WAN Virtualization
Looking beyond Point to Point Circuits

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II. Network Virtualization

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Office of Science

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Fundamental Network Abstraction:
a end-to-end circuit

At all layers of the network
Wavelength, PPP, MPLS LSP, L2TP, GRE, PW …

A ●————○————————○————————○————————○————————● Z

Switching points, store and forward, transformation …

Simple, Point-to-point, Provisionable

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New Network Abstraction: "WAN Virtual Switch"

WAN Virtual Switch

Abstract Network Model

Network Virtualization

Simple, Multipoint, Programmable

Configuration abstraction:
- Expresses desired behavior
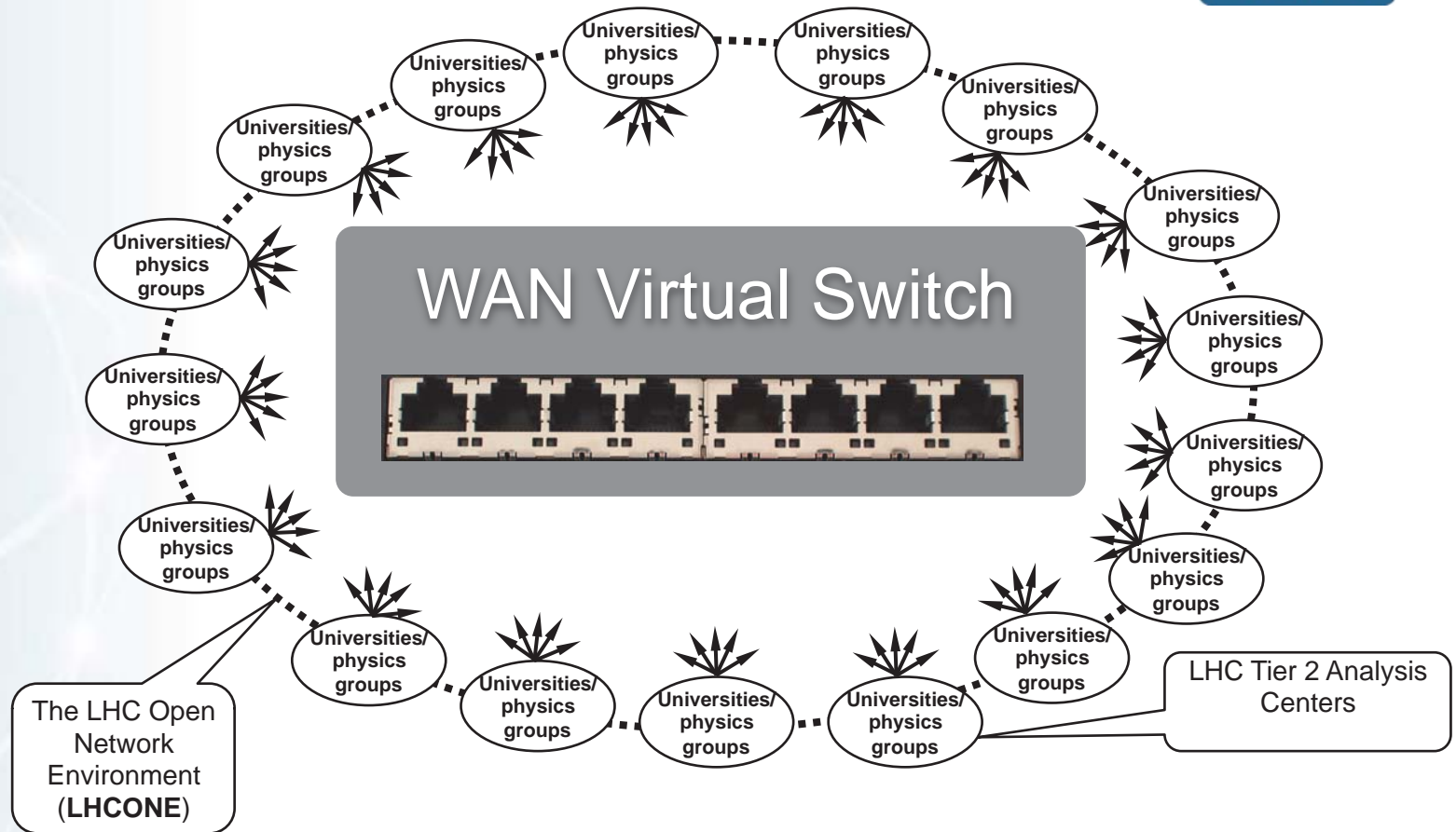- Hides implementation on physical infrastructure

