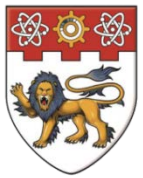
Future Internet: Are we there ?

By

A/Prof. Bu-Sung Lee, Francis

President, SingAREN

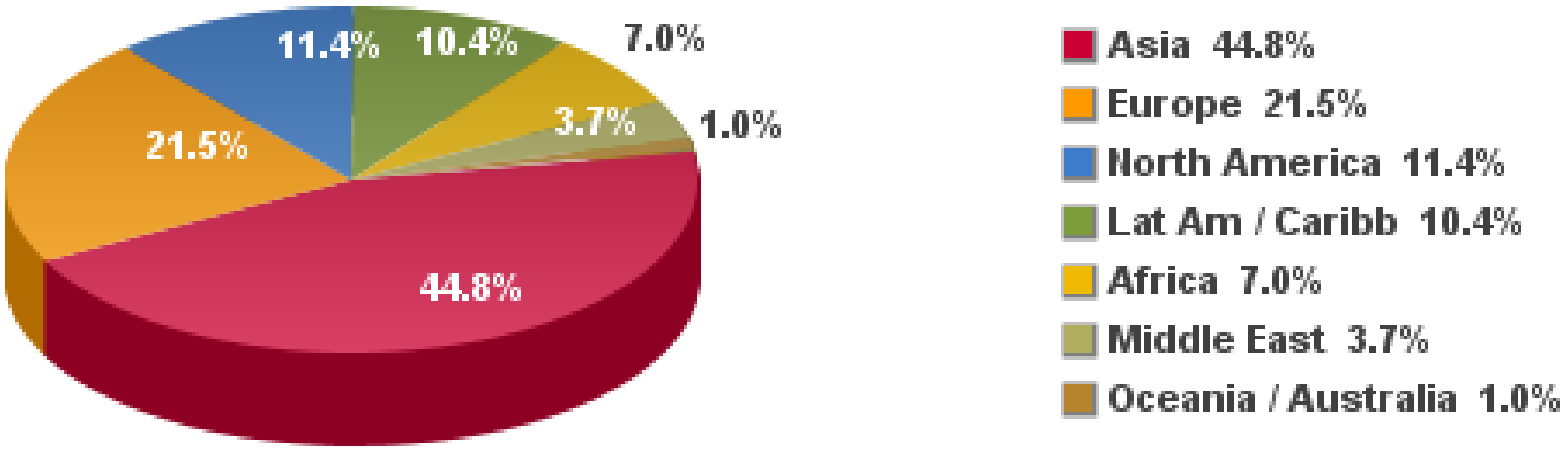


NANYANG TECHNOLOGICAL UNIVERSITY

Symposium
on
Future Internet Architecture and Technologies
Kyoto , 2013

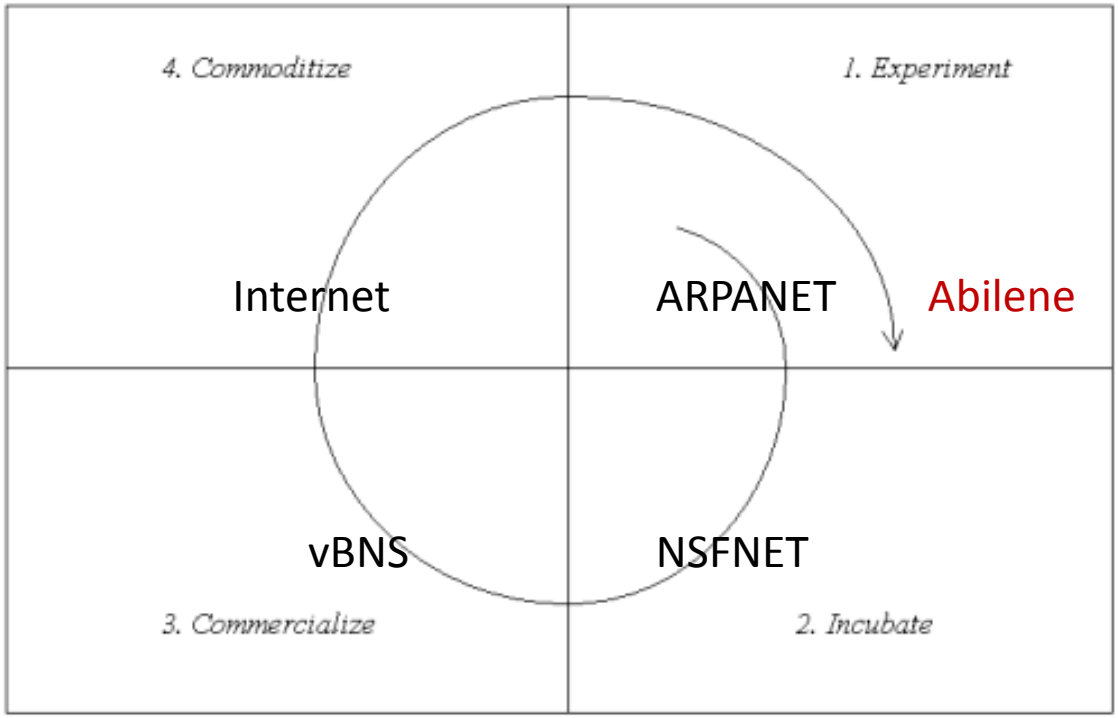
SingAREN
Singapore
Advanced Research
and Education Network

Internet Users in the World
Distribution by World Regions - 2012 Q2



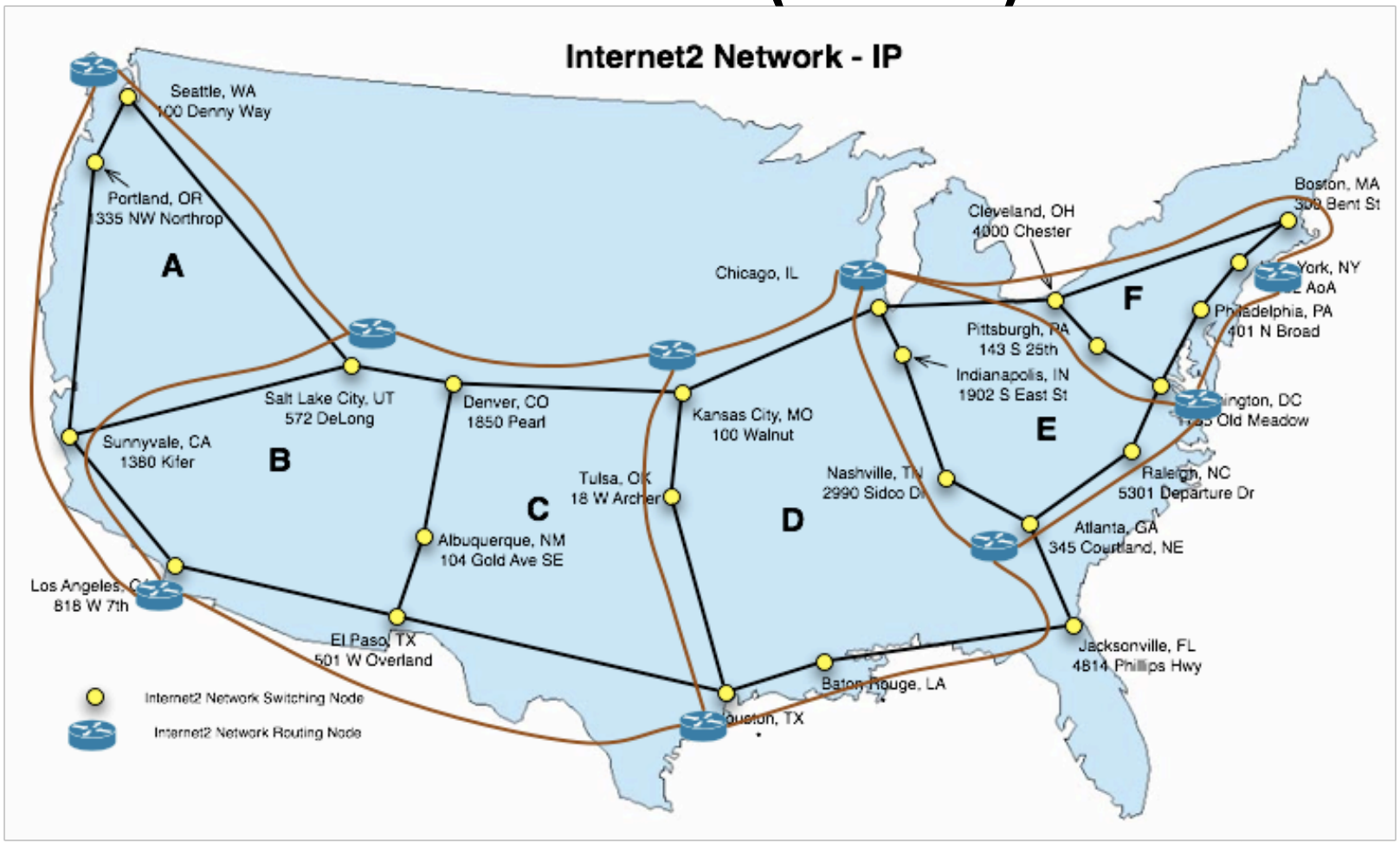
Source: Internet World Stats - www.internetworldstats.com/stats.htm
Basis: 2,405,518,376 Internet users on June 30, 2012

Life cycle model



Internet2 - 1996

Internet2 Nationwide Backbone(2006)



NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore Advanced Research and Education Network


Internet2 Network
GlobalNOC
RealTimeAtlas
100w 40n
Legend
Radar
Data Last Received: Thu Jul 25 09:06:56 UTC 2013
0
150
300
450
600 mi

