Software defined networks

Our experience

Pau Minoves
Professional Services Manager

The i2CAT Foundation @ a glance

FUNDACIÓ I2CAT, INTERNET I INNOVACIÓ DIGITAL A CATALUNYA

i2CAT was created in 2003 as a center of research and innovation focusing its activities on the development of the future Internet, with the following main objectives:

- Foster technological development in Catalonia.
- Promote advanced research into networks and broadband applications.
- Develop Internet technologies in Catalonia, particularly in terms of applications, services and network technologies.
- Set up platforms for collaboration between the private sector and university research bodies.
- 6 areas: Distributed Applications and Networks Area (DANA), Ubiquitous Technologies, eHealth & Dependence, Audiovisual & eLearning, Industrial and Technology Transfer

since **2003**
filling the gap
between **industry**
and **university**

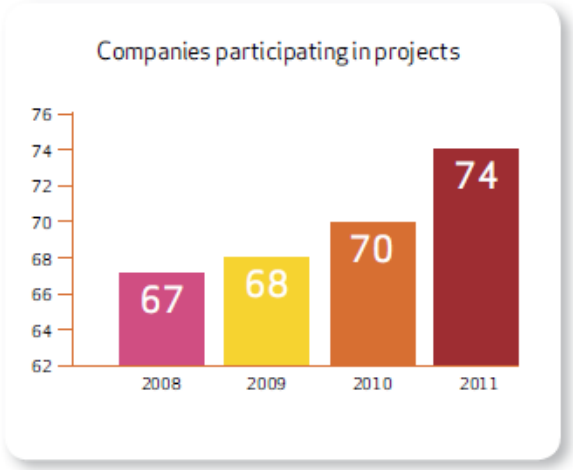
35+ researchers
72+ collaborators
119+ projects
68+ companies
8+ international projects
43+ research publications

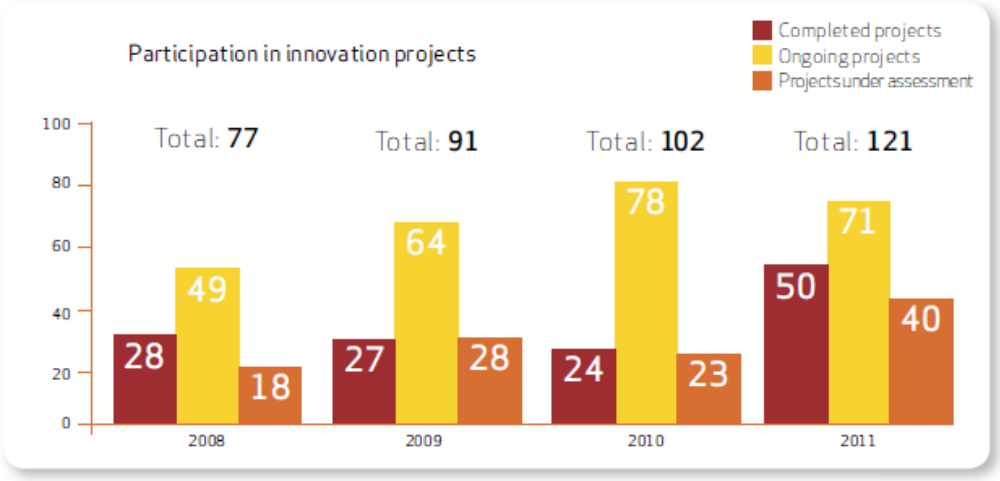
making the **Future Internet** become a **reality** *

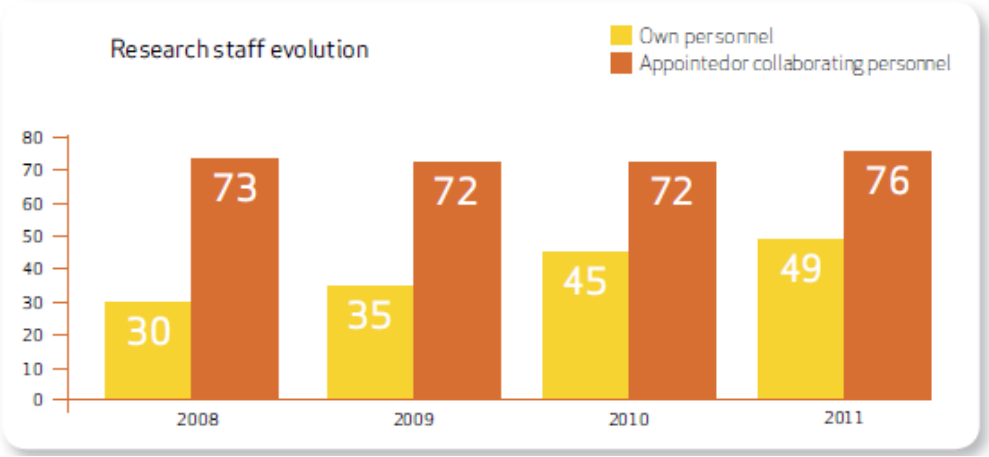
helping **real companies** increase their **future competitivity** *

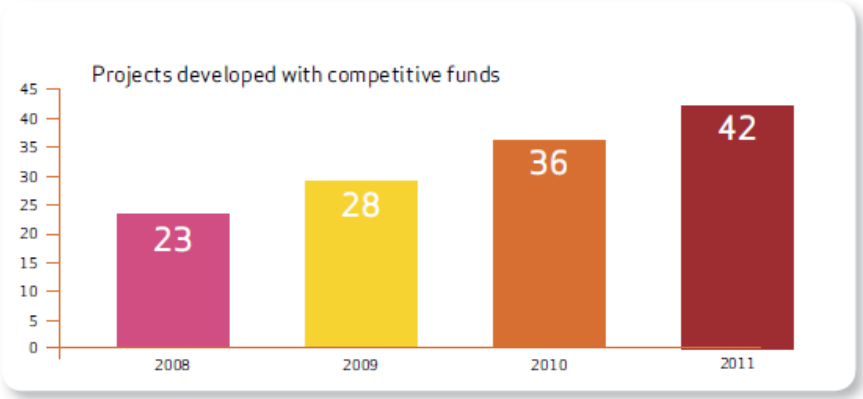
Generalitat de Catalunya Departament de Salut
Generalitat de Catalunya Departament de Governació i Administracions Públiques Secretaria de Telecomunicacions i Societat de la Informació
Generalitat de Catalunya Corporació Catalana de Mitjans Audiovisuals
Generalitat de Catalunya Centre de Telecomunicacions i Tecnologies de la Informació
Ajuntament de Barcelona
Universitat Ramon Llull
Universitat Pompeu Fabra
UPC
CIDEM Centre d'Innovació i Desenvolupament Empresarial
MEDIAPRO
orange
vodafone
Cisco Systems
Alcatel·Lucent
Fujitsu
Cromosoma
interoute
abertis telecom
Juniper Networks

i2CAT in numbers









DANA EC & International projects

Mission: Research, develop and innovate on new network technologies to offer to the ICT sector new tools and technologies to promote the adoption of new business models and the development of local business initiatives.

Project		Funding	Goal	Role	Core Technologies
fibre	2011-2014	FP7 (STREP) 1.099.965 €	Create and operate a join Future Internet testbed between Brazil and Europe	Coordinator, WP Leader	OpenFlow, OFELIA Control Framework, WiFi, OMF, Wimax, Python, SFA
Mantychore	2010-2013	FP7 (I3) 1.399.740 €	Deploy operational tools to provide custom IP Networks as a Service in NRENs	Coordinator, WP Leader	IP Routing protocols, MPLS, Ethernet, NetConf, Java, OSGi, Spring DM
OFELIA	2010-2013	FP7 (IP) 4.449.912 €	Deploy and operate an European-wide OpenFlow Future Internet Facility	WP Leader	OpenFlow, Ethernet, IP, OpenVSwitch, Python, Django, Expedient, SFA, XEN
BonFIRE	2010-2013	FP7 (IP) 6.700.000 €	Deploy and operate a European Cloud Computing Future Internet Facility	WP Leader	OpenNebula, XEN, Cells, Zabbix, OVF, OCCI, Java, Jersey
nni	2010-2013	FP7 (STREP) 2.363.999 €	Advances in the federation of Future Internet facilities control frameworks	Task Leader	SFA, PlanetLab (myplc), Globus Toolkit 4, NDL, perfSONAR, VMWare, XEN
RAISME	2010-2012	FP7 (STREP) 692.345 €	Allow SMEs to build and scale ICT applications through the use of mashups	WP Leader	Mashups, REST, Semantic web, Ontologies, Hadoop, OpenNebula
GEYSERS	2010-2012	FP7 (IP) 7.035.000 €	Provide technical solutions to bring the cloud computing model to networks	Technical and WP Leader	Enhanced GMPLS, PCE, SML, REST, optical network virtualization, Java
GÉANT	2009-2013	FP7 (I3) 93.000.000 €	Deploy and operate the European core research network, linking all the NRENs	Partner subcontractor	Autobahn, GMPLS, perfSONAR, Java, SOAP, OSGi, RDF,
FEDERICA	2008-2010	FP7 (I3) 3.932.212 €	Build an European Research Facility for Computer Network Scientists	WP Leader	IP, Ethernet, xORP, XEN, VMware, Java, Globus Toolkit 4,
PHOSPHORUS	2006-2009	FP7 (I3) 5.125.000 €	Provide solutions for single-step provisioning of grid+network resoruces	WP Leader	Harmony, Argia, Argon, DRAC, GMPLS, G2MPLS, UNICORE, NSI

RINA A Better Network Structure

Other selected initiatives: Joint collaboration with **Boston University** (John Day), **TSSG** and **Tria Network Systems** to implement an Internetworking architecture based on the principle that networking is a recursive set of layers that provide IPC services (Inter Process Communication).

New projects coming from FP7 ICT call 8

These projects still have to be negotiated with the EC (the amount of funding is an approximation). They are expected to start during the 3Q or 4Q of 2012.