It is not only about the concept, but implementation is key

Thought experiment:
Build an N-port virtual switch for a collaboration

CERN →T1	miles	kms
France	350	565
Italy	570	920
UK	625	1000
Netherlands	625	1000
Germany	700	1185
Spain	850	1400
Nordic	1300	2100
USA – New York	3900	6300
USA - Chicago	4400	7100
Canada – BC	5200	8400
Taiwan	6100	9850

Source: Bill Johnston

WAN Virtual Switch

Universities/physics groups

The LHC Open Network Environment (**LHCONE**)

LHC Tier 2 Analysis Centers

Client-driven "Flow Routing" replaces static Routing policies

Science Flow1: A → B, QoS, Label
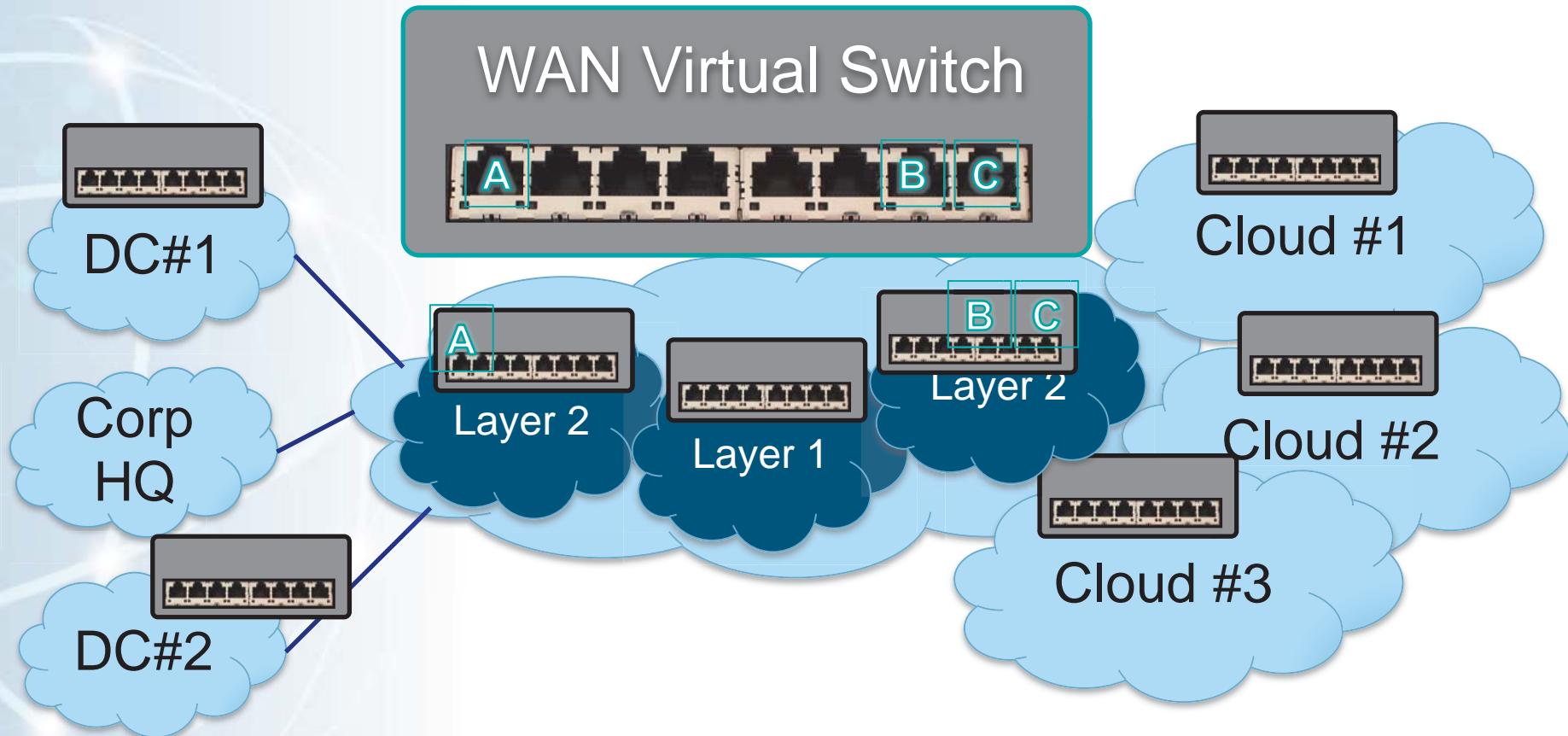Science Flow2: {A, VLAN X} → {C, VLAN Y}
Science Flow3: A → B,C
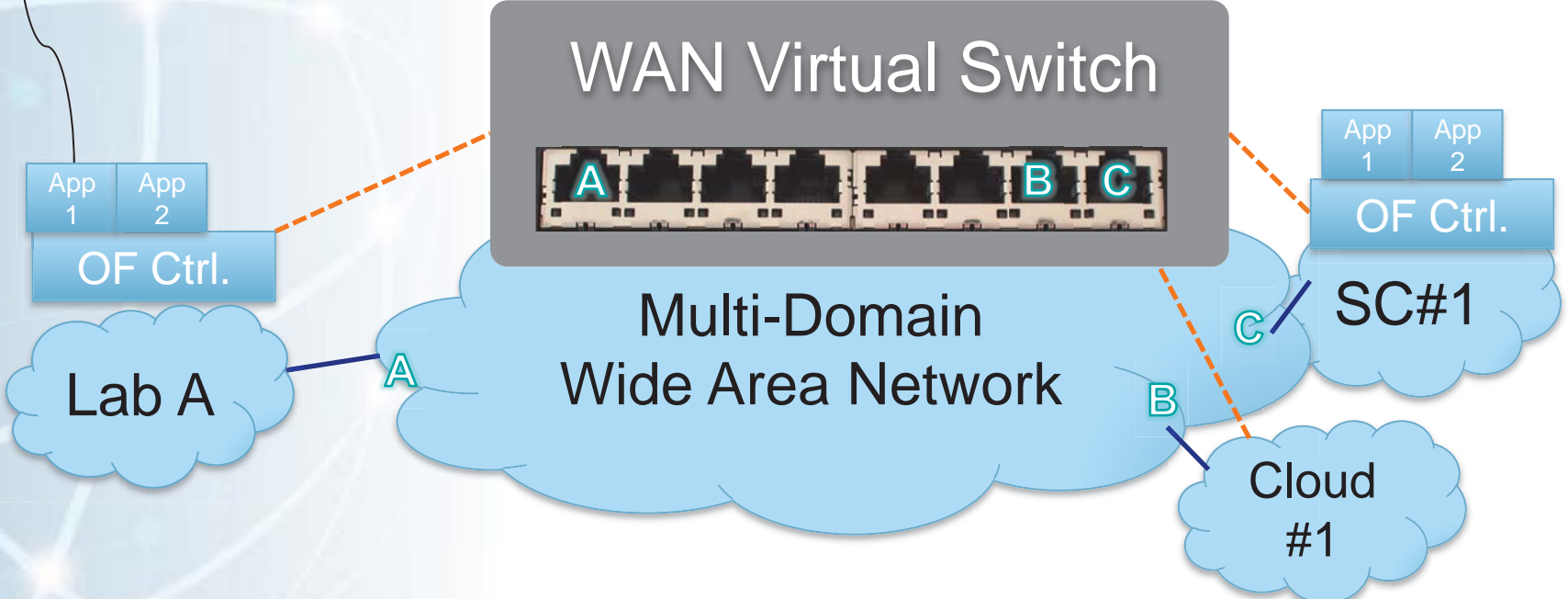
Combine distributed enforcement of Routing Policy to a single logical entity

