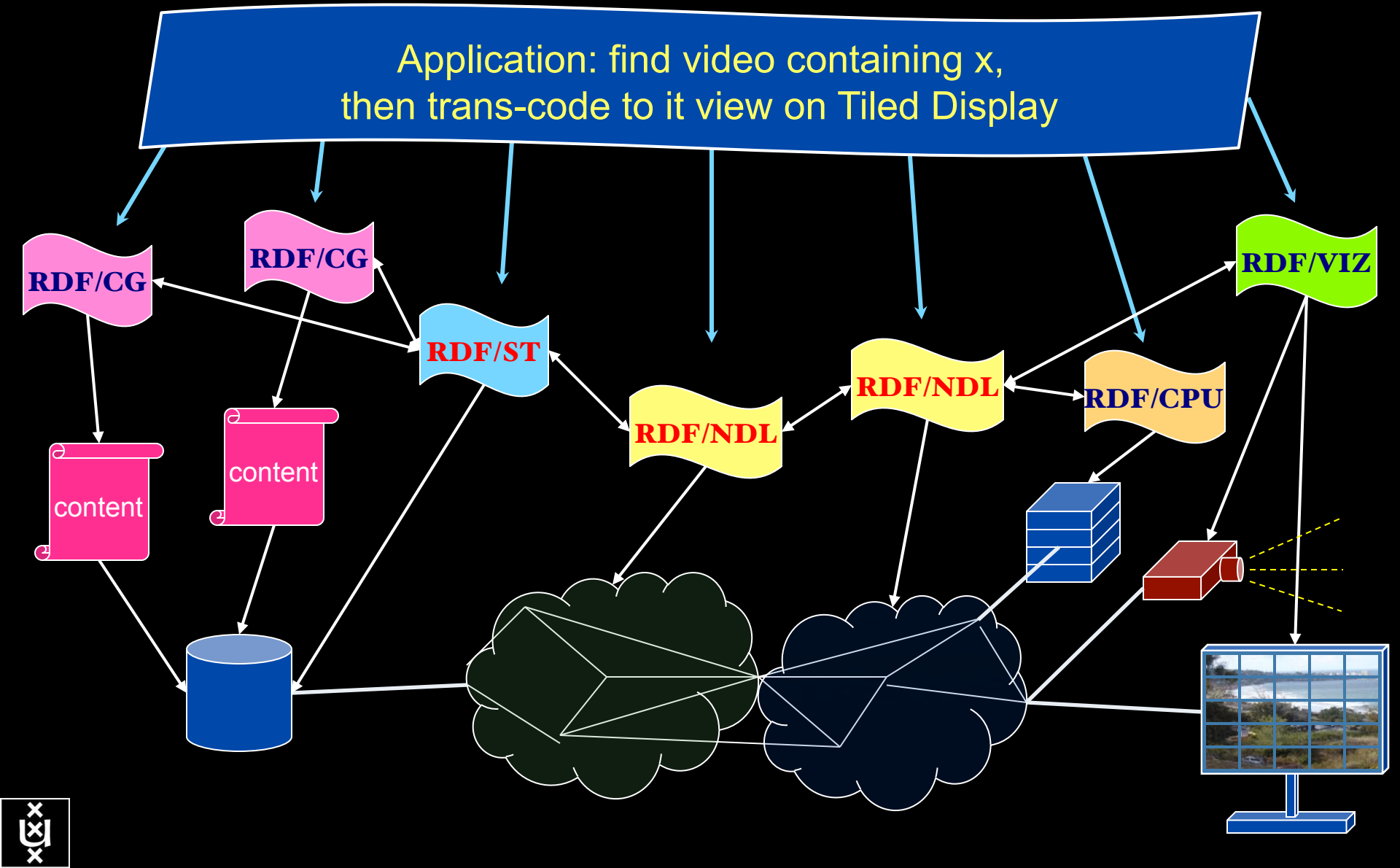
A1-A2-B1-B4-D4-D2-C3-C4-C1-C2-B2-B3-D3-D1-E2-E1