Project		Funding	Goal	Role	Core Technologies
IRATI	2012-2014	FP7 (STREP) 850.000 €	Design and Develop a RINA prototype over Ethernet for UNIX and JunOS	Coordinator, WP Leader	UNIX, C, RINA, Ethernet, JunOS
OFERTIE	2012-2014	FP7 (STREP) 1.300.000 €	Use SLA-based management of cloud hosting across multiple data-centres over OpenFlow networks for ROIA applications	WP Leader	Real-time Online Interactive Applications (ROIA), OpenFlow, IP, SLA management
FED4FIRE	2012-2016	FP7 (IP) 8.000.000 €	Provide a federation of FIRE experimentation facilities, developing an implementing a federation architecture	Task Leader	SFA, OFELIA Control Framework, OMF, OML, PKI
CONTENT	2012-2015	FP7 (STREP) 2.000.000 €	Define a novel convergent network architecture supporting technologies in the wired and the wireless network domains interconnecting computational resources in support of cloud services and the IaaS paradigm	WP Leader	WiFi, LTE, TSON, IaaS, Cloud Computing, Orchestration of virtualized resources
SODALES	2012-2015	FP7 (STREP) 2.000.000 €	Define and Develop a converged optical/ wireless access network architecture that increases the spectrum utilization efficiency and supports carrier-grade Ethernet services	WP Leader	FTTH, WDM-PON, Active Remote node, Ethernet OAM, statistical multiplexing, LTE

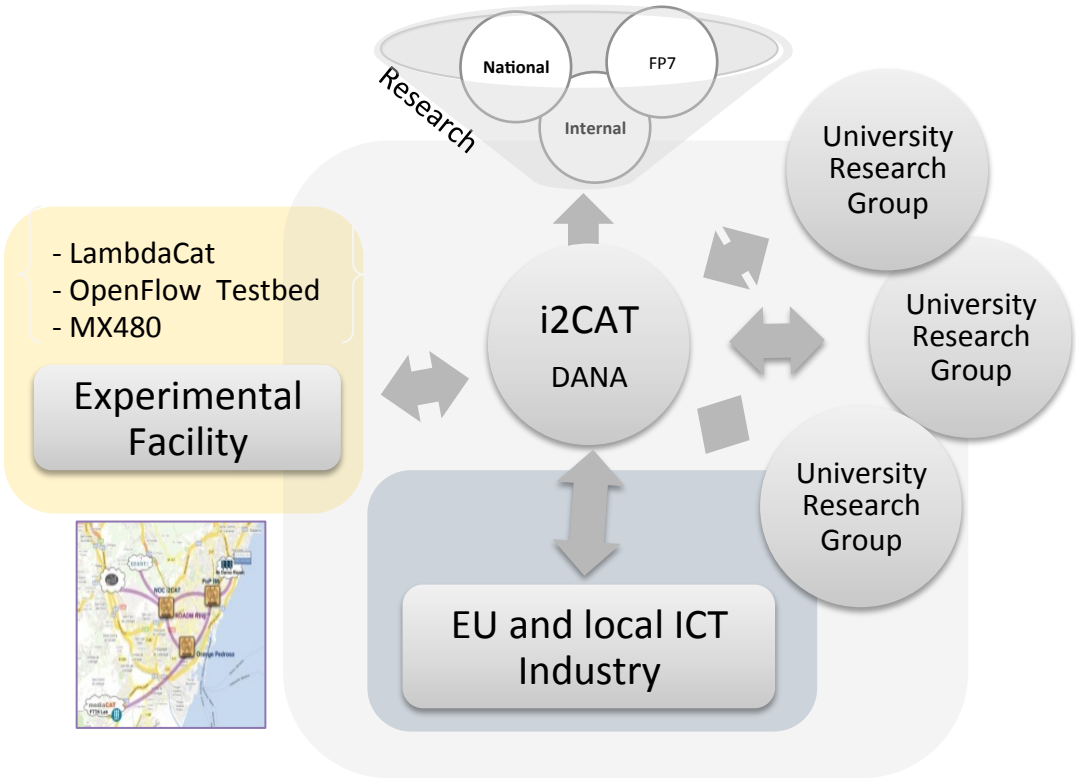
PROFESSIONAL SERVICES

DANA Technology domains

- Network infrastructure management applications (DWDM, SONET/SDH, IP, MPLS)
  - Open Source framework for NaaS (OpenNaaS)
  - Management interfaces: TL-1, vendor-specific CLI, Netconf, SNMP
  - Recursive access rights delegation (IaaS)
  - Automated network provisioning, bandwidth on demand (NSI)
  - Extensible, modular and pluggable multi-vendor applications
  - Early prototyping of standards (TMF IPsphere, OGF NSI)
- Recursive InterNetwork Architecture (RINA)
  - Full replacement for the current networking stack (from TCP down to the physical level)
- Future Internet Testebds and Interoperability management solutions based on SFA (Slice-based Facility Architecture)

i2CAT's Environment

- Expertise.
  - Knowledge transfer (Assessments, Trainings, etc).
  - Innovation partner, added value, state of the art consulting.
    - Assessment, viability reports, PoC and/or prototyping, access to third party know-how, etc.
- Domain specific development.
  - Experts on third-party assets (no IPR).
    - Vendor-specific developers, tier 3 support.
  - Experts on shared-IPR assets.
- Research projects partnership.
  - EU JRU.
- Technology transfer
  - Sell IPR
  - Patents, assets licensing.
- Commercial initiatives
  - Spin-offs, Joint ventures, etc.



i2CAT collaboration with Juniper Networks; past and present

2007 | 2008 | 2009 | 2010 | 2011

Manticore

Netconf, Logical routers, Juniper M7, Configuration management, NRENs

Manticore II

Netconf, Logical routers, Juniper M20, Configuration management, NRENs, IP Network as a Service

JUNOS

Start collaboration on JunOS SDK

FEDERICA

Netconf, Juniper MX480, Juniper EX 3200, Configuration Management, Testbed Management, Future Internet research

IPsphere FORUM **tmforum**

IPSphere Framework Release 1, SMS Child Open Source Implementation, Juniper SRC,

JUNOS SPACE

JunOS Space SDK Early Access Program, REST APIs, DMI, MPLS, Quality of Service

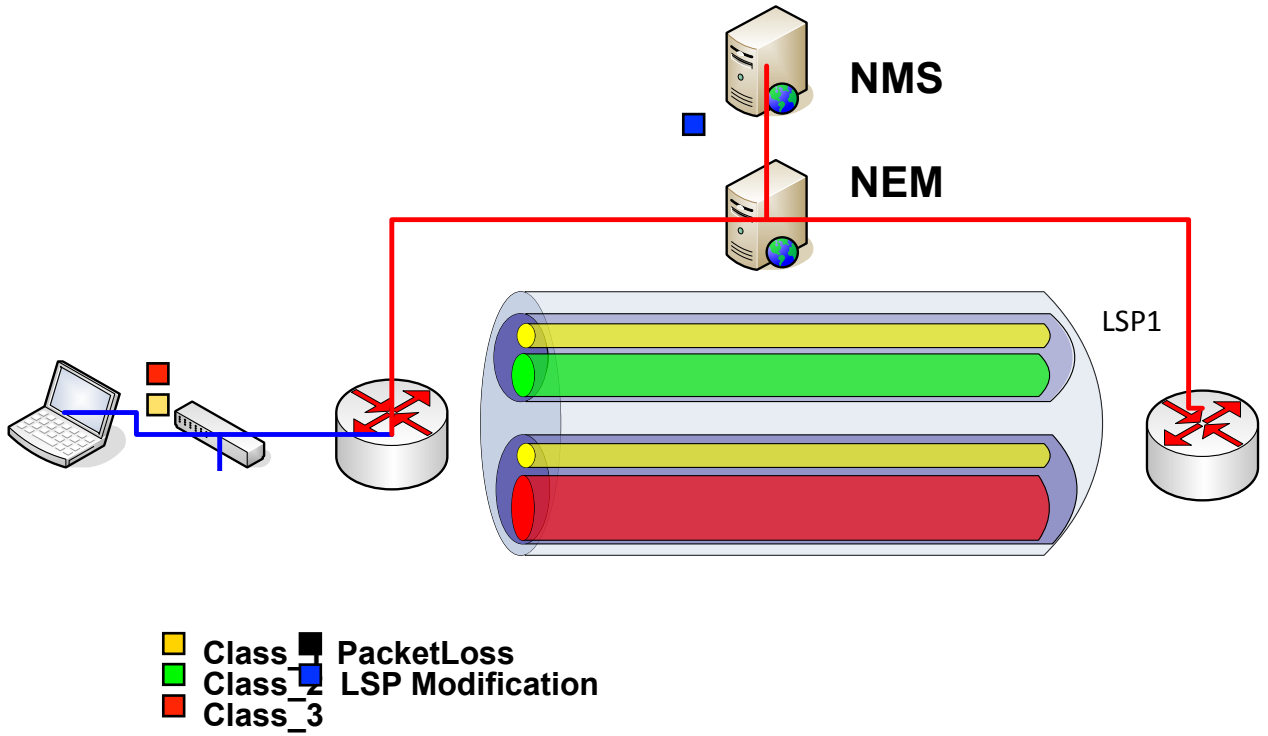
i2cat FUNDACIÓ **JUNIPER NETWORKS**

Juniper becomes a member of the i2CAT board, donation of a MX480 router

Equipment donated by Juniper to i2CAT for experimentation and development purposes

JEnigma - Main Subsystems

- **Call Admission Control (CAC)**: The CAC is the sub-system in charge of allowing or denying the creation of new paths(LSPs) within the MPLS cloud (Patent-pending algorithm).
- **Background Monitoring System (BMS)**: Monitors network state and reconfigures the network appropiately (using CAC), so network resources are optimized.
- **Alarm subsystem:** Alarm/trap management. The user is able to receive alarms and traps from the NMS and network equipment.



i.e. a DANA research partnership model example.

Expertise

- **Know-how:**

Acquired during the national and EC projects.

