StarLight Software Defined Exchange (SDX) And The Global Research Platform

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Director, Metropolitan Research and Education Network (www.mren.org)
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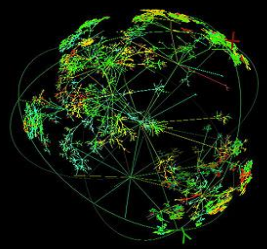
PI: StarLight SDX, Co-PI Chameleon, PI-iGENI, PI-OMNINet

Global Research Platform
Co-Located With The 19th IEEE International Conference on eScience
Osaka, Japan
September 16-17, 2024



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STARLIGHT SDX

The GRP: A Platform For Global Science

A Next Generation, Software Defined, Globally Distributed, Multi-Domain Computational Science Environment

STARLIGHT℠

Global Research Platform: Global Lambda Integrated Facility
Available Advanced Network Resources

Next Generation eScience Ecosystem

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

www.glif.is

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AutoGOLE Open R&E Exchanges

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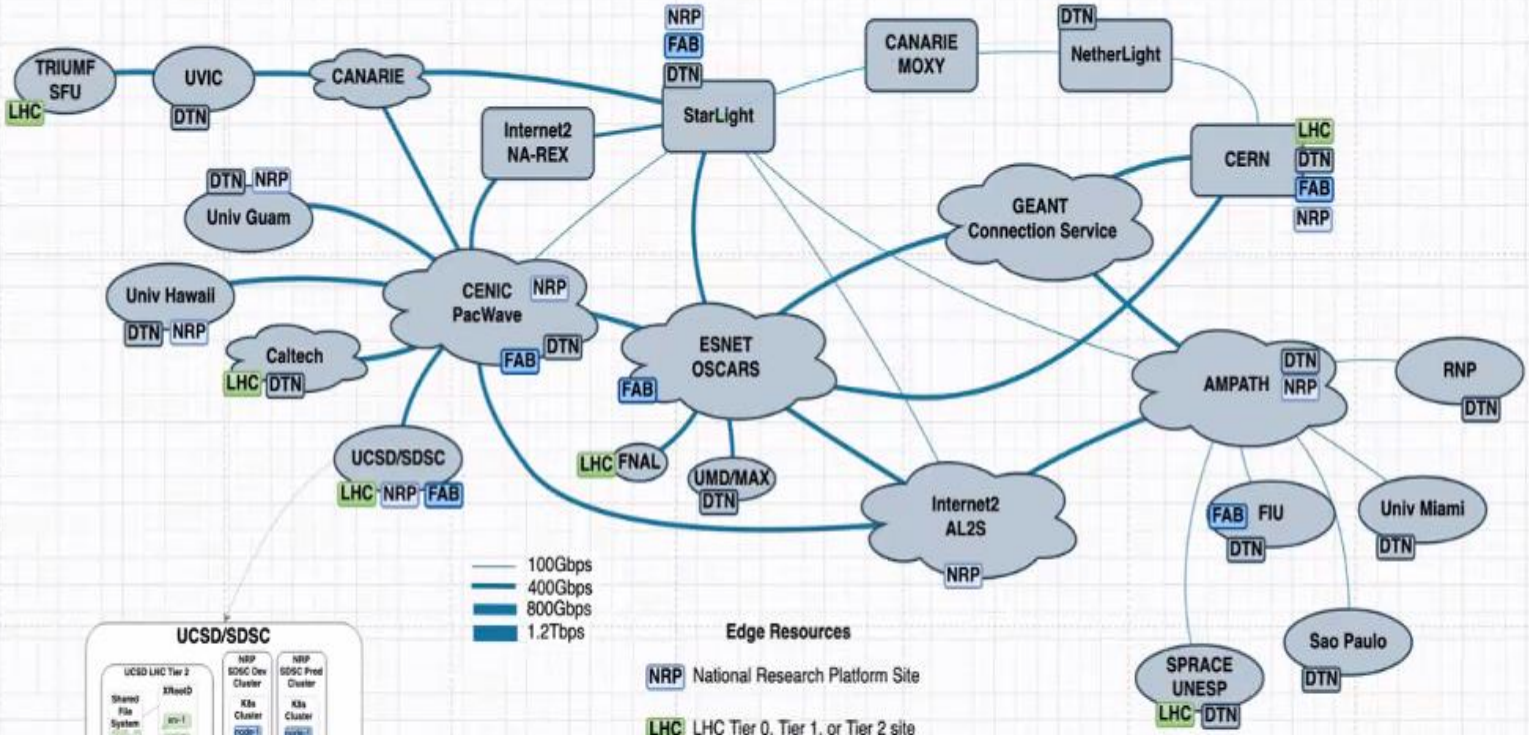