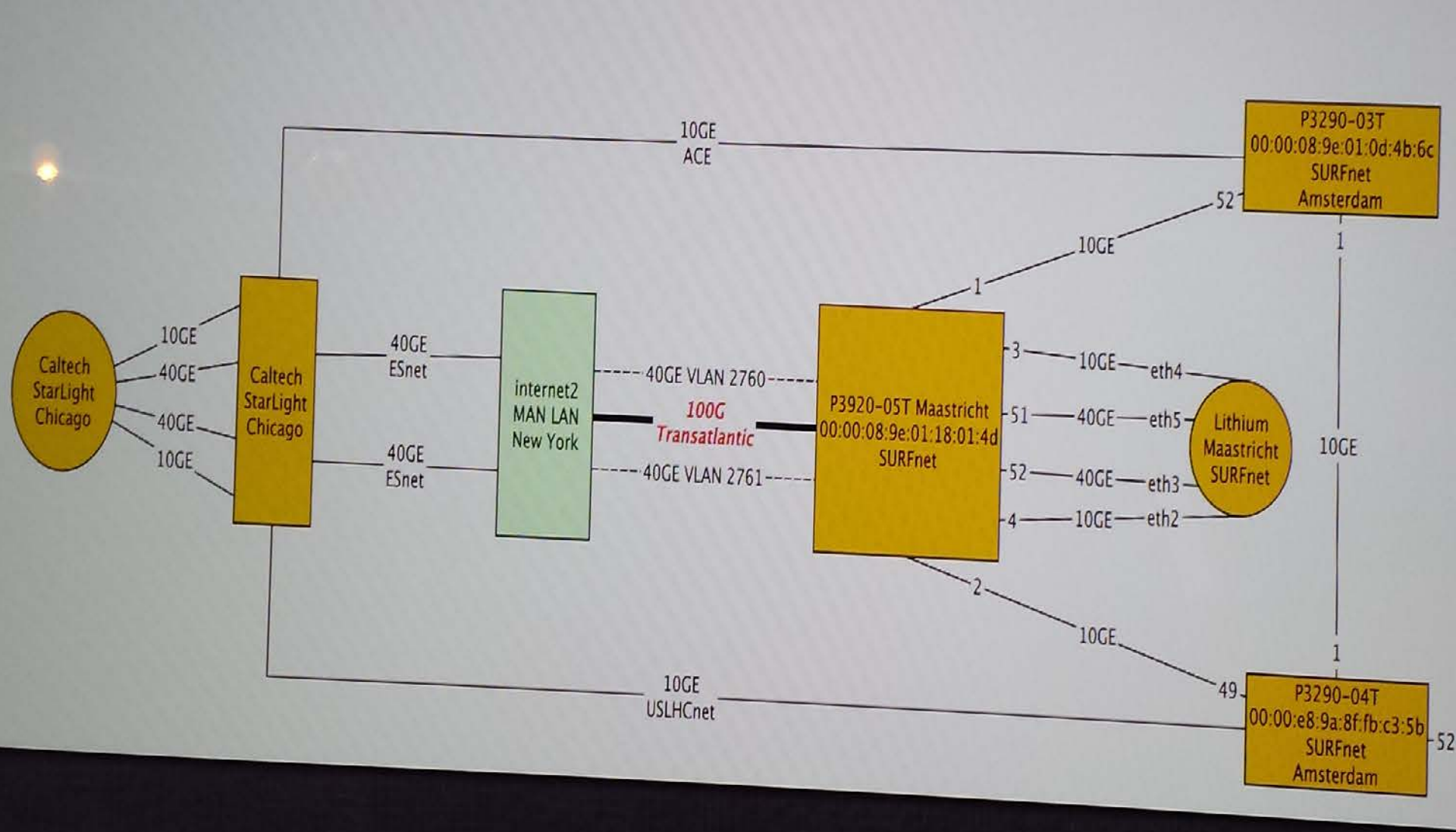
MAN LAN → AMS 93.20 Gb/s

AMS → MAN LAN 93.50 Gb/s

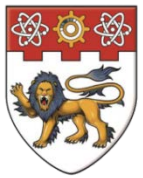
Data will refresh in 23 seconds.

Transatlantic Traffic

Refresh graph Time period: All | **24h** | 6h


10GE
ACE
P3290-03T
00:00:08:9e:01:0d:4b:6c
SURFnet
Amsterdam
52
10GE
1
1
Caltech
StarLight
Chicago
10GE
40GE
40GE
10GE
Caltech
StarLight
Chicago
40GE
ESnet
40GE
ESnet
internet2
MAN LAN
New York
40GE VLAN 2760
100G
Transatlantic
40GE VLAN 2761
P3920-05T Maastricht
00:00:08:9e:01:18:01:4d
SURFnet
3
10GE
eth4
51
40GE
eth5
52
40GE
eth3
4
10GE
eth2
Lithium
Maastricht
SURFnet
10GE
2
10GE
1
10GE
USLHCnet
49
P3290-04T
00:00:e8:9a:8f:fb:c3:5b
SURFnet
Amsterdam
52