  - Network architectures and protocols
  - Network management solutions
  - Juniper products (i.e. JUNOS Space EAP)
  - Software development
- **Added value:**
  - Close collaboration with universities and research groups
- **Juniper product stack access:**
  - JUNOS Space EAP
  - (in progress) JUNOS SDK
  - (in progress) Openflow-enabled JUNOS
  - (future) JUNOS Sphere
- **Experimental Facility:**
  - Experimenta
  - Juniper MX480 for experimentation
  - Openflow testbed (Ofelia)

Current strategic partnership

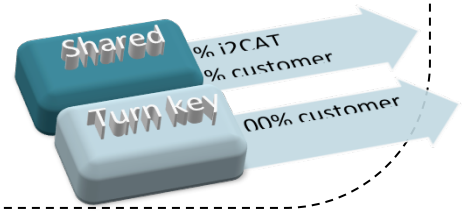
- Research projects
- Early Access Programs (i.e. JUNOS Space)

On demand/commercial services

- **Technological advisory:**
  - Project feasibility study
  - Software design
  - Training
- **Proof-of-concept design and implementation**
- **Innovation partner**

Services have two possible cost schemes:

- **Shared cost and IPR:** IPR and cost is shared between i2CAT and the customer.
- **Turn key:** customer affords the whole development costs and owns the whole IPR



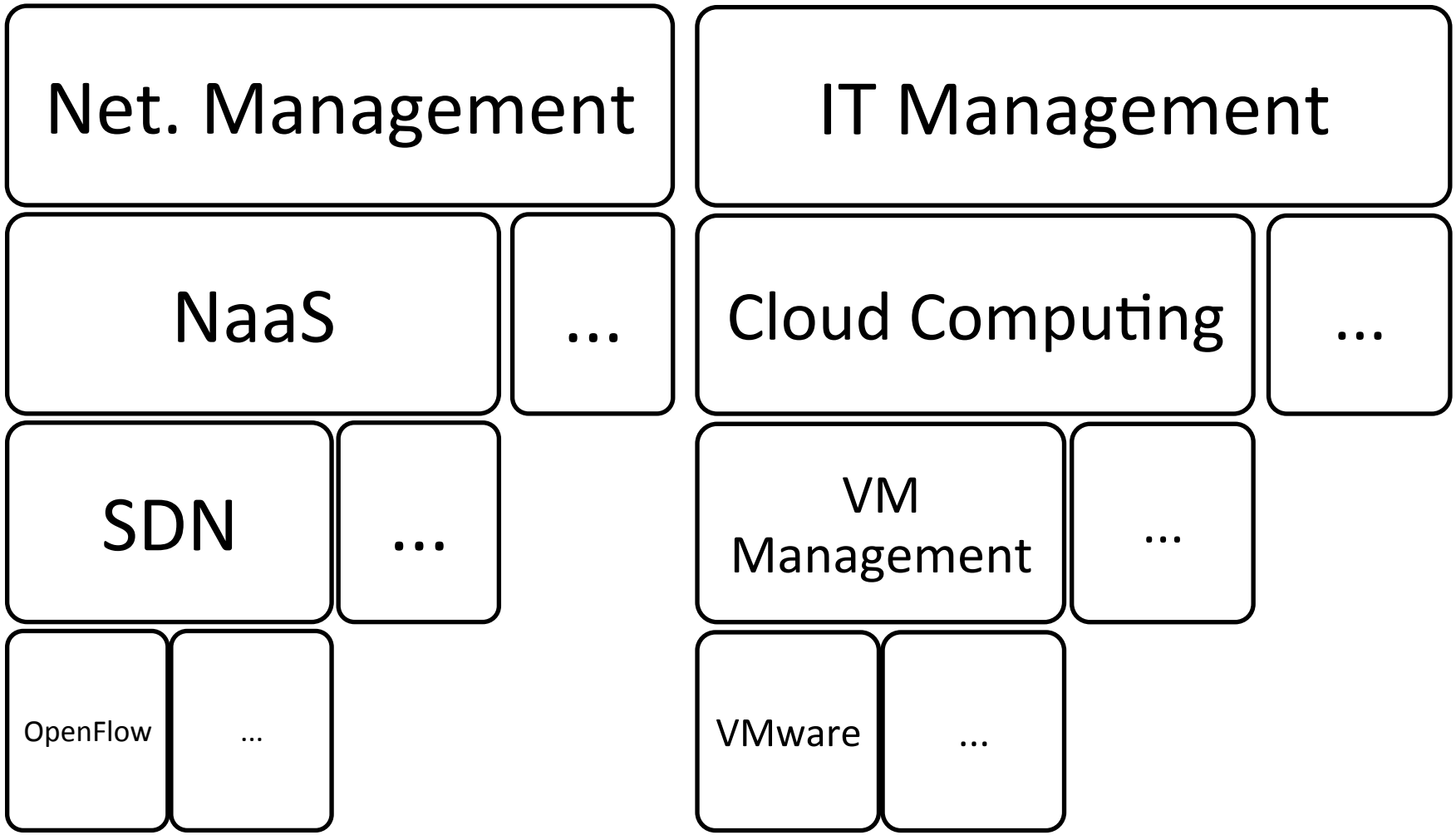
new partnership model

Current service activities

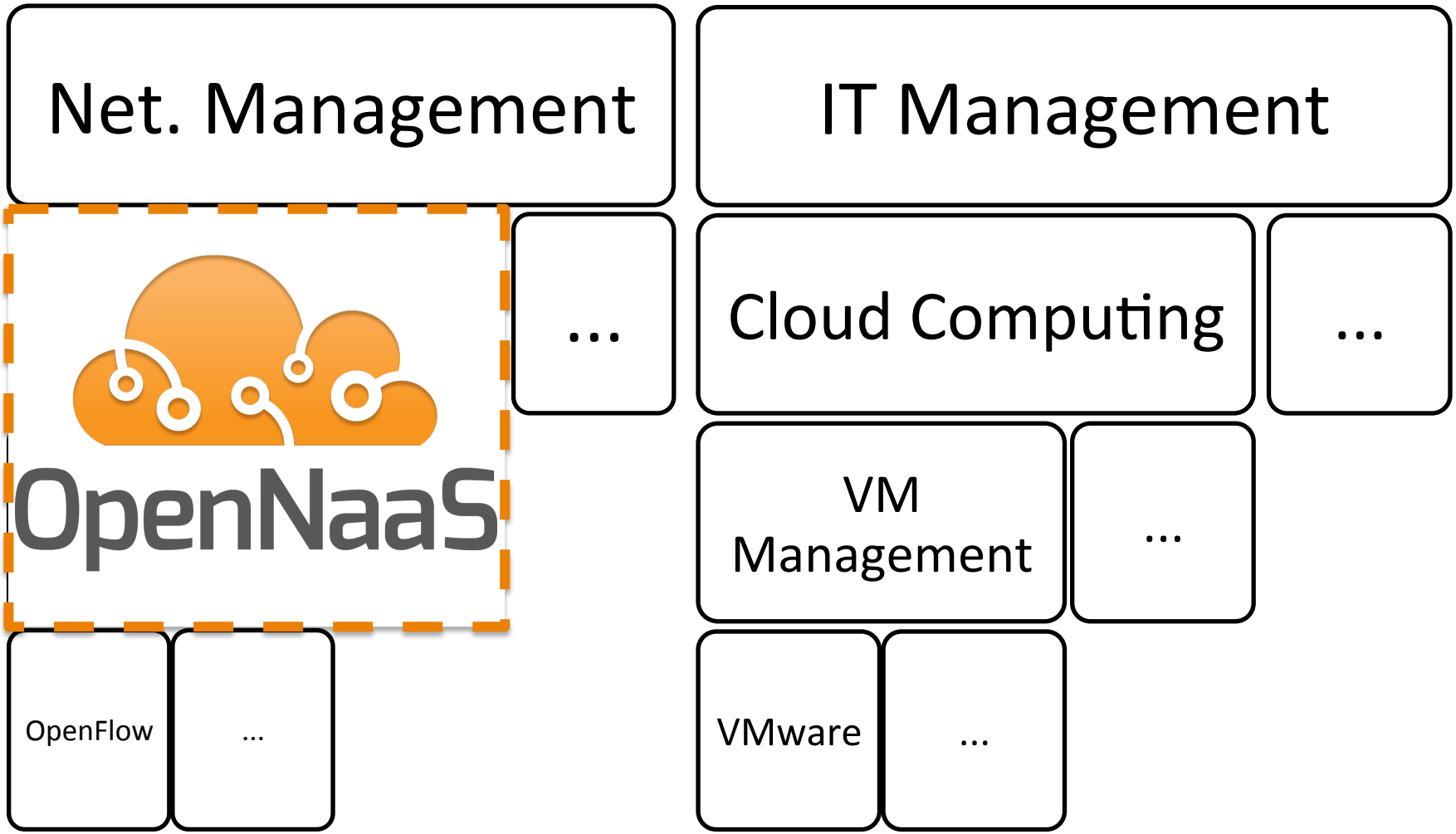
Company	Current instantiation
Quantech	FEMCloud
DRTS	RAISME FP7 Shamal FP7 Project partnership
Juniper Networks	Master Service Agreement with Juniper PS. FP7 Project partnership
Lyatiss	Services Contract
HEAnet, UNI-C, TID.	Mantychore FP7 (Virtual CPE, Private Cloud).
Vodafone	Enigma patent
CTTi, Aj. Barcelona.	Consulting framework agreement.

SOFTWARE DEFINED NETWORKING

Taxonomy


Net. Management
IT Management
NaaS
...
Cloud Computing
...
SDN
...
VM Management
...
OpenFlow
...
VMware
...

