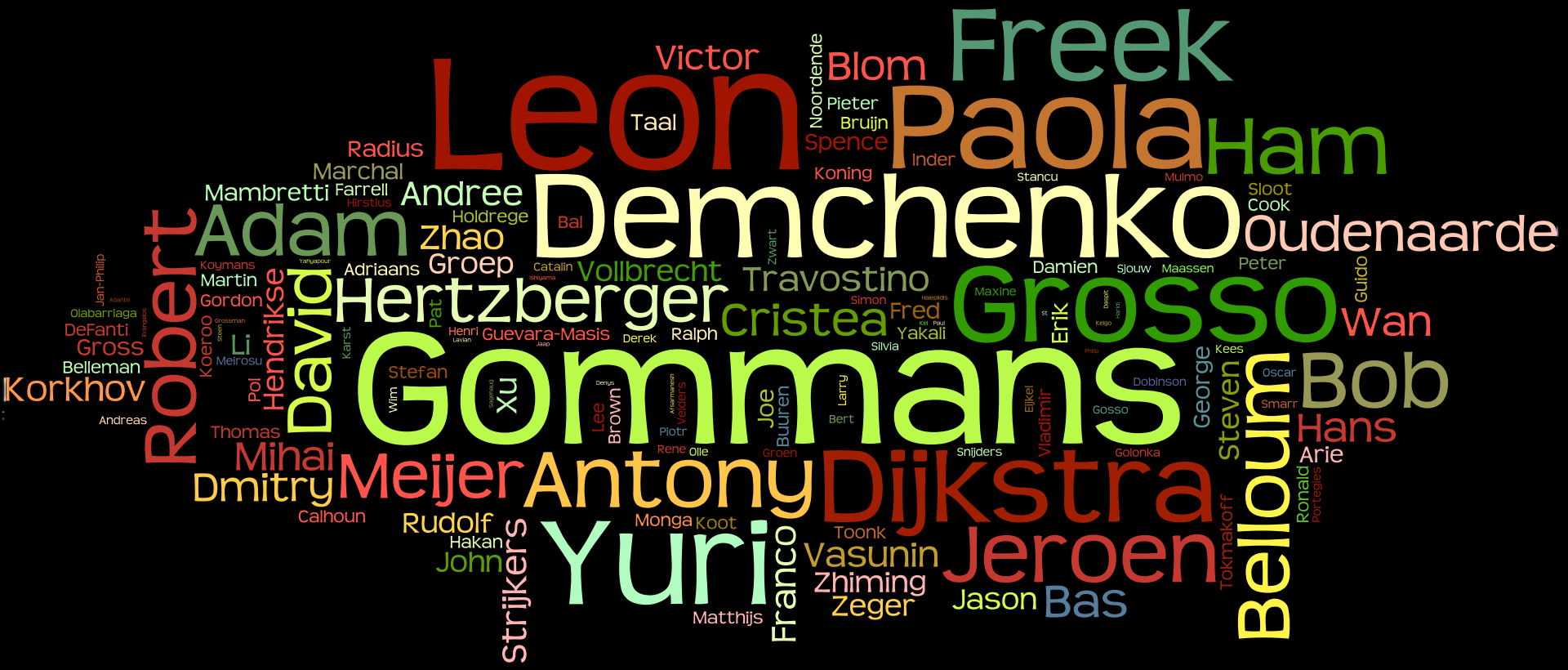
Smart Cyber Infrastructure for Big Data Processing

Paola Grosso & Cees de Laat



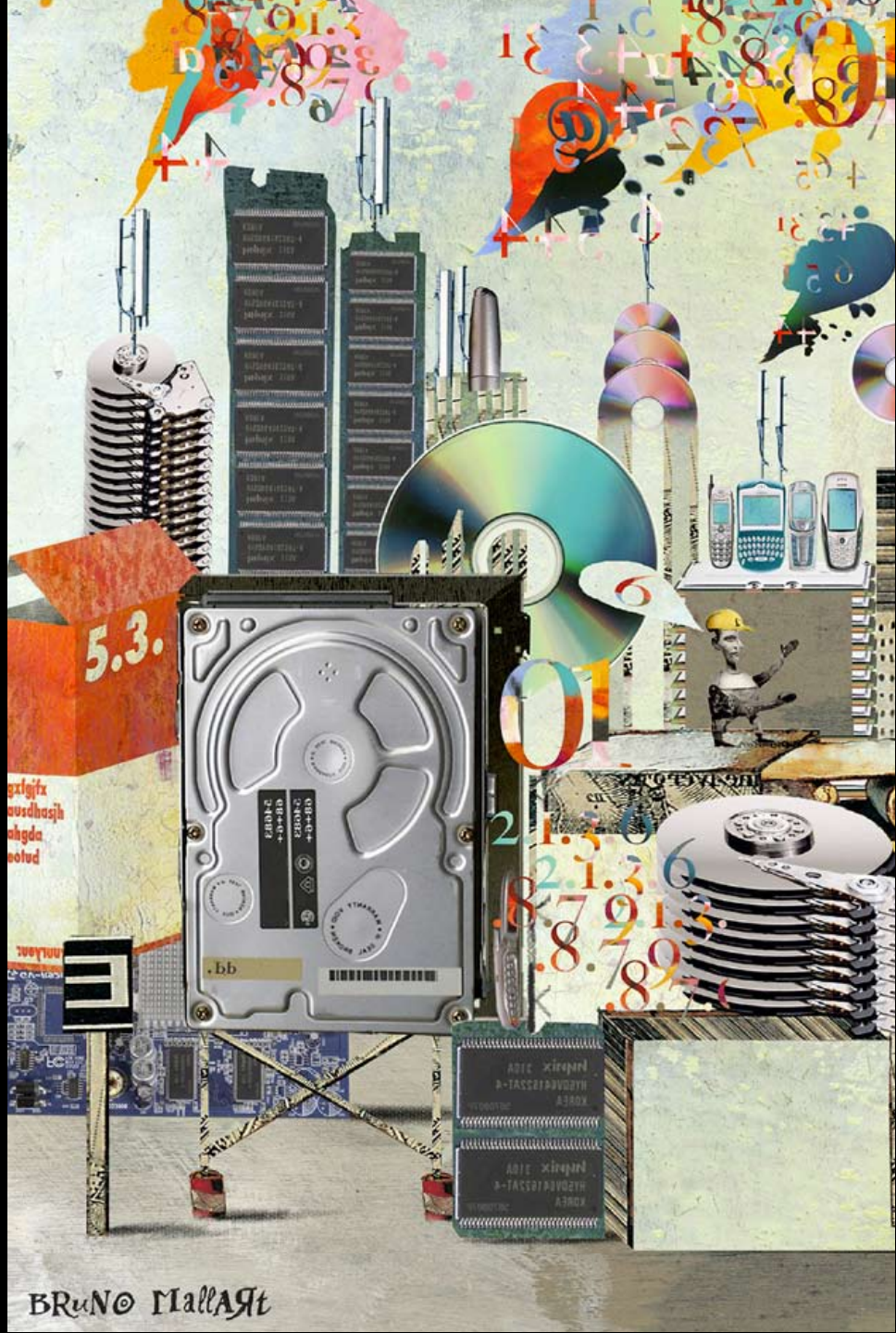
From King's Dutch Academy of Sciences

The Dutch Research Agenda

"Information technology (IT) now permeates all aspects of public, commercial, social, and personal life. bank cards, satnav, and weather radar... IT has become completely indispensable."

"But to guarantee the reliability and quality of constantly bigger and more complicated IT, we will need to find answers to some fundamental questions!"

https://www.knaw.nl/nl/actueel/publicaties/the-dutch-research-agenda/@@download/pdf_file/20111029.pdf



Reduction of Complexity by Integration

By combining services such as telephony, television, data, and computing capacity within a single network, we can cut down on complexity, energy consumption and maintenance.

- How can we describe and analyze complex information systems effectively?
- How can we specify and measure the quality and reliability of a system?
- How can we combine various different systems?
- How can we design systems in which separate processors can co-operate efficiently via mutual network connections within a much larger whole?
- Can we design information systems that can diagnose their own malfunctions and perhaps even repair them?
- How can we specify, predict, and measure system performance as effectively as possible?

SNE addresses a.o. the **highlighted** questions!

http://www.knaw.nl/Content/Internet_KNAW/publicaties/pdf/20111029.pdf

Mission

Can we create smart and safe data processing infrastructures that can be tailored to diverse application needs?

- *Capacity*
  - *Bandwidth on demand, QoS, architectures, photonics, performance*
- *Capability*
  - *Programmability, virtualization, complexity, semantics, workflows*
- *Security*
  - *Anonymity, integrity of data in distributed data processing*
- *Sustainability*
  - *Greening infrastructure, awareness*
- *Resilience*
  - *Systems under attack, failures, disasters*

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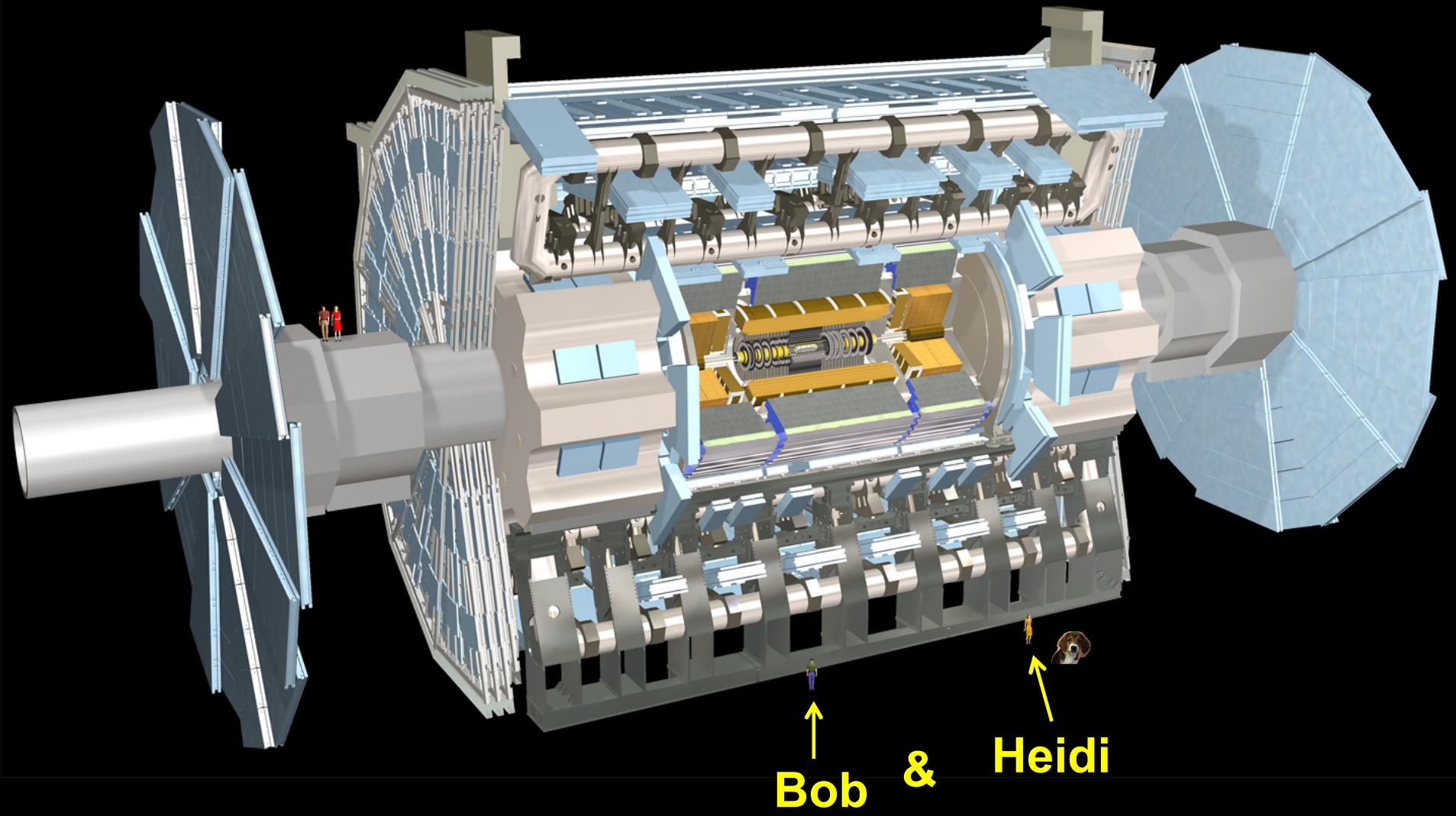
ATLAS detector @ CERN Geneve



What Happens in an **Internet Minute?**

And **Future Growth** is **Staggering**

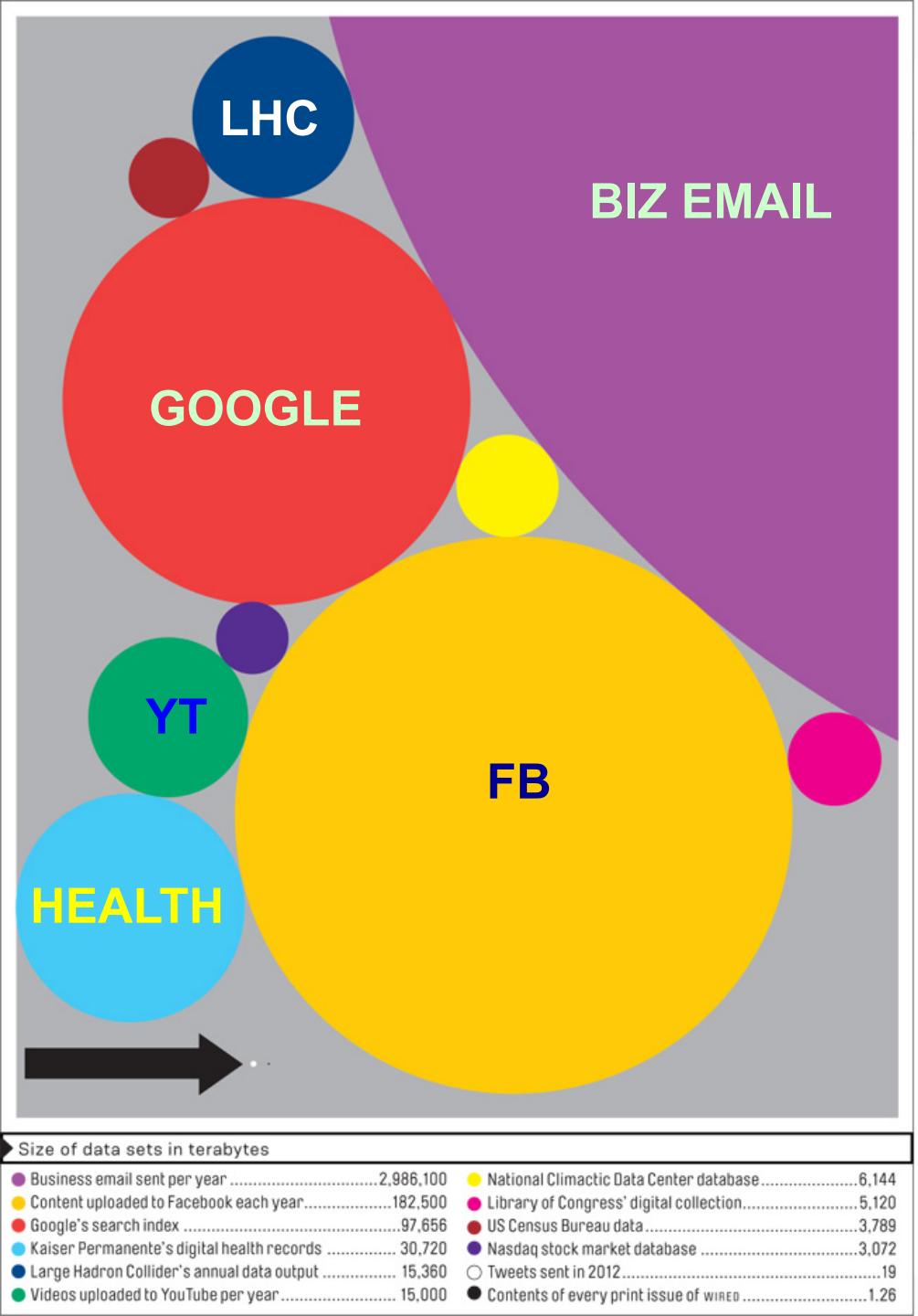
Today, the number of networked devices = the global population

By **2015**, the number of networked devices = 2x the global population

In **2015**, it would take you **5 years**

to view all video crossing IP networks each **second**

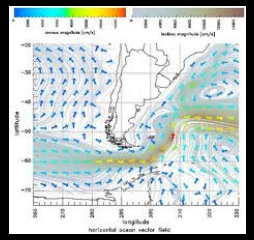
intel

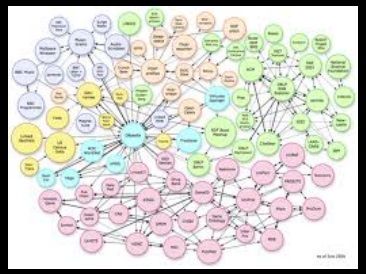


There
is
always
a
bigger
fish

Internet developments

... more data!