NRP Connections

P4 Testbed Site/End System Data

StarLight – "By Researchers For Researchers"

StarLight: Experimental Optical Infrastructure/Proving Ground For Next Gen Network Services

Optimized for High Performance Data Intensive Science

Multiple 100 Gbps (110+ Paths)

StarWave

100 G Exchange

World's Most Advanced Exchange

Multiple First of a Kind Services and Capabilities

View from StarLight

Abbott Hall, Northwestern University's Chicago Campus

Currently: 26+ 400 Gbps Paths Prototyping 800 Gbps Tbps

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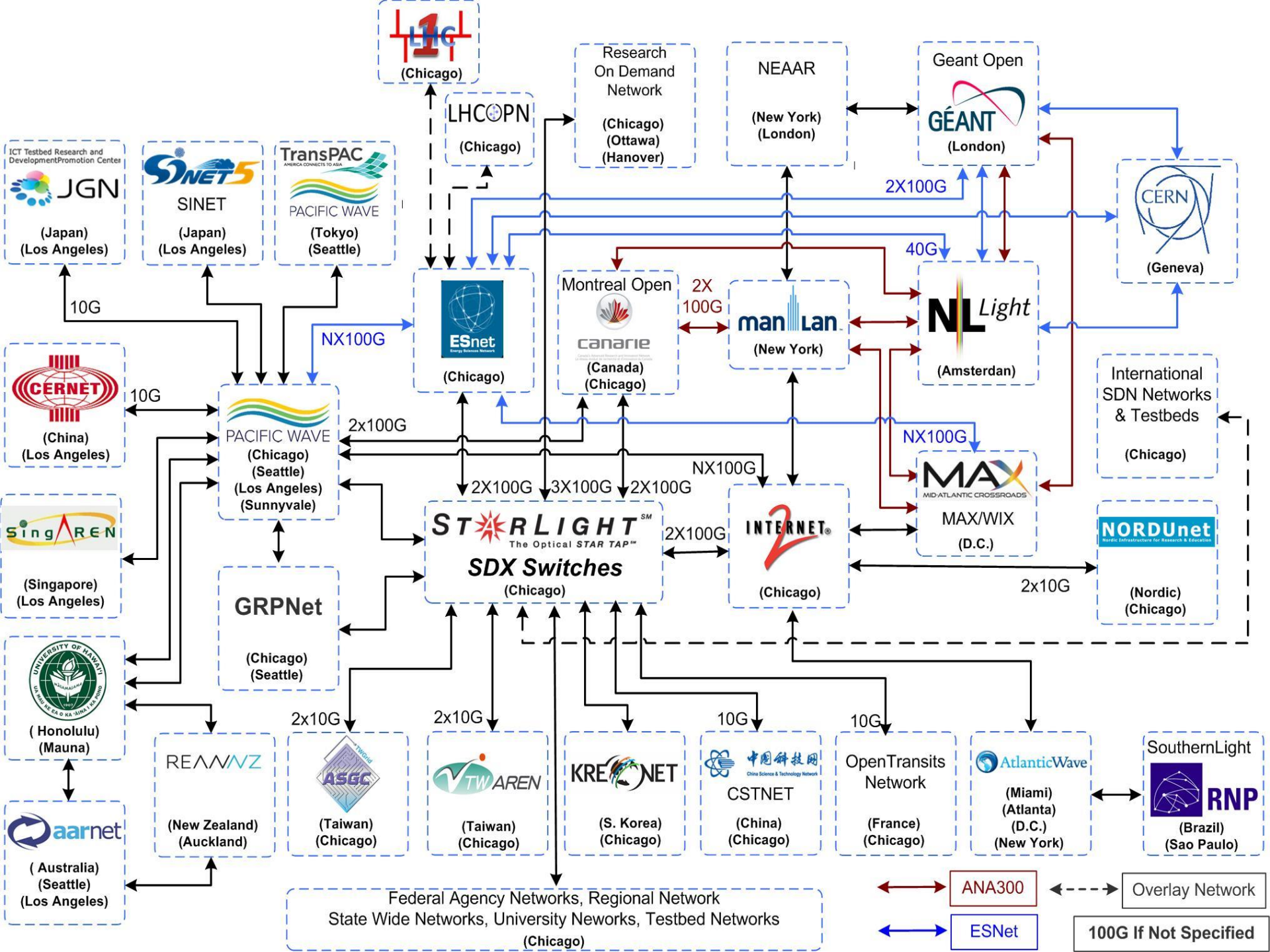
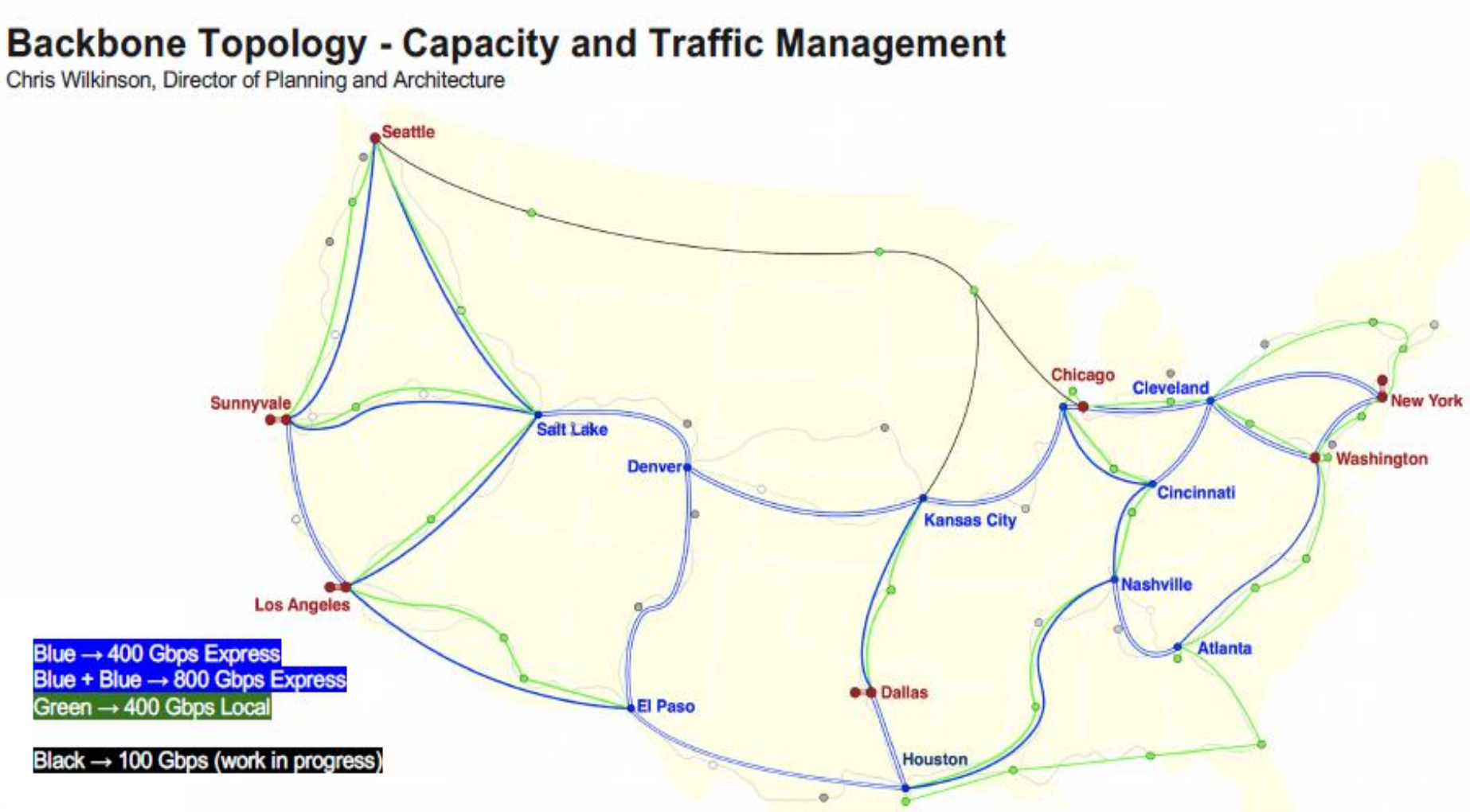
STARLIGHT℠