Dynamic, multiple virtual switches for Cloud and other on-demand applications

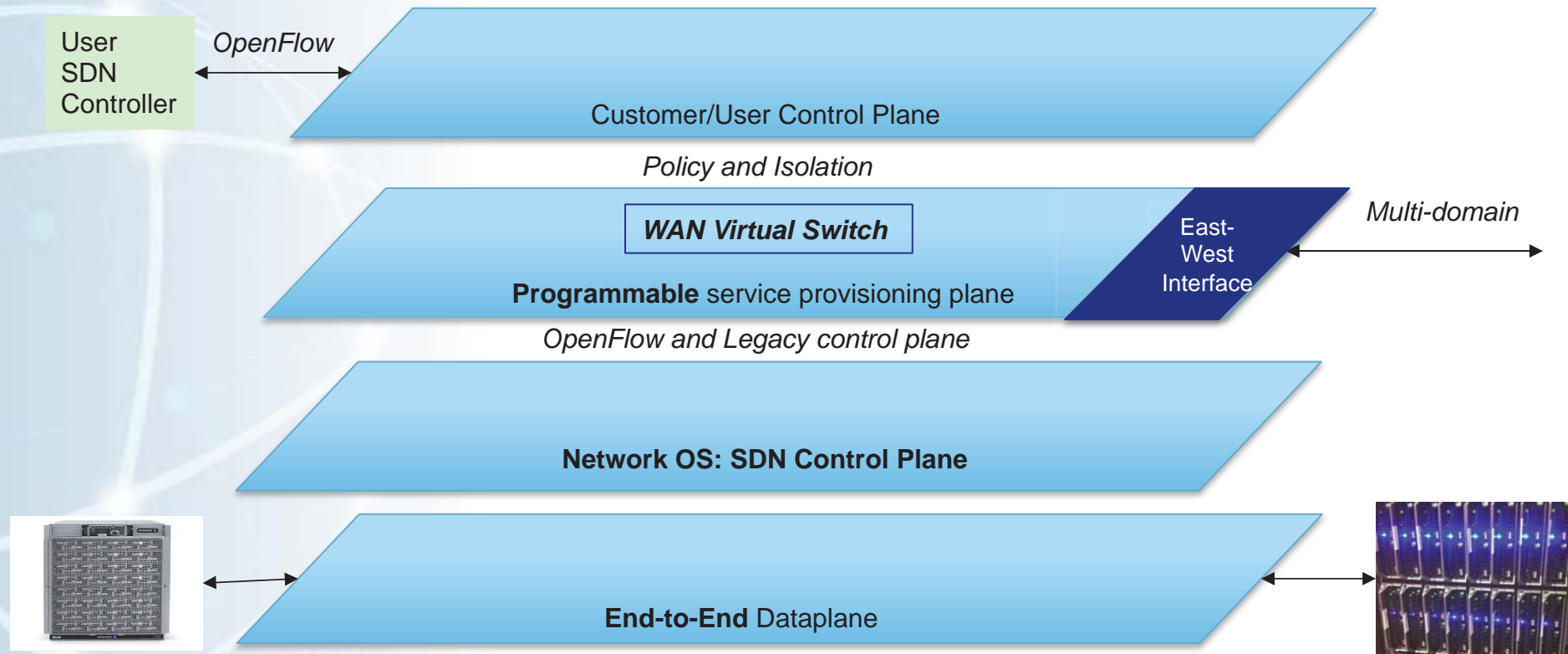WAN Virtual Switch

DC#1

Corp HQ

DC#2

Multi-Domain Wide Area Network

A | B | C

Cloud #1
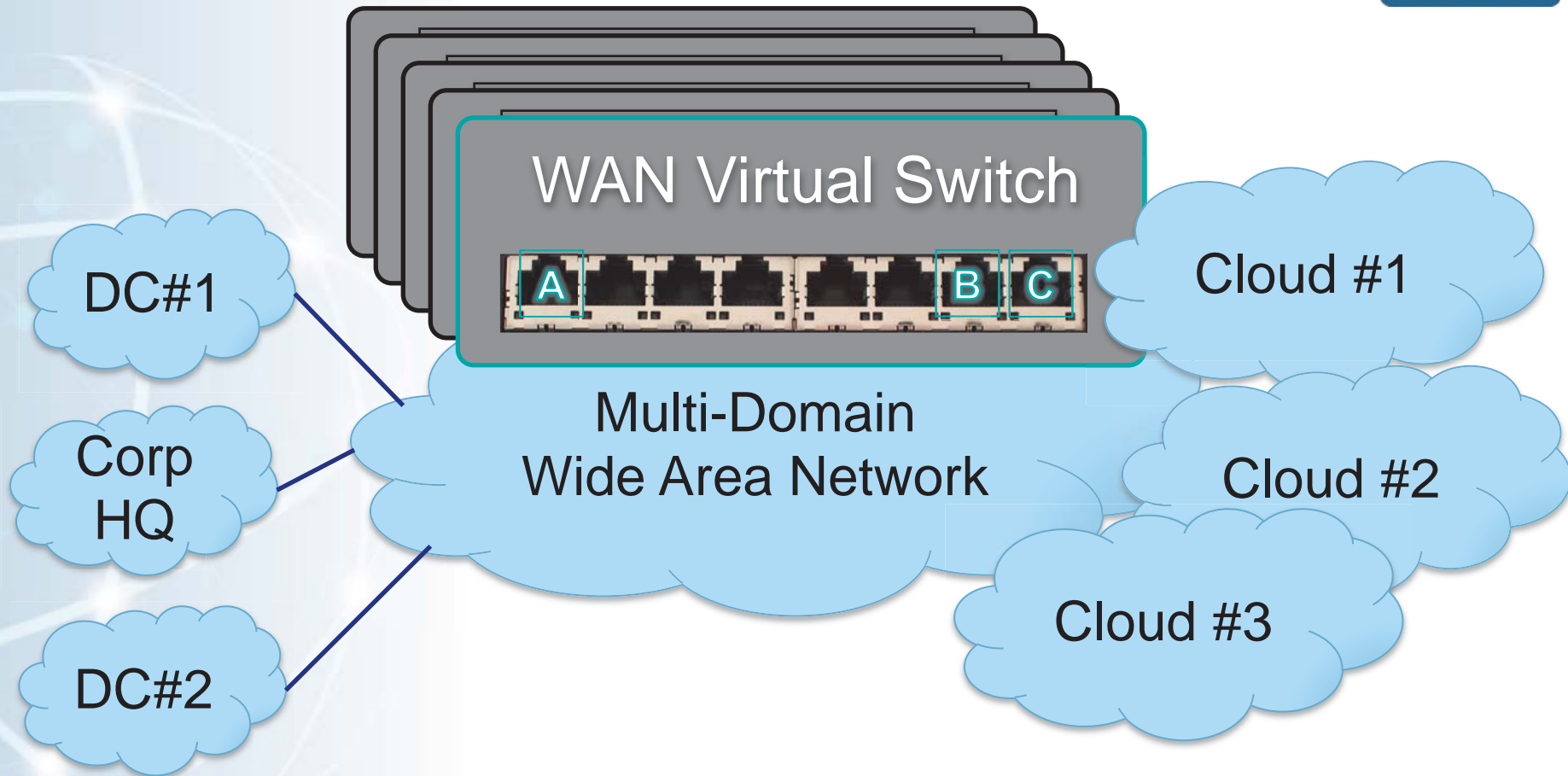
Cloud #2

Cloud #3

Virtual Switches can be as dynamic as your Cloud

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Recursive Nature:
Horizontally and Vertically

ESnet

WAN Virtual Switch

A   B C

DC#1

Cloud #1

A

B C

Layer 2

Layer 2

Corp
HQ

Layer 1

Cloud #2

DC#2

Cloud #3

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Layer-based representation

ESnet

User SDN Controller — *OpenFlow* →

Customer/User Control Plane

Policy and Isolation

WAN Virtual Switch

Programmable service provisioning plane

East-West Interface

Multi-domain

OpenFlow and Legacy control plane

Network OS: SDN Control Plane

End-to-End Dataplane

- Creation of a programmable network provisioning layer
- Sits on top of the "network OS"

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SC12 Demonstration
Physical Topology

