# OpenFlow Trials and Deployments

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NANOG 50

# IU GlobalNOC

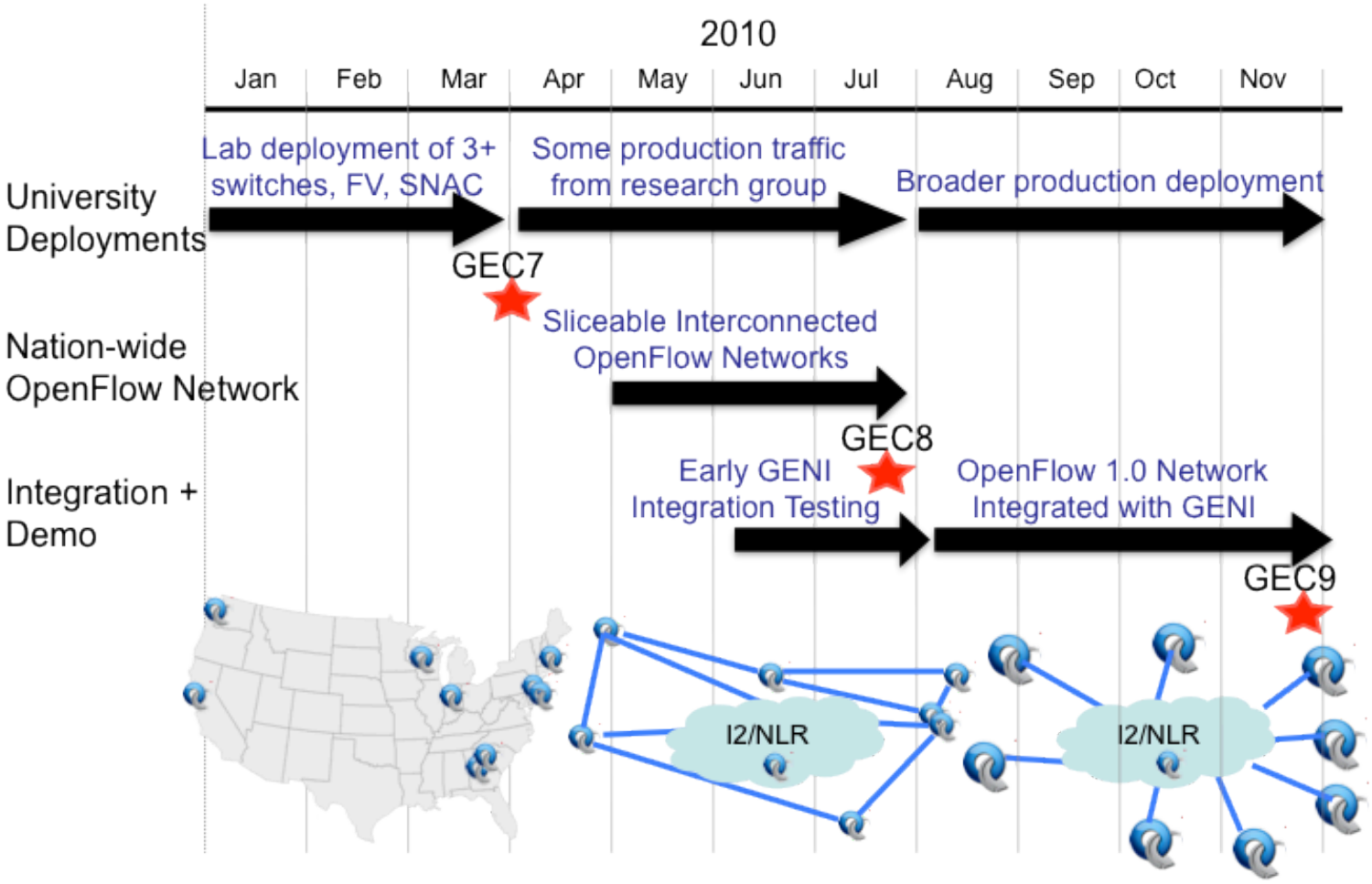
- Provide Network Management Services to Universities and Non-Profits
  - NMS Software-as-a-Service, NOC and Engineering Services
- 18 National and Regional Research & Education Networks
- 3,000+ Devices (DWDM, Switch, Routers)
- 5,000 circuits