Scaling: Combinatorial problem

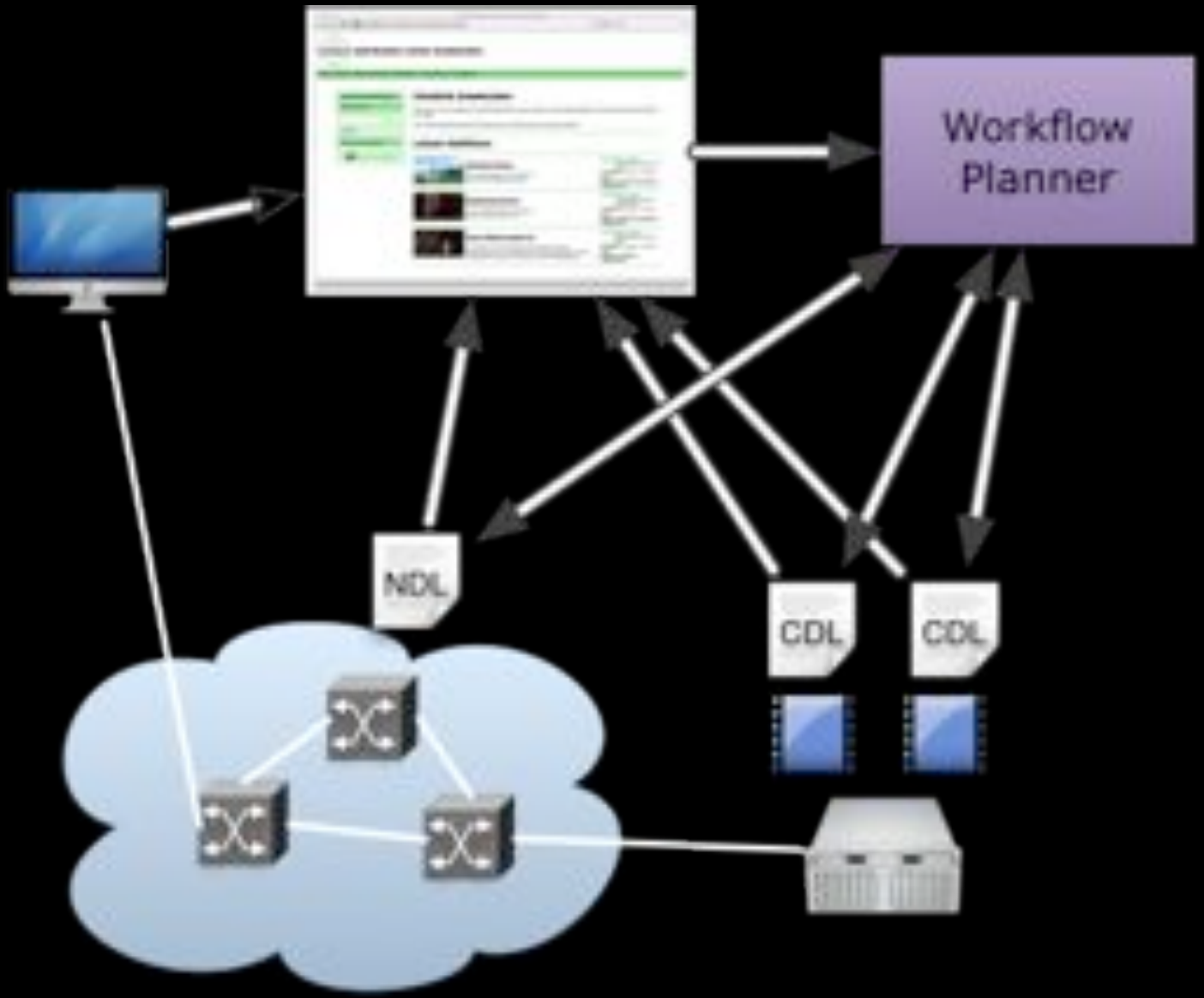
Standardization

- OGF-NML is slowly progressing
  - Schema Document
- OGF-NSI is working frantically
  - Terminology Glossary
  - Architecture Document
  - NSI Protocol Document