Ciena 5410
@Ciena booth

DTNs

SRS
Brocade
@SCinet

@ANL

@BNL

OSCARS virtual circuits

NEC IP8800
@ LBL
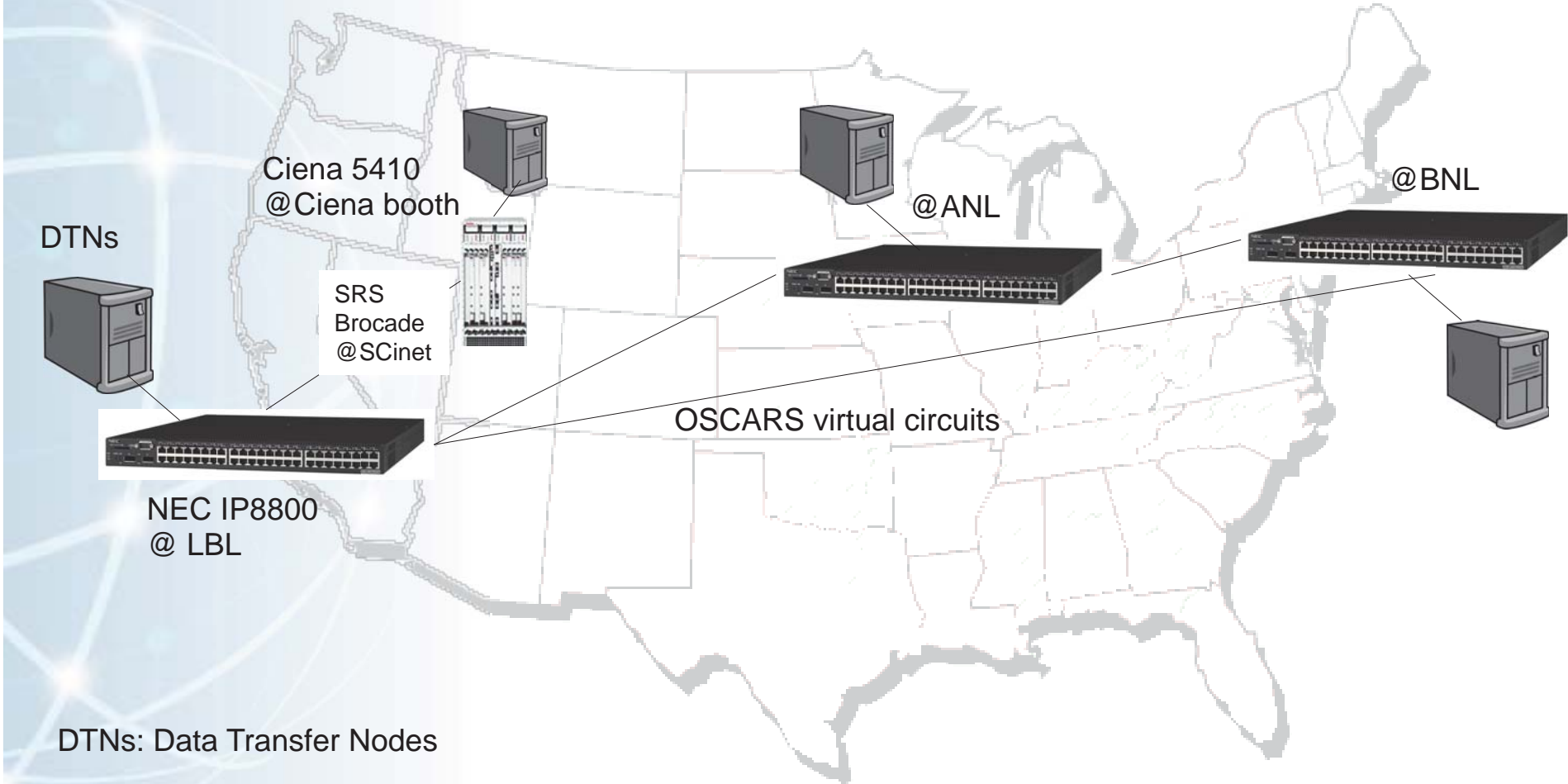
DTNs: Data Transfer Nodes
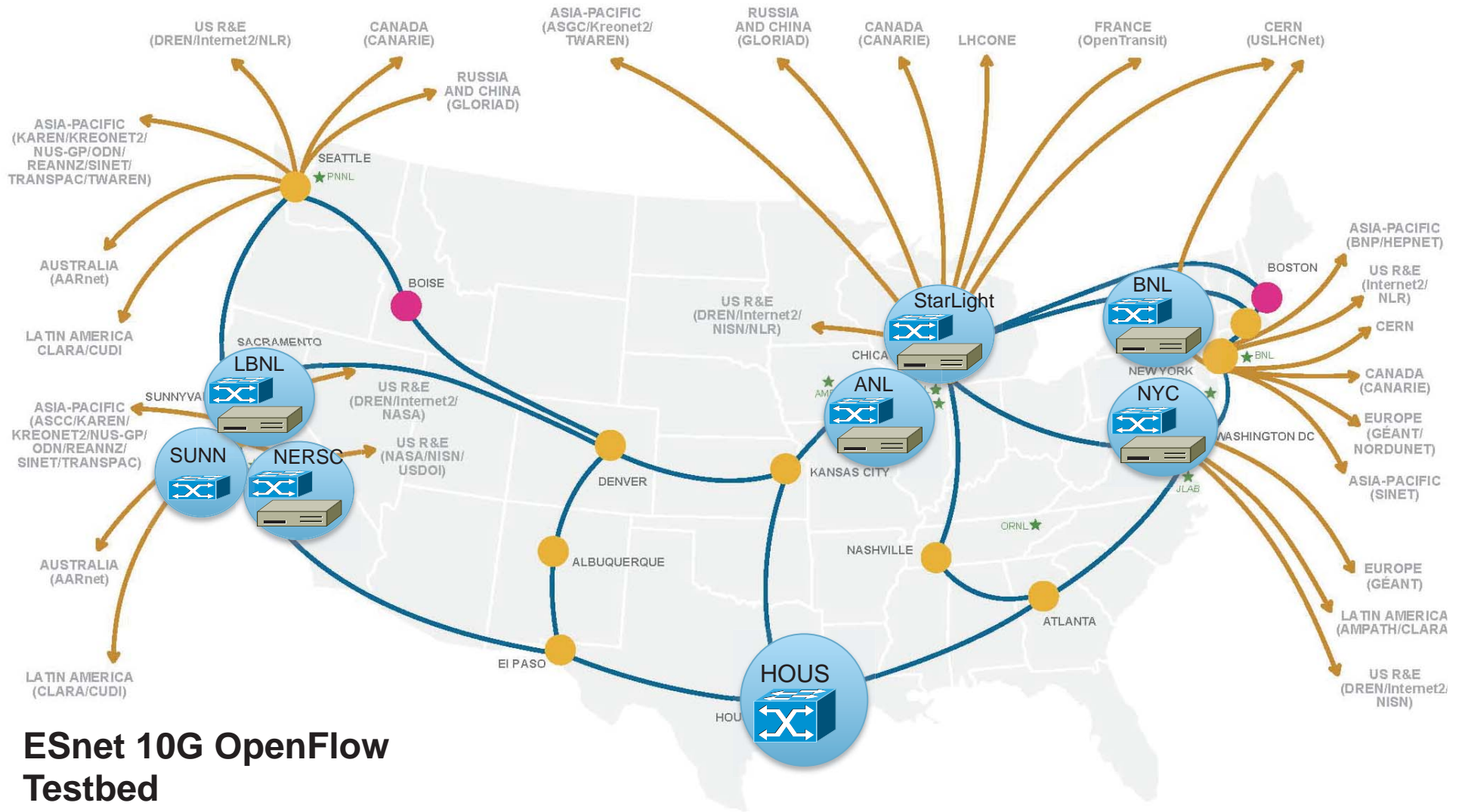
ESnet 10G OpenFlow Testbed

