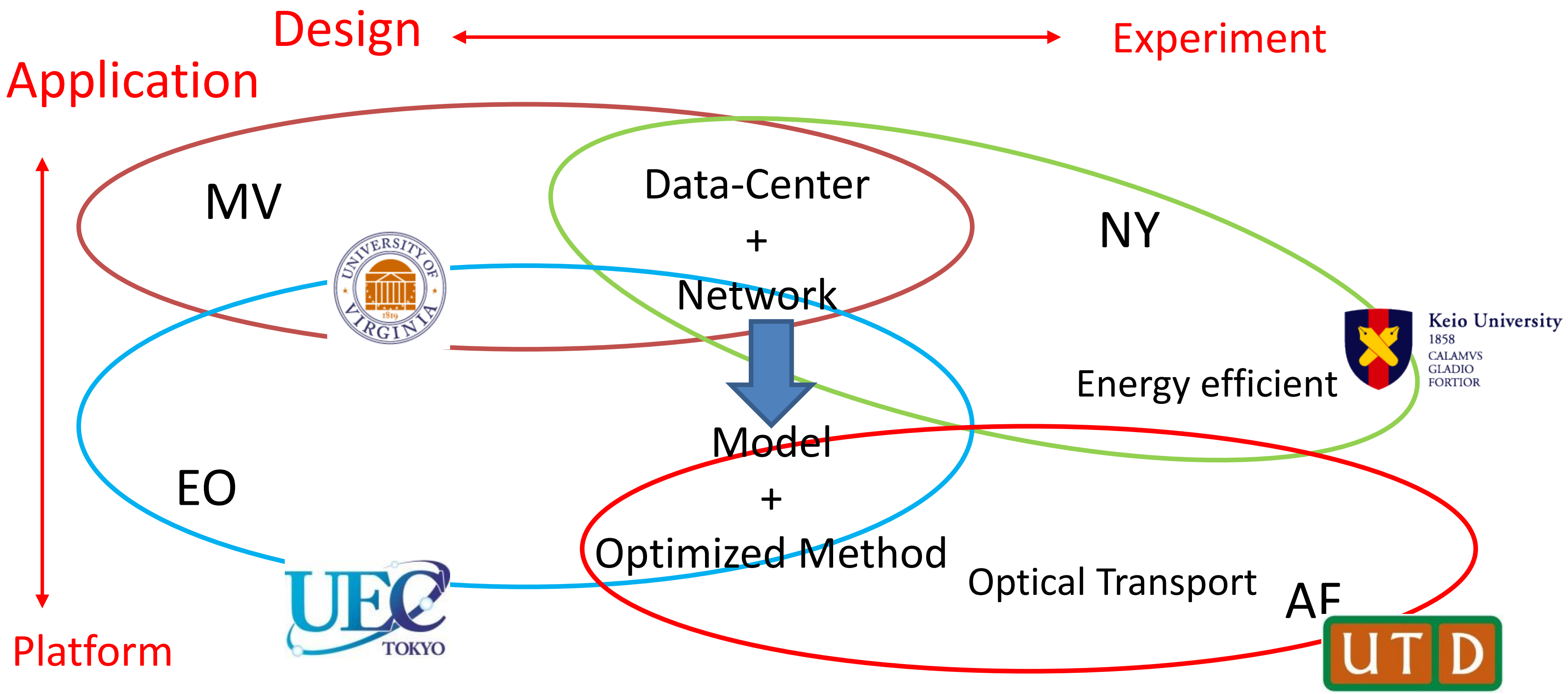
The ACTION Project
Preliminary Results and Project Plan

Eiji Oki, Naoaki Yamanaka,
Andrea Fumagalli and Malathi Veeraraghavan

JUNO PI Meeting

June 25, 2014

PI cover area



Outline

- Background
- Objectives and work program organization
- Short presentations from the individual PIs
- Research plan for 36 months with milestones
- Collaboration plan
- Dissemination plan

Background

- New enabling technologies
  1. Elastic Optical Networks (Flex Grid) [a]
     - WSS, Bandwidth Variable Transceivers (BVT), Energy Efficient Ethernet (EEE)
  2. Sub-wavelength circuits (OTN, DSON)
  3. Dynamic circuit/virtual circuit (VC) technologies
     - MPLS, VLAN, Ctrl. plane solutions (RSVP-TE, PCEP)
  4. Software Defined Network (SDN)/OpenFlow
- Measurements show that
  - Internet links are underutilized [b]
  - Networks are not operated in an energy-efficient manner [c]

[a] Gerstel, O.; Jinno, M.; Lord, A.; Yoo, S.J.B., "Elastic optical networking: a new dawn for the optical layer?," IEEE Comm. Mag., February 2012

[b] Sushant Jain, et al., B4: experience with a globally-deployed software defined WAN, SIGCOMM '13.