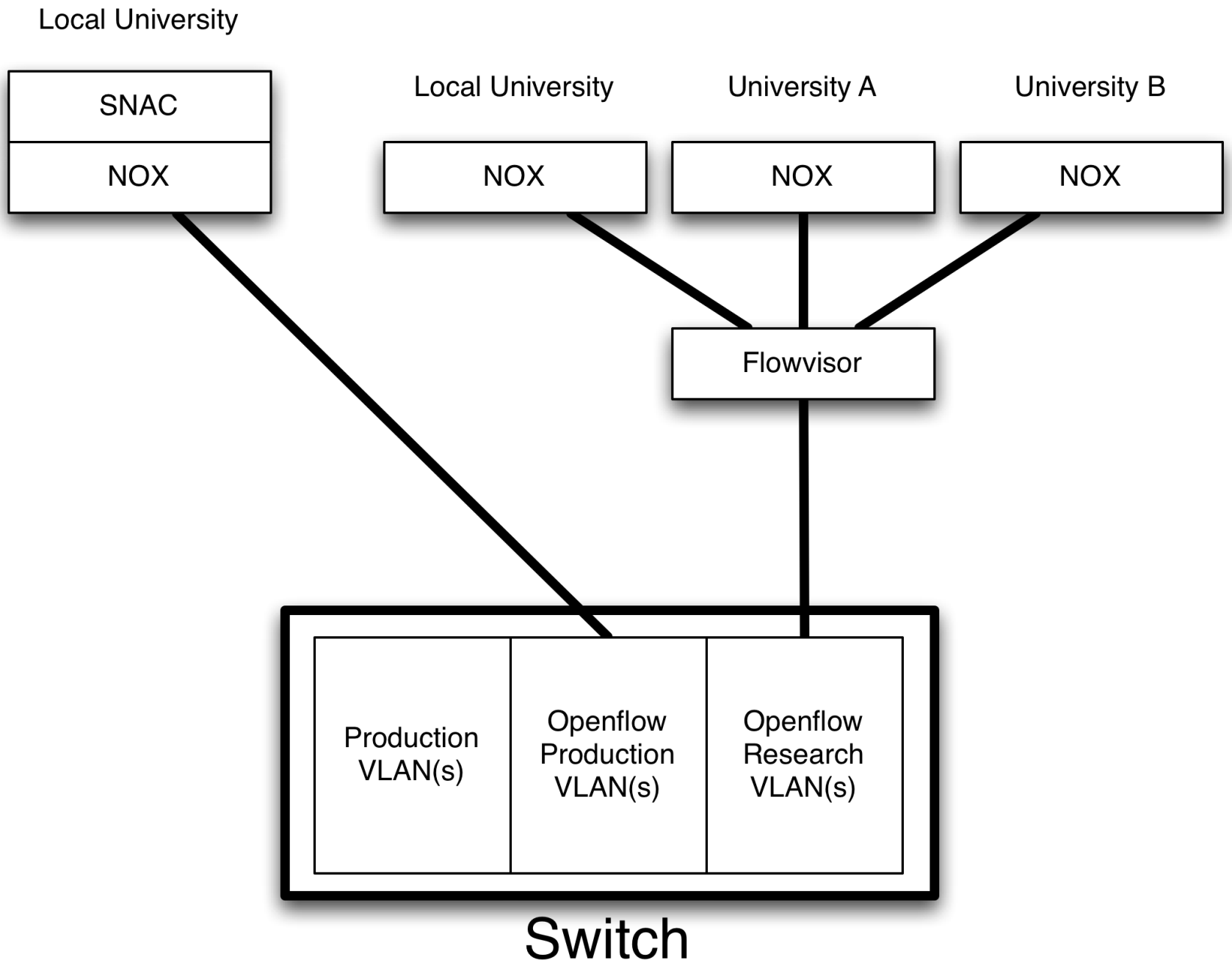

CEN
C·I·C
1958 – 2008
OmniPoP
gMOC
GENI META-OPERATIONS CENTER
MAX
AMPATH
PATHWAY OF THE AMERICAS
I - L I G H T
Indiana's Optical Network
Indiana GigaPOP
indiana.gigapop.net
INDIANA UNIVERSITY
INTERNET2
Open Science Grid
IP grid
manLan
Manhattan Landing
Exchange Point
NLR
light the future
TransPAC2
REN-ISAC