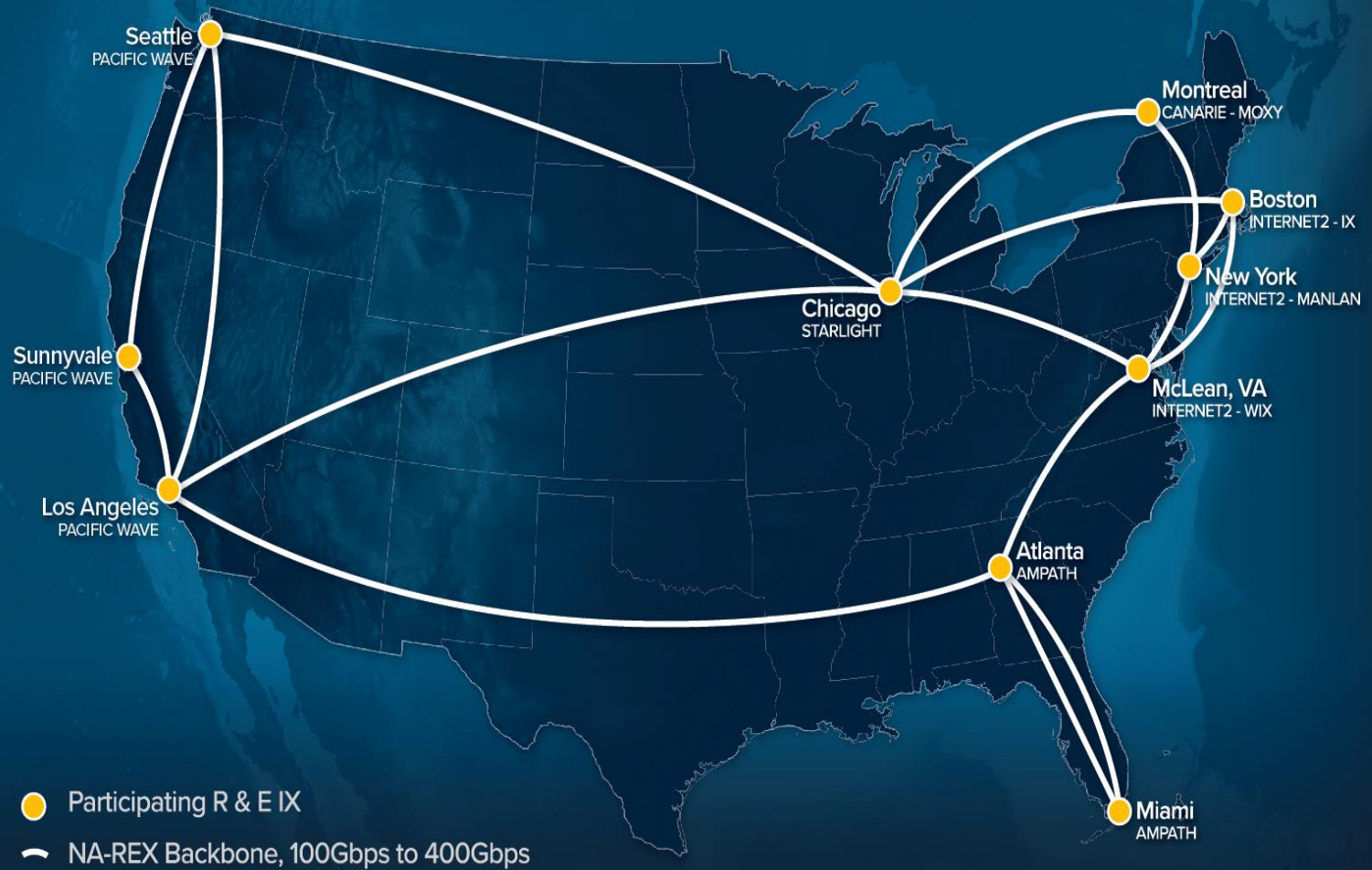

LHC
(Chicago)
LHCOPN
(Chicago)
Research On Demand Network
(Chicago)
(Ottawa)
(Hanover)
NEAAR
(New York)
(London)
Geant Open
GÉANT
(London)
CERN
(Geneva)
2X100G
40G
ICT Testbed Research and DevelopmentPromotion Center
JGN
(Japan)
(Los Angeles)
SINET
(Japan)
(Los Angeles)
TransPAC
PACIFIC WAVE
(Tokyo)
(Seattle)
10G
NX100G
ESnet
(Chicago)
Montreal Open
canarie
(Canada)
(Chicago)
2X 100G
manLan
(New York)
NL Light
(Amsterdan)
CERNET
(China)
(Los Angeles)
10G
PACIFIC WAVE
(Chicago)
(Seattle)
(Los Angeles)
(Sunnyvale)
2x100G
International SDN Networks & Testbeds
(Chicago)
NX100G
MAX
MID-ATLANTIC CROSSROADS
MAX/WIX
(D.C.)
NX100G
2X100G
3X100G
2X100G
SingAREN
(Singapore)
(Los Angeles)
STARLIGHT
The Optical STAR TAP
SDX Switches
(Chicago)
2X100G
INTERNET2
(Chicago)
2x10G
NORDUnet
(Nordic)
(Chicago)
GRPNet
(Chicago)