[c] Dennis Abts, et al. Energy proportional datacenter networks. *SIGARCH Comput. Archit. News* June 2010

Good reasons for operating today’s Internet links at low utilization (25-35%) ≡ Challenges of high-utilization operation of a network

1. Failure handling: Additional network load placed on links
2. Long-term growth: A provider upgrading the network in say 2012 designs network to handle loads upto say 2017
   – http://es.net/overview-of-the-network/network-maps/historical-network-maps/
3. High-speed file transfers: dedicated data-transfer nodes are designed to move data at high speeds relative to link capacity
   – e.g., ESnet 100G testbed has hosts that can each push data at 40 Gbps
   – with striped transfers across three hosts, can fill 100G links
4. Avoid packet losses: TCP throughput sensitive to losses
5. Allow sufficient headroom for poor planning (imperfect traffic forecasts) or poor routing (imbalanced load)

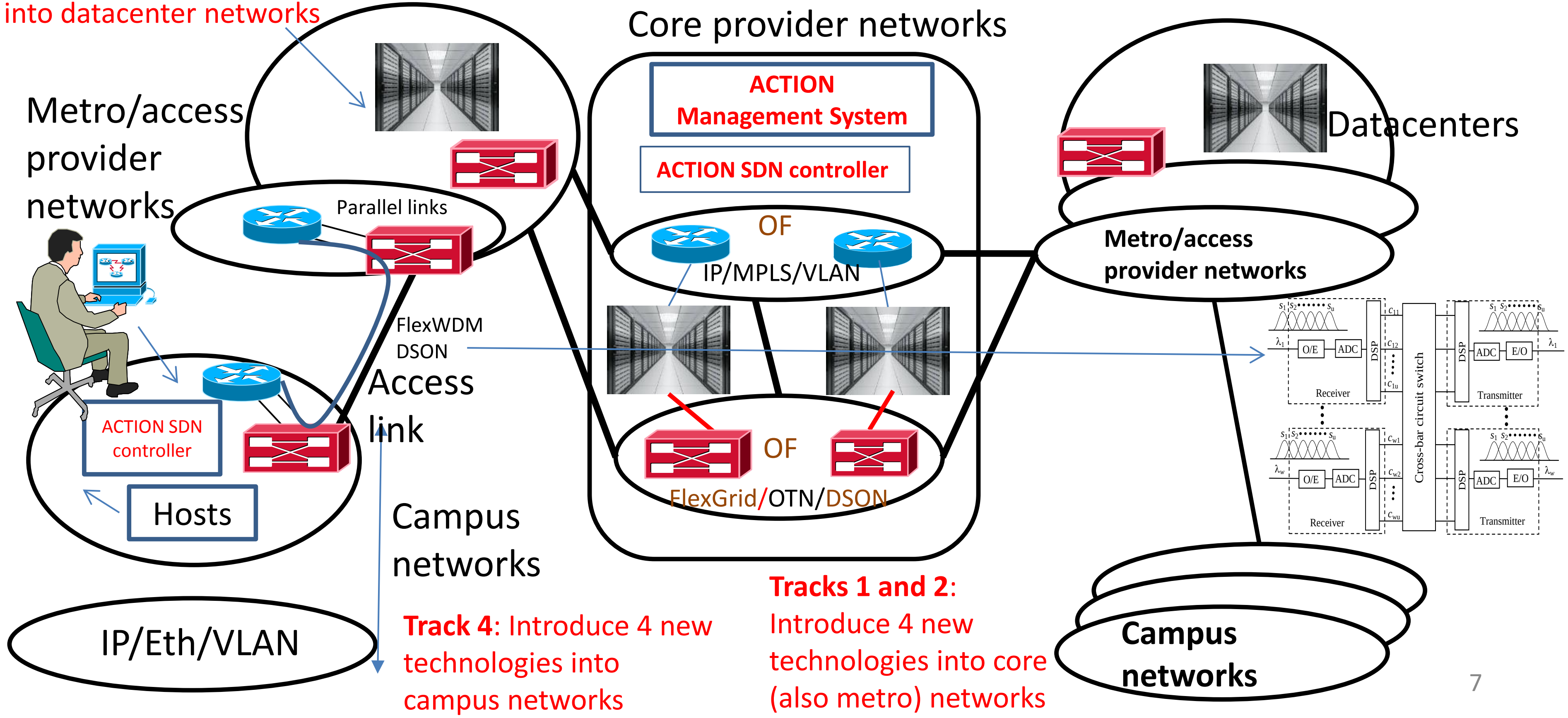
Objectives

- Develop an Applications Coordinating with Transport, IP, and Optical Networks (ACTION) architecture
  - by integrating four enabling technologies
  - by operating links at higher utilization while meeting the five challenges of high-utilization operation
- Why operate at high utilization: the network will need fewer powered-on links, and hence the network will consume smaller levels of energy (power) to move the same number of information bits (bits/sec)
  - analogy: flying a half-empty large airplane!

Track 0: ACTION PCE algorithms and design

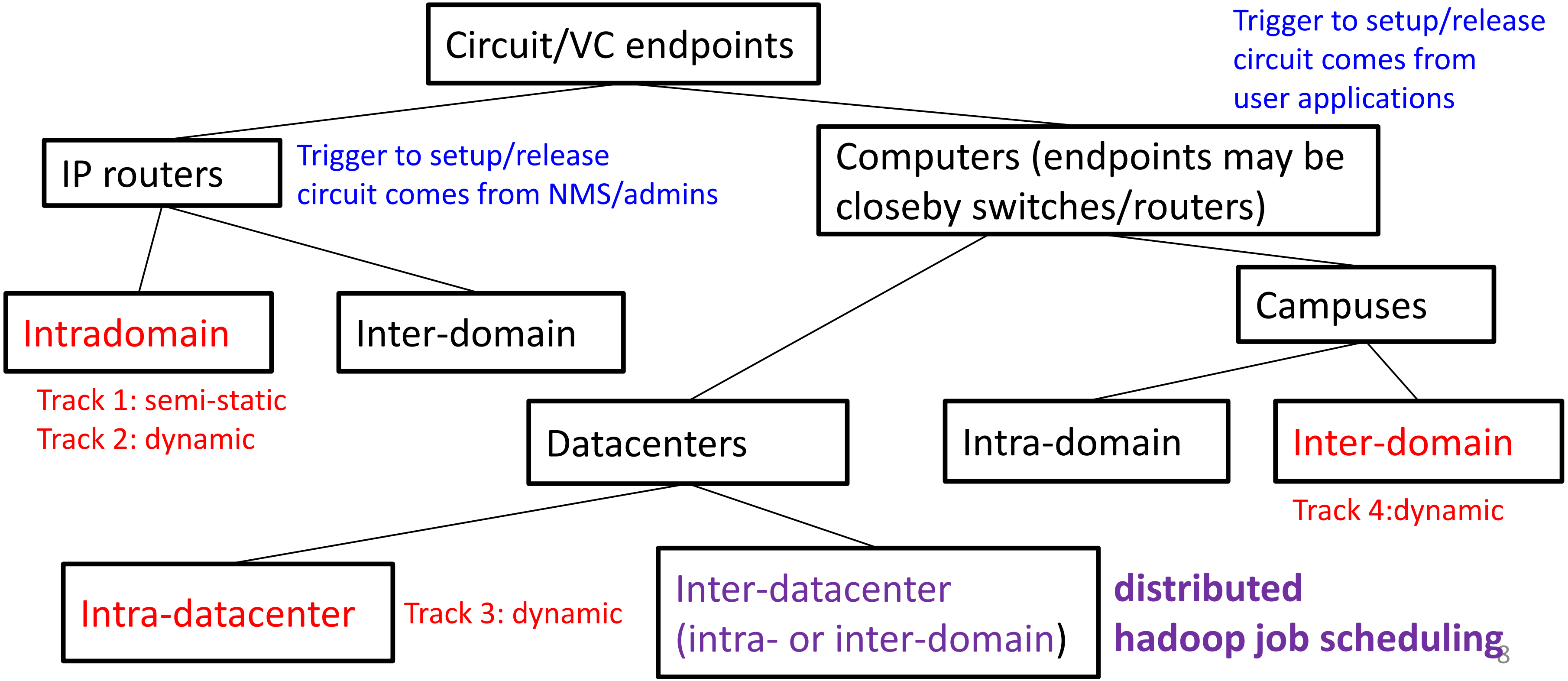
ACTION Project Overview

Track 3: Introduce 4 new technologies into datacenter networks



Long-term Vision (with Current Focus)