Taxonomy


Net. Management
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...
Cloud Computing
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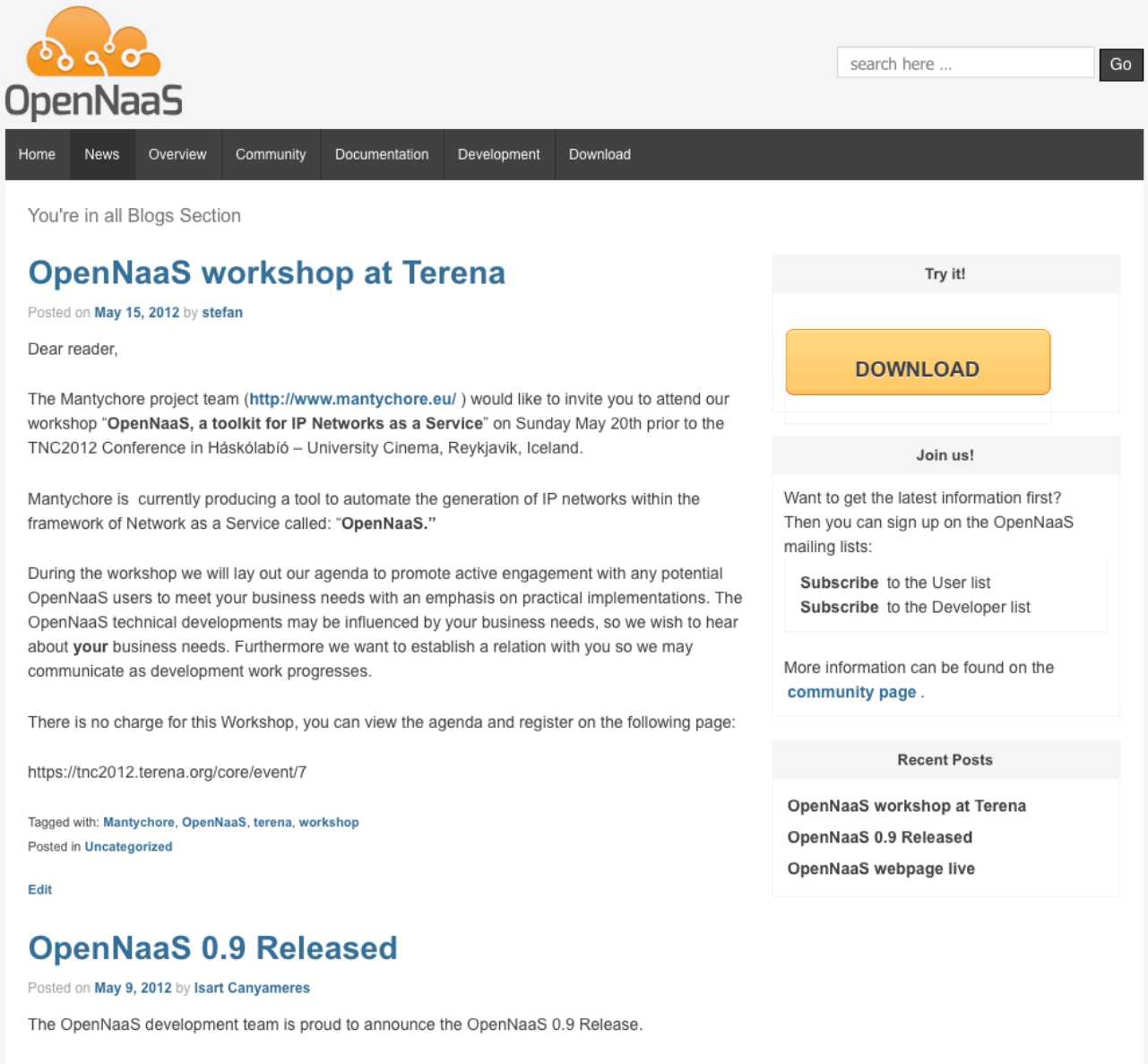
VM Management
...
OpenFlow
...
VMware
...

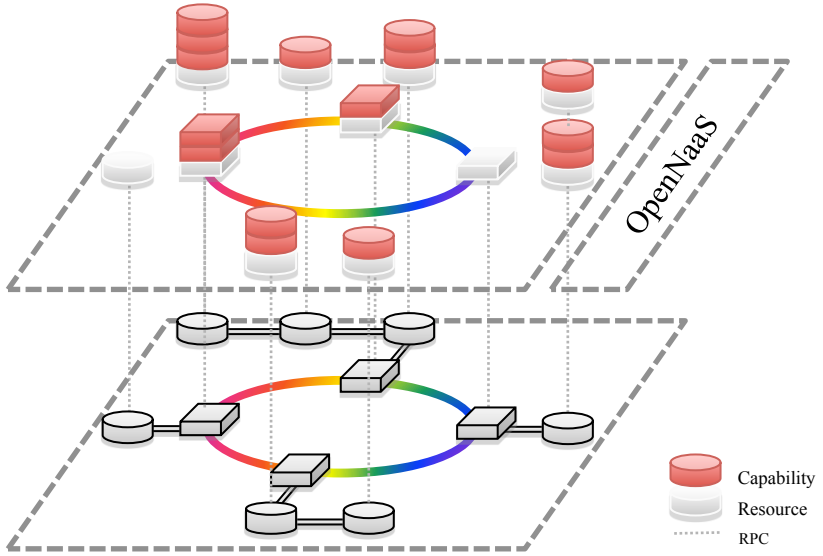
www.opennaas.org

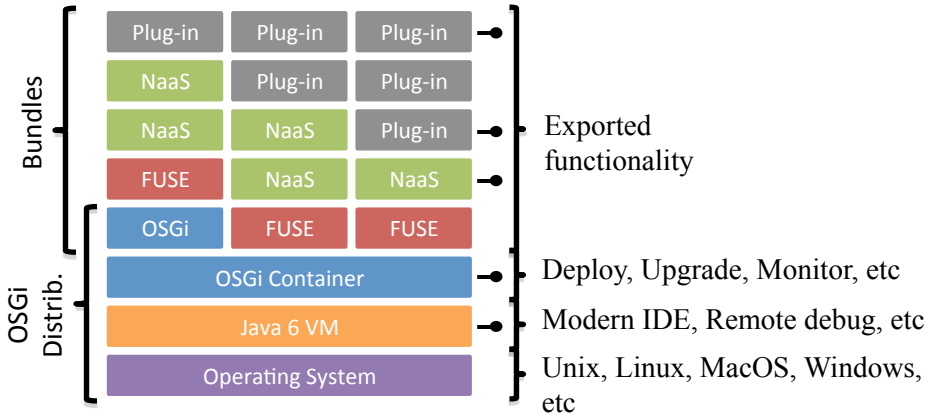


- All pointers to relevant information and news at our homepage.
- You are welcome to the mailing list!

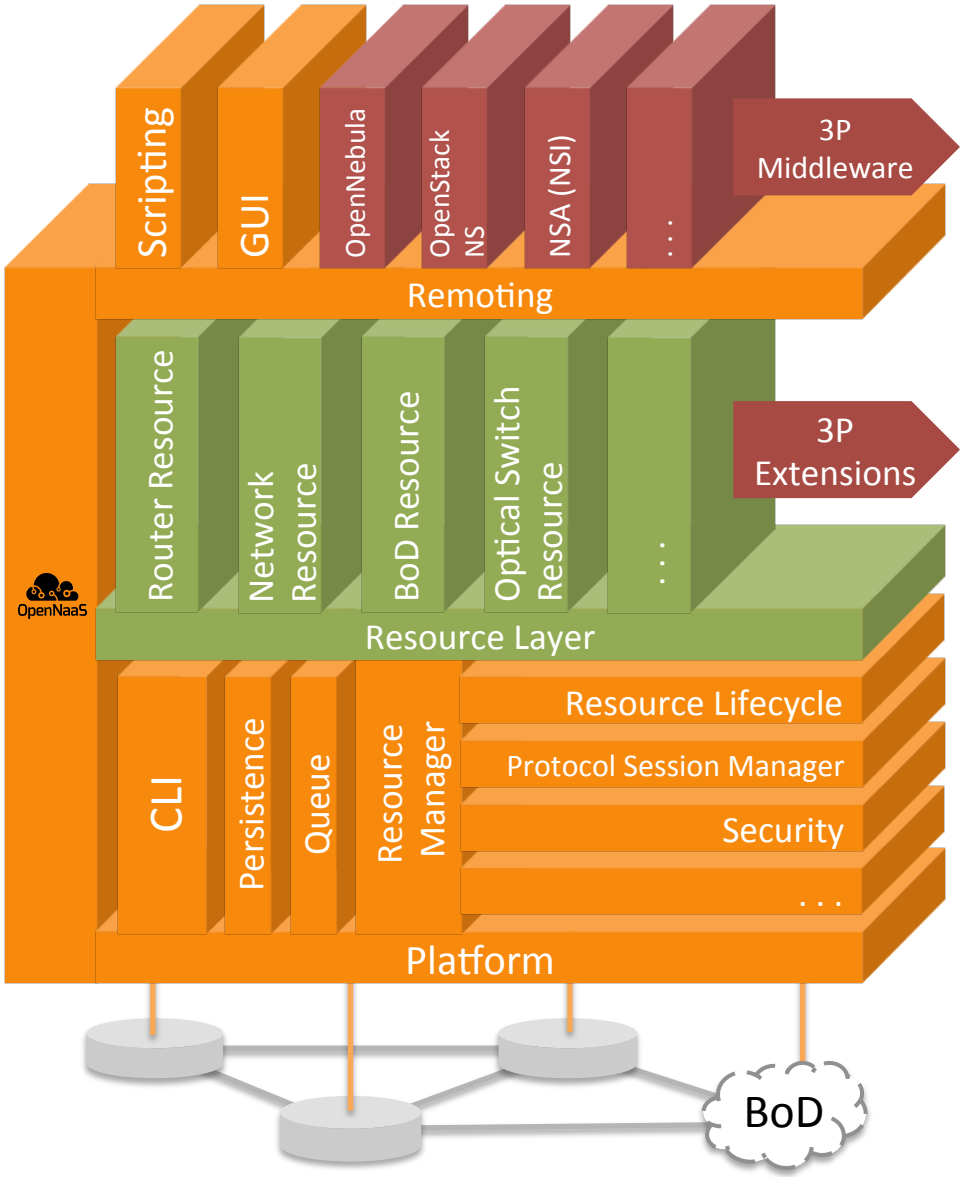
OpenNaaS Lightweigth Abstraction

- On demand (commonly user-triggered) provisioning of network resources.
- Recursive delegation of access right over managed resources.
- Lightweight Abstracted operational model.
  - Decoupled from actual vendor-specific details.
  - Flexible enough to accomodate diferent designs and orientations
  - Fixed enough so common tools can be build and reused across plugins.
    - Security
    - Lifecycle
    - Monitoring
    - Deployment and upgrade.