Asia Pacific Region

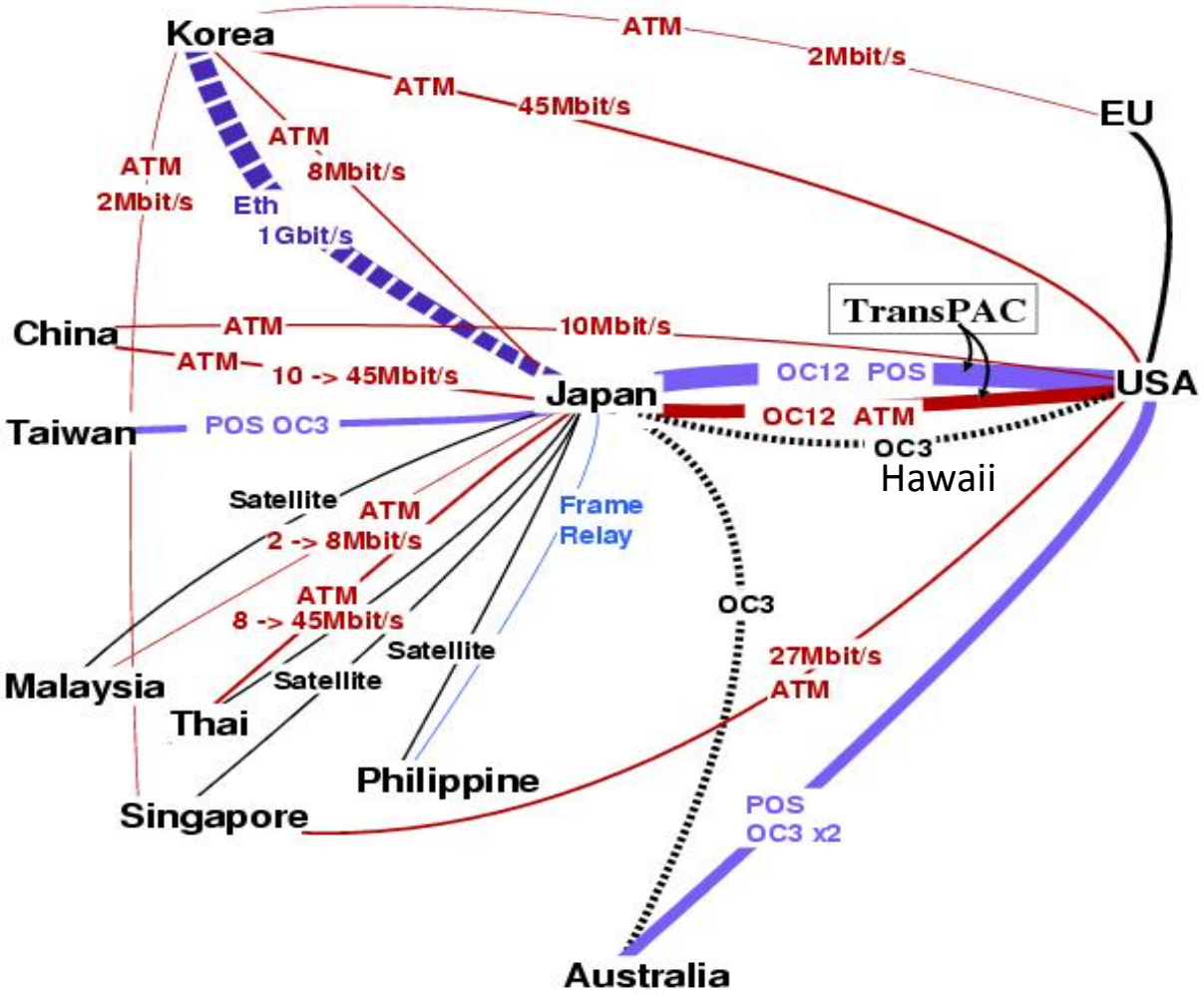


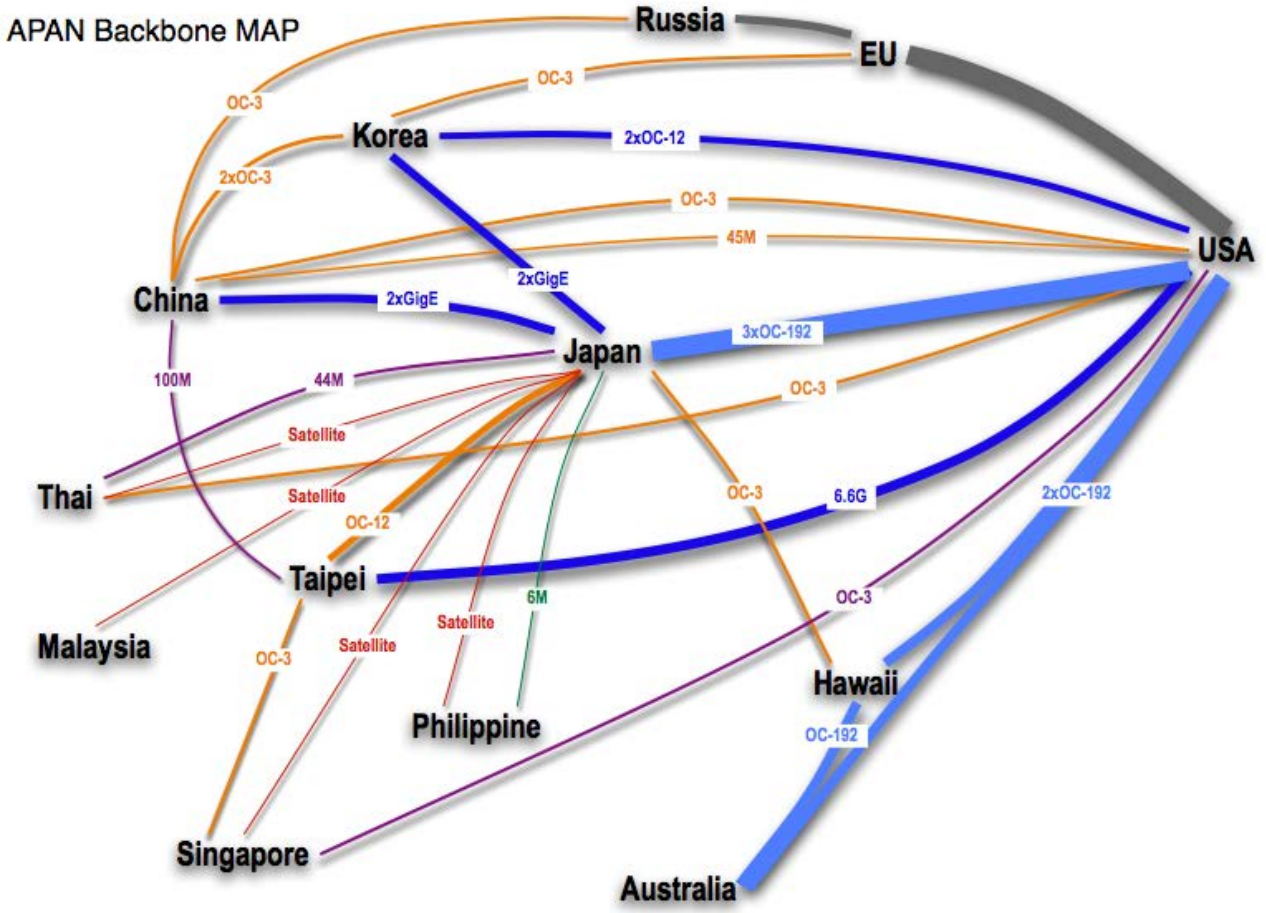
NANYANG
TECHNOLOGICAL
UNIVERSITY

SingAREN

Singapore
Advanced Research
and Education Network

APAN Backbone





APAN Backbone Topology as of 1 June 2005
[Diagram Courtesy of APAN-JP NOC]

NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore
Advanced Research
and Education Network

What is GENI?

Global Environment for Network Innovation

A Nationwide Programmable Facility for Research into Future Internet Technologies

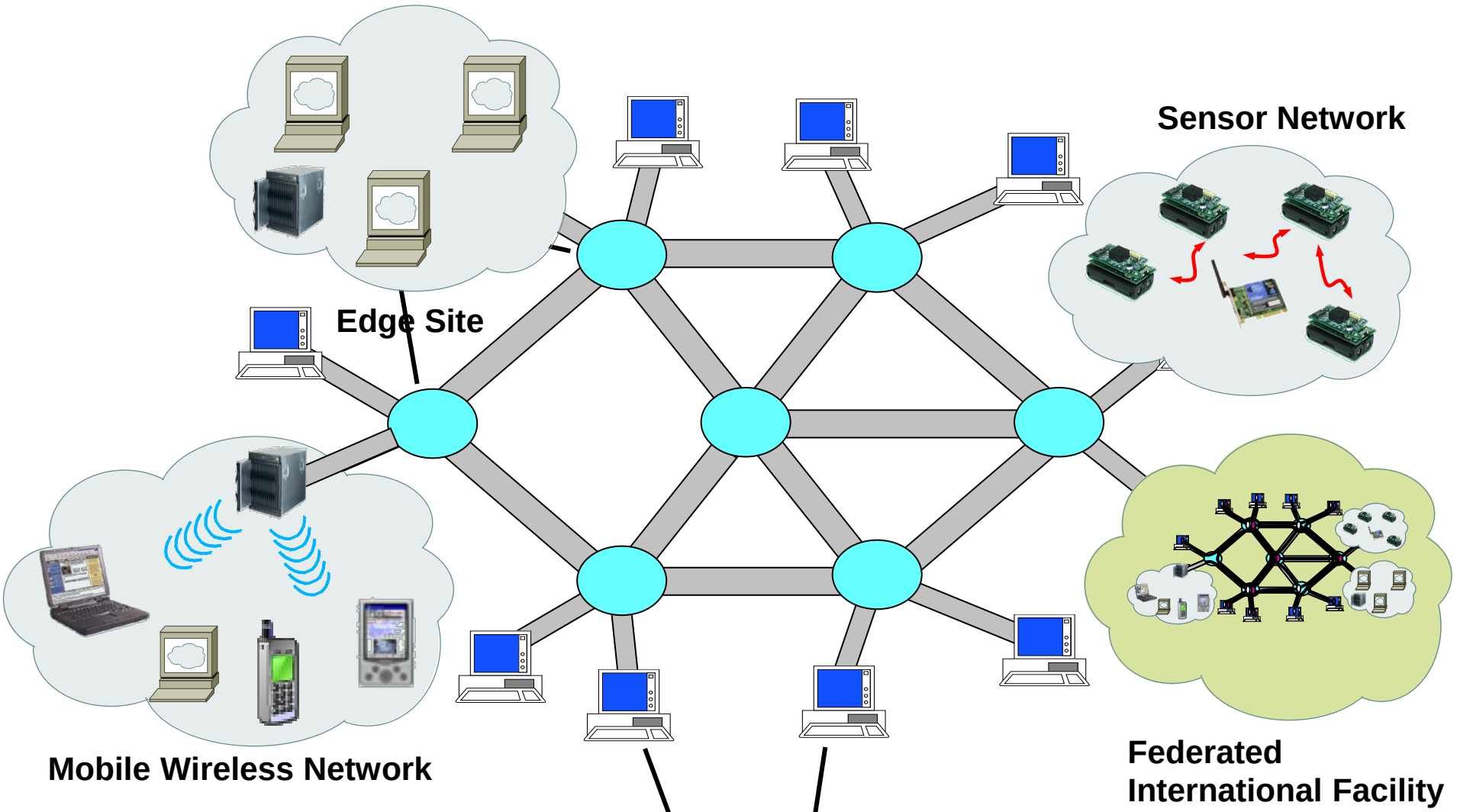
Using a 'Clean-Slate' Approach

- 'Out of the Box' Thinking

Strong Coupling with Physical Technologies

- Wireless Networking
- Optical Networking

Schematic GENI Network

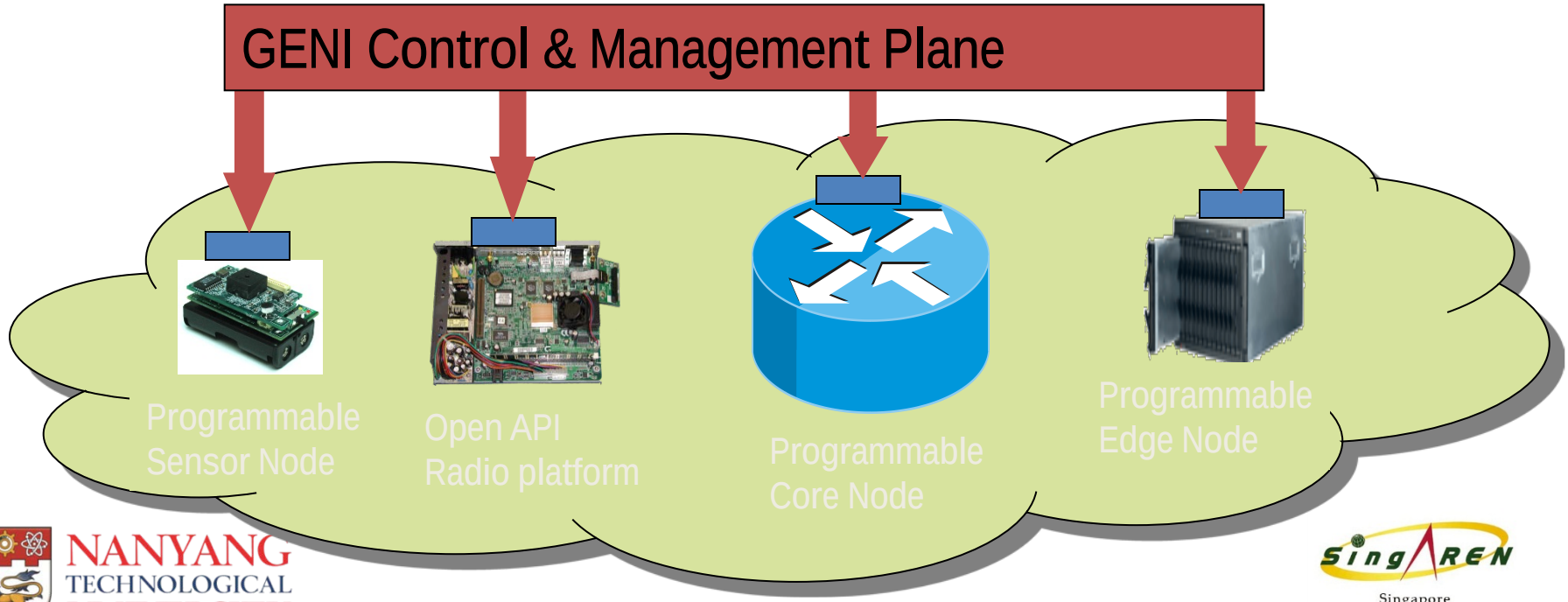


NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore
Advanced Research
and Education Network