Broaden scope of dynamic circuit/VC services



Work Program Organization

- Track 0: ACTION SDN controller
  - Controls both OpenFlow Ethernet switches/IP routers PLUS optical crossconnects
- Four application tracks (applications for dynamic circuit services)
  - Routers are circuit endpoints (aggregate traffic: ACTION Management System)
    - Track 1: Virtual Topology Management: Leverage long-timescale variations (such as night/day traffic patterns) to power off or reduce link rates for energy savings while planning for failures
    - Track 2: Link Self-Sizing : Analyze short-timescale variations by observing IP-network link-level traffic (via SNMP MIB reads) and then ask ACTION SDN controller to adjust rate of elastic optical paths (used to realize IP-layer links) whenever possible for energy savings
  - Computers are circuit/VC "endpoints" (individual flows: application triggers from endpoints)
    - Track 3: Hybrid Data-Center Networks: EON + applications (Hadoop scheduling)
    - Track 4: Campus Networks: Router access links adjustment

Track 0: ACTION SDN Controller

- New path computation algorithms
  - Take into account Quality of Transmission (QOT) metrics
  - Consider energy consumption
  - Account for failures
  - Handle traffic fluctuations
  - Intra-domain path selection
  - Inter-domain path selection (East-West API)
  - Multi-layer path selection
    - e.g., by coordinating with per-layer SDN controllers
- Architecture, design and prototyping
  - Reduction of circuit setup delay

Domain definition: a network owned and operated by one organization

ACTION SDN

Confidential

(Structure and function of ACTION SDN)

- Quality of Transmission (QoT)
- Circuit setup performance
- Power consumption of NW

Core

data

OA

- Optical amplifiers

Track 1 (lead: Eiji)

- Issued to be addressed
  - Difficult to estimate exact traffic demand each edge nodes
  - Avoid frequent dynamic route changes according to traffic fluctuation
- Objective
  - Virtual Topology Management: Leverage long-timescale variations (such as night/day traffic patterns) to power off or reduce link rates for energy savings while planning for failures
    - Account for failures
    - Handle traffic fluctuations
    - Utilize flexibility of elastic optical networks
- Application
  - Robust and stable energy-efficient network
  - Changeable traffic demand of IP and layer 2 networks

Virtual topology management for

Dete
IP/L
Ban
Link
(pro
in co
elas

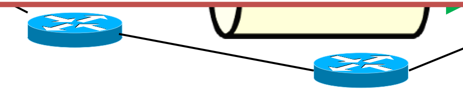
Confidential

(Aggregated traffic model)

- Path Computation Engine
- ACTION SDN
- Monitor traffic
- ACTION Management system

raffic
ge node
k

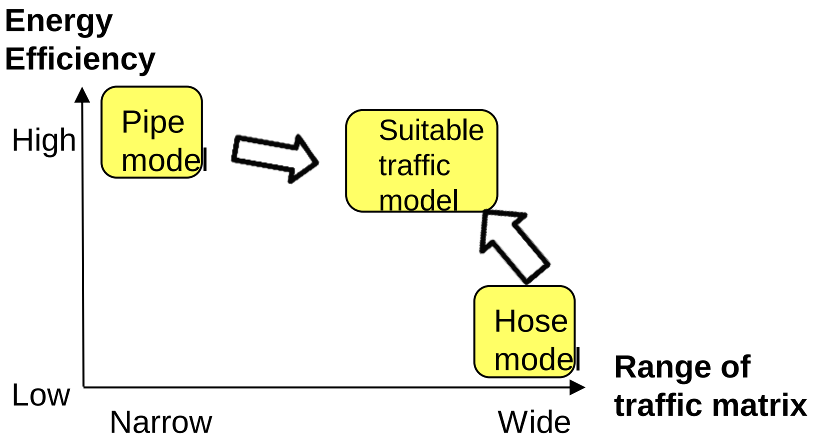
In
a

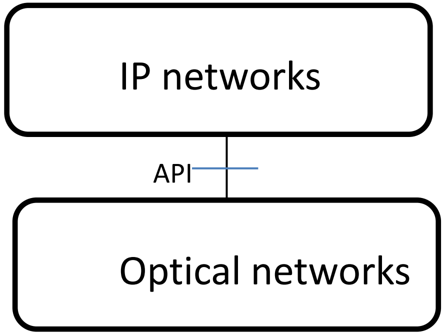


Aggregated link traffic

Work plan (Track 1)