(Seattle)
(Honolulu)
(Mauna)
2x10G
2x10G
10G
10G
REANNZ
(New Zealand)
(Auckland)
ASGC
(Taiwan)
(Chicago)
TWAREN
(Taiwan)
(Chicago)
KREONET
(S. Korea)
(Chicago)
CSTNET
(China)
(Chicago)
OpenTransits Network
(France)
(Chicago)
AtlanticWave
(Miami)
(Atlanta)
(D.C.)
(New York)
SouthernLight
RNP
(Brazil)
(Sao Paulo)
aarnet
(Australia)
(Seattle)
(Los Angeles)
Federal Agency Networks, Regional Network
State Wide Networks, University Neworks, Testbed Networks
(Chicago)
ANA300
ESNet
Overlay Network
100G If Not Specified


ESnet6
LSQ
HLAN
NETL-ALB
PNWL
INL
LBNL
NERSC
SLAC
LLNL
SNLCA
NREL
NGA-SW
Salt Lake City
AMES
ANL
FNAL
FRIB
KCNSC
NETL-PGH
NETL-MGN
BNL
LNS
PSFC
CERN
NREL-DC
JLAB
PPPL
ORAU
ORCC
Y-12
ORNL
LANL
LANL-NNSS
KCNSC-NM
SNLA
GA
NNSS
PANTEX
SRS
Hubs
increasing bandwidth
SITES
*Locations generalized for clarity
ESnet
ENERGY
Office of Science
STARLIGHT SM