# OpenFlow and GENI


8 Universities, GPO/BBN, & 2 National Backbones

# OpenFlow GENI Roadmap



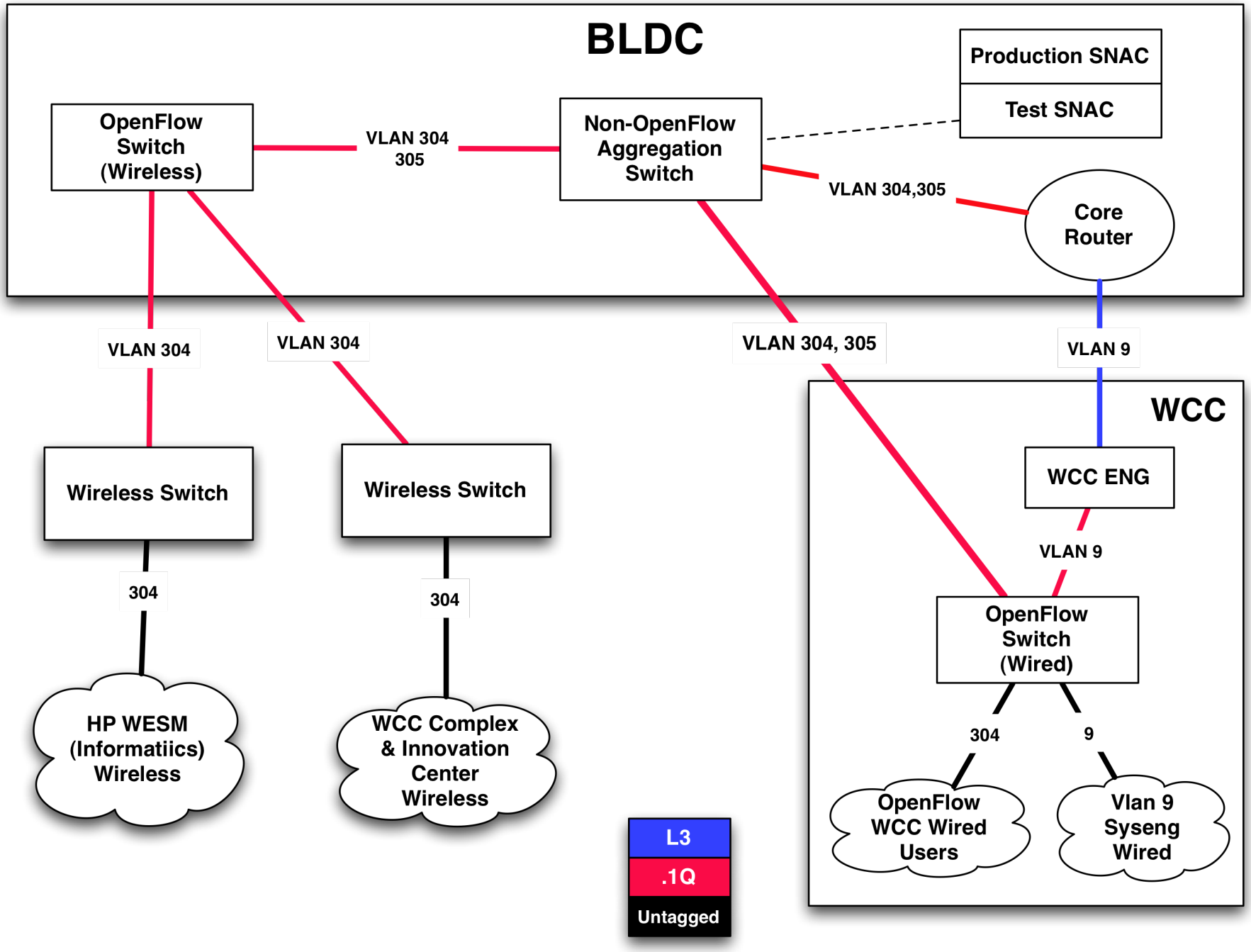

Local University
SNAC
NOX
Local University
NOX
University A
NOX
University B
NOX
Flowvisor
Production VLAN(s)
Openflow Production VLAN(s)
Openflow Research VLAN(s)
Switch

# IU Deployment

- Focused on Edge (Closet) Deployment
- Goals:
  - Stress-Test Current Implementations
  - Verify “Sandboxing” of Openflow
  - Develop Monitoring Tools
  - Prepare for Production Deployments

# Deployment Methodology

- Initially Deploy Separate Switches
- Production VLAN + OF VLAN w/o OF
- Enable OF & Move Users onto OF  VLAN
- Wireless SSID Plumbed into OF VLAN
  - Quick/Easy User Opt-in/Opt-out
  - Easy way to add user traffic (4,000 APs)


BLDC
Production SNAC
Test SNAC
OpenFlow Switch (Wireless)
VLAN 304 305
Non-OpenFlow Aggregation Switch
VLAN 304,305
Core Router
VLAN 304
VLAN 304
VLAN 304, 305
VLAN 9
WCC
WCC ENG
VLAN 9
Wireless Switch
Wireless Switch
304
304
OpenFlow Switch (Wired)
304
9
HP WESM (Informatiics) Wireless
WCC Complex & Innovation Center Wireless
OpenFlow WCC Wired Users
Vlan 9 Syseng Wired
L3
.1Q
Untagged

# Status

- Indiana University
  - 7 switches deployed
  - ~40 users on OF production network
- National LambdaRail
  - 5 OF switches deployed on nat'l footprint
- Internet2
  - 1 OF switch deployed
- Multiple Experiments Running at GEC9

# Next Steps @ IU

- Add More OpenFlow Specific Monitoring
- Actively Recruit Users to Increase Load
- Develop Initial OpenFlow Applications
- Deploy OpenFlow to Production Switches
- Deploy Internal, Open-Source and Commercial Applications

# What will we do with OpenFlow ?

- 1k-3k TCAM Entries in Typical Edge Switch
- Difficult to take advantage of:
  - Manual Config, SNMP Writes, RADIUS
  - Limited Actions (allow/deny)
  - Vendor Specific
- But what if you could program these through a standard API ?