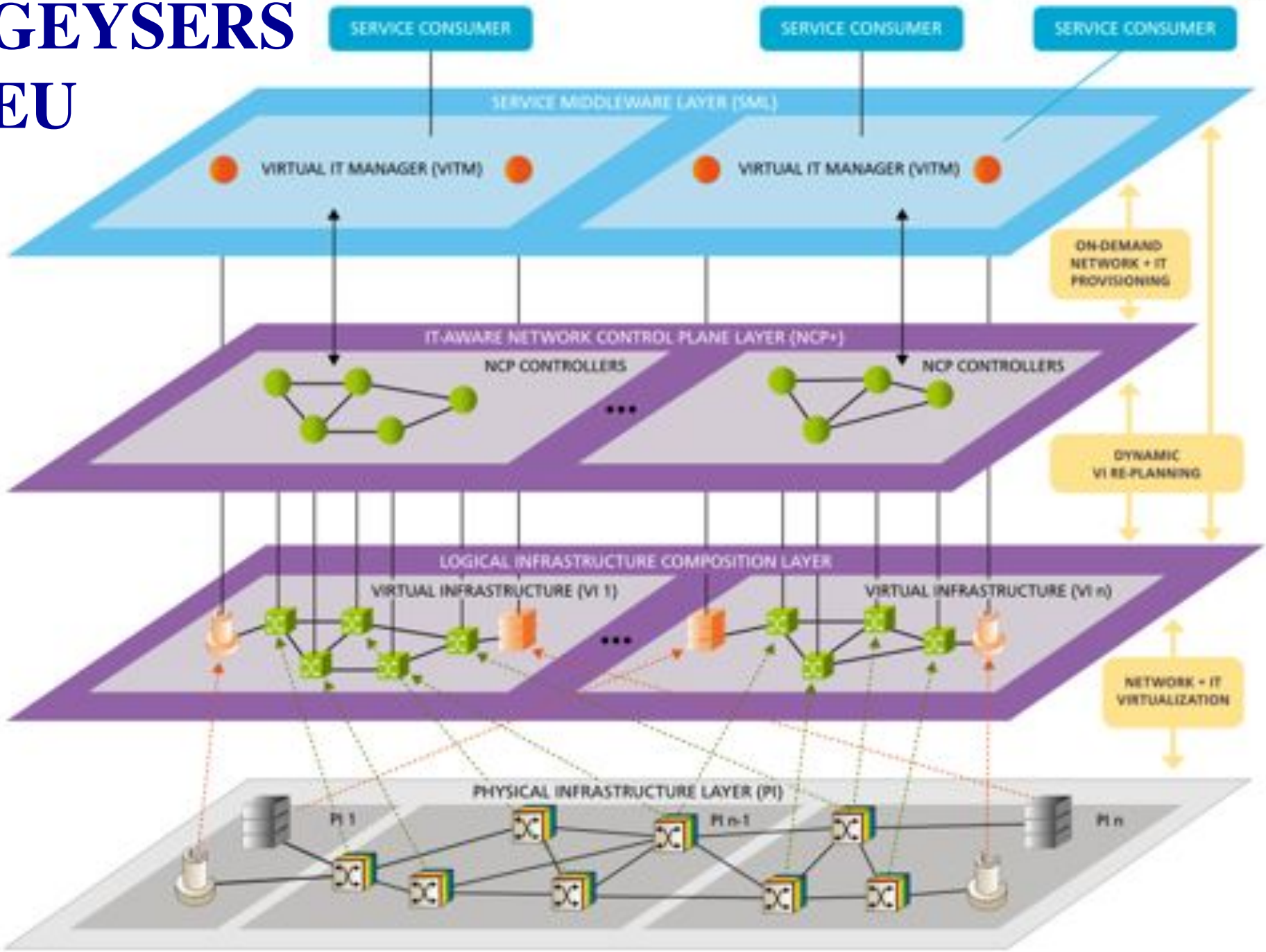
RDF describing Infrastructure



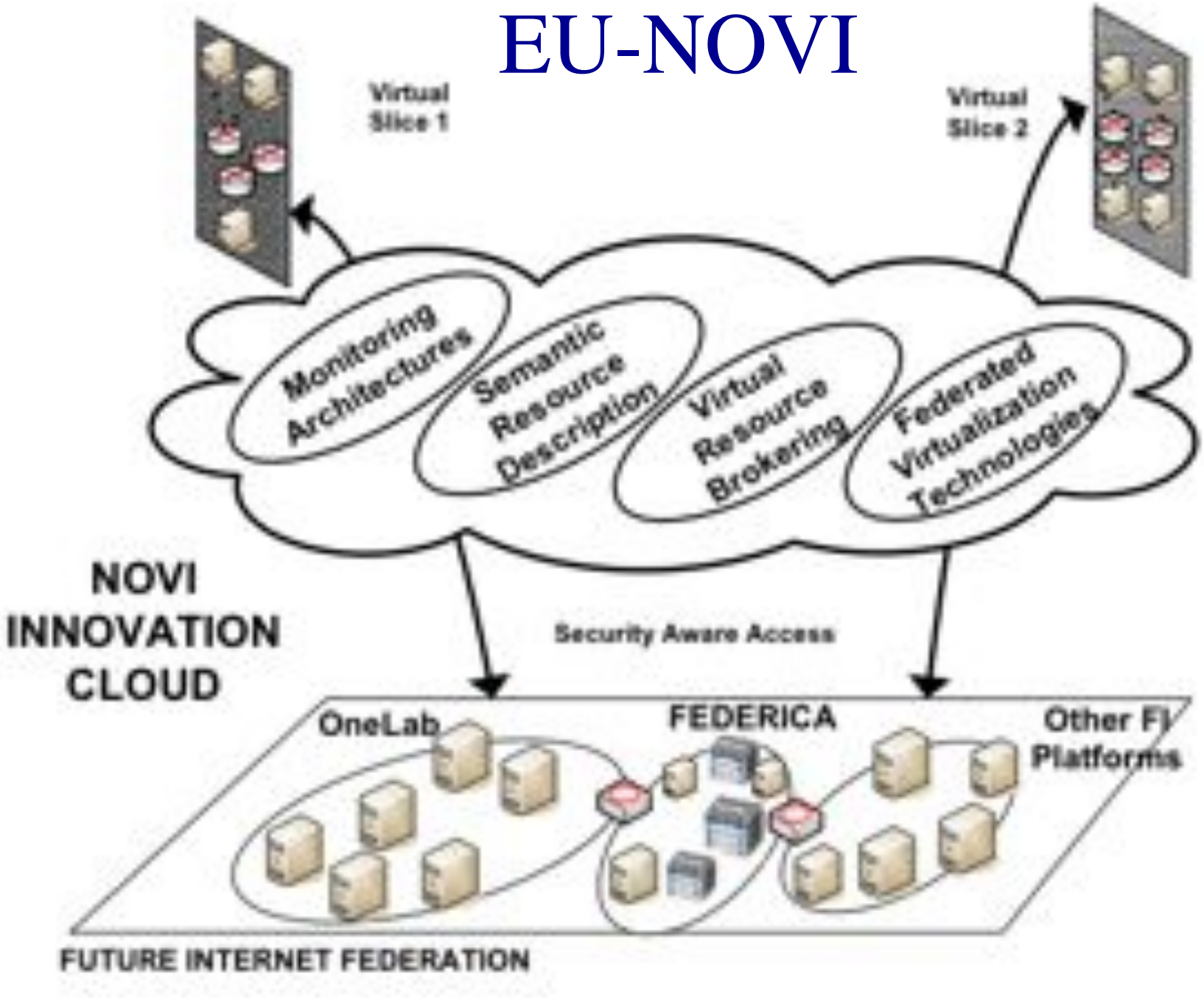
CineGrid Workflow Planner



GEYSERS EU


SERVICE CONSUMER
SERVICE CONSUMER
SERVICE CONSUMER
SERVICE MIDDLEWARE LAYER (SML)
VIRTUAL IT MANAGER (VITM)
VIRTUAL IT MANAGER (VITM)
ON-DEMAND NETWORK + IT PROVISIONING
IT-AWARE NETWORK CONTROL PLANE LAYER (NCP+)
NCP CONTROLLERS
NCP CONTROLLERS
DYNAMIC VI RE-PLANNING
LOGICAL INFRASTRUCTURE COMPOSITION LAYER
VIRTUAL INFRASTRUCTURE (VI 1)
VIRTUAL INFRASTRUCTURE (VI n)
NETWORK + IT VIRTUALIZATION
PHYSICAL INFRASTRUCTURE LAYER (PI)
PI 1
PI n-1
PI n

EU-NOVI


Virtual Slice 1
Virtual Slice 2
Monitoring Architectures
Semantic Resource Description
Virtual Resource Brokering
Federated Virtualization Technologies
NOVI INNOVATION CLOUD
Security Aware Access
OneLab
FEDERICA
Other FI Platforms
FUTURE INTERNET FEDERATION