Programmability

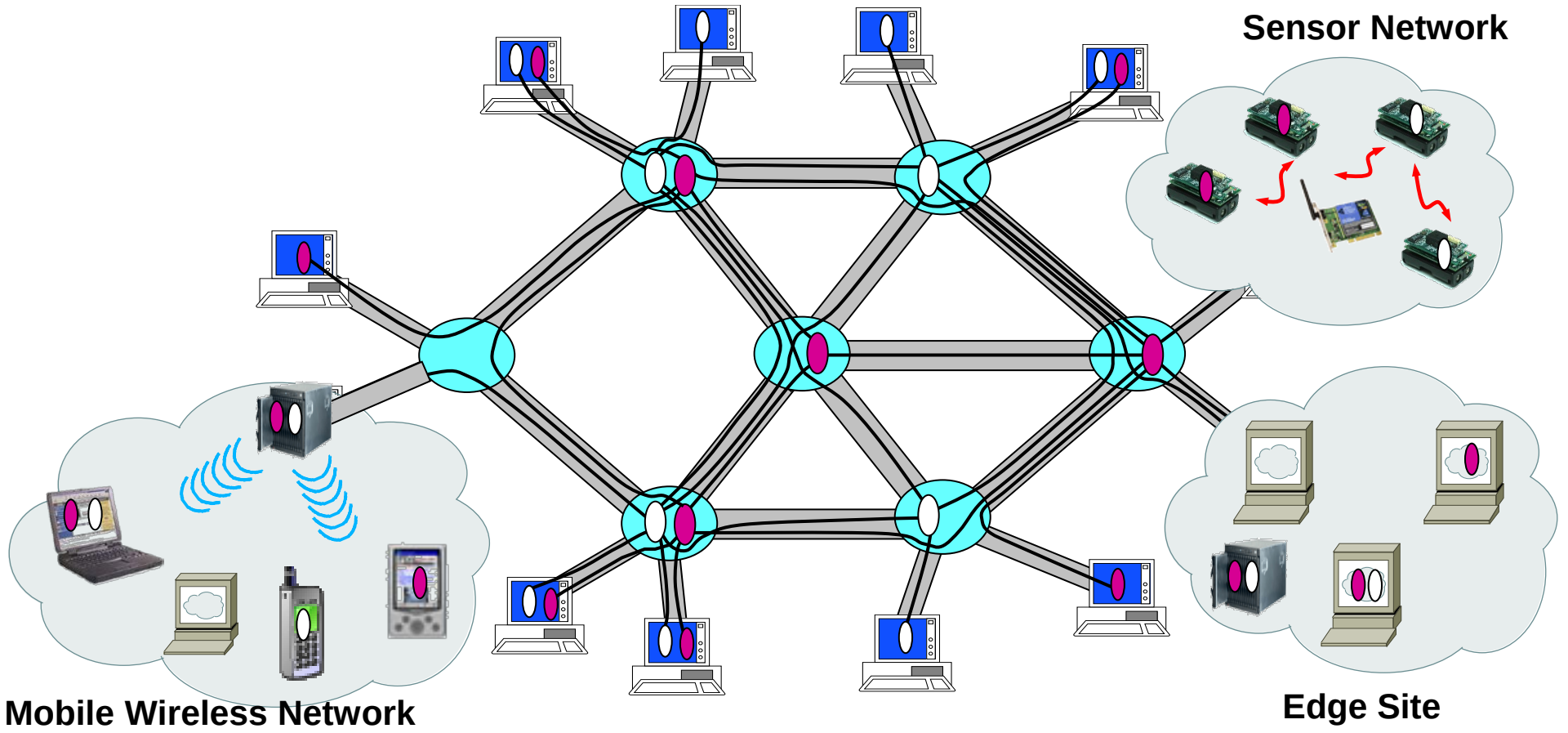
All network elements programmable via open interfaces and/or downloadable user code



NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN Singapore Advanced Research and Education Network

Slicing and Virtualization



- share resources to support many simultaneous experiments

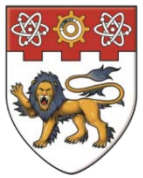
NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore Advanced Research and Education Network

GENI Design Principles

- Physical network 'substrate'
  - building block components
  - elements / nodes / links / subnets
- Software control & management framework
  - knits building blocks together
  - allows many parallel experiments (slices)
  - creates arbitrary logical topologies (virtualization)
- Programmable for 'Clean Slate' research
- Instrumented for accurate analysis
- Flexible and Phased Design
  - Support Technology Introduction during GENI Lifetime