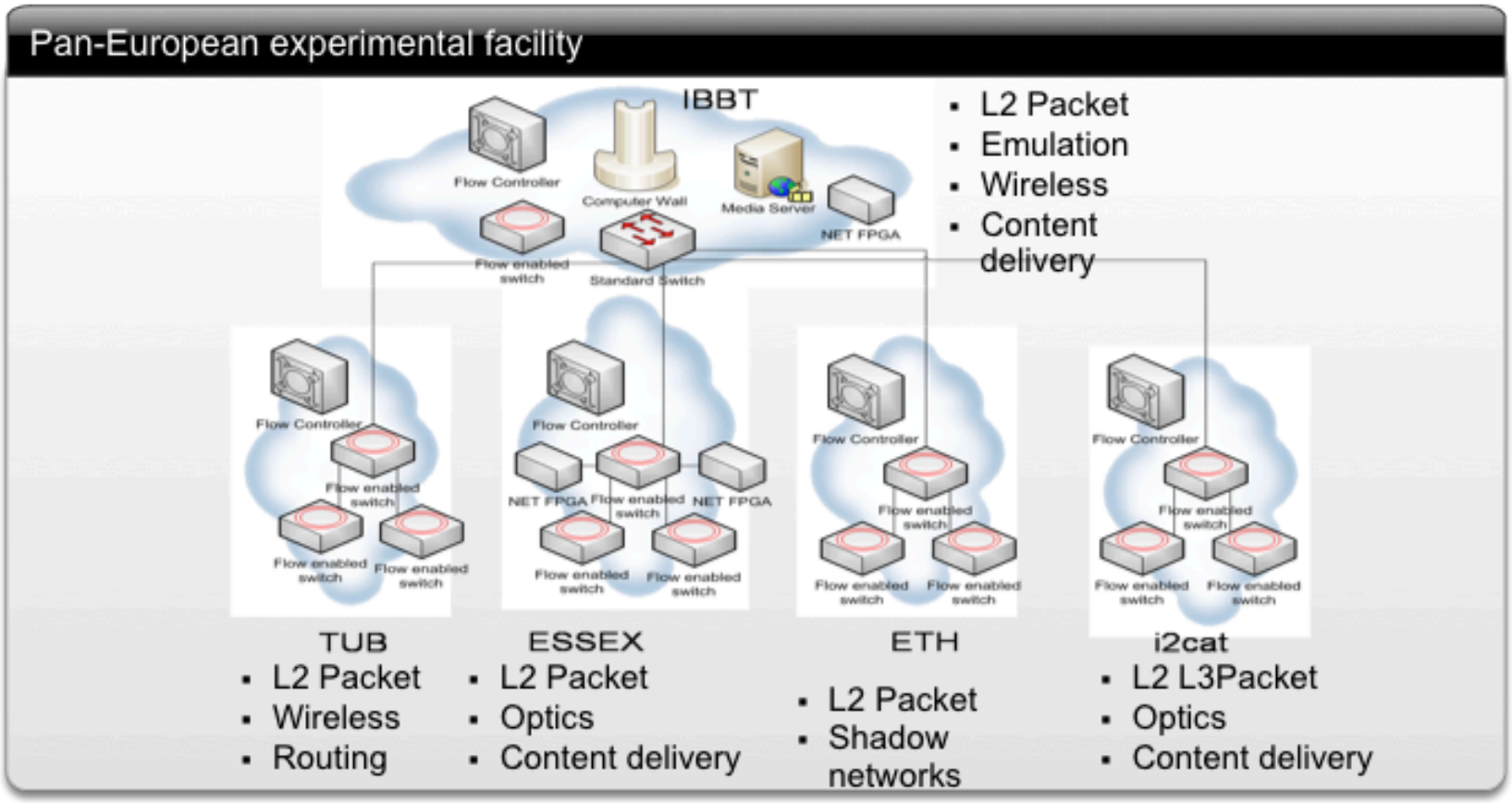
# Edge Applications

- NAC
  - Auth, Redirect, Block
- Integrate with IDS/IPS
  - Push Filters to Edge
- Virtualization (FlowVisor)
  - Different Control-Planes for Different Classes of Traffic

# Core Applications

- Dynamic Bandwidth/Path Provisioning
  - Low Average Utilization with Periodic Large Flows (Scientific Datasets)
  - Tools that Allow Apps to Proactively Reserved Bandwidth/Path
  - OpenFlow Provides Better Mechanism for Provisioning - esp. multi-vendor