- Virtual topology optimization framework developed with
  - Suitable traffic demand model
  - Failure model
  - Multi-layer orchestration
- Simulator developed
  - Simulate energy saving effect in cooperation with elastic optical network simulator
  - Provide simulated for integrated demonstration





Track 2 (lead: Naoaki)

- Aggregate flows (aggregate link traffic: all flows): Next, consider aggregate traffic. In today's network (commercial and REN), utilization is around 30-35%. Say we decide to operate at 70% utilization by lowering the link rates (using Bandwidth Variable Transceivers). We start using a network management system (NMS) read SNMP MIBs at IP routers of all links and monitor these levels. We can set some thresholds to adjust link rates, e.g. (65, 75)%. In 30 sec or min.

- Objective:
  - Bring 2 new technologies to improve IP network performance using elastic optical technique
- Applications:
  - Improve link efficiency by leveraging SNMP MIB data
  - Change virtual link bandwidth to maintain a predefined link utilization, e.g. 70%

- Study issue 1: Speed of SNMP is enough? Or new NFV is needed?
- Study issue 2: BVT and elastic network adjustment speed: P2P link vs. network path

Track 2 : Self-sized link by SNMP data

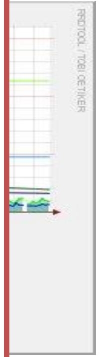
Confidential

(Link Self-sized technique)

- Path Computation Engine
- ACTION Manager
- ACTION SDN Controller
- Elastic Optical Network

ACTION
PCE

rate)
response

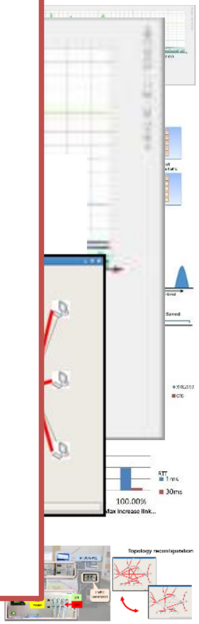


Method and Advantages

Confidential

(Method and Advantages)

- Monitor-Control-Openflow switch
- Power consumption results
- IP throughput



Work Plan (Track 2)

- Try to obtain real SNMP traces
- Measure Energy Efficient Ethernet (EEE) power consumption and response time for making rate changes (also make projections for future BVTs)
- Simulate Internet2 or ESnet or SINET using ns2 or P2A simulator to determine the optimal timescales and characterize energy savings tradeoffs (with and without elastic optical path modifications).
- Network structure by multiple parallel links or VON(Virtual optical network)
- Prototyping in Keio Univ. NW with test with VLAN switches on testbeds emulation and JGN using deeply programmable node
  - Test assumptions
  - Collect measurements
- Extended ideas to virtual optical network slice and/or inter datacenter

Track 3 (lead: MV)

- Objective:
  - Bring 4 new technologies to datacenter networks
- Applications:
  - Hadoop scheduler extended to co-schedule CPU and network resources (trigger dynamic circuits)
  - Filesystem writes of large files (host-application triggered dynamic circuits)

ACT
(inte

Dynam
trigger
schedu
or host

Confidential

(Data center model)

- ACTION Hadoop Scheduler
- SDN Controller
- Optical Dynamic Circuit by apps.

re

tion

ge

iented
vers

Pow
switch port only when required

Hybrid OpenFlow packet/optical circuit networks

OSCARS: On-Demand Secure Circuits and Advance Reservation System

Work Plan (Track 3)

- Prototype applications and test with VLAN switches on testbeds (e.g., ExoGENI, PRObE, Keio test-bed, CPqD test-bed)
  - Test assumptions
  - Collect measurements
- If possible, obtain real traces from datacenters
- Run simulations or create analytical models of large-scale datacenter network to estimate energy savings