OpenNaaS Architecture



Network Intelligence

- Integration with Northbound Middleware
  - IaaS/Cloud managers
  - Other NMS.
- The user

NaaS Layer

- Network HAL abstraction to infrastructure.
- Resources manageable by the user.
  - Access controlled by the Sec. Manager.

Platform

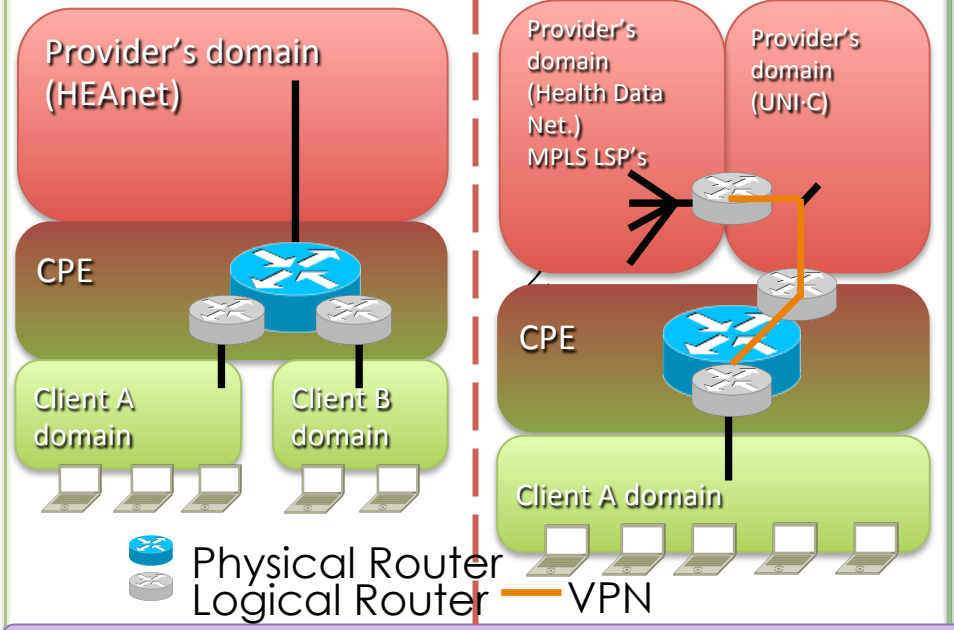
- Reusable building blocks, common to all extensions.
- Controls access to the infrastructure.
  - Integrity, Policy, etc..

Managed infrastructure

Use Cases

VIRTUAL CPE

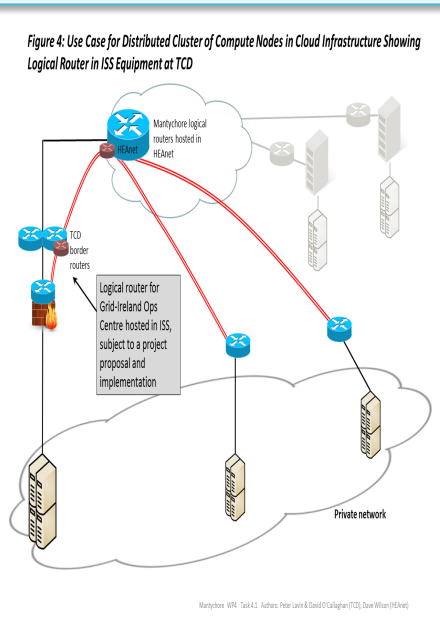
Scenario 1



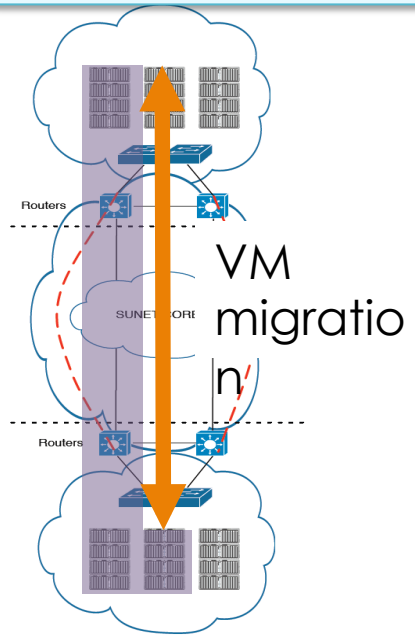
Scenario 2

DISTRIBUTED & PRIVATE CLOUD

Scenario 1



Scenario 2



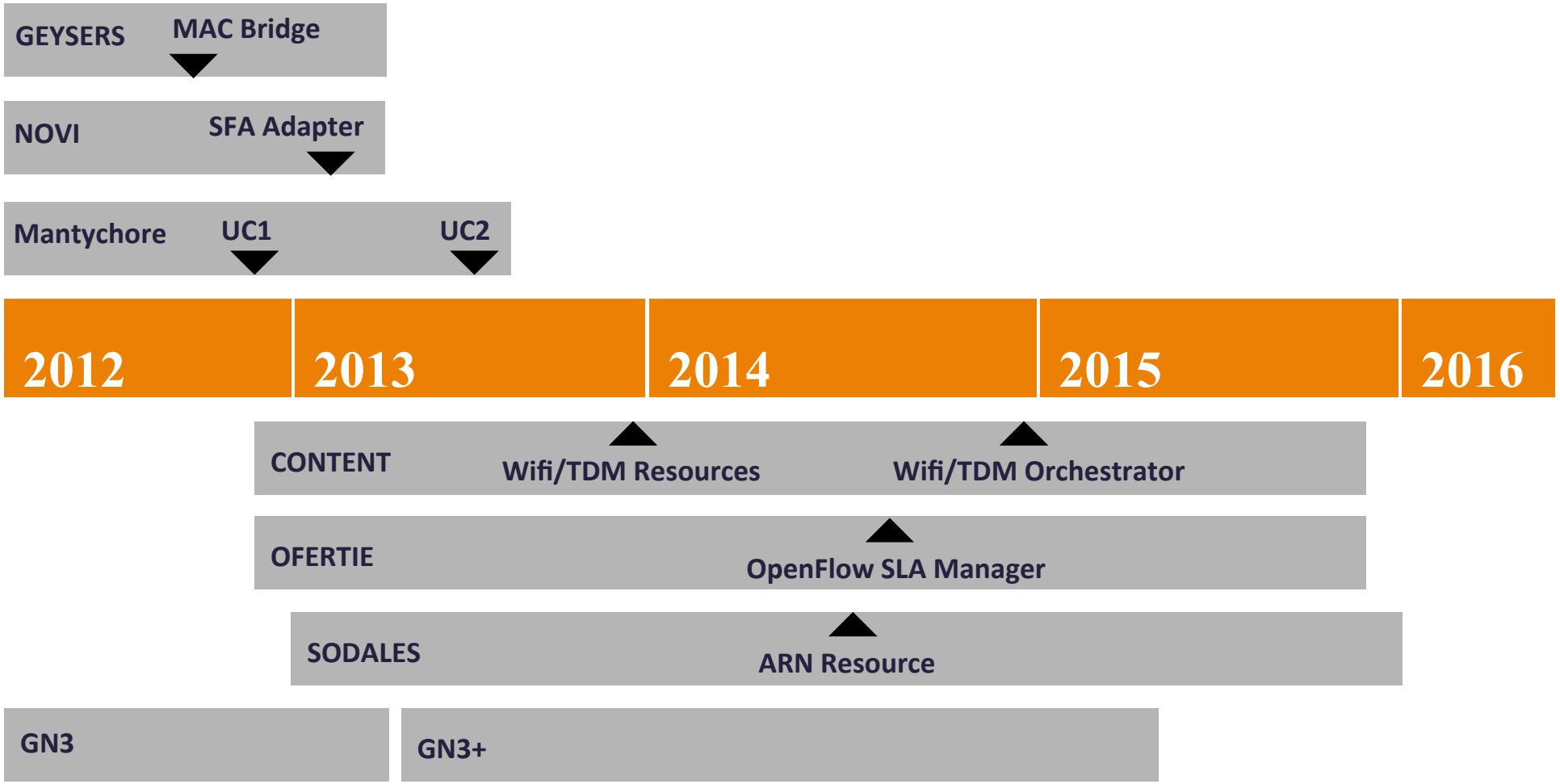
ULTRA HIGH DEFINITION APPLICATIONS

- Deployment of next generation multimedia applications
  - 3D, UHD
- Stream producers and consumers.
  - 3D medical applications.
  - 3D virtual tourism.
- Flexibility to adjust, network independent of underlying infrastructure.
  - Bandwidth on Demand.
  - Advance Reservation.

Extensions Roadmap

Done	Current	Short-term (<6m)	Mid-Term (>6m)
L1 ROADM			
L2 MAC Bridge			
L2 BoD Domain client • AutoBAHN		**BoD Domain Server** • Porting Harmony IDB	**BoD Domain Server** • NSI interface.
	L2 / L3 Router		
	L3 Network		
		Manager GUI	
		Security Manager • SAML Idp	
		Cloud Manager connectors • OpenStack NetworkService drop-in replacement • OpenNebula 3.0	• Energy consumption metrics. • Infrastructure Marketplace.

Extensions Roadmap by Project



BREAKABLE NETWORKS

DANA Experimental Facilities

✓ **Open Testbed Facility**

Lambdacat open testbed allows access to network resources as a service at different network layers. Users can configure the network as they require.

The optical validation platform is designed to support multivendor equipment.

✓ **Advanced Experimental Services**

LambdaCat experimental platform offers multi-layer services to test network applications and devices at different OSI layers on a real environment.

✓ **Infrastructure as a Service (IaaS)**

Physical network substrate is virtualized to offer virtual isolated slices to final users. Users can manage and configure their virtual substrate.