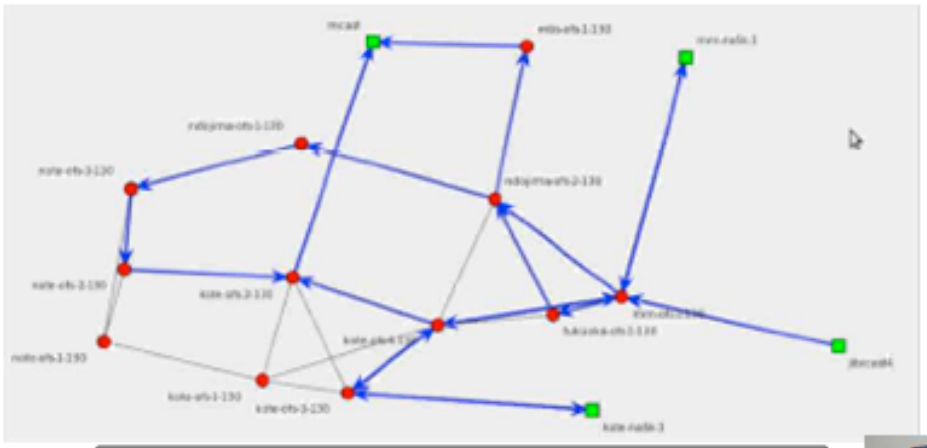
# 3 New EU Projects: OFELIA, SPARC, CHANGE



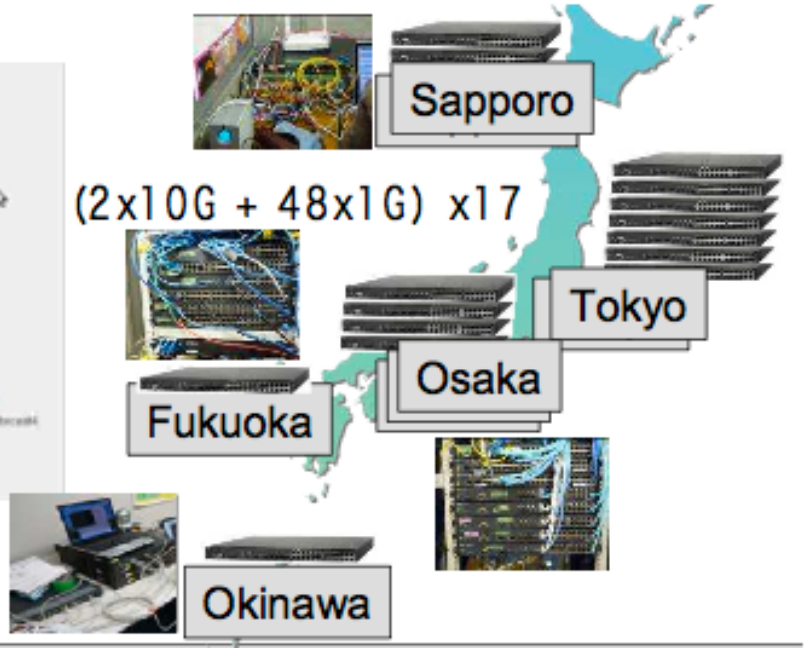
# EU Project Participants

- Germany
  - Deutsch Telekom Laboratories
  - Technishche Universitat Berlin
  - European Center for ICT
  - ADVA AG Optical Networking
  - NEC Europe Ltd.
  - Eurescom
- United Kingdom
  - University of Essex
  - Lancaster University
  - University College London
- Spain
  - i2CAT Foundation
  - University of the Basque Country, Bilbao
- Romania
  - Universitatea Politehnica Bucuresti
- Sweden
  - ACREO AB (Sweden)
  - Ericsson AB Sweden (Sweden)
- Hungary
  - Ericsson Magyarorszag Kommunikacios Rendszerek KFT
- Switzerland
  - Dreamlab Technologies
  - Eidgenossische Technische Hochschule Zurich
- Italy
  - Nextworks
  - Universita` di Pisa
- Belgium
  - Interdisciplinary Institute for Broadband Technology
  - Universite catholique de Louvain