Current status

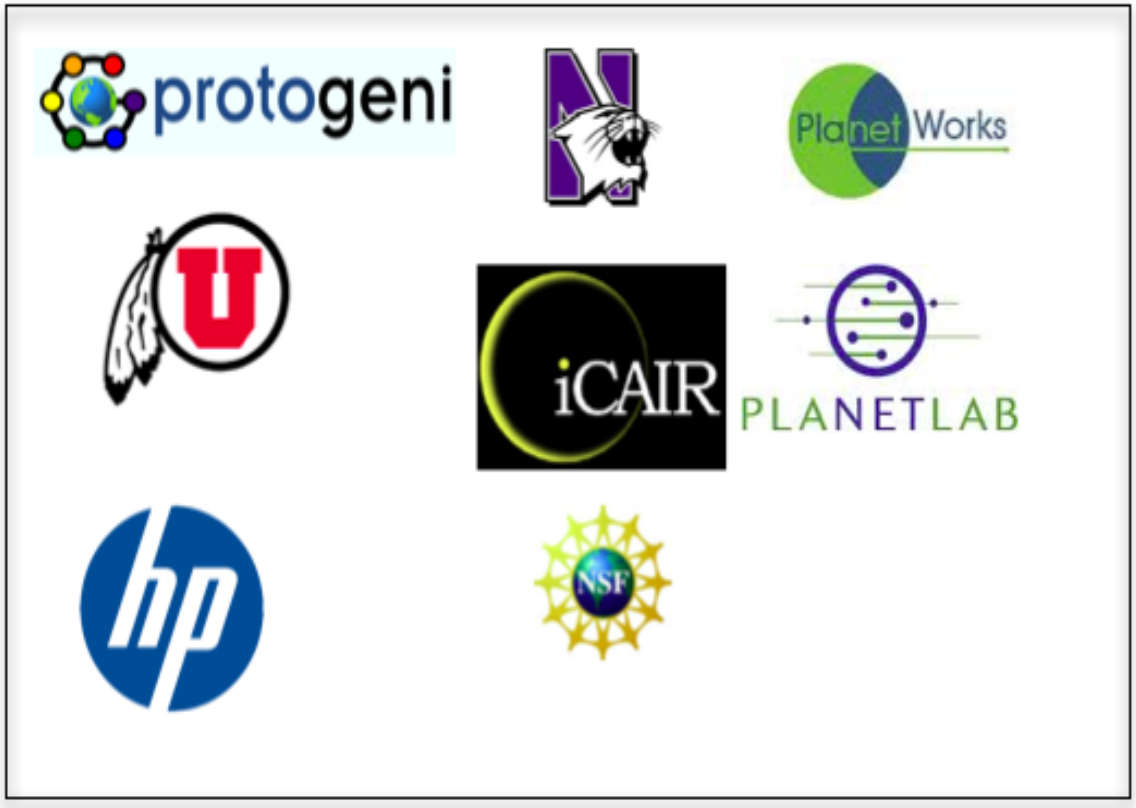


NANYANG
TECHNOLOGICAL
UNIVERSITY

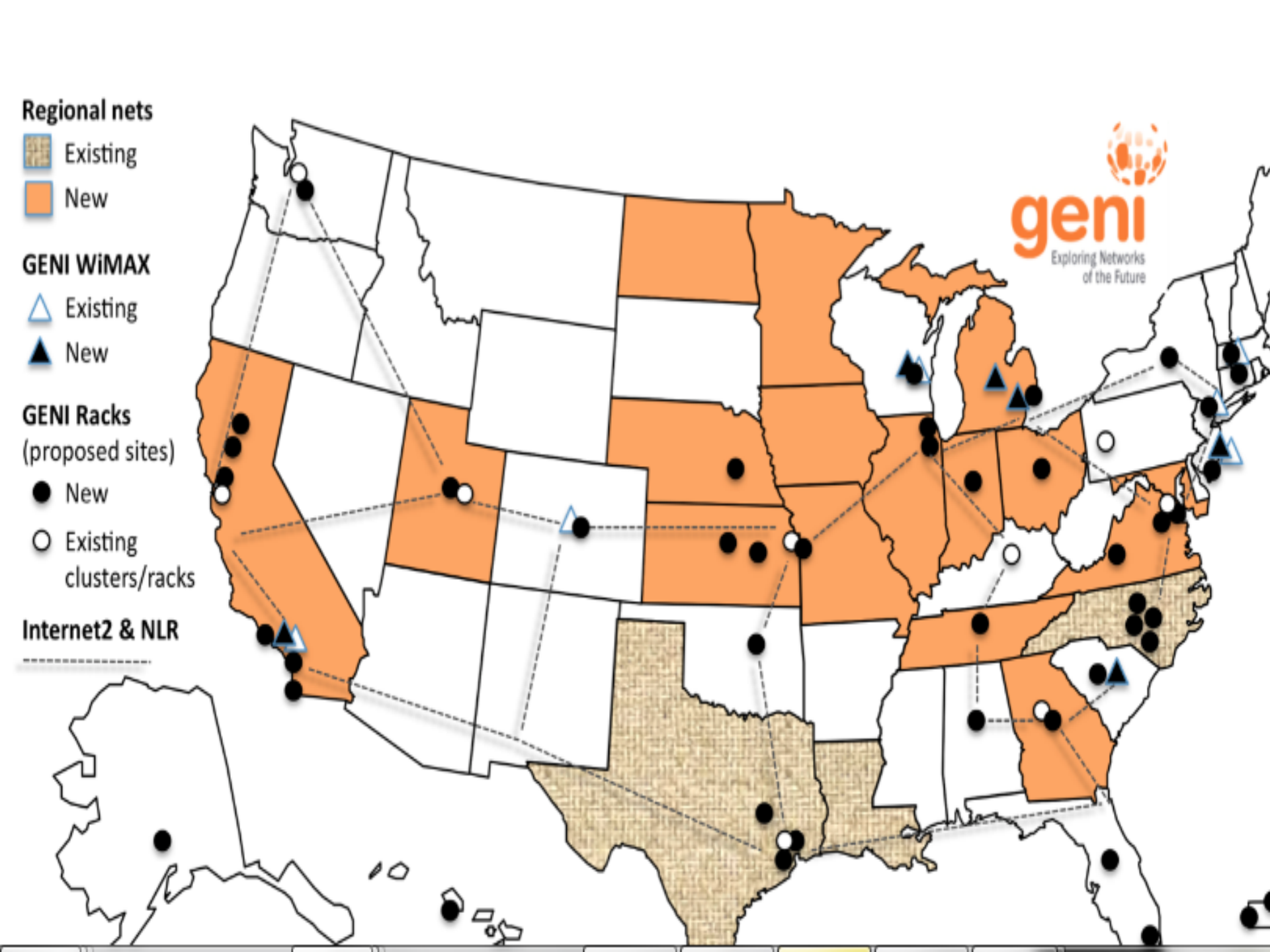
SingAREN
Singapore
Advanced Research
and Education Network

InstaGENI

www.geni.net



Singapore
Advanced Research
and Education Network


Regional nets
Existing
New
GENI WiMAX
Existing
New
GENI Racks
(proposed sites)
New
Existing clusters/racks
Internet2 & NLR
geni
Exploring Networks of the Future

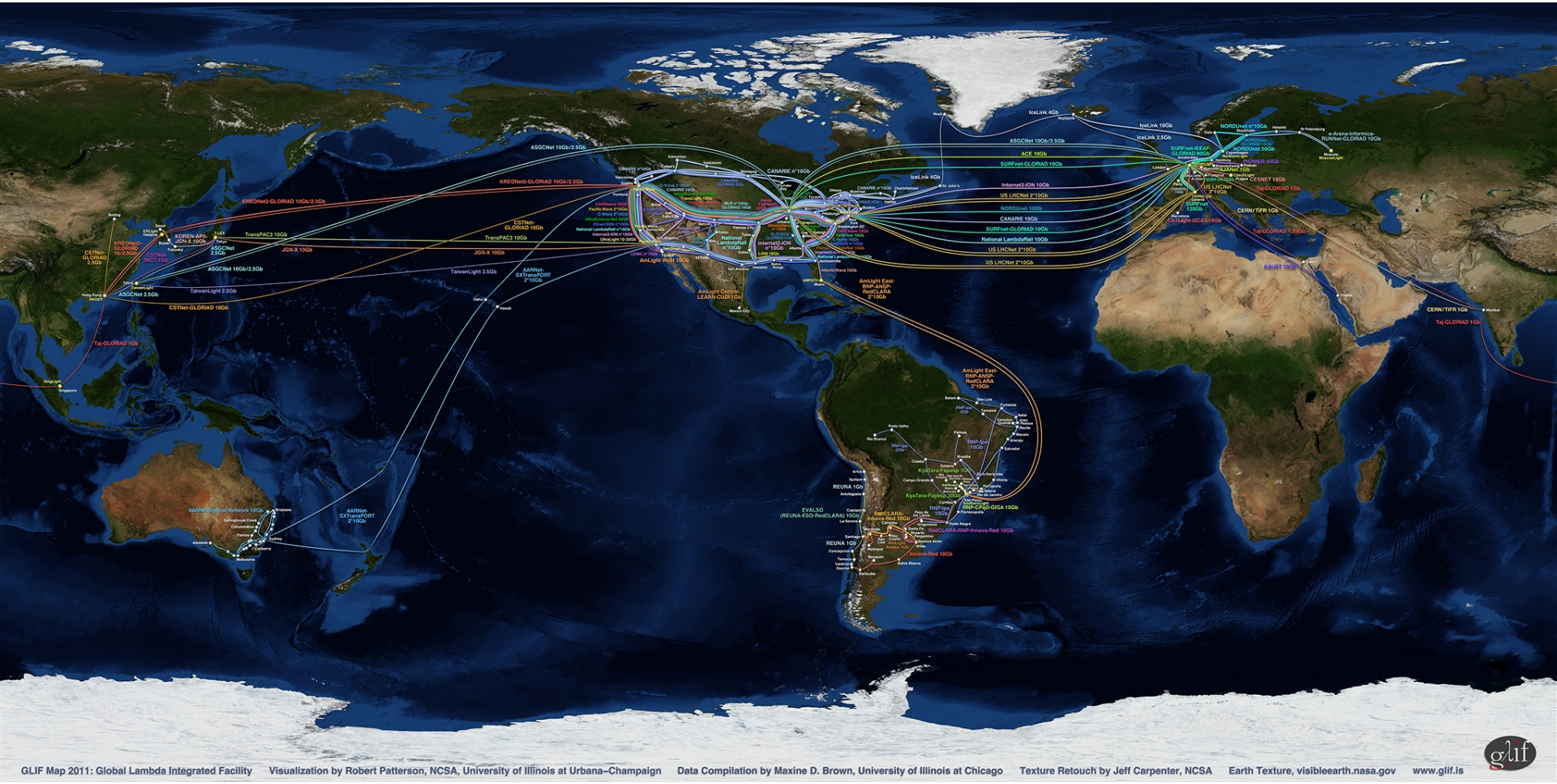
iGENI

Courtesy of Prof. Joel Mambretti, iCAIR

NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN Singapore Advanced Research and Education Network

The Global Lambda Integrated Facility (GLIF) Provides Advanced Resources and Facilities for Research Foundation Resource!



www.glif.is

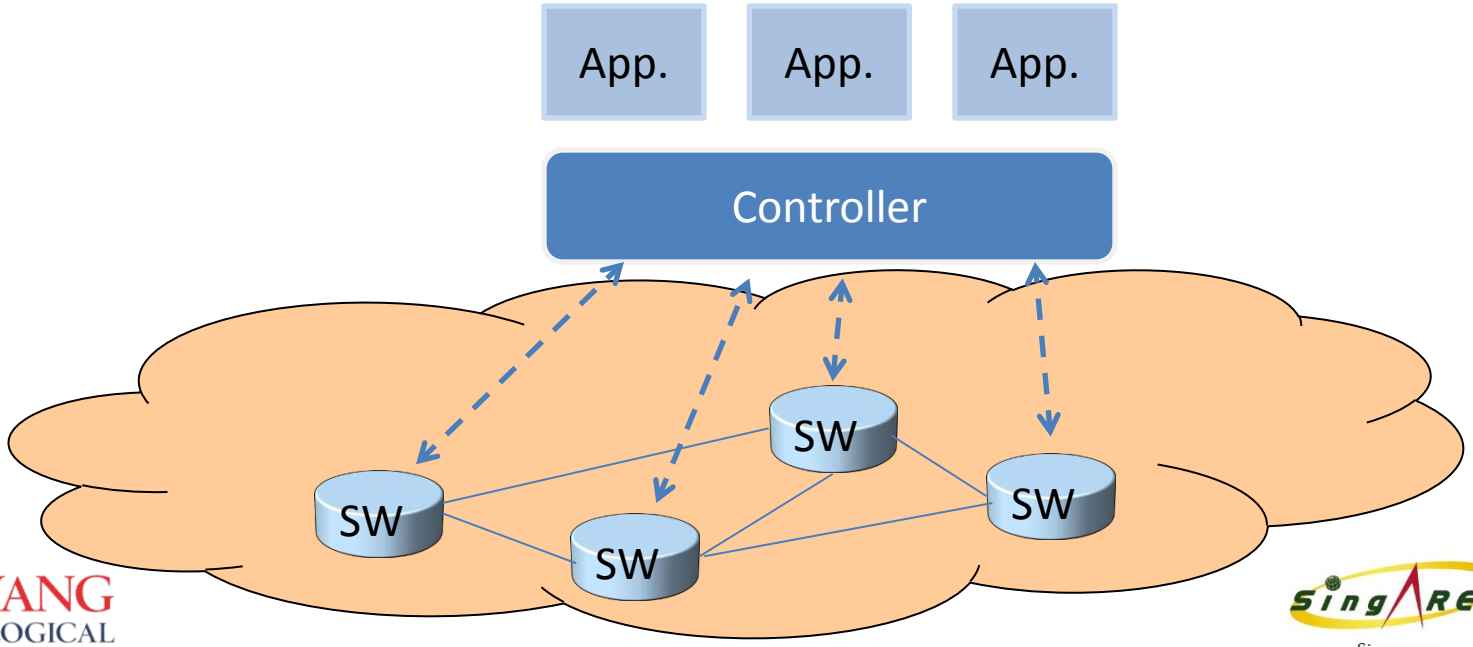
Visualization courtesy of Bob Patterson, NCSA; data compilation by Maxine Brown, UIC.

NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore Advanced Research and Education Network

What's Openflow ?