Legend:

- 🟡 100G IP Hubs
- 🔴 4x10G IP Hub
- Major R&E and International peering connections
- ⭐ Office of Science National Labs

Ames	Ames Laboratory (Ames, IA)	
ANL	Argonne National Laboratory (Argonne, IL)	
BNL	Brookhaven National Laboratory (Upton, NY)	
FNAL	Fermi National Accelerator Laboratory (Batavia, IL)	
JLAB	Thomas Jefferson National Accelerator Facility (Newport News, VA)	
LBNL	Lawrence Berkeley National Laboratory (Berkeley, CA)	
ORNL	Oak Ridge National Laboratory (Oak Ridge, TN)	
PNNL	Pacific Northwest National Laboratory (Richland, WA)	
PPPL	Princeton Plasma Physics Laboratory (Princeton, NJ)	
SLAC	Stanford Linear Accelerator Center (Menlo Park, CA)	

ESnet — Energy Sciences Network

Summary

Motivation

- Powerful network abstraction makes it easier for complex application and collaboration interactions
  - Files/Storage

Simplicity

- **Simplicity** for the end-site
  - Works with off-the-shelf, open-source controller
  - Topology simplification
- **Generic** code for the network provider
  - Virtual switch can be layered over optical, routed or switched network elements
  - OpenFlow support needed on edge devices only, core stays same
- **Programmability** for applications
  - Allows end-sites to innovate and use the WAN effectively

Architecture

- OpenFlow at the edge to start with, can upgrade the core opportunistically