# OpenFlow Deployment in Japan NEC and JGN2Plus (NICT)



Flow and topology visualization GUI




- Network virtualization and slicing
- HD video distribution in different slices
  - Baseball game
  - Snow festival

# Global Interest


**11,129 visits came from 1,252 cities**

Detail Level: City | Country/Territory | Sub Continent Region | Continent  Dimension: None

Site Usage | Goal Set 1

| Visits | Pages/Visit | Avg. Time on Site | % New Visits | Bounce Rate |
|---|---|---|---|---|
| 11,129 | 2.85 | 00:05:33 | 41.05% | 49.09% |
| % of Site Total: 100.00% | Site Avg: 2.85 (0.00%) | Site Avg: 00:05:33 (0.00%) | Site Avg: 40.89% (0.37%) | Site Avg: 49.09% (0.00%) |

| | Detail Level: City | Visits ↓ | Pages/Visit | Avg. Time on Site | % New Visits | Bounce Rate |
|---|---|---|---|---|---|---|
| 1. | Shibuya | 530 | 2.85 | 00:02:47 | 36.79% | 45.09% |
| 2. | Hanoi | 519 | 3.24 | 00:06:16 | 26.01% | 46.85% |
| 3. | San Jose | 381 | 3.01 | 00:03:36 | 39.63% | 46.19% |
| 4. | Stanford | 368 | 3.61 | 00:03:39 | 12.23% | 41.85% |
| 5. | Tokyo | 290 | 2.78 | 00:03:53 | 45.17% | 56.90% |
| 6. | Atlanta | 230 | 2.86 | 00:05:26 | 18.70% | 43.04% |
| 7. | San Ch'Ung | 226 | 3.53 | 00:05:45 | 23.89% | 31.86% |
| 8. | San Francisco | 185 | 2.63 | 00:02:58 | 39.46% | 52.43% |
| 9. | Mountain View | 176 | 3.24 | 01:36:33 | 22.73% | 48.43% |
| 10. | Bangalore | 167 | 2.37 | 00:05:11 | 39.52% | 47.90% |

# Current Trials and Deployments

## 68 Trials/Deployments - 13 Countries

# Current Trials and Deployments

**USA-Academia**

Stanford University, CA
University of Washington, WA
Rutgers University, NJ
Princeton University, NJ
Clemson University, SC
Georgia Tech, GA
University of Wisconsin at Madison, WI
Indiana University
ICSI Berkeley, CA
University of Massachusetts at Lowell
Clarkston University
Columbia University (course offered)
University of Kentucky
UC San Diego
UC Davis
iCAIR/Northwestern
Rice University
Purdue University
Northern Arizona University

**USA-Industry**

Internet2
Cisco
Juniper
HP
Ciena
Deutsche Telekom R&D Lab
Marvell
Broadcom
Google
Unnamed Data Center Company
Toroki
Nicira
Big switch networks
Orange Labs

**USA-Government**

BBN
Unnamed Federal Agency

# Current Trials and Deployments

**Brazil**
University of Campinas
Federal University of Rio de Janeiro
Federal University of Amazonas
Foundation Center of R&D in Telecomm.

**Canada**
University of Toronto

**Germany**
T-Labs Berlin
Leibniz Universität Hannover

**France**
ENS Lyon/INRIA

**India**
VNIT
Mahindra Satyam

**Italy**
Politecnico di Torino

**United Kingdom**
University College London
Lancaster University
University of Essex

**Taiwan**
National Center for High-Performance Computing
Chunghwa Telecom Co

**Japan**
NEC
JGN Plus
NICT
University of Tokyo
Tokyo Institute of Technology
Kyushu Institute of Technology
NTT Network Innovation Laboratories
KDDI R&D Laboratories
Unnamed University

**South Korea**
KOREN
Seoul National University
Gwangju Institute of Science & Tech
Pohang University of Science & Tech
Korea Institute of Science & Tech
ETRI
Chungnam National University
Kyung Hee University

**Spain**
University of Granada

**Switzerland**
CERN