... more realtime!

... more users!

Internet developments

... more data!

Speed

Volume

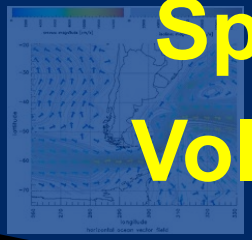
Deterministic

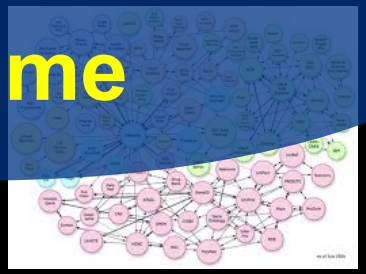
Real-time

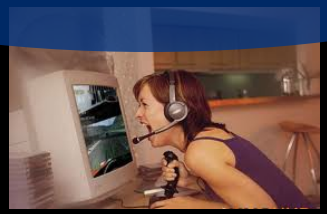
Scalable

Secure

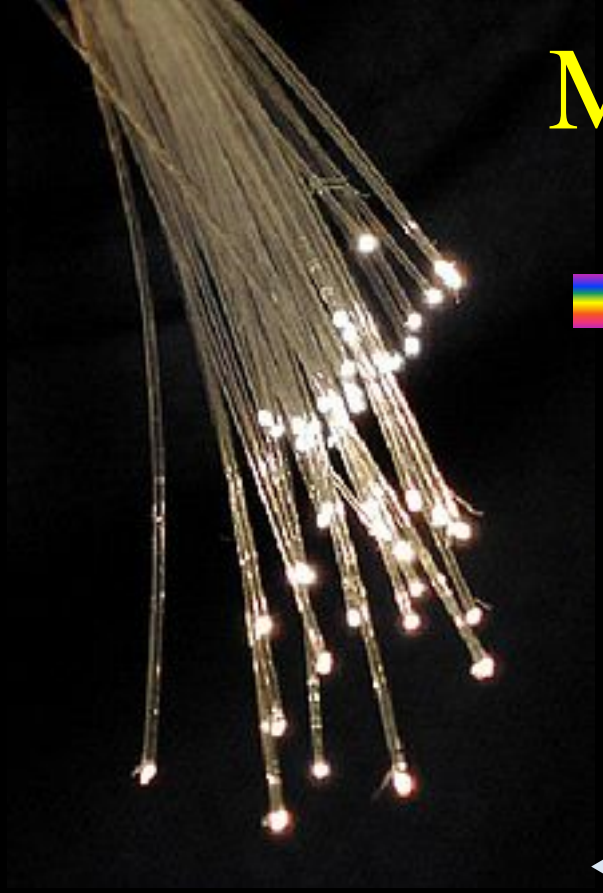
... more users!

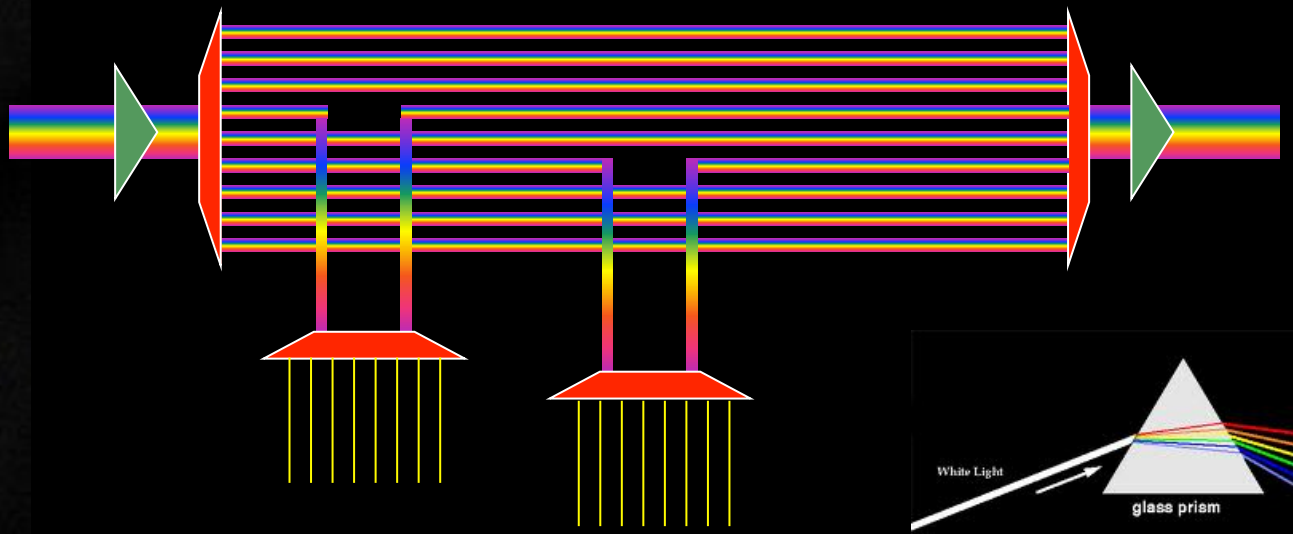


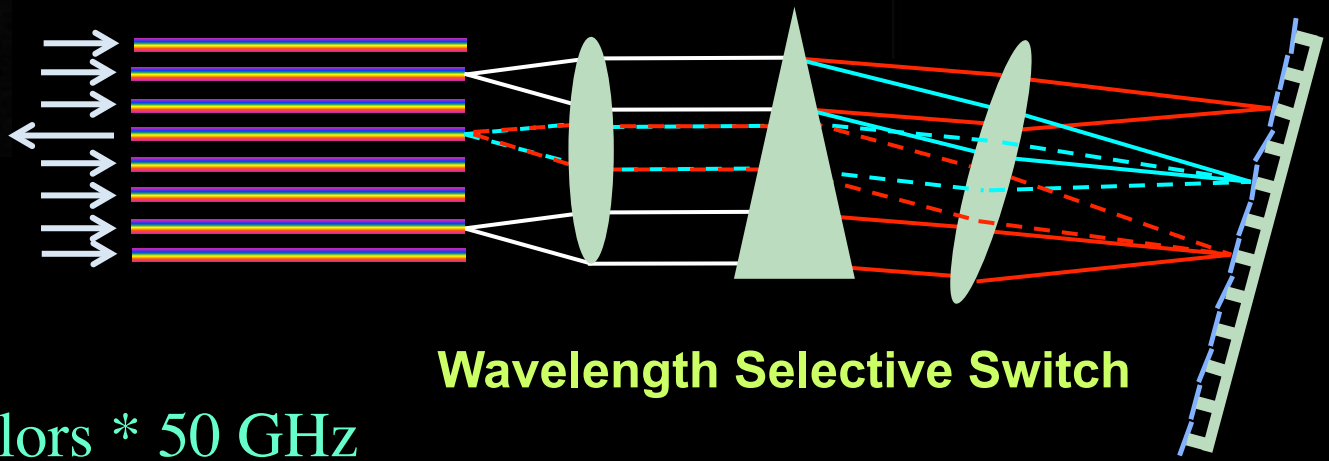




Multiple colors / Fiber







Wavelength Selective Switch

Per fiber: ~ 80-100 colors * 50 GHz

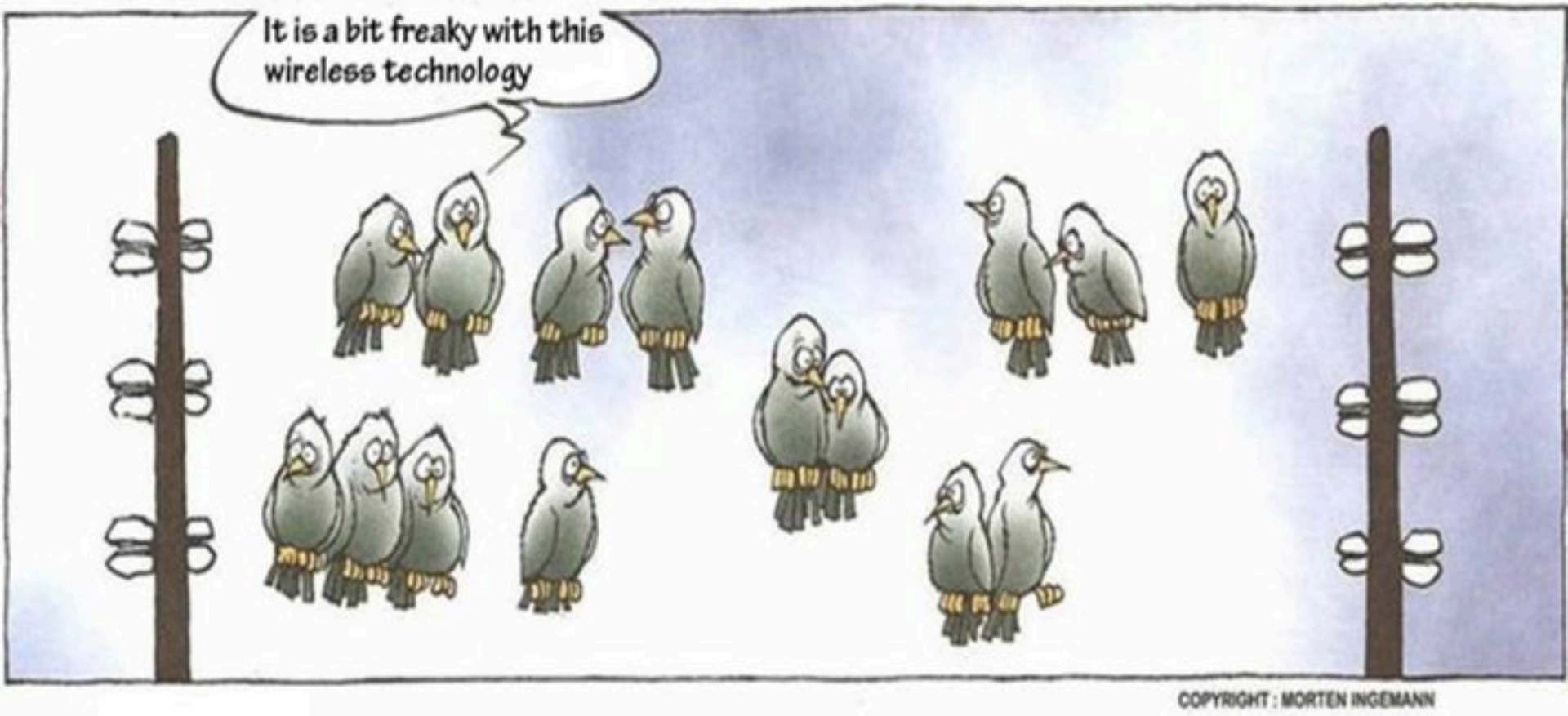
Per color: 10 – 40 – 100 Gbit/s

BW * Distance ~ $2*10^{17}$ bm/s

New: Hollow Fiber!

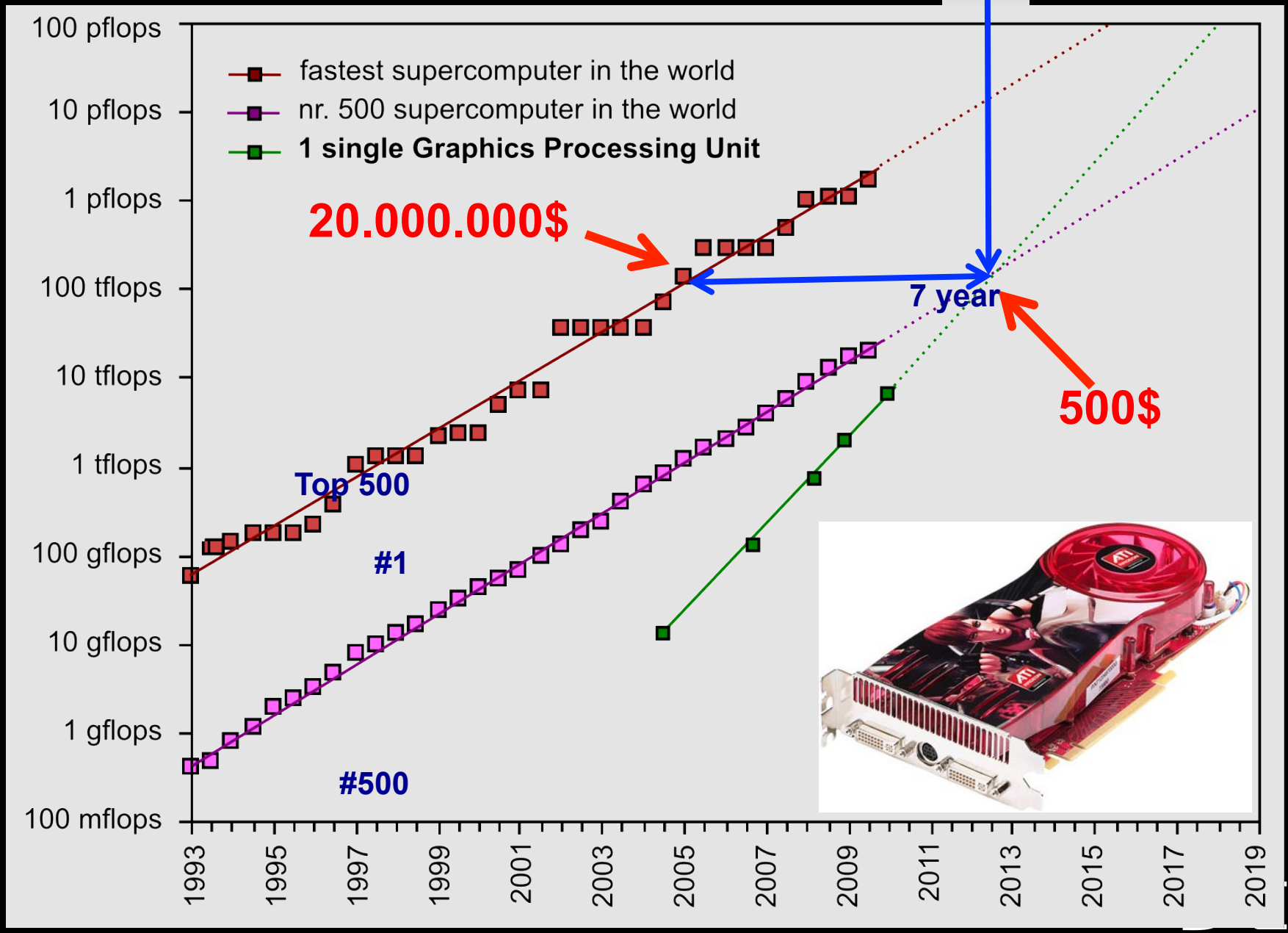
➔ less RTT!

Wireless Networks



protocol LAN due to the easy comparison and convenience in the **digital home**. While consumer PC products has just started to migrate to a much higher bandwidth of 802.11n wireless LAN now working on next-generation standard definition is already in progress.

GPU cards are distruptive!