Track 4 (lead: Andrea)

- Objective:
  - Bring 4 new technologies to campus networks
- Applications:
  - Network administrator requests temporary augmentation of access link capacity for special events on campus (e.g., football game)
  - Host-application triggers dynamic circuits (e.g., moving human genome sequence rough or processed data)

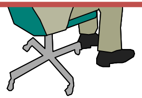
Current Campus

ACTION Track 4

Confidential

(Campus network and inter-campus)

- Metro/access elastic network
- Inter-Campus dynamic network



Work Plan (Track 4)

- Prototype campus applications and test with VLAN switches on test-beds (e.g., Keio test-bed)
  - Test assumptions
  - Collect measurements
- Define and implement simulation modules based on experimental data (e.g., CPqD test-bed)
  - PLI models for EON and DSON
  - Circuit setup delay models for optical components, physical control plane and signaling
  - Energy consumption models
- Obtain real traffic traces from campuses
- Run simulations and/or create analytical models of campus network to estimate energy savings

Outline

- Background
- Objectives and work program organization
- Short presentations from the individual PIs
- ➢ Research plan for 36 months with milestones
- Collaboration plan
- Dissemination plan

Y	Track 0	Track 0 - QoT	Track 1	Track 2	Track3	Track 4
0.5	ACTION Architecture&Design (NY, EO, MV, AF)	Non-coherent TI-PLIs				
0.5		Estimate of power consumption for key already existing devices	Modeling and formulation for IP/layer 2 switch networks (EO,MV)			
1	Intra-domain PCE (EO,AF)	OA: EDFA non-flat gain and noise level from experimental work	Test hypothesis of day-night traffic patterns being different (MV)	Analyze Internet2 SNMP MIB traces: heuristic for rate-adjustment duration (MV,NY)		
1		Coherent TI-PLIs and TD-PLIs and WSS equalization	Modeling and formulation for IP+optical networks (EO,AF)	Obtain energy and response time measurements for EEE and switch port (NY)		
1.5	Cross-layer PCE (EO,AF)		Designing & solving PCE for IP/layer 2 and optical PCE (EO,AF,NY)	Modeling and formulation (EO)	ACTION Hadoop scheduler + characterize comm. traffic (MV,NY)	
1.5	PCE prototype for IP/layer 2 networks w/ EON interfaces (EO,AF,NY)	Circuit setup latency models for control plane and key optical devises	paper #1	Prototype Link Self Sizing Emulation Module of ACTION Mgmt System(NY,MV)	Energy and response time data for Ethernet and optical switch configuration (NY)	
2	Prototype SDN Controller (IP and layer 2) (NV,NY)			Prototype system demo (NY and MV); Performance evaluation (EO)	Prototype Integrated system demo: apps+scheduler+SDN controller (MV and NY)	Analyze campus access NetFlow records for alpha flows and SNMP data (MV)
2		DSCM transmission and power consumption models		paper #2	DSCM Architecture and spectrum allocation algorithms (AF,NY)	Applications redesigned to make full use of circuits oriented services (MV)
2.5	Inter-domain PCE RSA strategies (MV,NY,EO, AF)				Contain circuit setup delays and their impact on applications (AF,MV)	Definition of APIs required between application and SDN controller (MV, NY, AF)
2.5	SDN controller East-West interfaces				paper #3	Define SDN controller East-West SDN interfaces (AF, NY, MV)
3	Campus application-SDN controller APIs					Prototype system demo (NY and MV)
3						paper #4

Collaboration Plan

- Have been meeting via WebEx (almost) every week since the start of the project
- IP Agreement is finalized
- Face-to-face meetings done: NOC14, ICC14 and PI meeting (June 2014)
  - Plan by coordinating conference attendance
  - Also, hold dedicated meetings
- Dropbox folder: already under heavy use!
- Joint platforms for simulations, software/shell scripts for running experiments, software for data analysis
- Support graduate student/PI visits to other labs for more immersive learning
- Joint workshop

Dissemination Plan

- http://venividiwiki.ee.virginia.edu/mediawiki/index.php/ACTION
- Papers: Journals and conferences
  - COIN paper
- Software: post on wiki site
- Data: store measurements from testbed, SNMP from Internet2, SINET in university library data stores
- Organize workshop or special session
  - IEEE/IEICE HPSR 2016 (TBD)