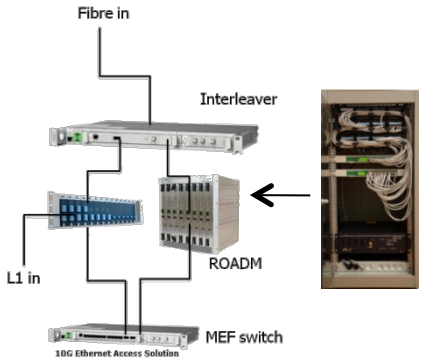
✓ **Parallel disruptive validations and experiments**

By virtualizing the network, parallel disruptive tests are supported running above the same physical infrastructure.

✓ **Promote an innovative environment to empower technology validation**

The collaborative platform environment promotes research, development and innovation between public and private (PPP) entities.

PoP equipment



Service Description

Connectivity and testbed Services

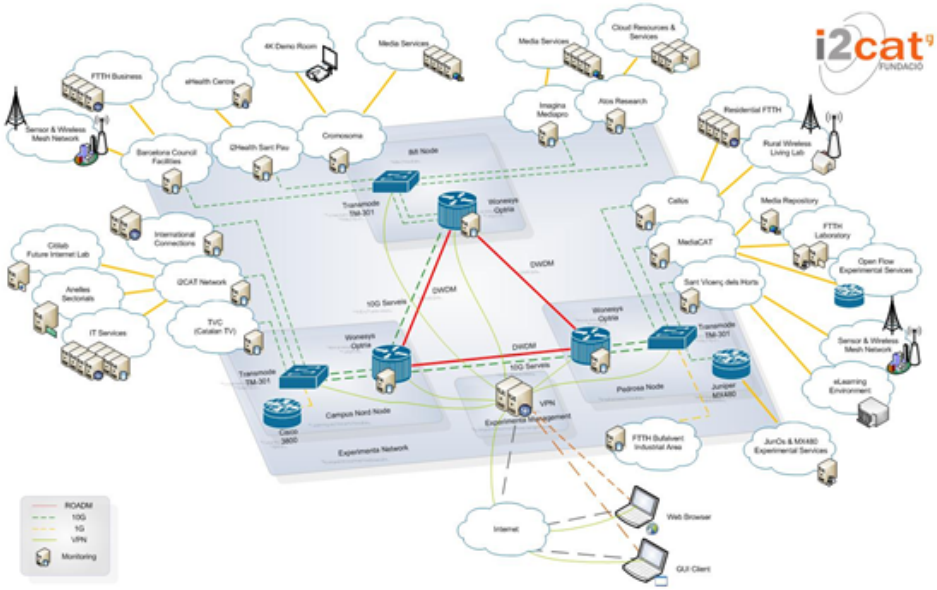
- Add/drop capabilities on each ROADM node
- 2.5 & 10G line connections
- L1, L2, end-to-end services
- E2E network performance monitoring services
- Collocation services at the PoPs
- Dark fibre field trial availability
- Virtual machine instances service
- L2/L3 network as a Service
- Cloud and GRID computing service

Media Services

- 10G lambda media services
- 4k media demonstration room
- Advanced Video-conference and VoIP services

Current validation & research activities

- ROADM technology validation
- GMPLS deployment tests
- FTTH Lab testbed @ UPC Castelldefels
- FTTH EPON/GPON validation & research platform
- Residential & eHealth Living Labs
- Experimental testbed for several FP7 EU projects:
  - GEYSERS, MANTYCHORE, BONFIRE, OFELIA, …



Point of Presence Equipment

- Colorless ROADM with 2.5 & 10G cards
- L1/L2 and L3 interfaces
- Logical L2/L3 switch & OpenFlow Switchs
- Virtual machine servers

Outcome from several R+D+I projects

- European
  - FEDERICA (FP7), PHOSPHORUS (FP6), ...
  - MANTICORE, ARGIA, ...
- National & Regional
  - DREAMS (PROFIT 07, CIDEM 07/08)
  - PAIS (InfoRegió 09) & SILVIA (Inforegió 10)

Other platforms:

- OFELIA FP7
- JUNIPER MX 480

i2CAT OFELIA island overview

i2CAT OFELIA island (Barcelona)

Multi-vendor extensive L2 deployment. Complete meshed topology on the experimental Openflow network. No “opted-in user” traffic, only experimental traffic.

Computing equipment

(In production) 5x SuperMicro SYS-6010T-T servers.

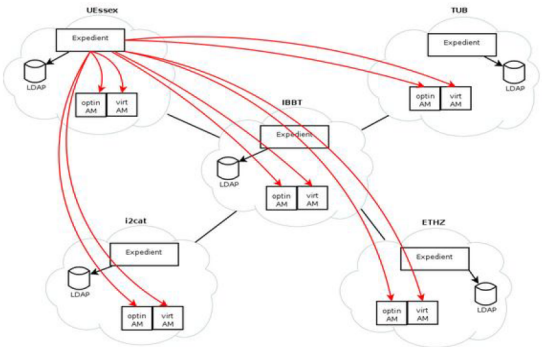
Network equipment (OF enabled)

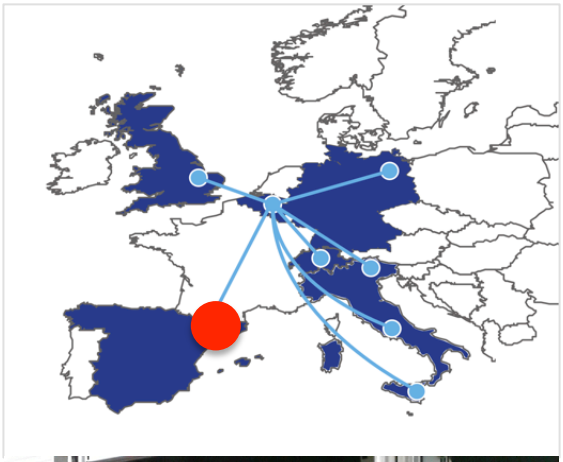
(In production) 5x NEC IP8800/S3640-24T2XW switches

(Not yet in production) 3x HP E3500-48G-PoE+yl switches

EXPERIMENTA’s i2CAT testbed

(Conn. on demmand) 1x Juniper MX480 3D + OF supp.

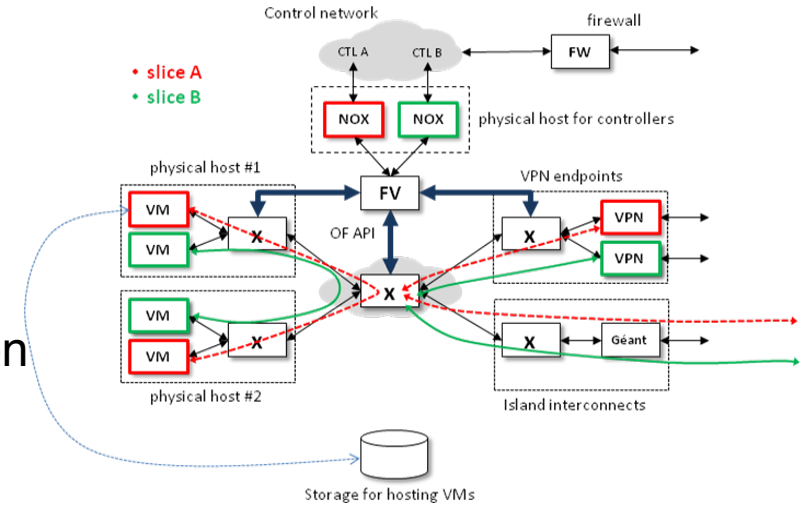


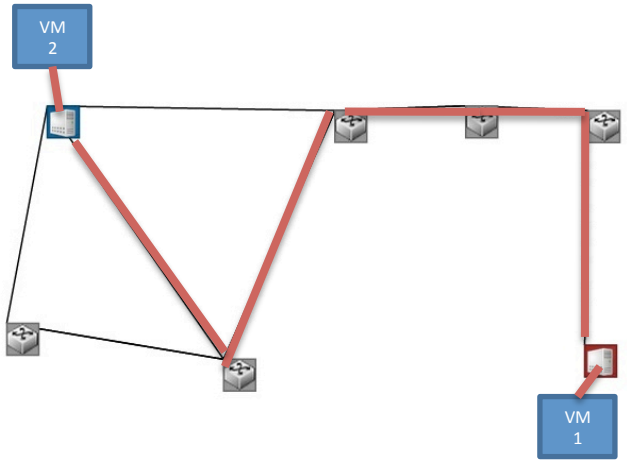


What can an experimenter get?