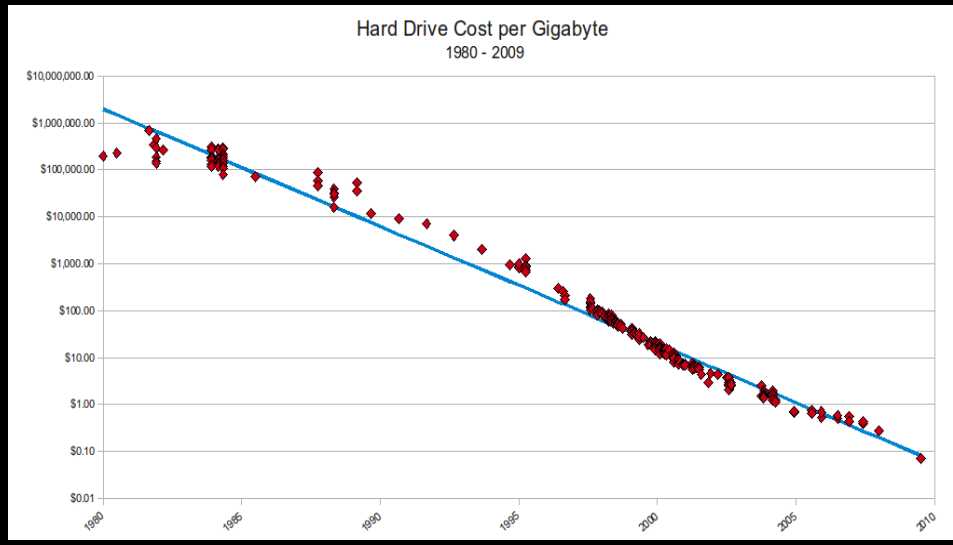


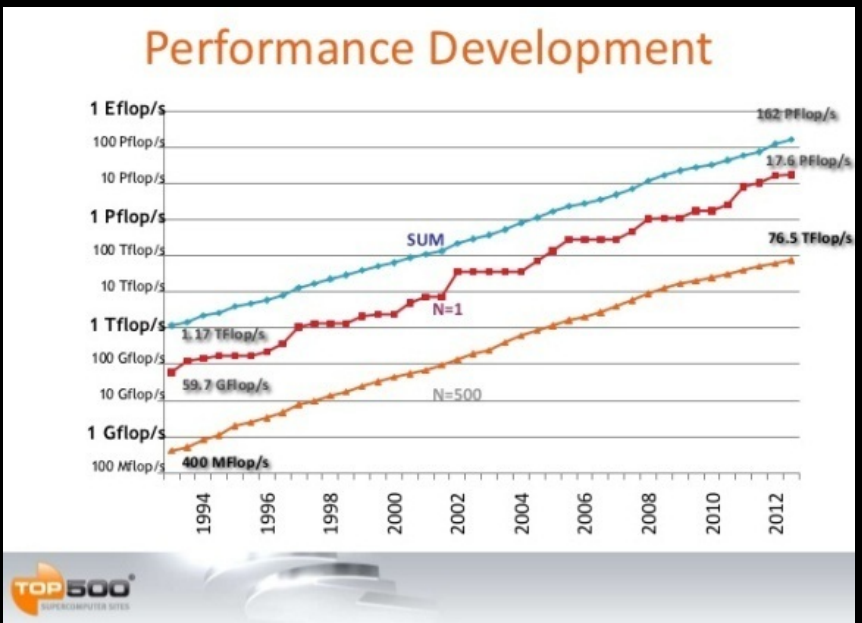
Reliable and Safe!

This omnipresence of IT makes us not only strong but also vulnerable.

- A virus, a hacker, or a system failure can instantly send digital shockwaves around the world.

The hardware and software that allow all our systems to operate is becoming bigger and more complex all the time, and the capacity of networks and data storage is increasing by leaps and bounds.



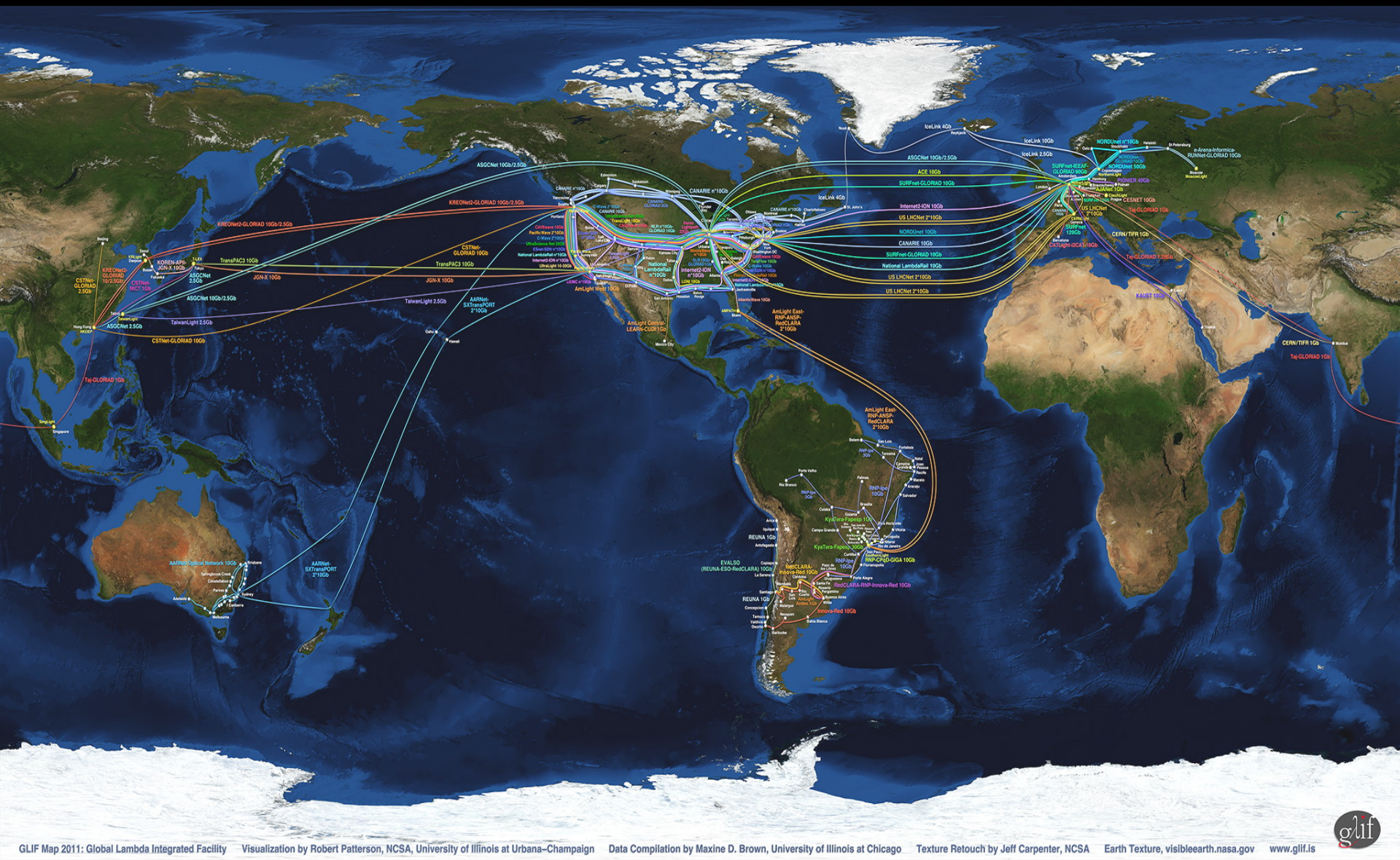


We will soon reach the limits of what is currently feasible and controllable.

https://www.knaw.nl/shared/resources/actueel/publicaties/pdf/20111029.pdf

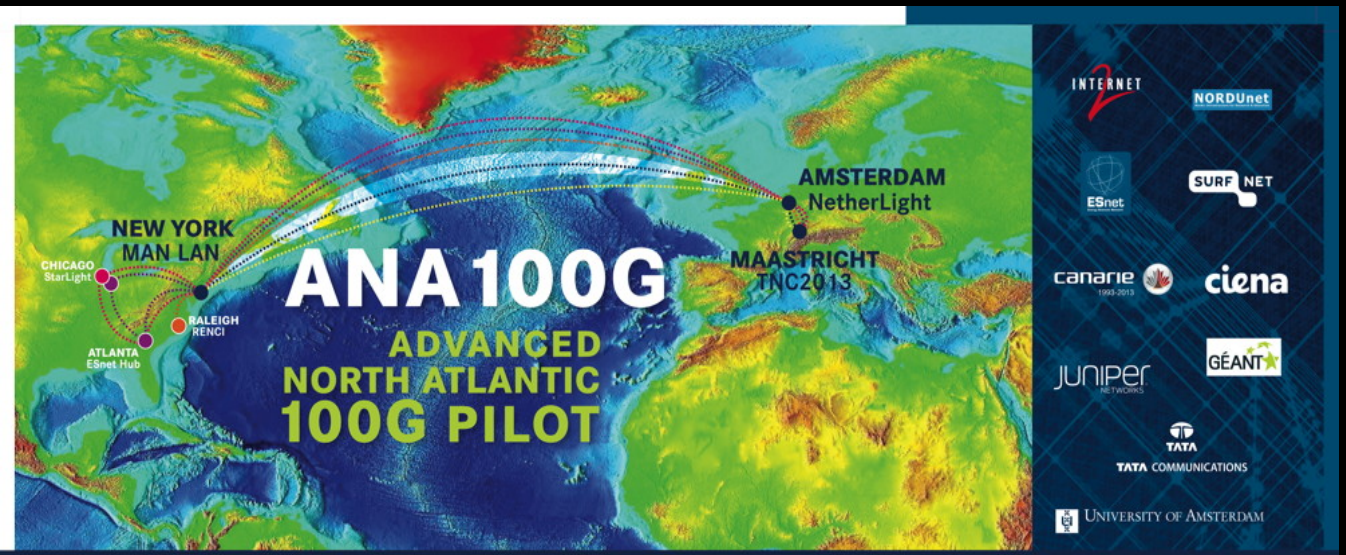
The GLIF – LightPaths around the World

F Dijkstra, J van der Ham, P Grosso, C de Laat, “A path finding implementation for multi-layer networks”, Future Generation Computer Systems 25 (2), 142-146.



ExoGeni @ OpenLab - UvA

Installed and up June 3th 2013



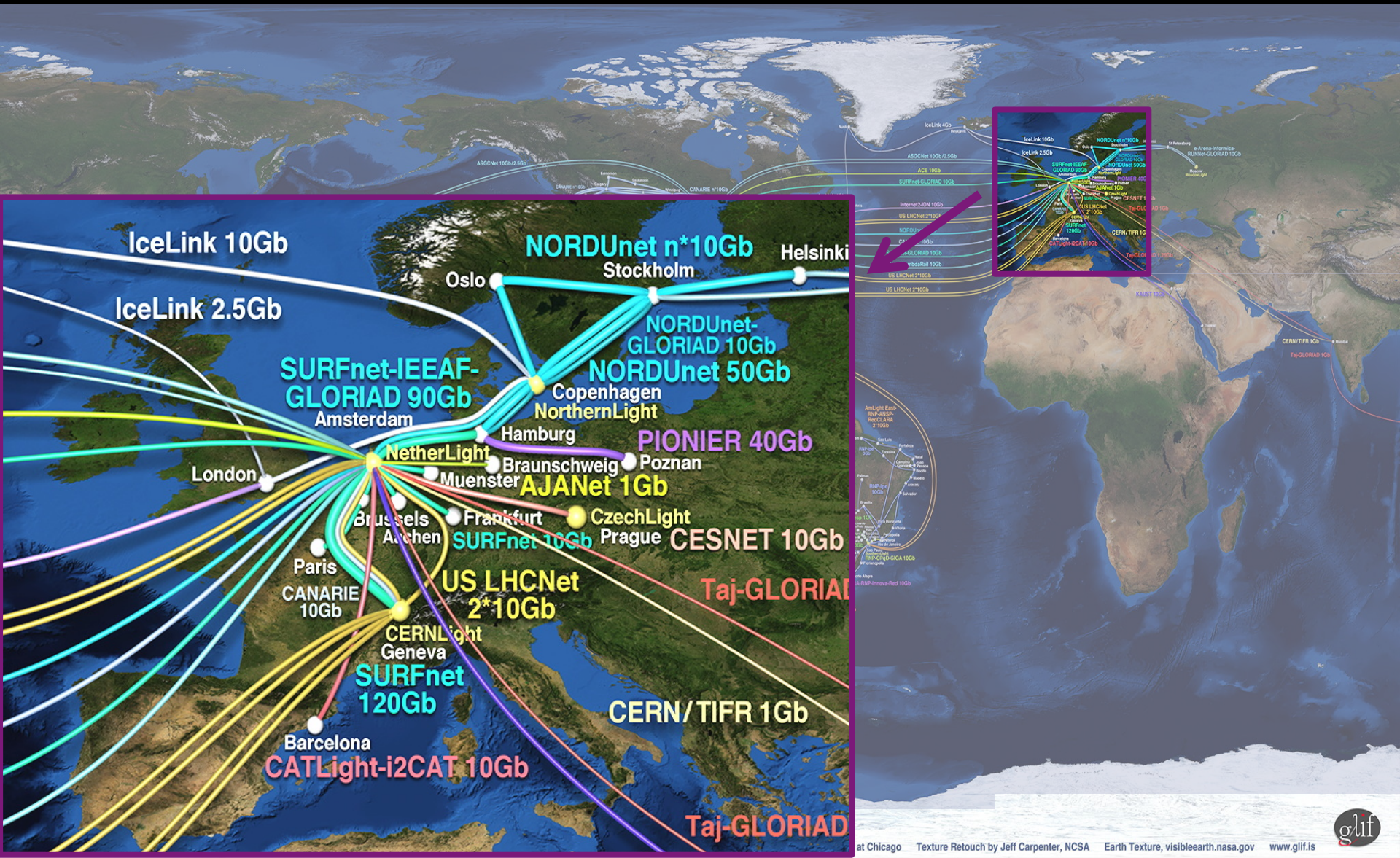
TNC2013 DEMOS JUNE, 2013

DEMO	TITLE	OWNER	AFFILIATION	E-MAIL	A-SIDE	Z-SIDE	PORTS(S) MAN LAN	PORTS(S) TNC2013	DETAILS
1	Big data transfers with multipathing, OpenFlow and MPTCP	Ronald van der Pol	SURFnet	ronald.vanderpol@surfnet.nl	TNC/MECC, Maastricht NL	Chicago, IL	Existing 100G link between internet2 and ESnet	2x40GE (Juniper)+ 2x 10GE (OME6500)	In this demonstration we show how multipathing, OpenFlow and Multipath TCP (MPTCP) can help in large file transfers between data centres (Maastricht and Chicago). An OpenFlow application provisions multiple paths between the servers and MPTCP will be used on the servers to simultaneously send traffic across all those paths. This demo uses 2x40G on the transatlantic 100G link. ESnet provides 2x40G between MAN LAN and StarLight, ACE and USLHCnet provide additional 10GEs.
2	Visualize 100G traffic	Inder Monga	ESnet	imonga@es.net					Using an SNMP feed from the Juniper switch at TNC2013,and/or Brocade ALZS node in MANLAN, this demo would visualize the total traffic on the link, of all demos aggregated. The network diagram will show the transatlantic topology and some of the demo topologies.
3	How many modern servers can fill a 100Gbps Transatlantic Circuit?	Inder Monga	ESnet	imonga@es.net	Chicago, Ill	TNC showfloor	1x 100GE	8x 10GE	In this demonstration, we show that with the proper tuning and tool, only 2 hosts on each continent can generate almost 80Gbps of traffic. Each server has 4 100 NICS connected to a 40G virtual circuit, and has iperf3 running to generate traffic. ESnet's new "iperf3" throughput measurement tool, still in 'beta', combines the best features from other tools such as iperf, nuttcp, and netperf. See: https://my.es.net/demos/tnc2013/
4	First European ExoGENI at Work	Jeroen van der Ham	UvA	vdham@uva.nl	RENCI, NC	UvA, Amsterdam, NL	1x 10GE	1x 10GE	The ExoGENI racks at RENCI and UvA will be interconnected over a 10G pipe and be on continuously, showing GENI connectivity between Amsterdam and the rest of the GENI nodes in the USA.
5	Up and down North Atlantic @ 100G	Michael Enrico	DANTE	michael.enrico@dante.net	TNC showfloor	TNC showfloor	1x 100GE	1x 100GE	The DANTE 100GE test set will be placed at the TNC2013 showfloor and connected to the Juniper at 100G. When this demo is running a loop @ MAN LAN's Brocade switch will ensure that the traffic sent to MAN LAN returns to the showfloor. On display is the throughput and RTT (to show the traffic traveled the Atlantic twice)

Connected via the new 100 Gb/s transatlantic To US-GENI

Amsterdam is a major hub in The GLIF

F Dijkstra, J van der Ham, P Grosso, C de Laat, “A path finding implementation for multi-layer networks”, Future Generation Computer Systems 25 (2), 142-146.