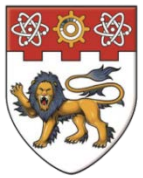
- Openflow is an implementation of Software Defined Network. Openflow defines a clear API interface between the controller and switches/forwarding devices.



Challenges in Openflow

- Designed for network engineers and programmers
- Network monitoring and management
- Limited deployment of switches supporting Openflow(especially in WAN)
- Inter-domain

Openflow experiments over RISE



NANYANG
TECHNOLOGICAL
UNIVERSITY

SingAREN

Singapore
Advanced Research
and Education Network

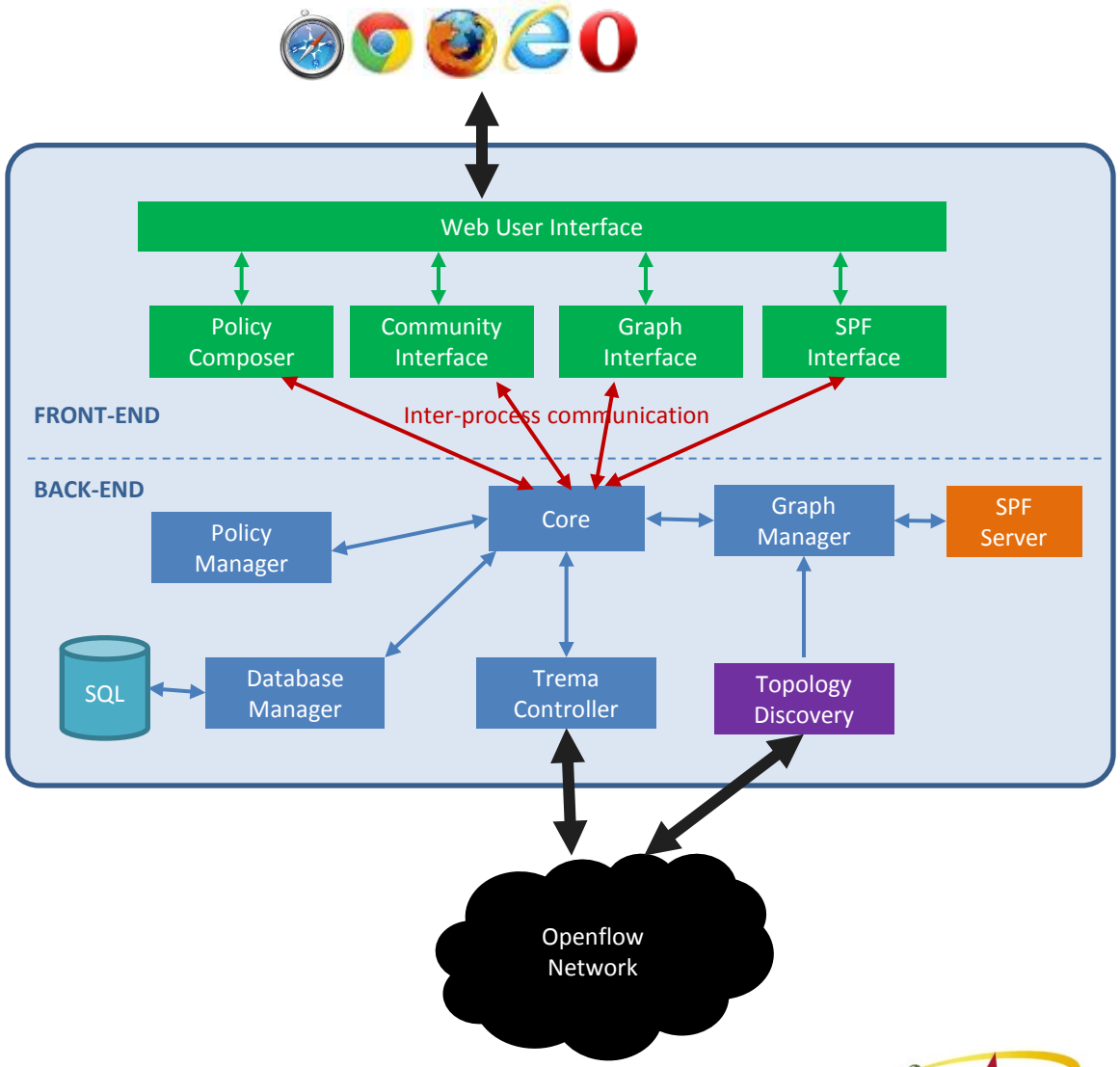
OpenFlow Web Service (cont'd)

System Front-End

- Web User Interface

System Back-End

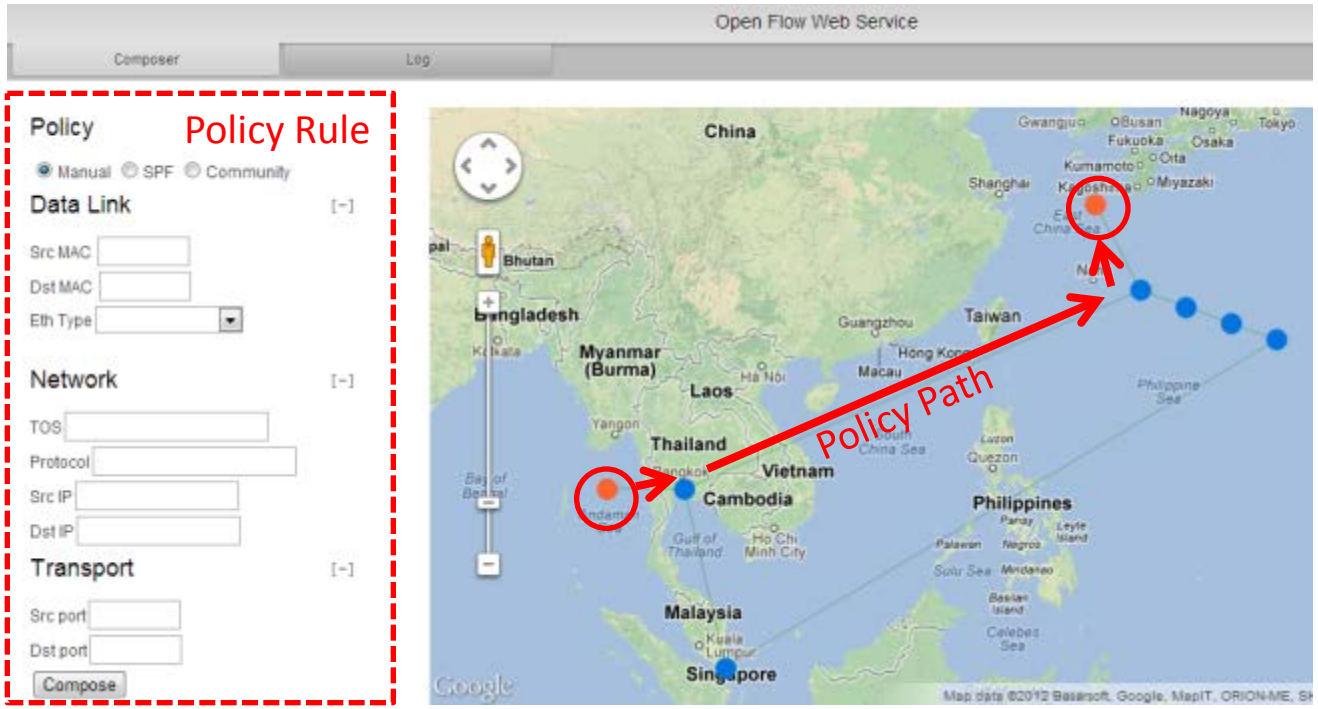
- Trema Openflow Controller
- Trema Application (Topology Discovery)
- Shortest Path First Application