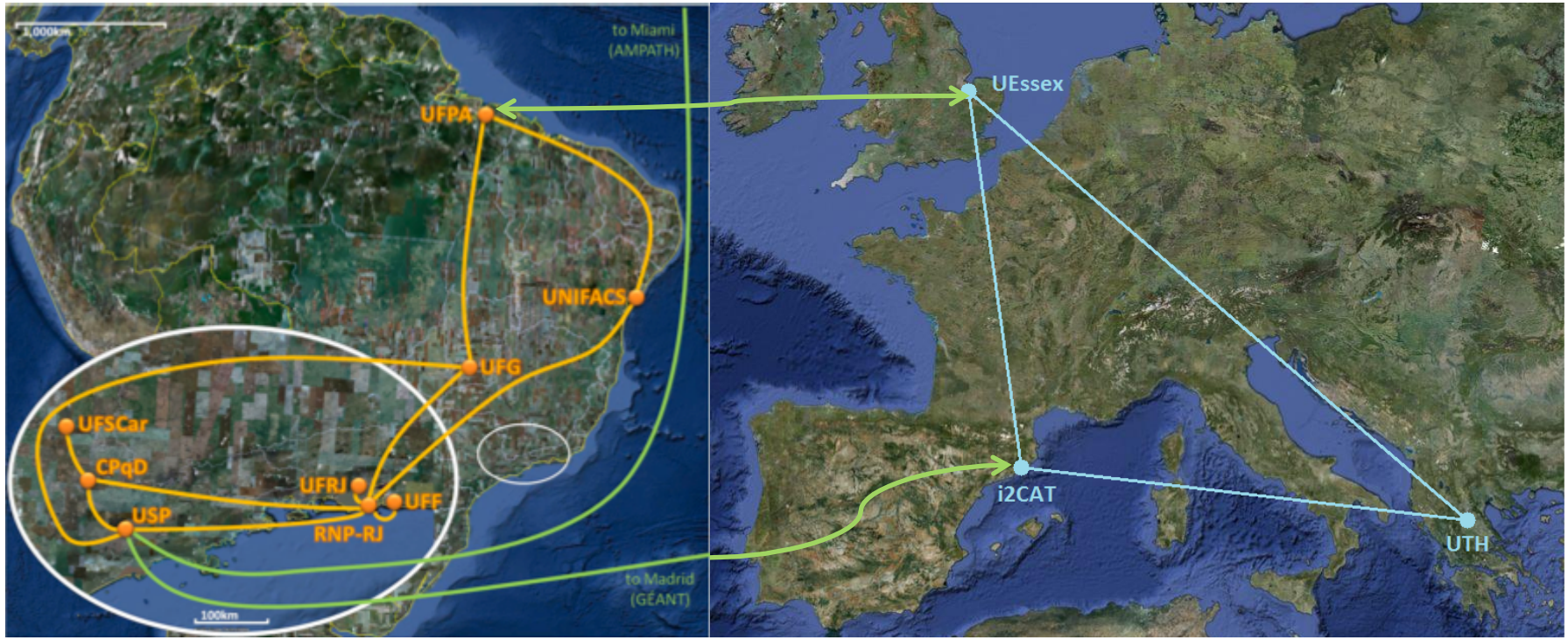
- An experiment/slice consists of
  - A number of end points
    - Xen-based virtual machines, currently
  - OpenFlow access to a set of switches that connect the end points
    - User's OF controller can be deployed on one of the VMs
  - Links between end points and switch ports
    - best effort (shared), mostly
    - Dedicated capacity will be available at least on some lines
  - VirtualWall nodes (Ghent)
  - Wireless nodes in BOWL (Berlin
  - Optical resources, NetFPGAs
  - Virtual Topologies (Vertigo)

In progress…





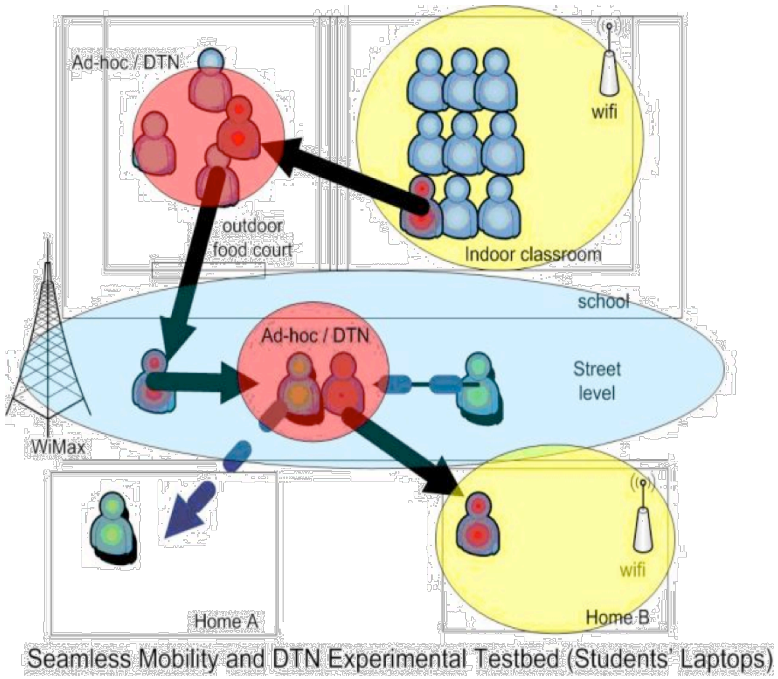
Testbeds in Europe and Brazil



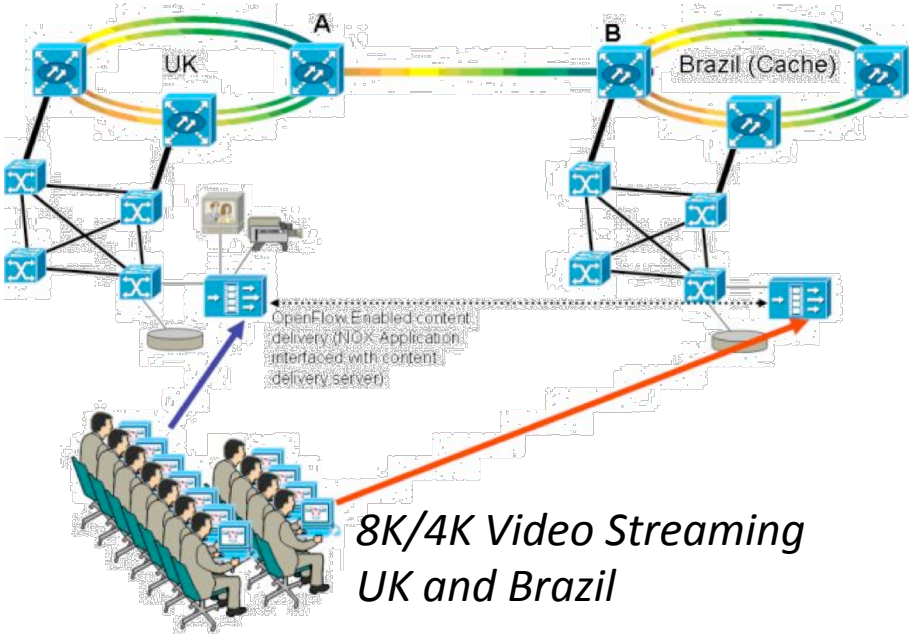
- **Europe**
  - 3 islands
  - The EU large-scale experimental facilities are an extension and federation of the existing OFELIA, and Openlab projects.

Pilot Use Cases

Seamless Mobility for Educational Laptops



Seamless Mobility and DTN Experimental Testbed (Students' Laptops)