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.

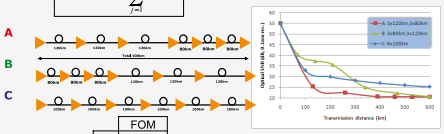
In this demonstration we will investigate the performance of a 40Gb/s PM-QPSK alien wavelength installed on a 10Gb/s DWDM infrastructure.

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

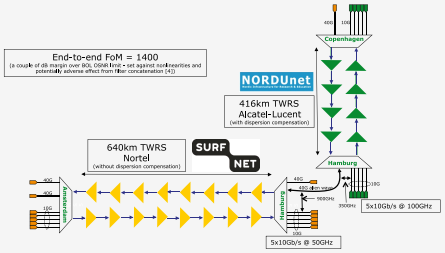


	FOM
A	5504
B	5504
C	1897

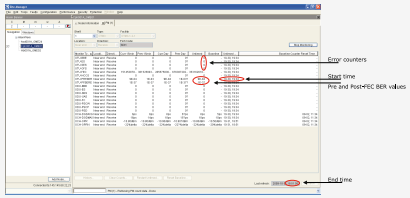
Easy-to-use formula that accurately quantifies transmission system performance

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 ISTY 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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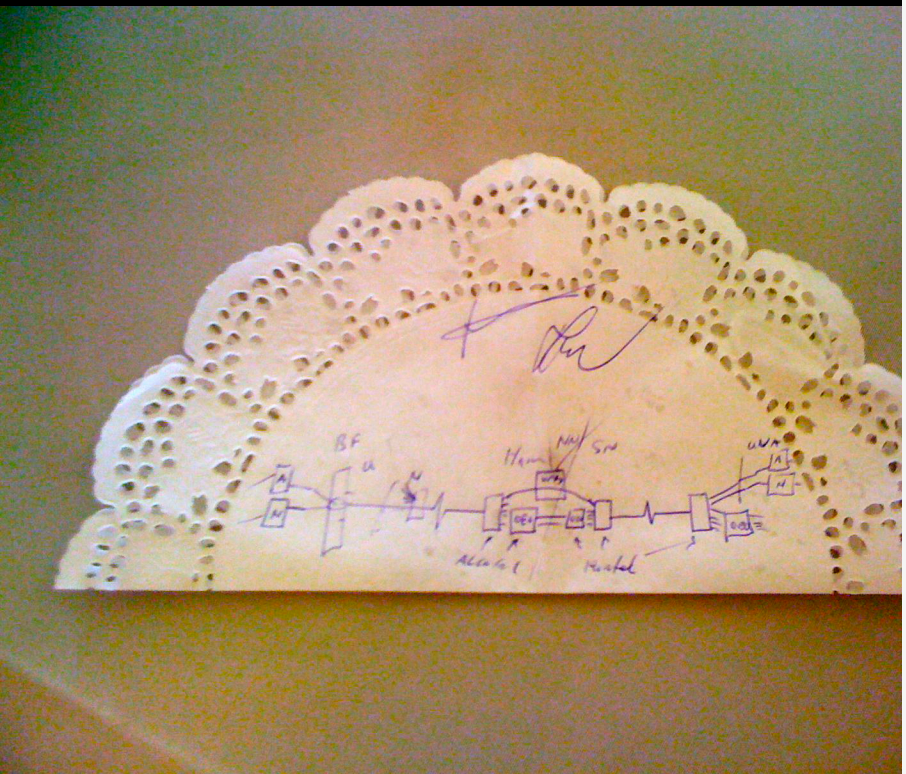

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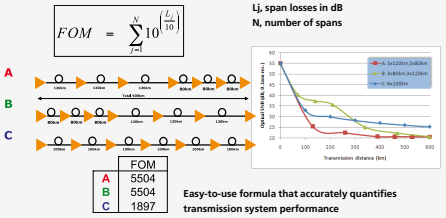

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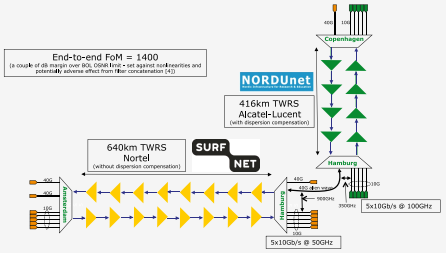

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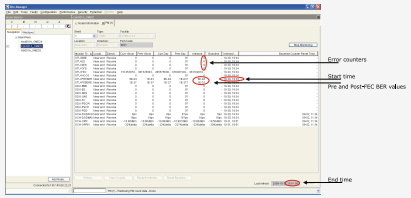

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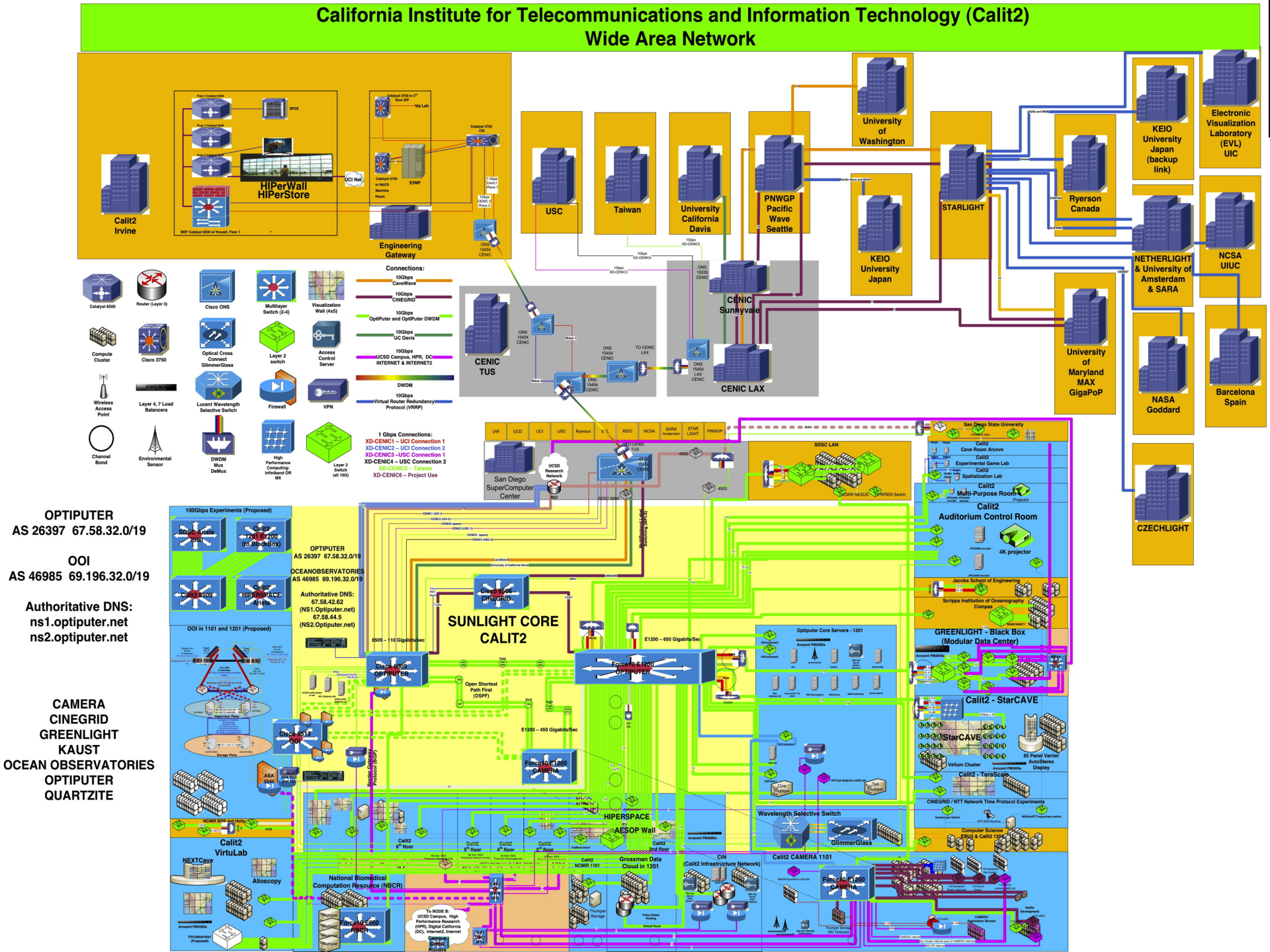
California Institute for Telecommunications and Information Technology (Calit2)
Wide Area Network



INDL

An effort started in 2010 (in parallel with our involvement in the FP7 projects Geysers and NOVI).

The goal was to capture the concept of virtualization in computing infrastructures and to describe the storage and computing capabilities of the resources.

A key feature is the decoupling of virtualization, connectivity and functionalities.

It is built upon the NML ontology.

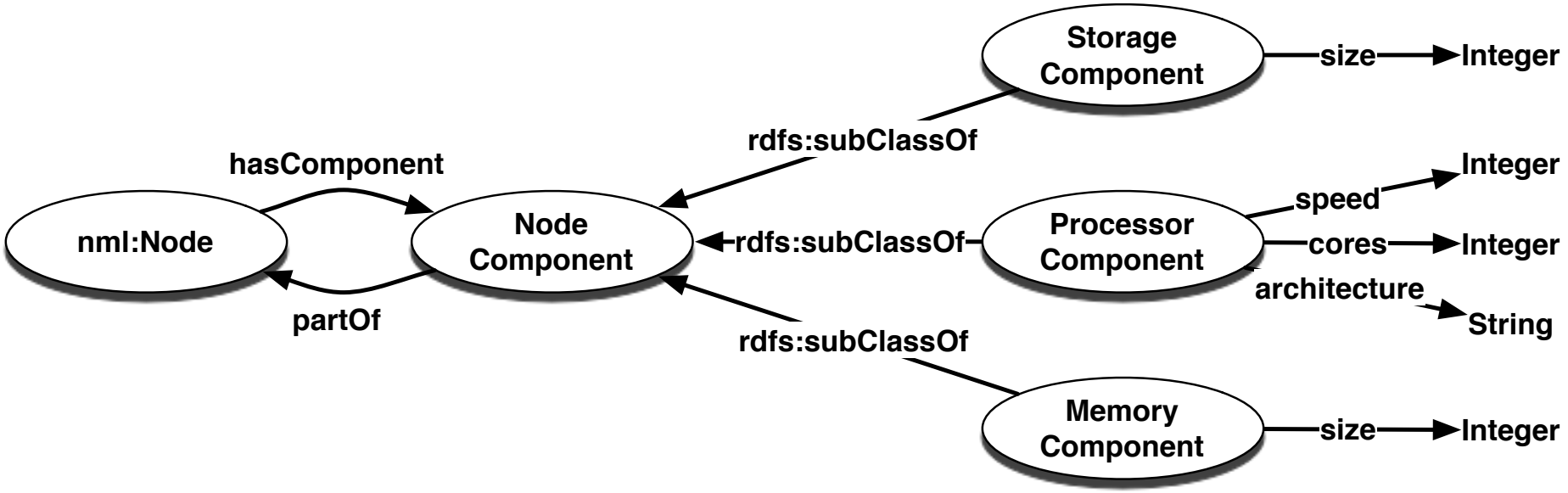
It uses the nml:node concept as basic entity to describe resources in computing infrastructures.

It can be used as:

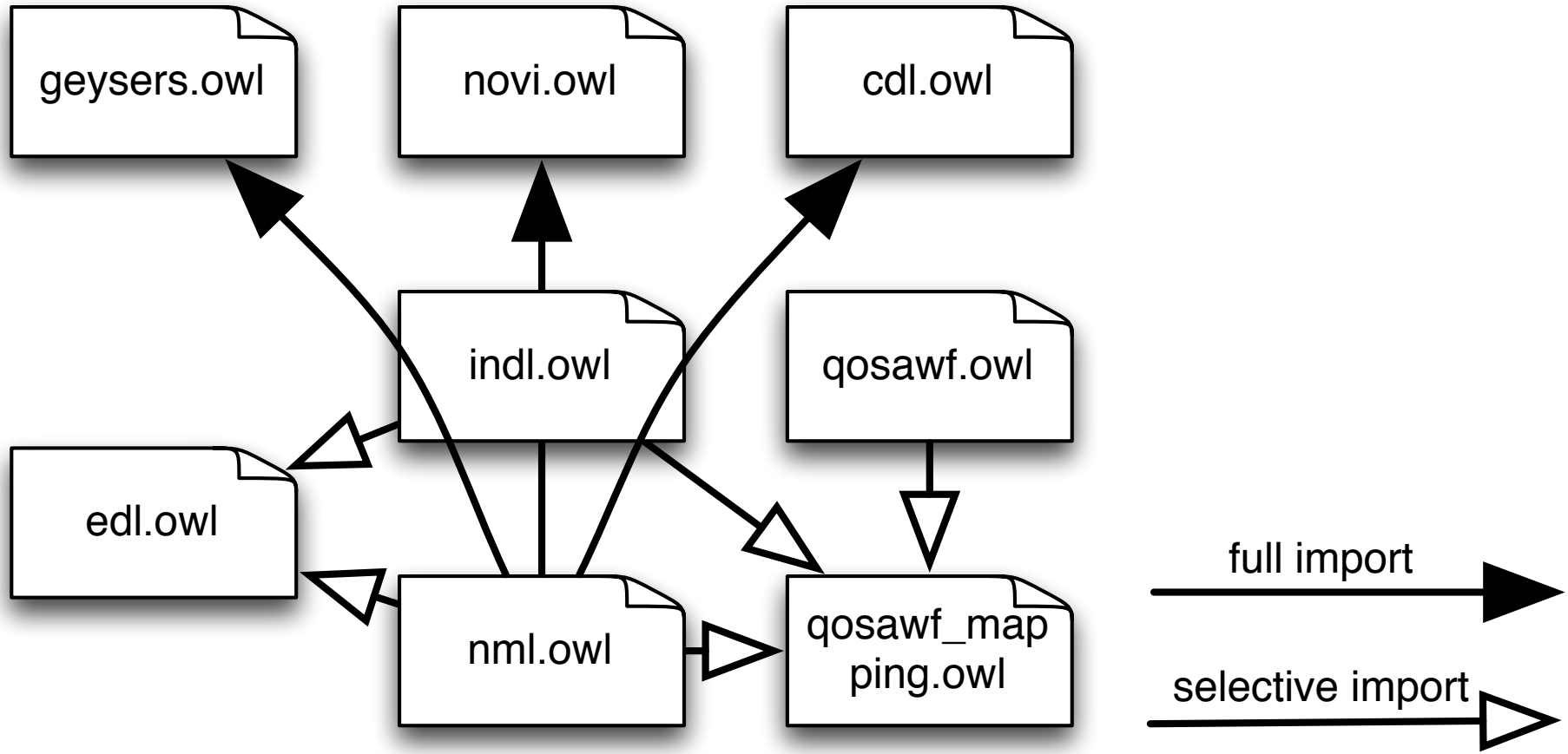
- a stand-alone model (i.e. without any network descriptions),
- in combination with NML by importing the NML ontology into the INDL definition.

M.Ghijsen, J. van der Ham, P. Grosso, C.Dumitru, H.Zhu, Z.Zhao and C.de Laat
Semantic-Web Approach for Modeling Computing Infrastructures
In: Elsevier Journal of Computers and Electrical Engineering - 2013

Node components



Our connecting models



NML and NSI

NML - Network Markup Language and NSI – Network Service Interface

within the OGF.

- See: "Network Markup Language Base Schema version 1"

The Network Markup Language purpose is to create a functional description of multi-layer and multi-domain networks.

It can be used for aggregated or abstracted topologies.