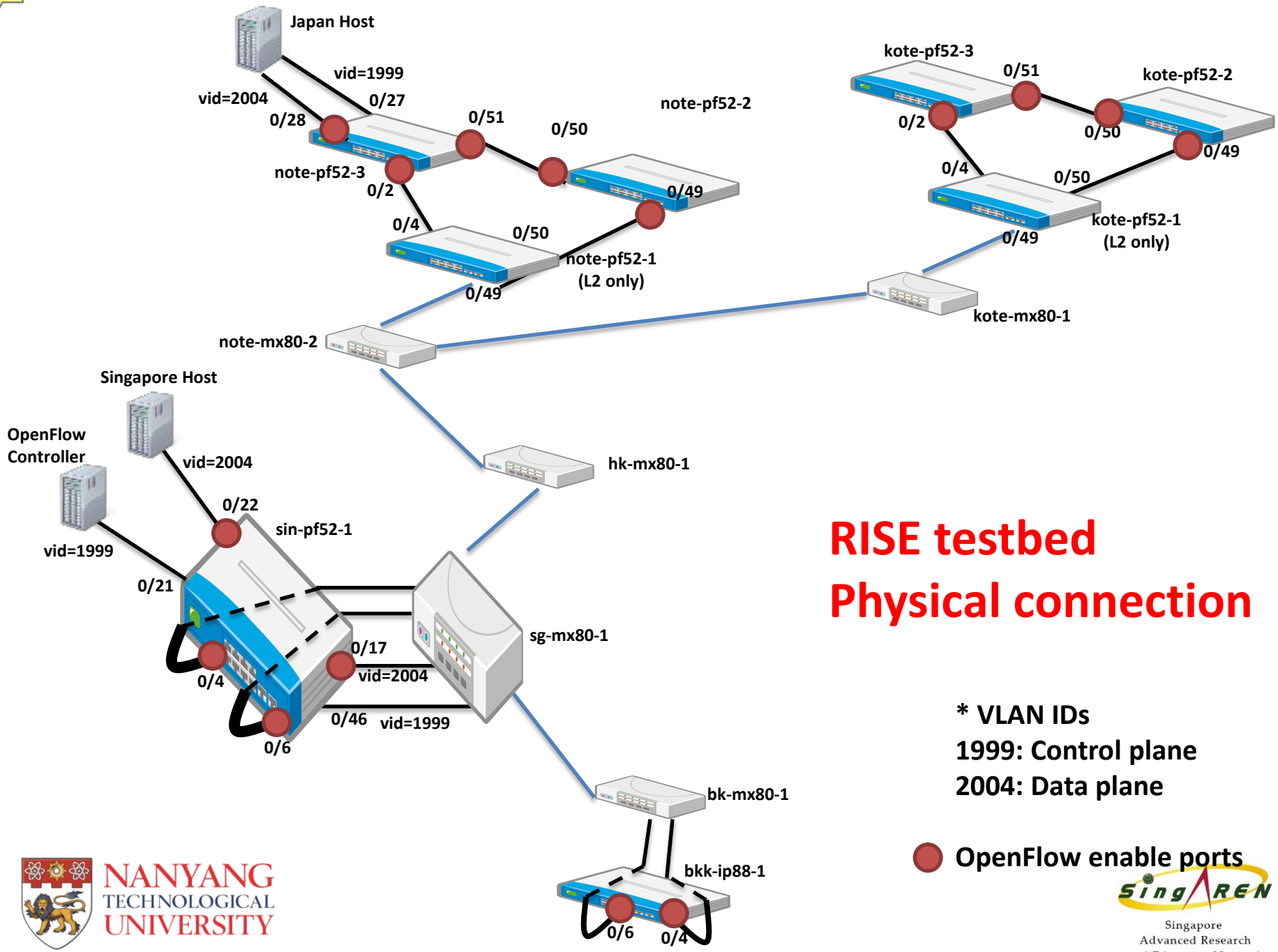


OpenFlow Web Service (cont'd)

Policy Rule : Similar to Openflow Flow (v1.0) match fields, except **in_port**

Policy Path : Directional path from source host to destination host via Openflow switches





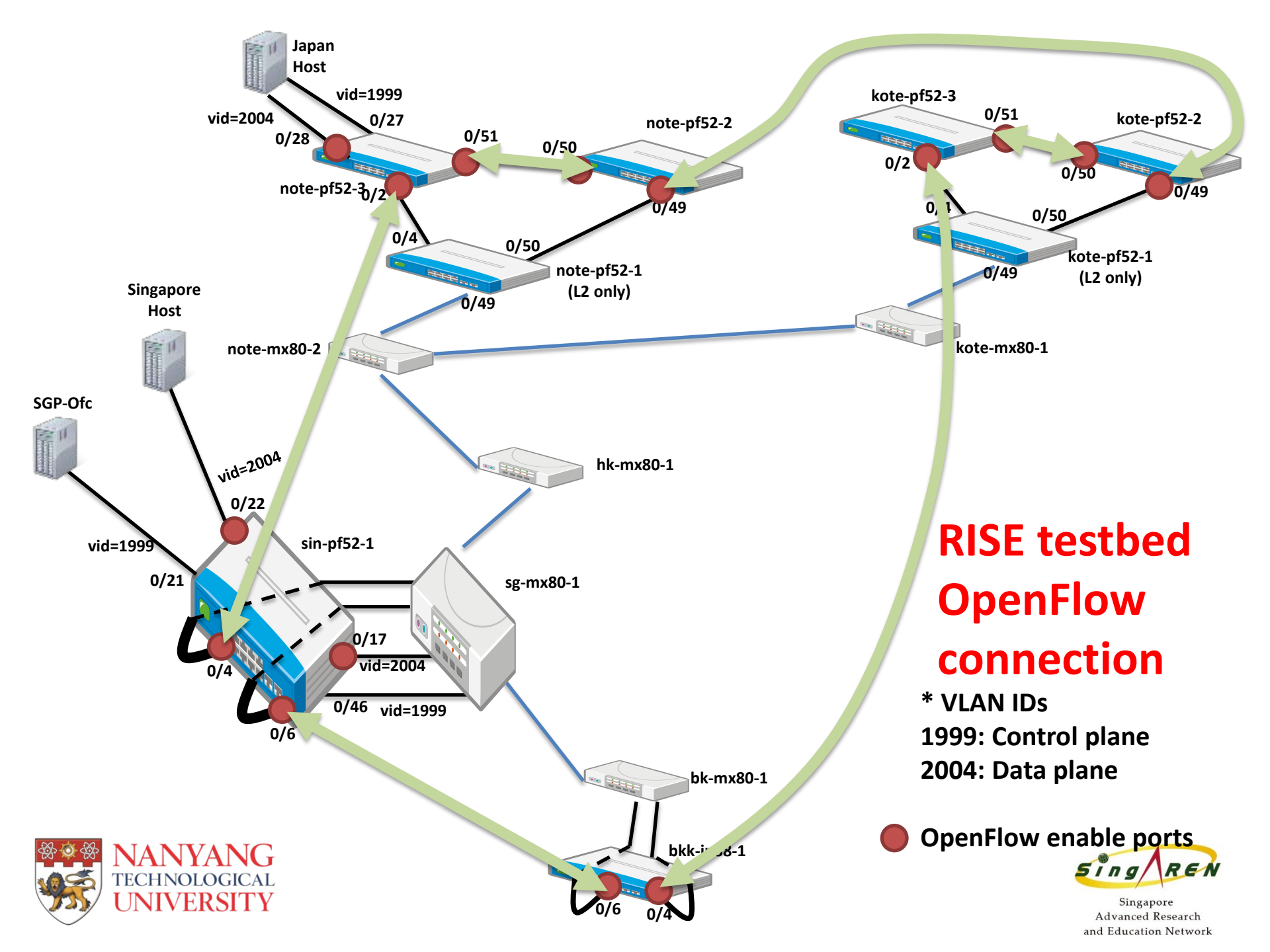
RISE testbed
Physical connection

* VLAN IDs
1999: Control plane
2004: Data plane

OpenFlow enable ports

NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore Advanced Research and Education Network



RISE testbed OpenFlow connection

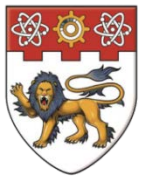
* VLAN IDs
1999: Control plane
2004: Data plane

OpenFlow enable ports

NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore Advanced Research and Education Network

HYBRID Openflow NETWORK



NANYANG
TECHNOLOGICAL
UNIVERSITY

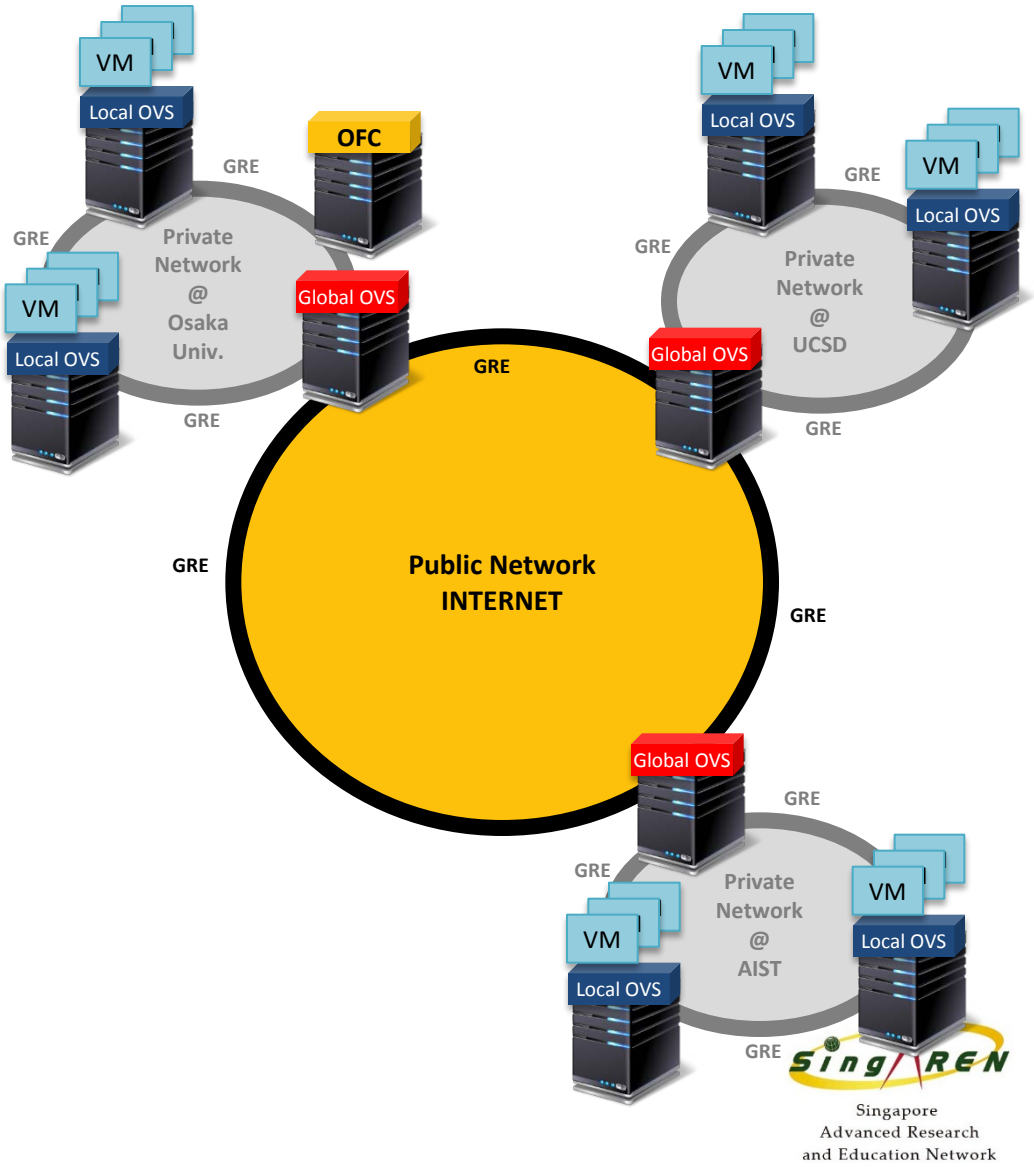
SingAREN

Singapore
Advanced Research
and Education Network

NTU OpenvSwitch (cont'd)