EU

SARA

SURF-eSRC

Pieken-in-de-Delta

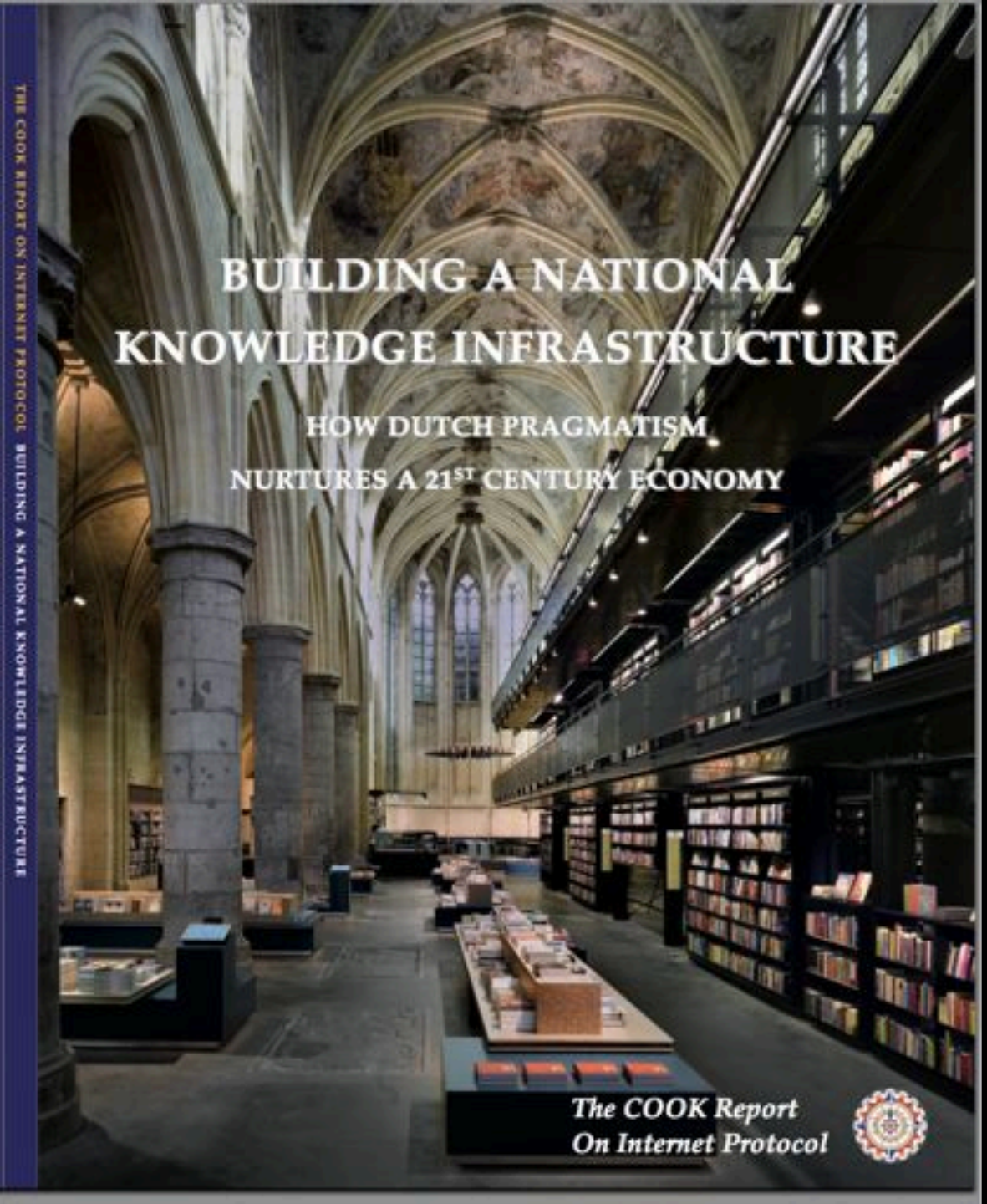
SURFnet

FES

NWO-NCF

UvA

NWO



Questions ?

CookReport
feb 2009 and feb-mar 2010

november '08
interview with
Kees Neggers (SURFnet),
Cees de Laat (UvA)

and furthermore
on november '09

Wim Liebrandt (SURF),
Bob Hertzberger (UvA) and
Hans Dijkman (UvA)

BSIK projects
GigaPort &
VL-e / e-Science

SURF NET

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