Under development: the Network Service Interface Topology Extensions (Draft OGF Standard)

COMMIT/

OMN
Open Multinet

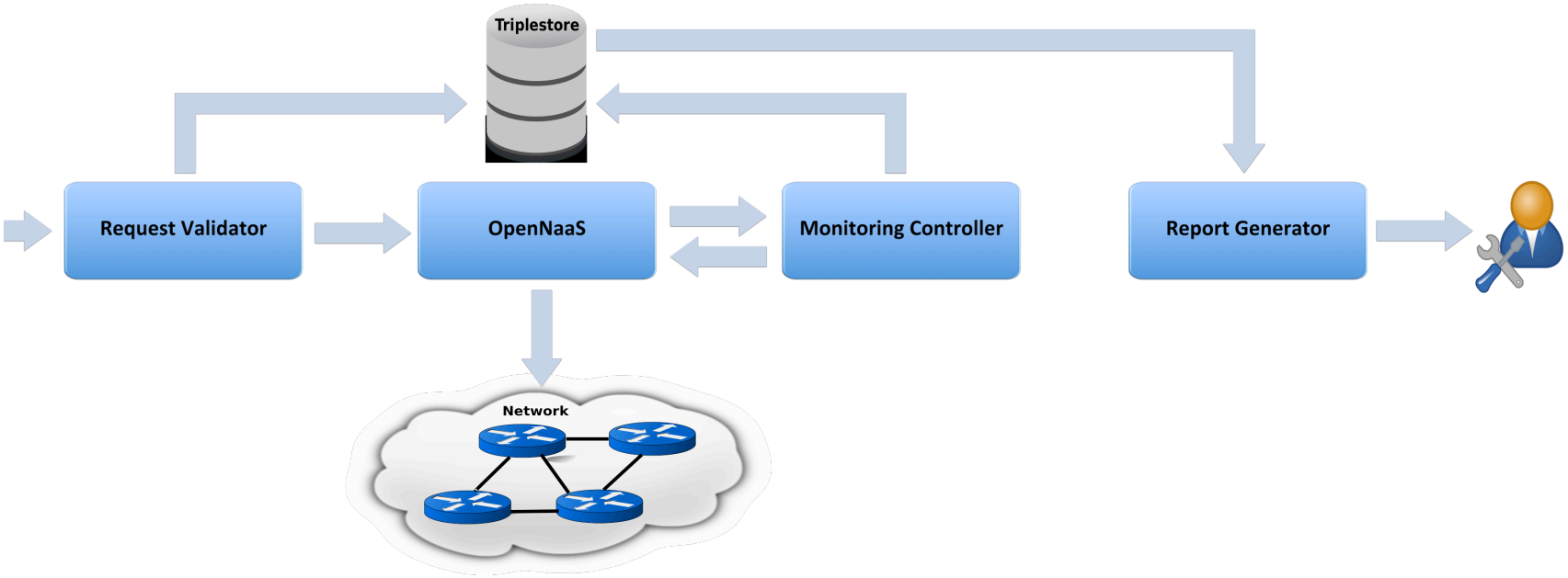
Instead of the one internet, we will have a multitude of parallel networks, customized by you to include anything and anyone you wish.

Support semantically GENI and FIRE.
The testbeds for network experimentation

A.Willner, C.Papagianni, M.Giatili, M.Morsey, P.Grosso, Y. Al-Hazmi and I.Baldin.
The Open-Multinet Upper Ontology - Towards the Semantic-based Management of Federated Infrastructures
In: TRIDENTCOM 2015

NaaS

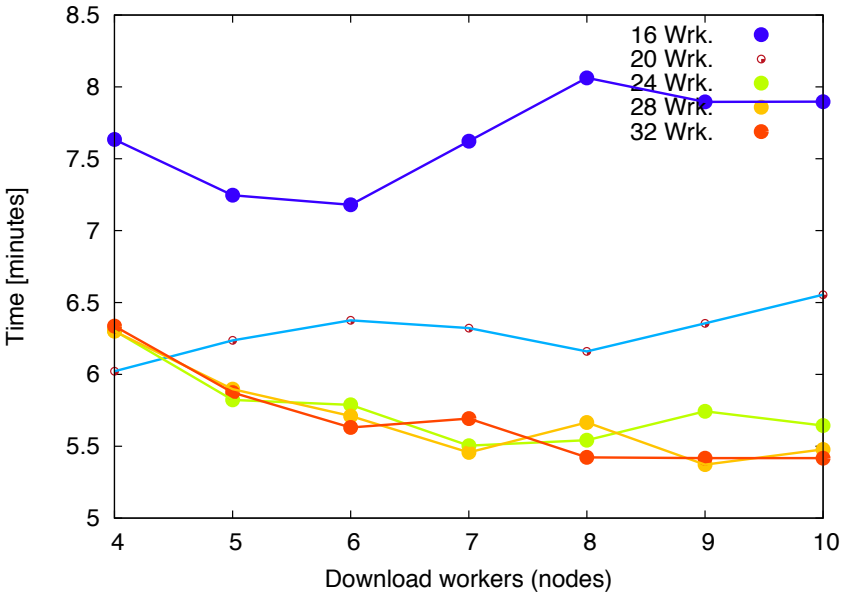
- The emerging NaaS software systems require powerful and rich vocabularies, such as the ones that can be provided by Semantic Web ontologies.
- OWL ontologies have several advantages as models for NaaS; i.e. they are easy to extend, they allow for automatic validation of both requests and provisioned services, and they enhance network resource discovery.

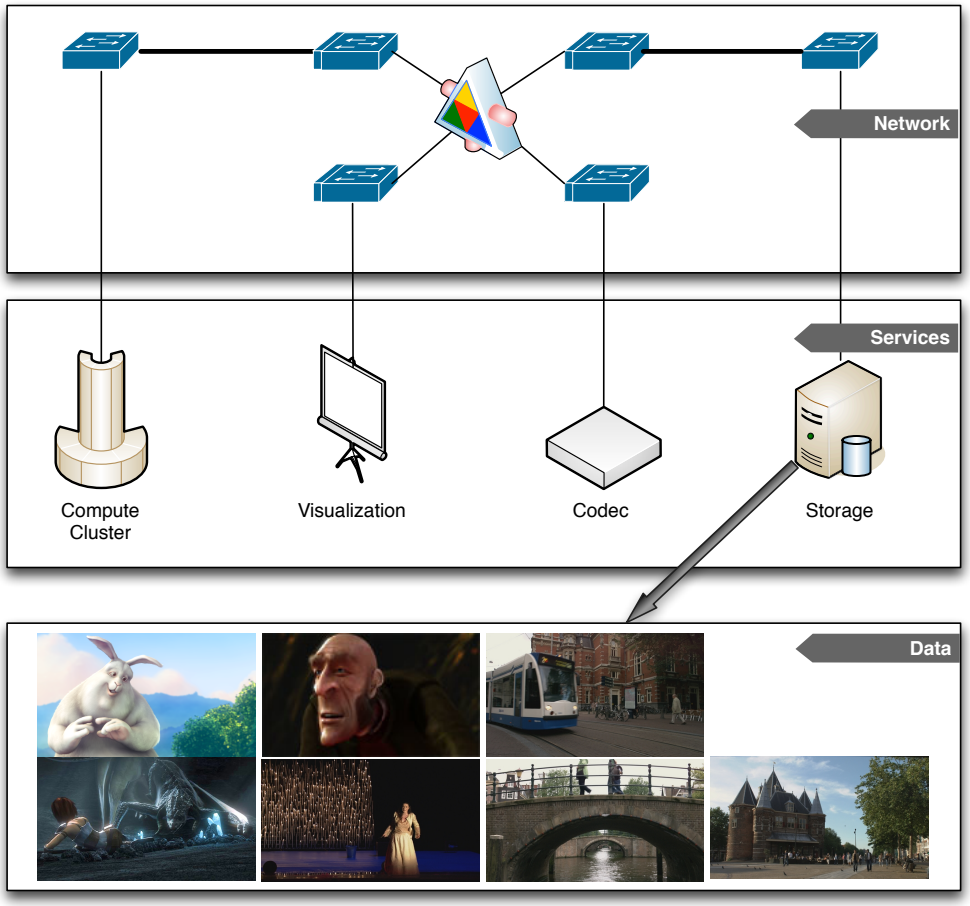


M. Morsey, H.Zhu, I.Canyameres and P. Grosso
SemNaaS: Add Semantic Dimension to Network as Service (In ESWC2015))

HyperFlow

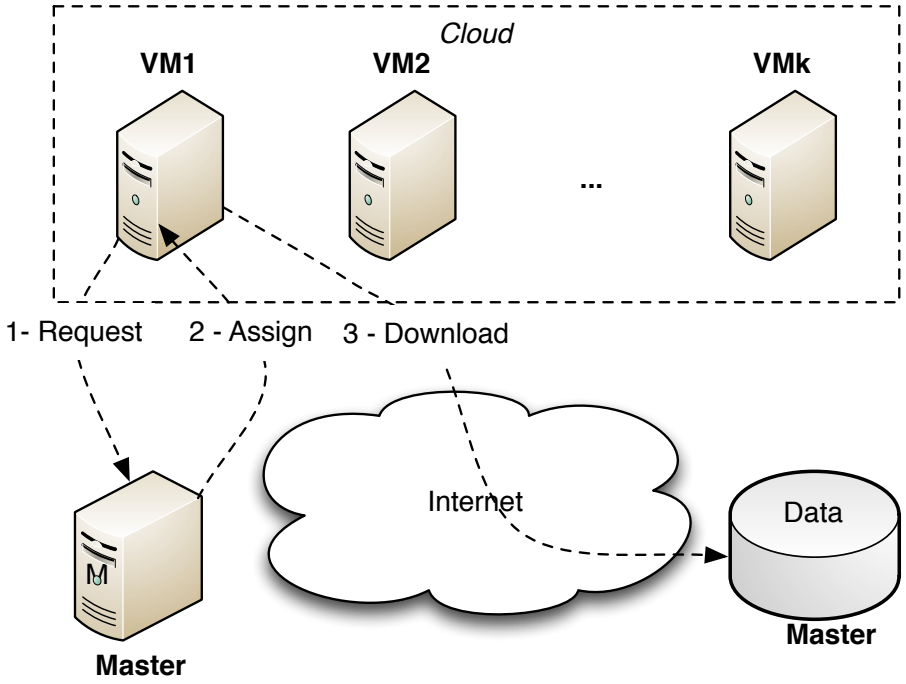
Encoding times improve as the end nodes are connected via dynamic lightpaths

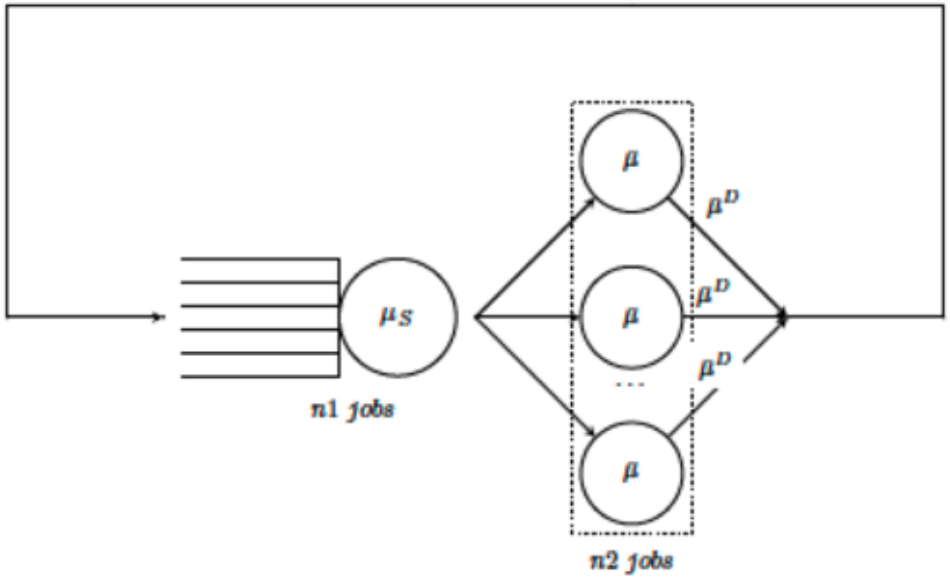




C. Dumitru, Z. Zhao, P. Grosso and C. de Laat
HybridFlow: Towards Intelligent Video Delivery and Processing Over Hybrid Infrastructures
(In CTS 2013))

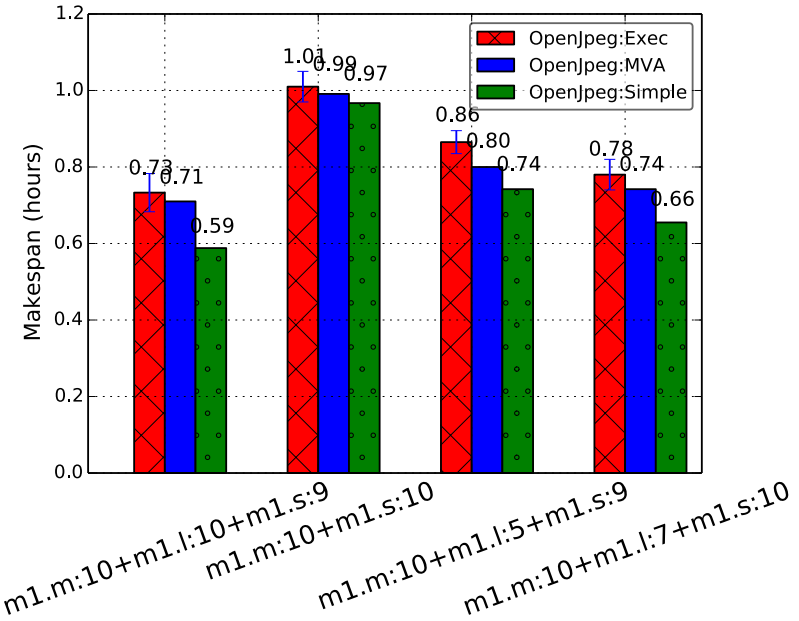
A queuing model approach

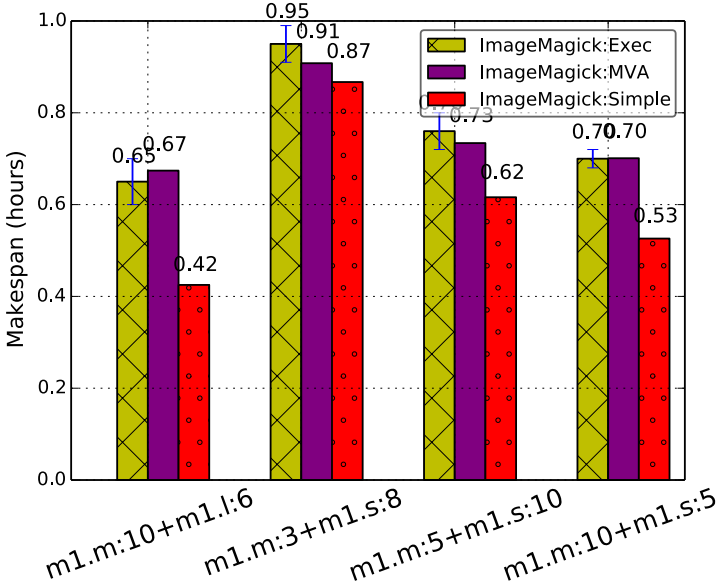


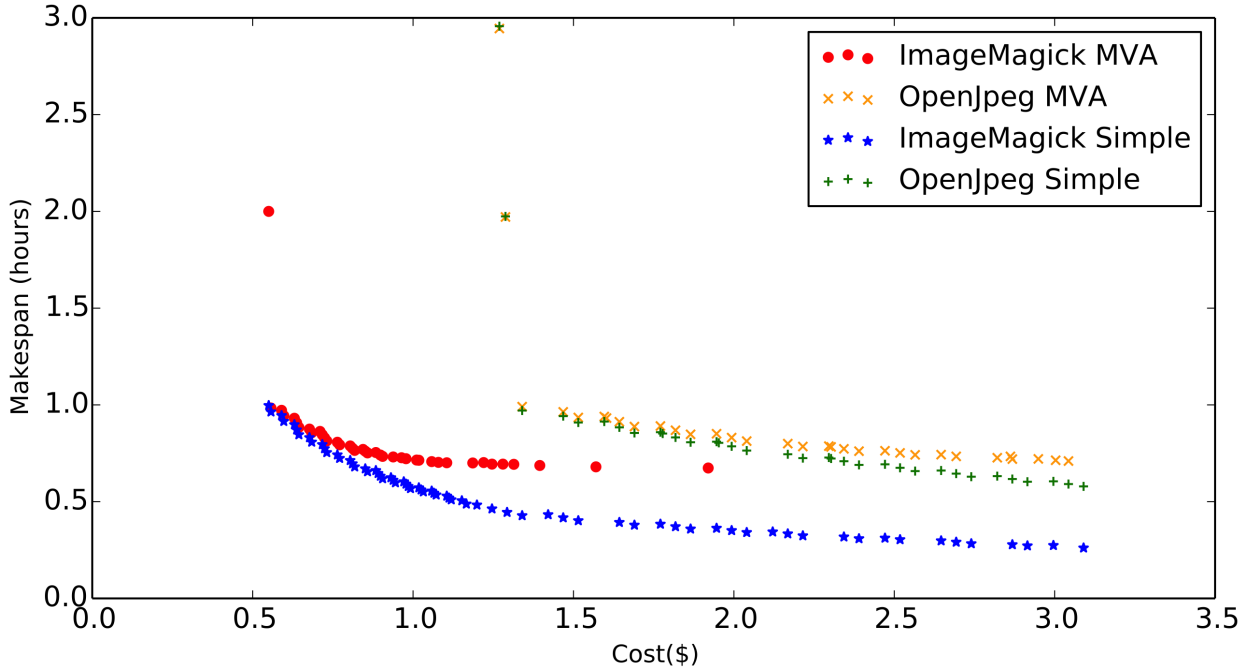


COMMIT/

Pareto fronts







C. Dumitru, AM/Oprescu, M.Zivkovic, R.van der Mei, P.Grosso, C.de Laat, "*A Queueing Theory Approach to Pareto Optimal Bags-of-Tasks Scheduling on Clouds*", In: Euro-Par 2014