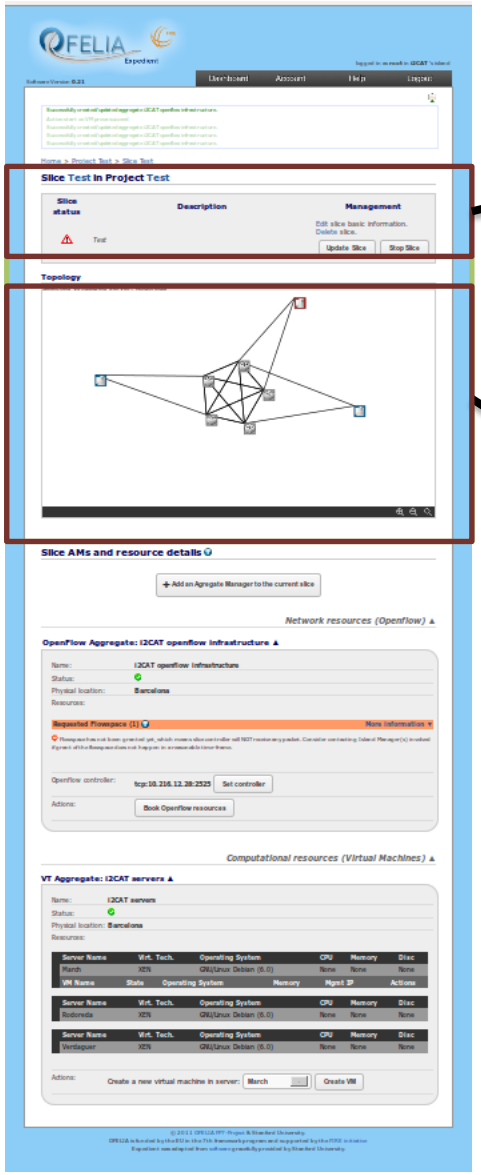


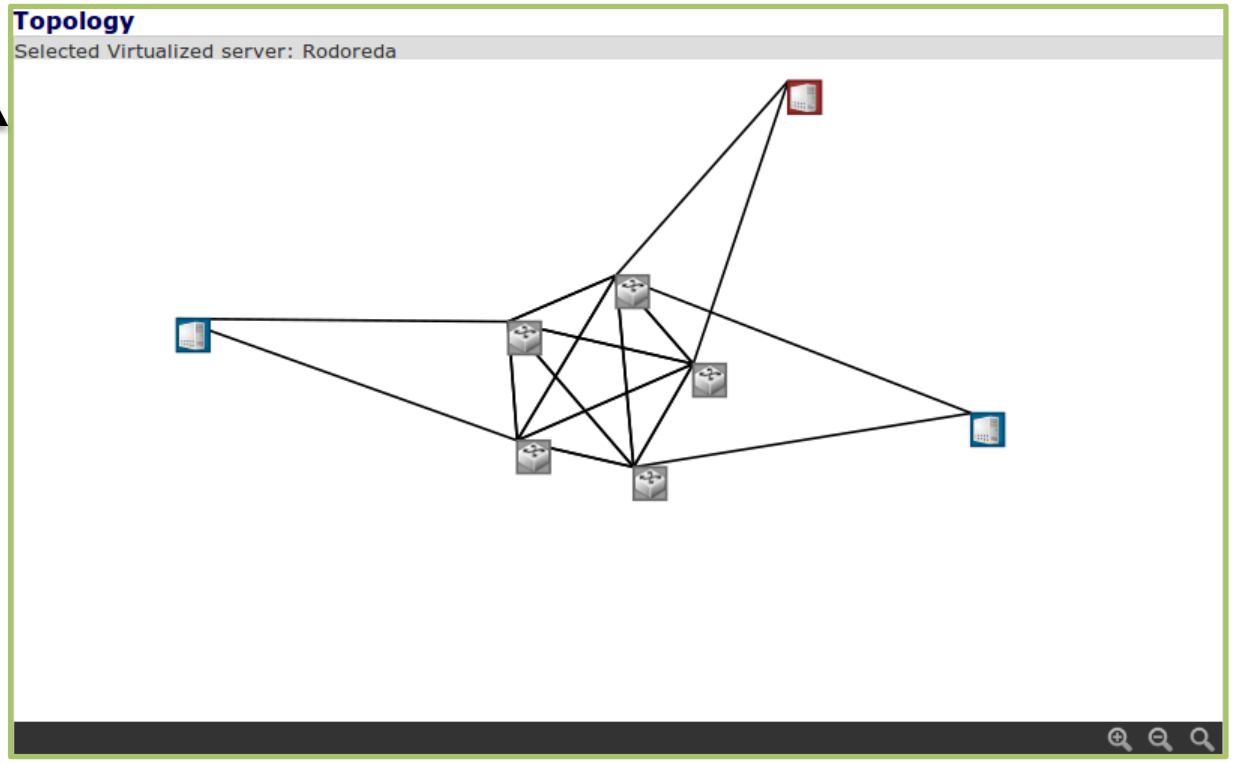
8K/4K Video Streaming UK and Brazil

High definition content delivery across different sites

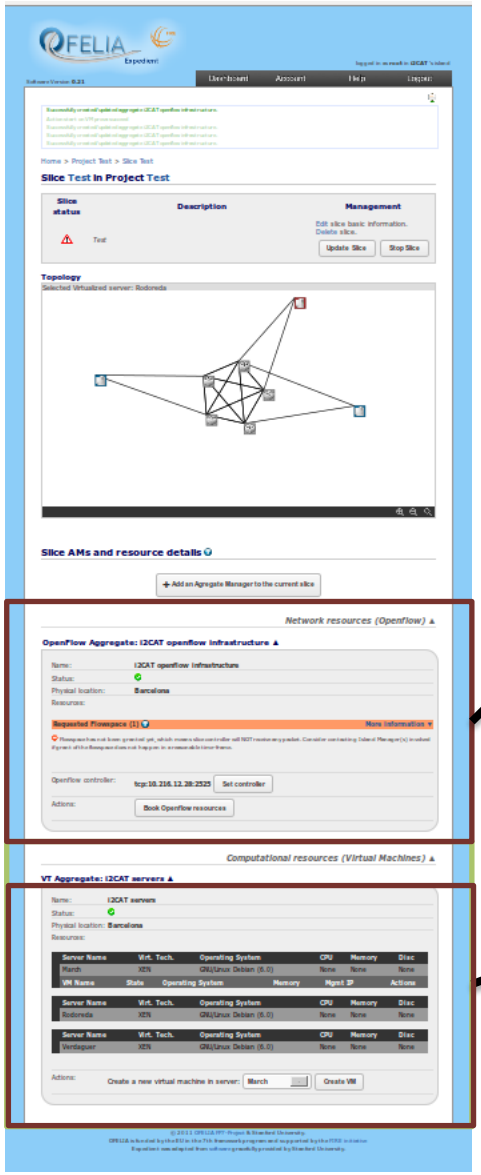
Bandwidth on Demand through OpenFlow GMPLS in the FIBRE facility

OFELIA Control Framework (OCF)





OFELIA Control Framework (OCF)



Network resources (Openflow) ▲

OpenFlow Aggregate: i2CAT openflow infrastructure ▲

Name: **i2CAT openflow infrastructure**

Status:

Physical location: **Barcelona**

Resources:

Requested Flowspace (1) More information ▼

Flowspace has not been granted yet, which means slice controller will NOT receive any packet. Consider contacting Island Manager(s) involved if grant of the flowspace does not happen in a reasonable time-frame.

Openflow controller: **tcp:10.216.12.28:2525** Set controller

Actions: Book Openflow resources

Computational resources (Virtual Machines) ▲

VT Aggregate: i2CAT servers ▲

Name: **i2CAT servers**

Status:

Physical location: **Barcelona**

Resources:

Server Name	Virt. Tech.	Operating System	CPU	Memory	Disc
March	XEN	GNU/Linux Debian (6.0)	None	None	None

VM Name	State	Operating System	Memory	Mgmt IP	Actions

Server Name	Virt. Tech.	Operating System	CPU	Memory	Disc
Rodoreda	XEN	GNU/Linux Debian (6.0)	None	None	None

Server Name	Virt. Tech.	Operating System	CPU	Memory	Disc
Verdaguer	XEN	GNU/Linux Debian (6.0)	None	None	None

Actions: Create a new virtual machine in server: March Create VM

Thank for your attention.

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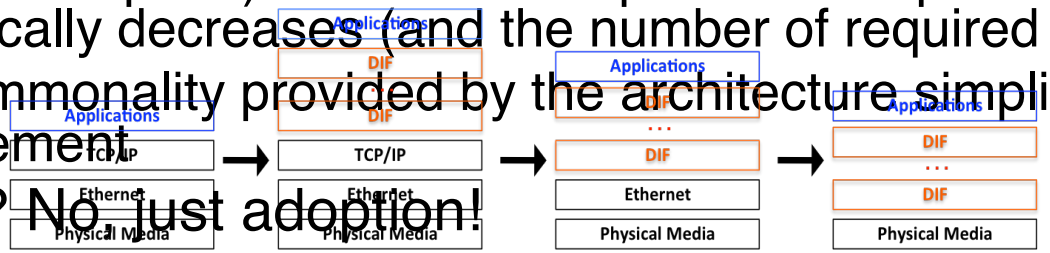
Pau Minoves
Professional Services Manager

BACKUP

RINA

- InterNetwork Architecture, InterProcess Communication, Recursive Layers, Complete naming and addressing schema
- RINA is a clean slate internetwork architecture based on the fundamental networking principles proposed by John Day in his book “Patterns in Network Architecture”.
- Basic principle: Networking is IPC and only IPC. Main characteristics:
  - There is a single type of layer, that repeats as many times as required by the network designer (vs. fixed number of different layers today)
  - With a complete naming and addressing schema (names for applications, nodes and points of attachment) multi-homing and mobility are supported without the need of any special protocol
  - By separating mechanism from policy (the fix parts from the configurable parts) the number of protocols required in the network dramatically decreases (and the number of required standards)
  - The commonality provided by the architecture simplifies r… management
- Migration? No, just adoption!



BOSTON UNIVERSITY i2cat FUNDACIÓ TSSG TRIA

Recursive InterNetwork Architecture: RINA

RINA Better Network Structure

pouzin society

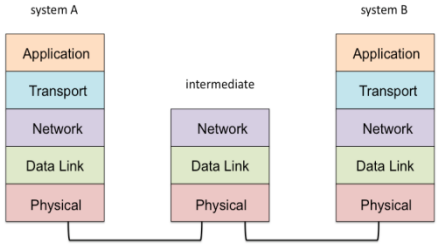
Networking is Inter-Process Communication (IPC) and only IPC

What's different?

structure

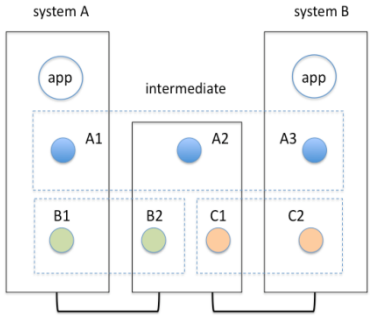
CURRENT INTERNET

- Functional layering, where each layer has the responsibility of a different function
- Fixed number of layers



RINA

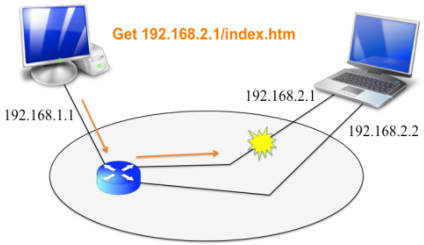
- A layer (DIF) is a distributed application that provides IPC services over a given scope
- Relative number of layers, each layer manages a range of bandwidth and QoS
- DIFs recurse providing IPC services to each other



routing

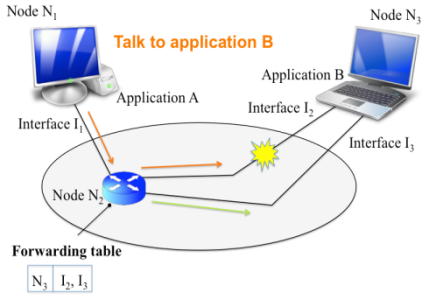
CURRENT INTERNET

- Routing on the interface (data link layer)
- Exposing addresses to applications
- Use of well-known ports
- Incomplete naming and addressing schema



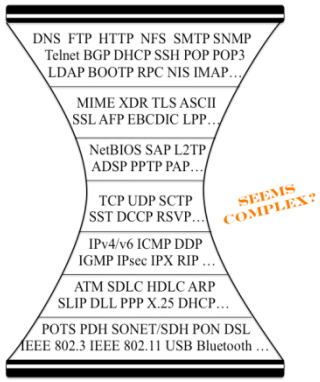
RINA

- Routing on the node
- A complete naming and addressing schema
- Applications have an independent namespace
- Mobility and multi-homing are supported inherently



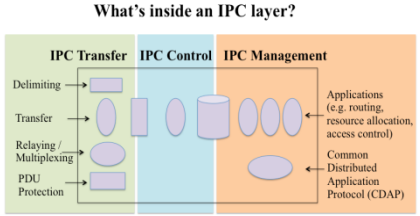
simplicity

CURRENT INTERNET



RINA

- Fundamental functions to provide communication
- Separation of mechanism and policy
- All layers use the same protocols but are configured differently through policy to achieve the desired service
- A single application protocol
- A single data transfer protocol



and more

CURRENT INTERNET

- Lack of a security mechanism: A long list of threats and vulnerabilities
- Lack of a built-in mechanism to provide specific QoS: Only best effort service
- Exploding size of router tables
- Lack of a directory that maps applications to nodes

RINA

- Joining a DIF requires authentication, addresses are not exposed to the applications, well-known ports are not used, which results to a more secure network
- Each DIF can support a set of QoS cubes and provides an API to allow applications to request service with certain QoS parameters
- Each DIF has its own private internal addresses, which means that a global address space is not required
- Names for applications, nodes and Points of Attachments to the network exist, as well as a directory, mapping applications to nodes

A collaboration between:

i2cat · Boston University · TSSG · TRIA

What's coming next?

- Development of a first RINA prototype on top of TCP/IP
- Measurements and evaluation against the current Internet architecture
- Refinement of the current specification

Adoption, no migration!