PRAGMA testbed

- Provided by PRAGMA
- Developed and implemented by Osaka University, AIST and UCSD
- Setup virtual networks on virtual machines forming Pragma testbed
- Virtual network can be organised using Trema OpenFlow Controller with Sliceable Routing Switch application
- Demonstrated in Pragma22, Bangkok 2013



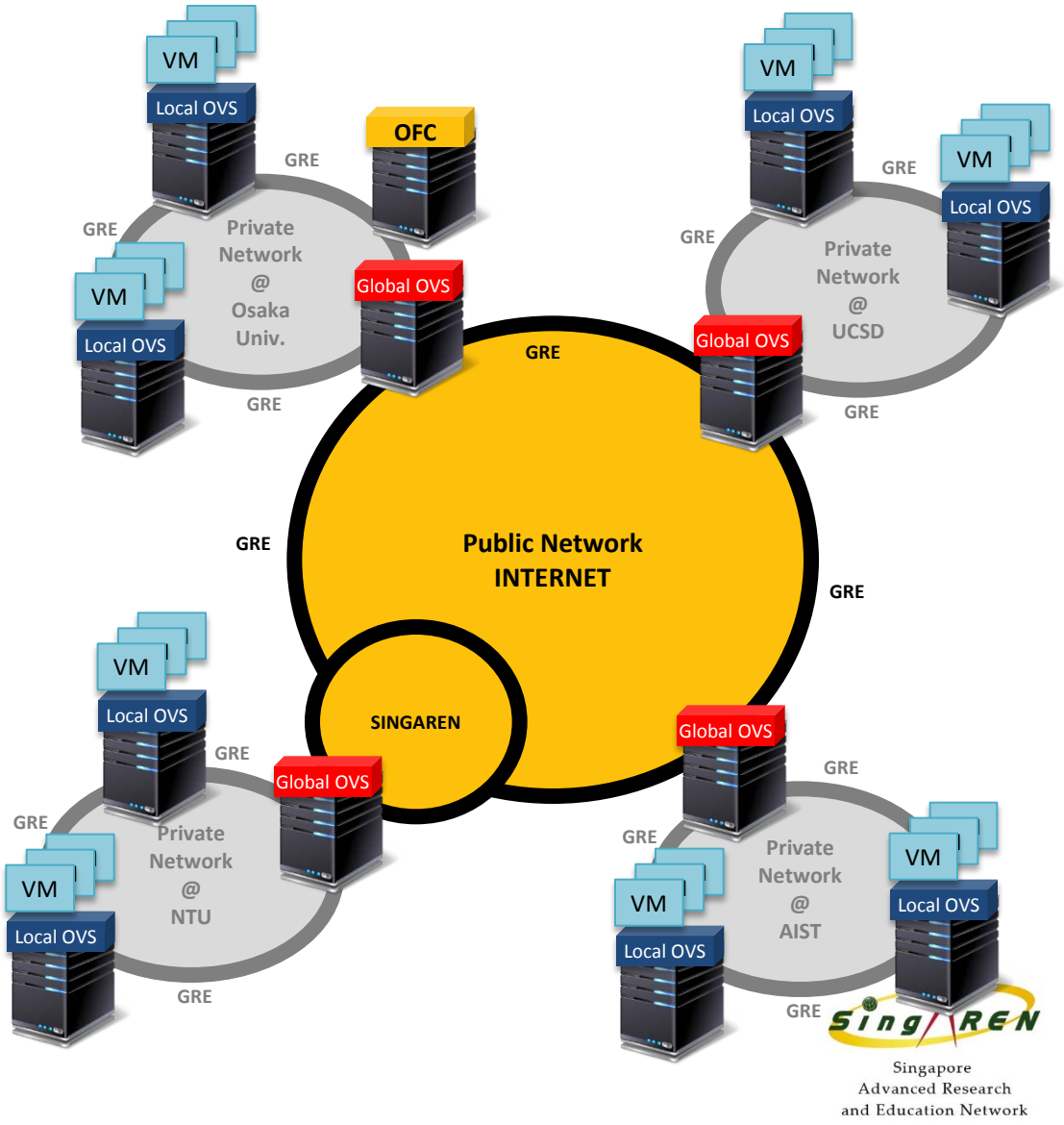
NANYANG TECHNOLOGICAL UNIVERSITY

Singapore Advanced Research and Education Network

NTU OpenvSwitch (cont'd)

PRAGMA + NTU

- Aims to connect to existing Pragma testbed in trying deploying remote VM at other site
- Implemented Openvswitch tested in NTU
- Managed to setup connection to Openflow controller at Osaka University



NANYANG TECHNOLOGICAL UNIVERSITY

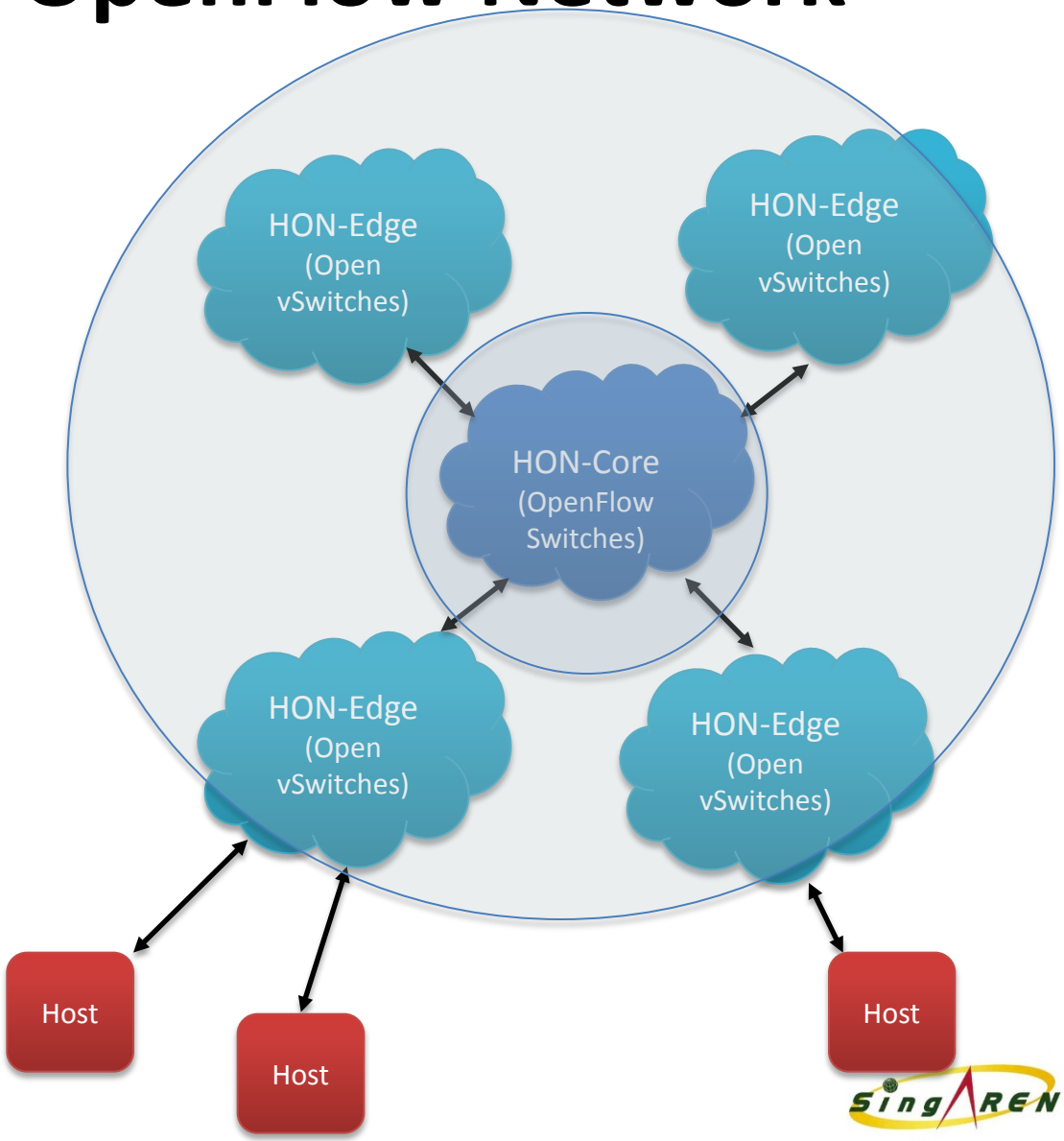
HON – Hybrid OpenFlow Network

Lead researcher:

Zoebir Bong

Aim: To extend hardware-based OpenFlow network with software-based OpenFlow network

- Hardware-based network is an OpenFlow network formed by OpenFlow switches and serves as HON core network
- Software-based network is an OpenFlow network formed by OpenvSwitch servers as HON edge switches



NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore Advanced Research and Education Network

Summary

- Future Internet has progressed
  - Large International deployment, eg. iGENI
  - Programmable and Open Interface – SDN/Openflow
- What has it enabled ?
  - IN-network services
  - Resilient network

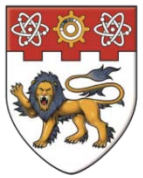
NANYANG TECHNOLOGICAL UNIVERSITY

SingAREN
Singapore Advanced Research and Education Network

(.flv)

Opening our eyes
a new world of information.

Thank You



NANYANG
TECHNOLOGICAL
UNIVERSITY

SingAREN

Singapore
Advanced Research
and Education Network