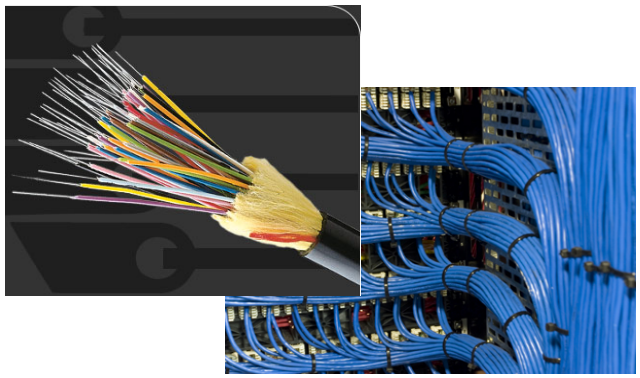
Mission

Can we create smart and safe data processing infrastructures that can be tailored to diverse application needs?

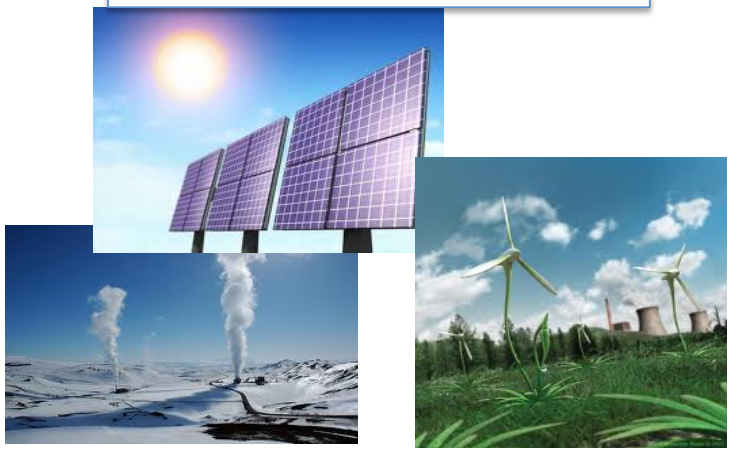
- *Capacity*
  - *Bandwidth on demand, QoS, architectures, photonics, performance*
- *Capability*
  - *Programmability, virtualization, complexity, semantics, workflows*
- *Security*
  - *Anonymity, integrity of data in distributed data processing*
- ***Sustainability***
  - ***Greening infrastructure, awareness***
- *Resilience*
  - *Systems under attack, failures, disasters*

Green scheduling

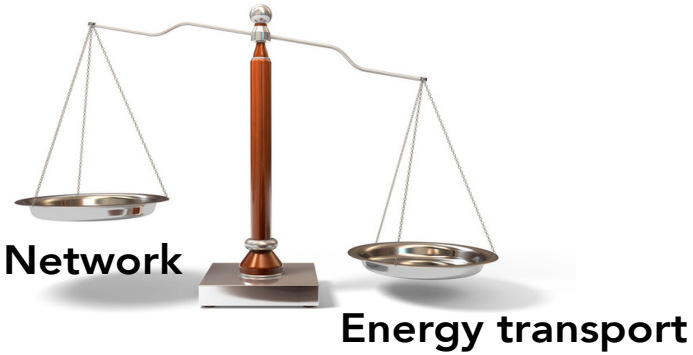
Network infrastructures



Green energy sources

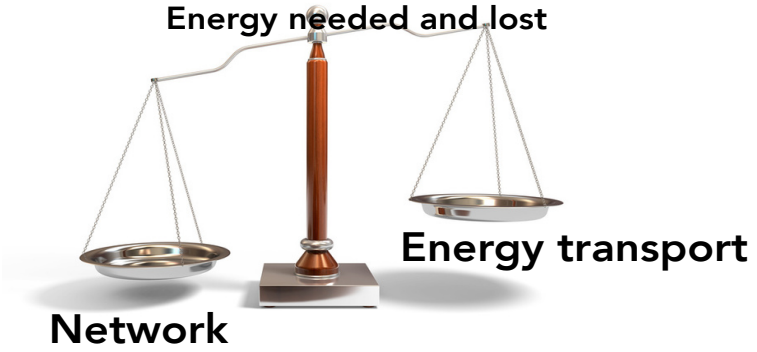


CO_2 footprint;
Energy needed and lost



Bits to energy

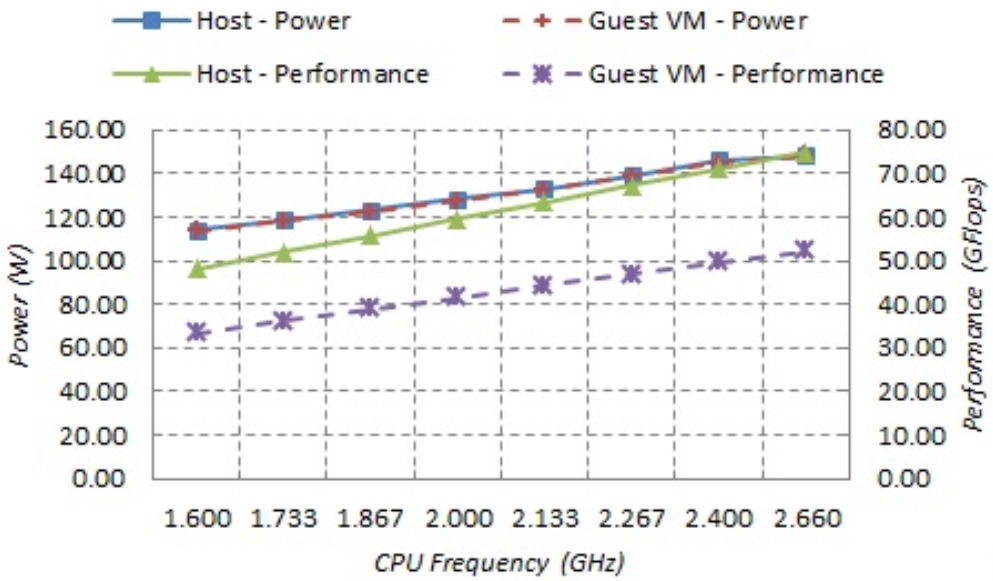
CO_2 footprint;
Energy needed and lost



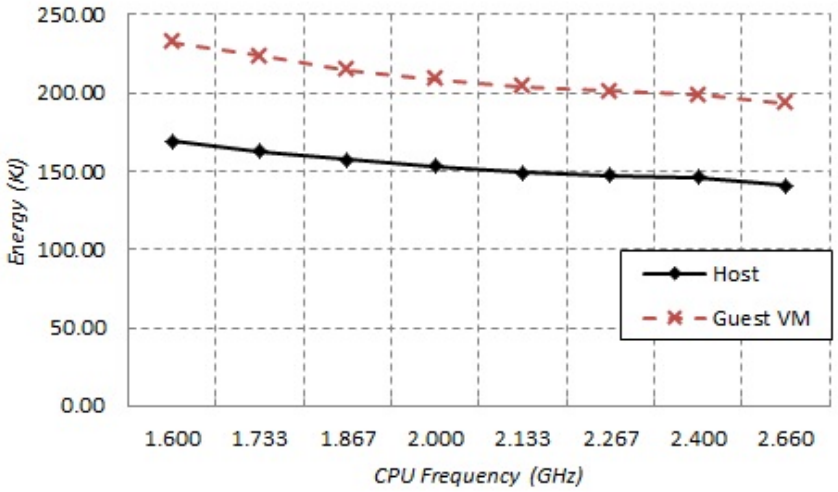
Energy to bits

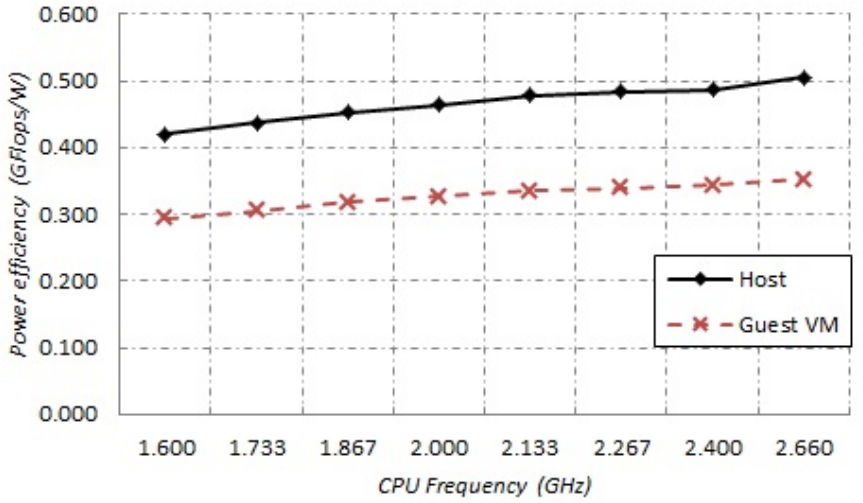
COMMIT/

Energy saving in clouds



Quantifying the energy performance of VMs is the first step toward energy-aware job scheduling.

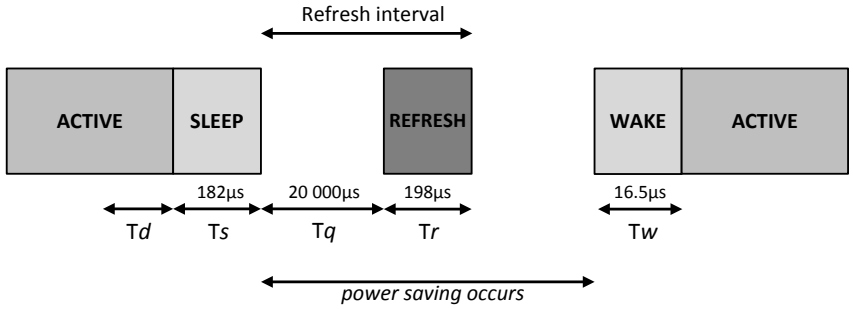


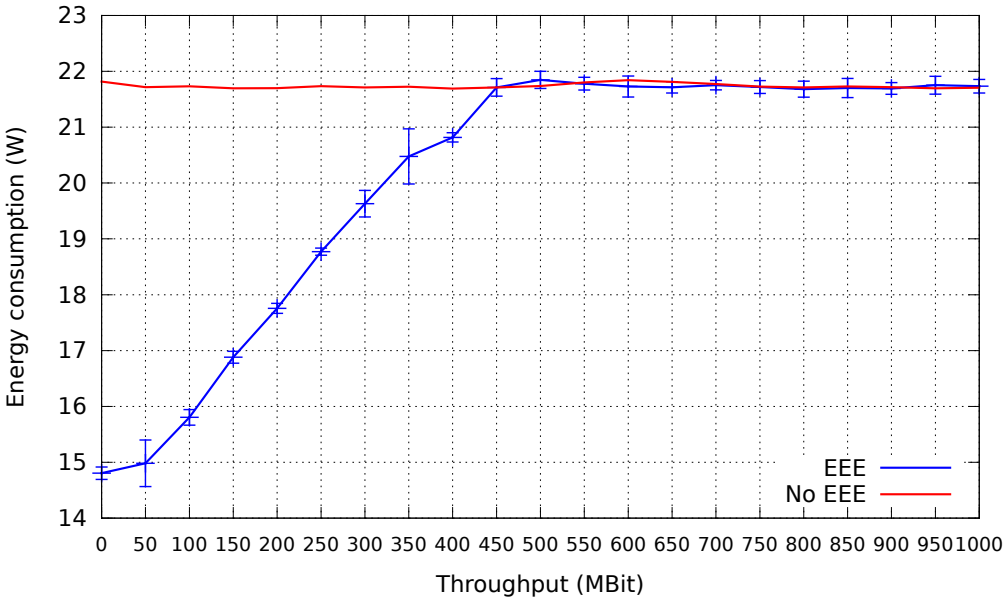


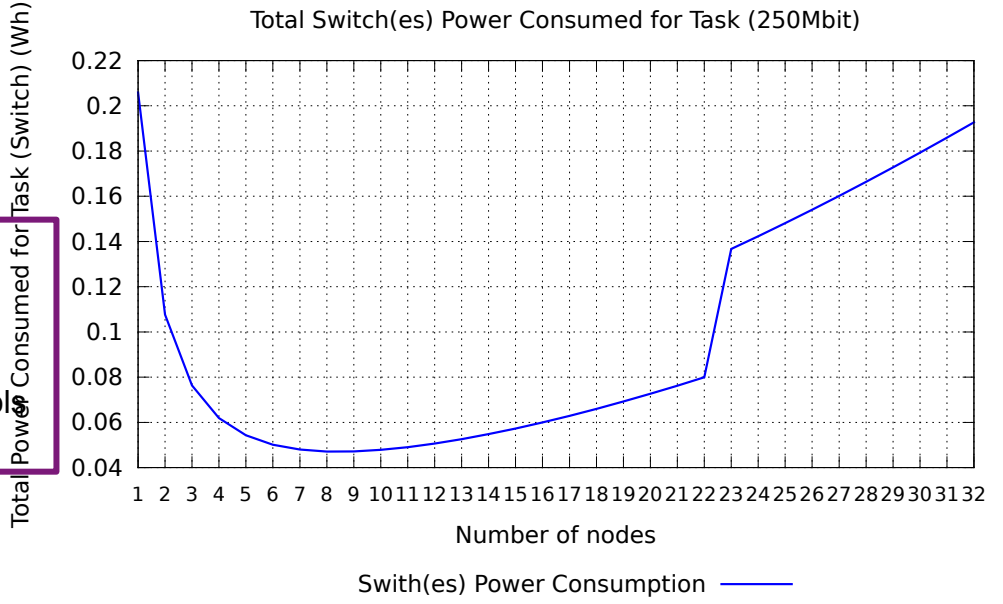
Q. Chen, P. Grosso, K. van der Veldt, C. de Laat, R. Hofman and H.Bal.
Profiling energy consumption of VMs for green cloud computing
In: International Conference on Cloud and Green Computing (CGC2011), Sydney December 2011

Energy Efficient Ethernet (802.3az)

Power savings techniques in hardware can be leveraged in architecturing communication patterns in data centra





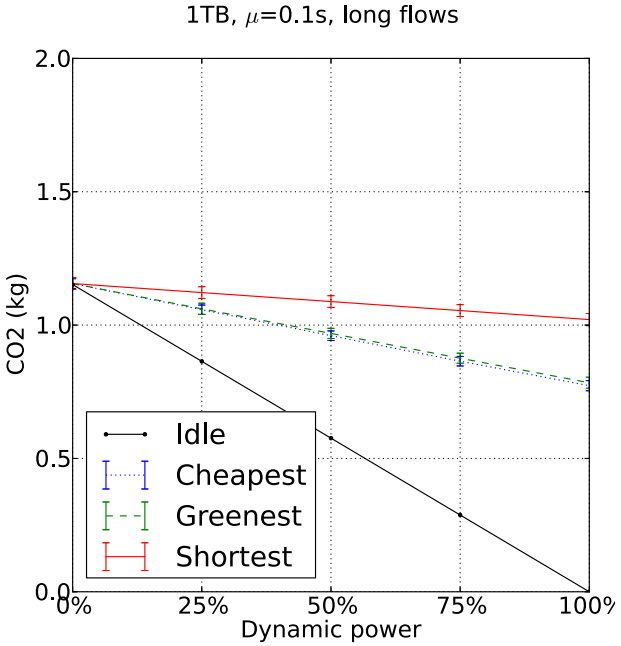


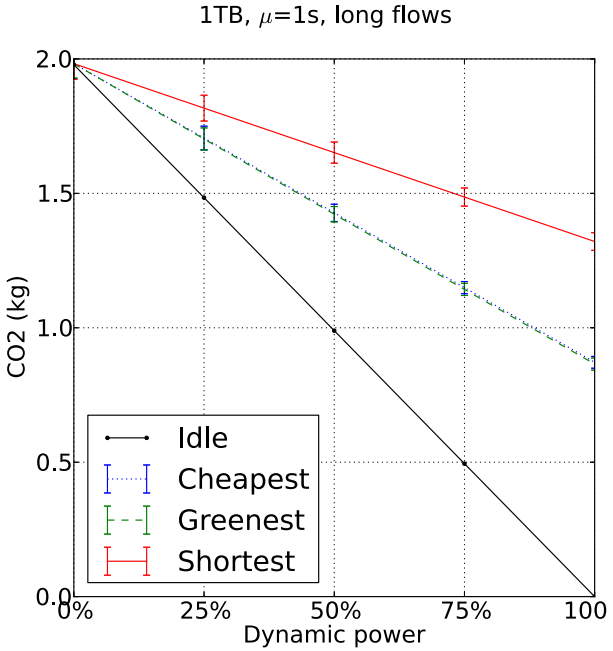
H. Zhu, K.van der Veldt, Z.Zhao, P.Grosso, D.Pavlov, J.Soeurt, X.Liao, C.de Laat
A semantic enhanced Power Budget Calculator for distributed computing using IEEE 802.3az
In: Cluster Computing - The Journal of Networks, Software Tools and Applications - Volume 18 Issue 1 pp 61-67

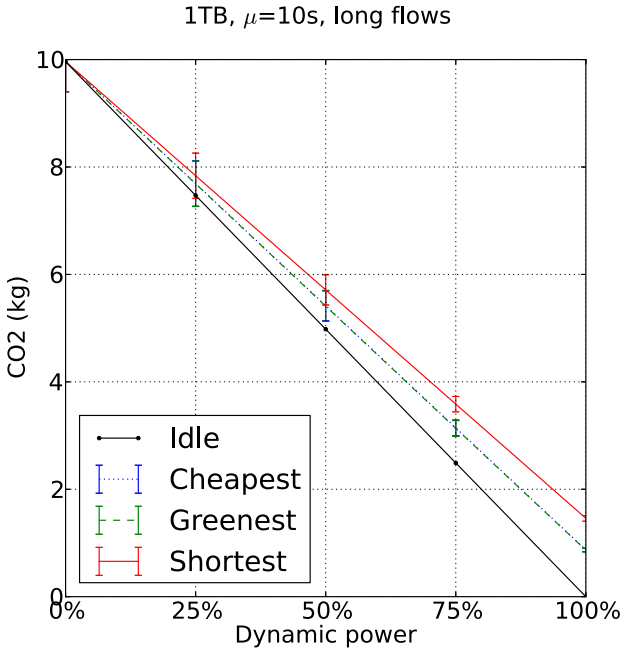
COMMIT/

Networks and CO2

- Take a network (Esnet, working on using SURFnet data)
- Define the traffic model running on it
- Use the energy monitoring information and energy costs data
- Compare path selection strategies : shortest, cheapest and greenest

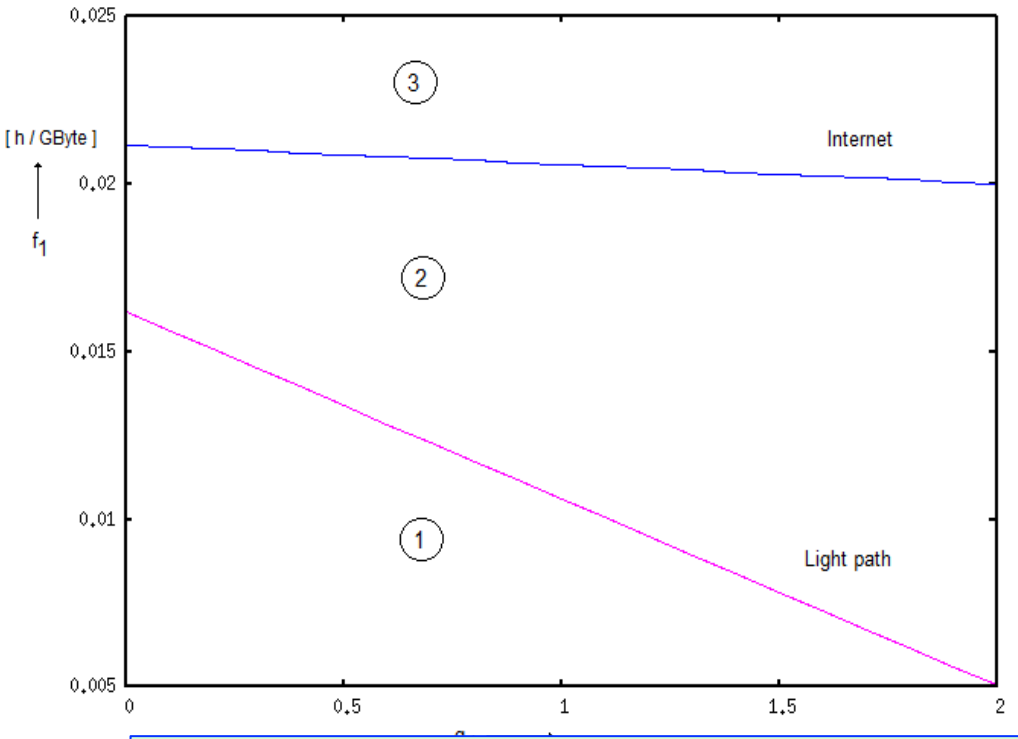






K. van der Veldt, I.Monga, J.Dugan, C.de Laat and P.Grosso *Carbon-aware path provisioning for NRENs* In: 2014 International Green Computing Conference (IGCC), 3-5 November 2014, Dallas TX USA

Decision boundaries



In region 1 the task should be performed locally, independently of the type of transport network.

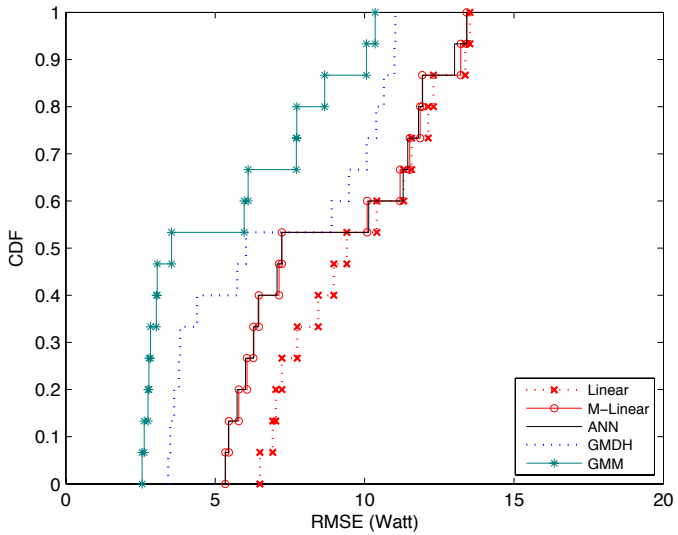
In region 2 the task can be performed remotely provided that the connection is a light path.

In region 3 the task should be done remotely for both types of transport networks.

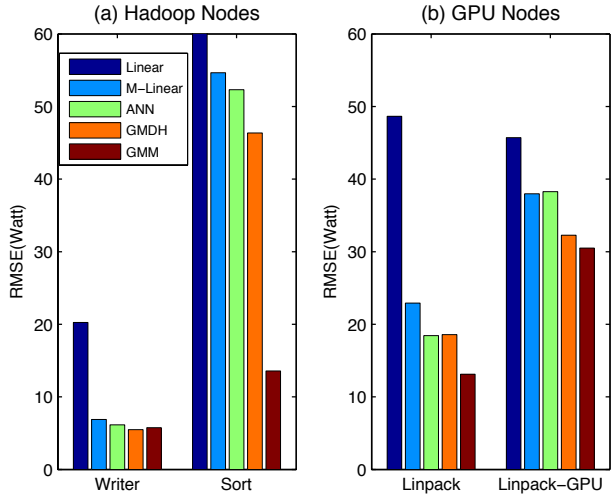
Given different network paths we can identify decision boundaries as function of the task complexity.

M.Makkes, A.Taal, A.Osseyran and P.Grosso
A decision framework for placement of applications in clouds that minimizes their carbon footprint
In: Journal of Cloud Computing: Advances, Systems and Applications 2013, Vol.2

Power estimation models



	Linear	M-Linear	ANN	GMDH	GMM
Model-training time (sec)	2 - 4	4 - 7	25 - 73	17 - 60	132 - 227
Estimation time for single example (sec)	<10e-8	<10e-7	10e-7 - 10e-6	10e-4 - 10e-3	10e-4 - 10e-3
CPU load during training	<7%	<7%	<10%	<10%	<10%
Large training data demand	No	No	Yes	Yes	Yes

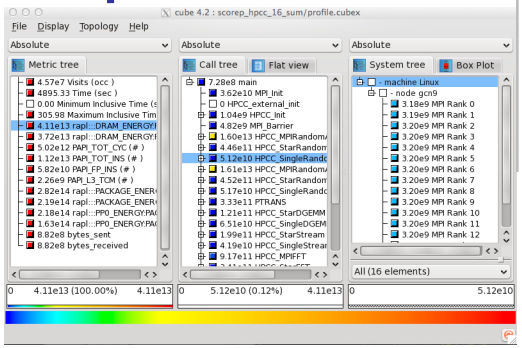


To find out precise and usable models for power estimation is necessary to evaluate their performance.

H. Zhu, P. Grosso, X. Liao & C.T.A.M. de Laat (2014). *Evaluation of approaches for power estimation in a computing cluster.* In: International Green Computing Conference. Dalls, TX: IEEE.

Green Software? User perspective

Which tools are more suitable depending on the type of user and the desired accuracy?



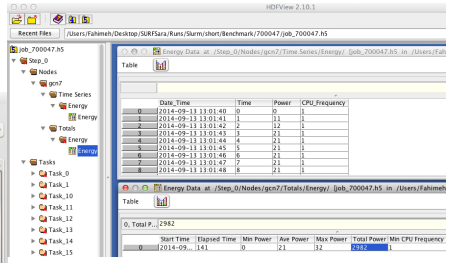


TABLE III. EVALUATION OF SLURM AND SCORE-P FOR DIFFERENT TYPES OF USERS WITH RESPECT TO THEIR REQUIREMENTS

SLURM						
Type of the User	***Expertise level***	***Documentation provided***	***Access to support team***	***Easiness to export data***	***Accuracy of provided information***	***Description***
generic user	✗	✓	✓	✗	✓	The user can benefit from the summary information provided by SLURM although the reported information is very coarse-grained.
software developer	✓	✓	✓	✓	✓	The user gets fine-grained information from time series collected from the RAPL sensors.
Score-P						
Type of the User	***Expertise level***	***Documentation provided***	***Access to support team***	***Easiness to export data***	***Accuracy of provided information***	***Description***
generic user	✗	✗	✓	✗	✗	Summary results are provided to the user. The summary information by this tool is more fine-grained than the summary information by SLURM as it shows the collected data of the RAPL sensors separately.
software developer	✓	✗	✓	✗	✗	The user can get energy related information for different parts of the application.

F. Alizadeh, T. Geenen, P. Lago and P. Grosso (2015). *"A user perspective on enery profiling tools in large scale computing environment"s.* In: SustainIT conference (Madrid, Apr. 2015)

ECO-Scheduling

Mission

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  - *Anonymity, integrity of data in distributed data processing*
- *Sustainability*
  - *Greening infrastructure, awareness*
- *Resilience*
  - *Systems under attack, failures, disasters*

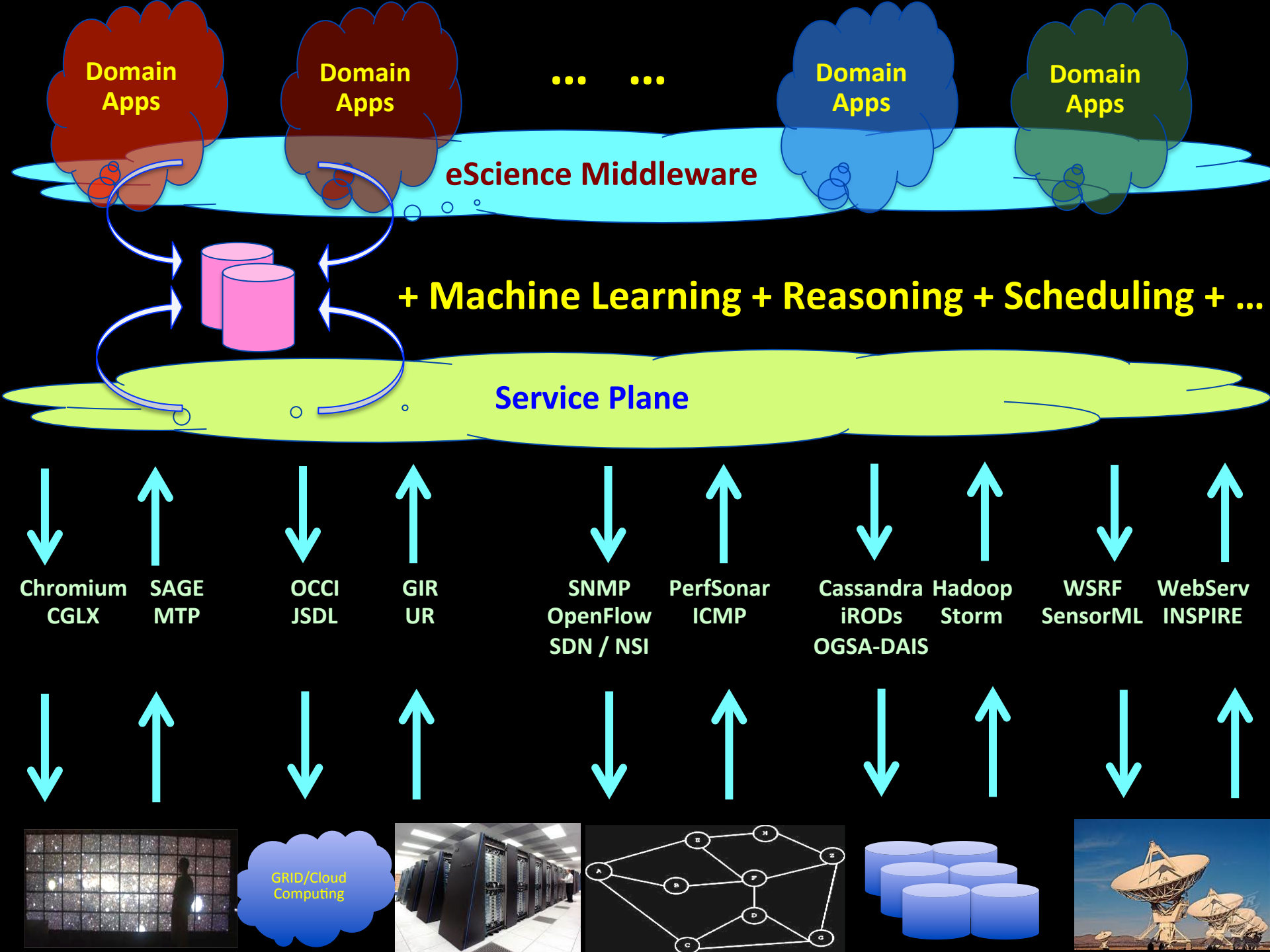
SMART

I want to

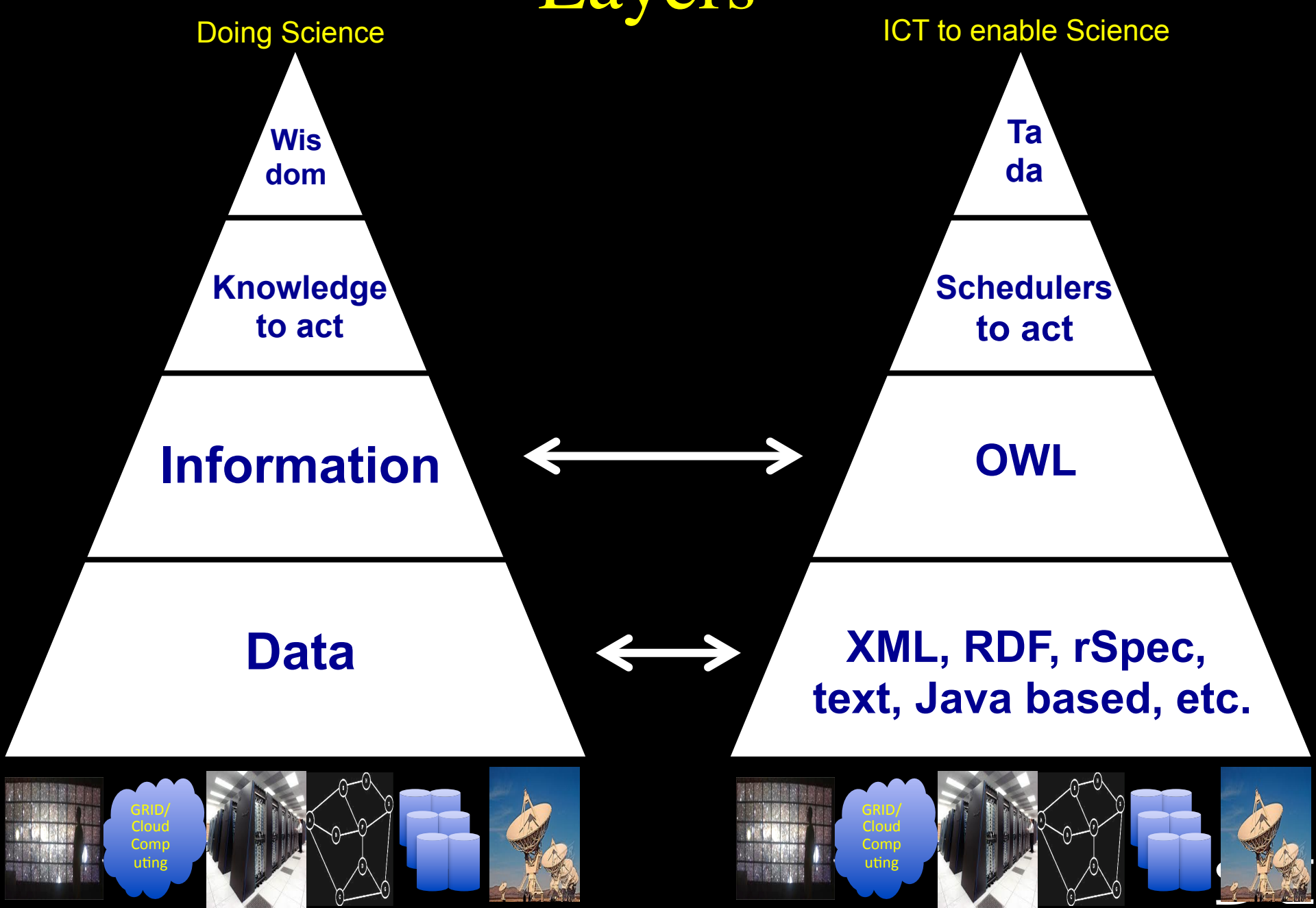
"Show Big Bug Bunny in 4K on my Tiled Display using green Infrastructure"

- Big Bugs Bunny can be on multiple servers on the Internet.
- Movie may need processing / recoding to get to 4K for Tiled Display.
- Needs deterministic Green infrastructure for Quality of Experience.
- Consumer / Scientist does not want to know the underlying details.

➔ His refrigerator also just works!


Domain Apps
Domain Apps
... ...
Domain Apps
Domain Apps
eScience Middleware
+ Machine Learning + Reasoning + Scheduling + …
Service Plane
Chromium CGLX
SAGE MTP
OCCI JSDL
GIR UR
SNMP OpenFlow SDN / NSI
PerfSonar ICMP
Cassandra iRODs OGSA-DAIS
Hadoop Storm
WSRF SensorML
WebServ INSPIRE
GRID/Cloud Computing

Layers


Doing Science
Wis dom
Knowledge to act
Information
Data
ICT to enable Science
Ta da
Schedulers to act
OWL
XML, RDF, rSpec, text, Java based, etc.
GRID/ Cloud Comp uting
GRID/ Cloud Comp uting

The Big Data Challenge

Doing Science

ICT to enable Science

Wis
dom

Knowledge

Data

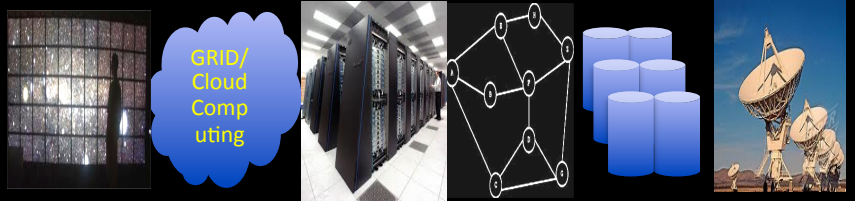
Ta
da

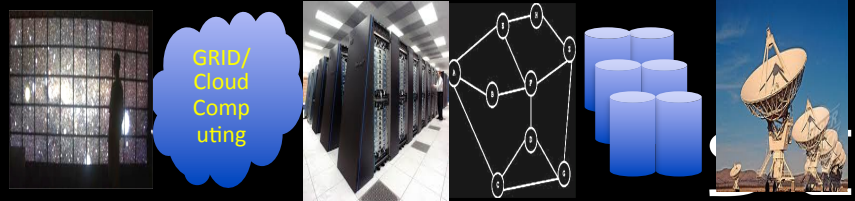
Schedulers

XML, RDF, rSpec,
text, Java based, etc.

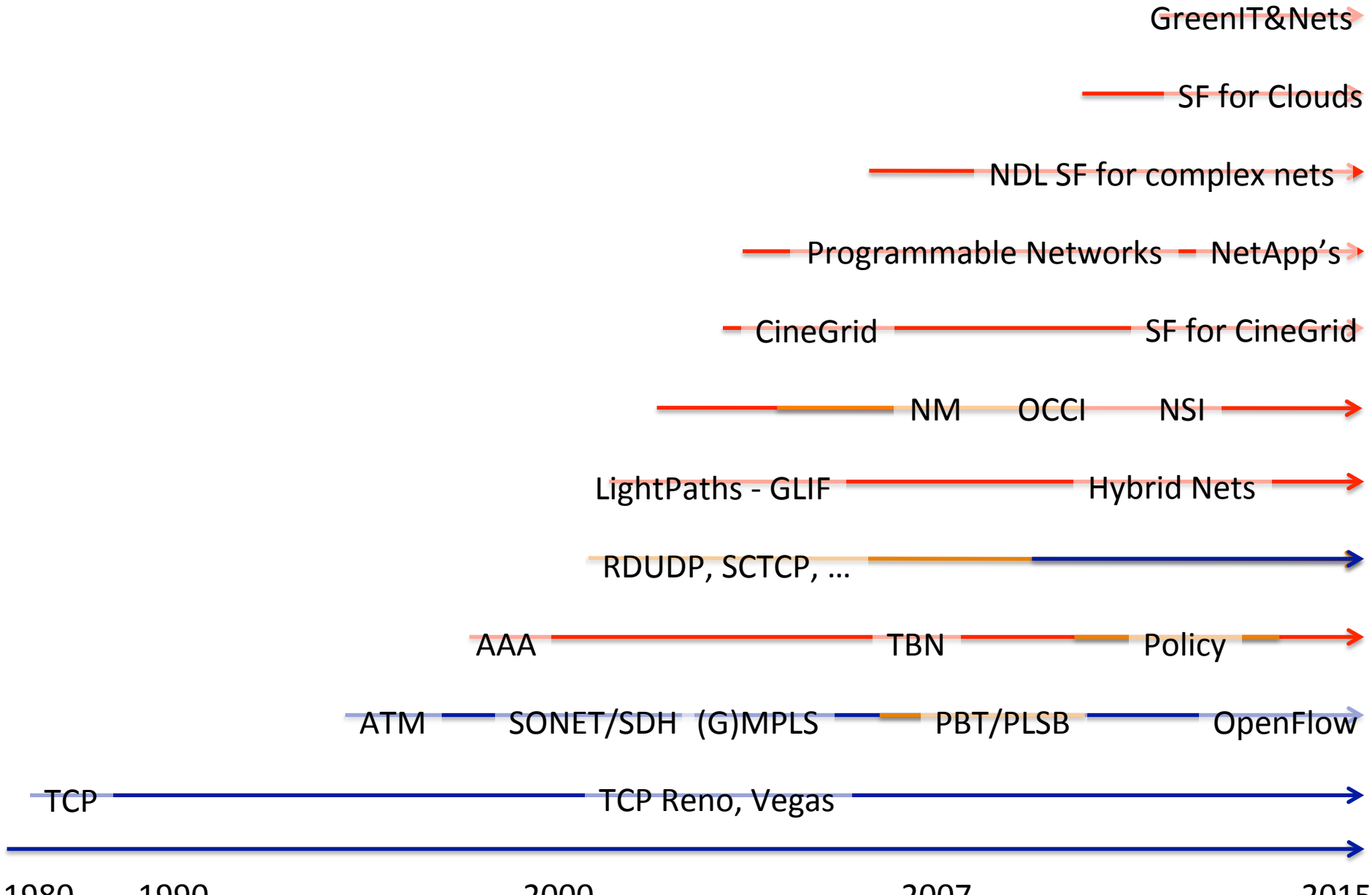
MAGIC DATA CARPET

curation – description – security – policy – integrity - storage

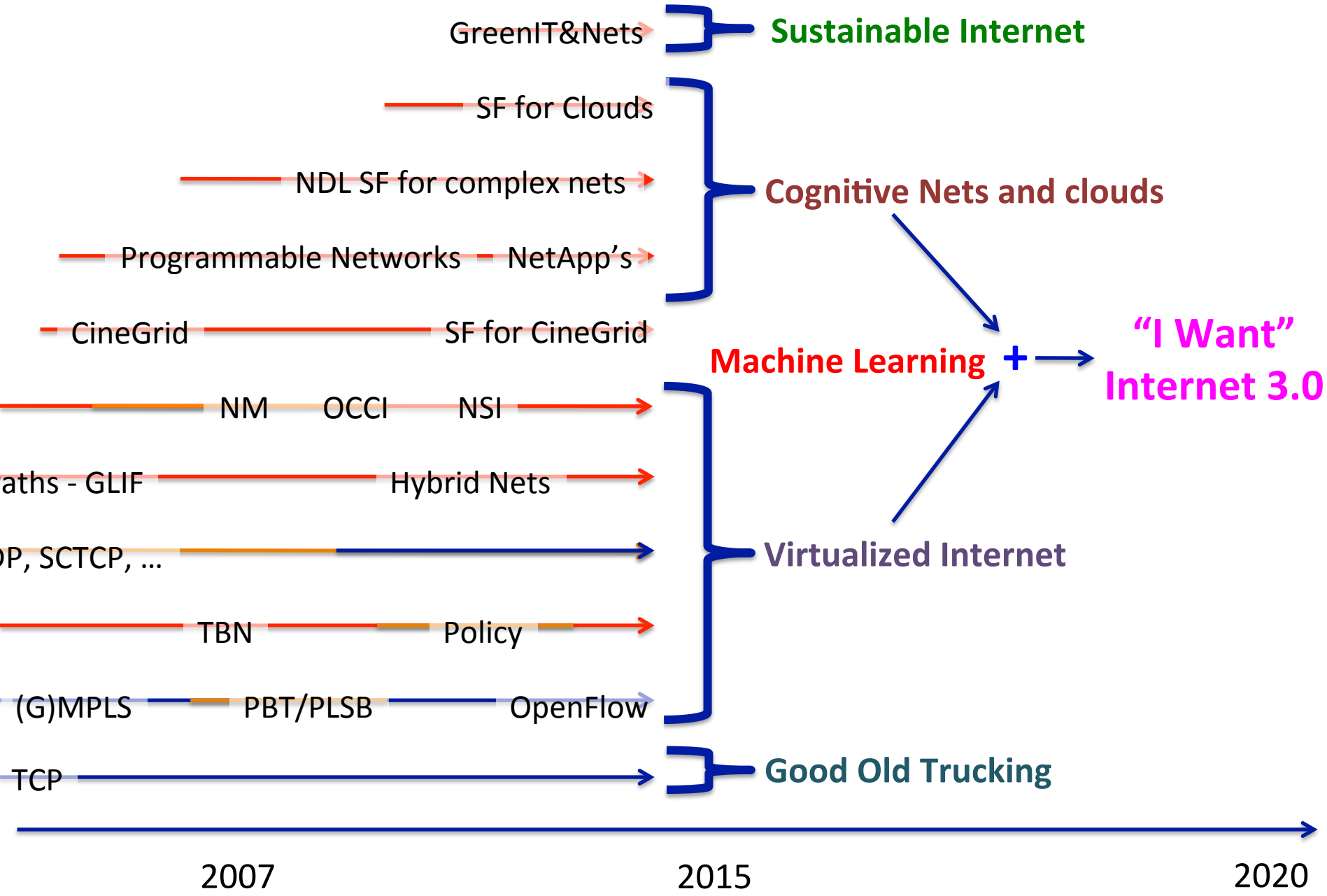




TimeLine


GreenIT&Nets
SF for Clouds
NDL SF for complex nets
Programmable Networks
NetApp's
CineGrid
SF for CineGrid
NM
OCCI
NSI
LightPaths - GLIF
Hybrid Nets
RDUDP, SCTCP, …
AAA
TBN
Policy
ATM
SONET/SDH
(G)MPLS
PBT/PLSB
OpenFlow
TCP
TCP Reno, Vegas
1980
1990
2000
2007
2015

TimeLine


GreenIT&Nets
Sustainable Internet
SF for Clouds
NDL SF for complex nets
Programmable Networks
NetApp's
Cognitive Nets and clouds
CineGrid
SF for CineGrid
Machine Learning
+
"I Want"
Internet 3.0
NM
OCCI
NSI
aths - GLIF
Hybrid Nets
OP, SCTCP, …
Virtualized Internet
TBN
Policy
(G)MPLS
PBT/PLSB
OpenFlow
TCP
Good Old Trucking
2007
2015
2020

TimeLine

- Sustainable Internet
- Cognitive Nets and clouds
- Machine Learning + → "I Want" Internet 3.0
- Virtualized Internet
- Good Old Trucking

I retire

2020

2040

The constant factor in our field is Change!

The 50 years it took Physicists to find one particle, the Higgs, we came from:

Assembler, Fortran, COBOL, VM, RSX11, Unix, c, Pascal, SmallTalk, DECnet, VMS, TCP/IP, c++, Internet, WWW, ATM, Semantic Web, Photonic networks, Google, Grid, Phyton, FaceBook, Twitter, Cloud, SDN, Data^3, App's

to:

DDOS attacks destroying Banks and BitCoins!

Conclusion:

Need for Safe, Smart, Resilient Sustainable Infrastructure.

Questions?

http://delaat.net

http://sne.science.uva.nl

http://www.os3.nl/

http://i4dw.nl/

http://dsrc.nl/

http://sne.science.uva.nl/openlab/

http://pire.opensciencedatacloud.org

http://staff.science.uva.nl/~delaat/pire/

https://rd-alliance.org

http://envri.eu

Data Science Research Center Amsterdam

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