Internet2 Backbone Topology



NA-REX North America Research & Education Exchange Collaboration



AMPATH PATHWAY TO THE AMERICAS

canarie

ESnet ENERGY SCIENCES NETWORK

INTERNET2

International Networks at Indiana University

STARLIGHT The Optical STAR TAP

CENIC

PACIFIC NORTHWEST GIGAPOP

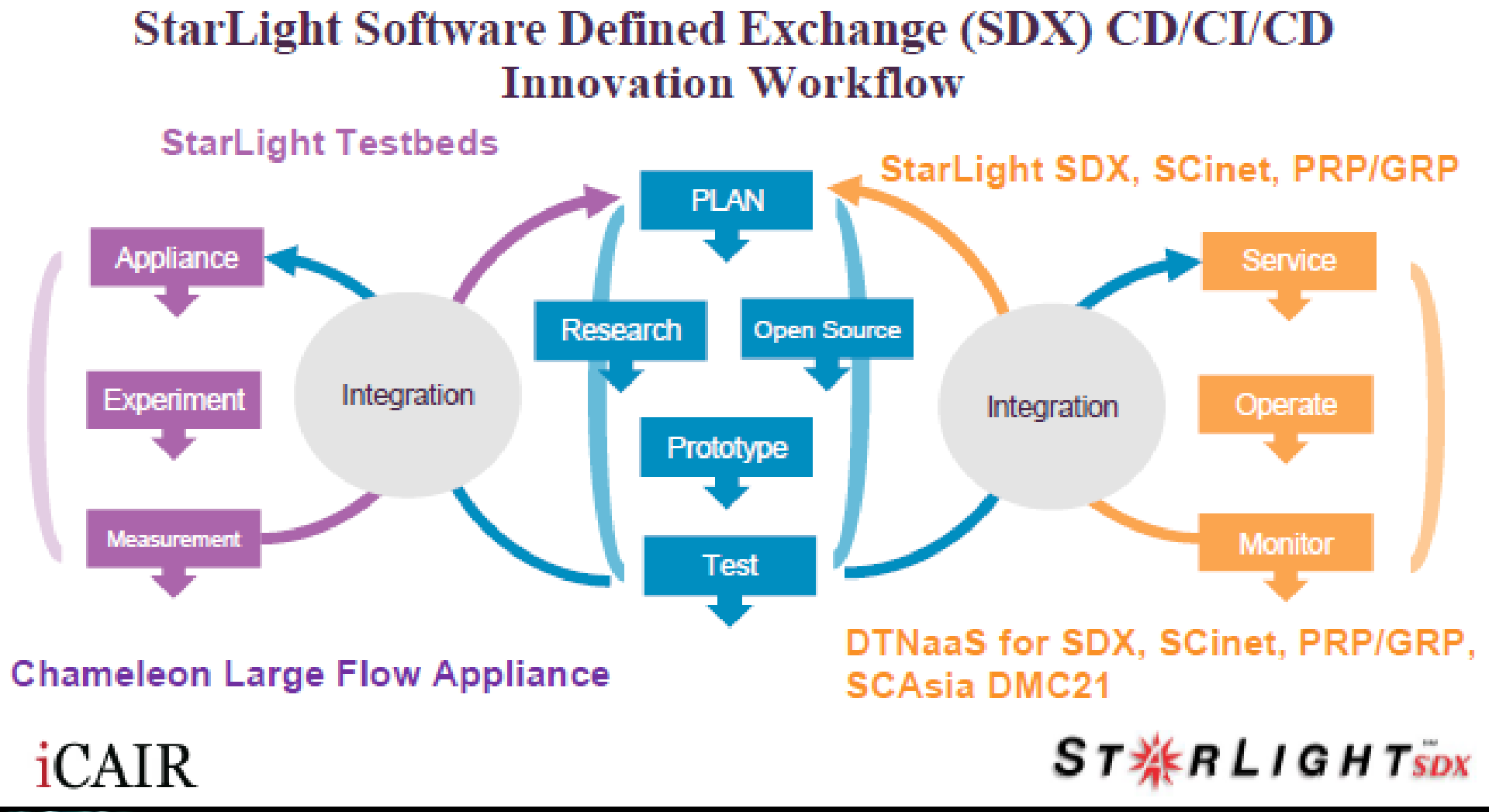
PACIFIC WAVE

November 2023

International Federated Testbeds As Instruments for Computer Science/Network Science

- The StarLight Communications Exchange Facility Supports ~ 28 Network Research Testbeds (Instruments For Computer Science/Networking Research)
- StarLight Supports Two Software Defined Exchanges (SDXs)
- An NSF IRNC SDX & A Network Research
- A Research SDX Supports National and International Federated Testbeds

StarLight Software Defined Exchange



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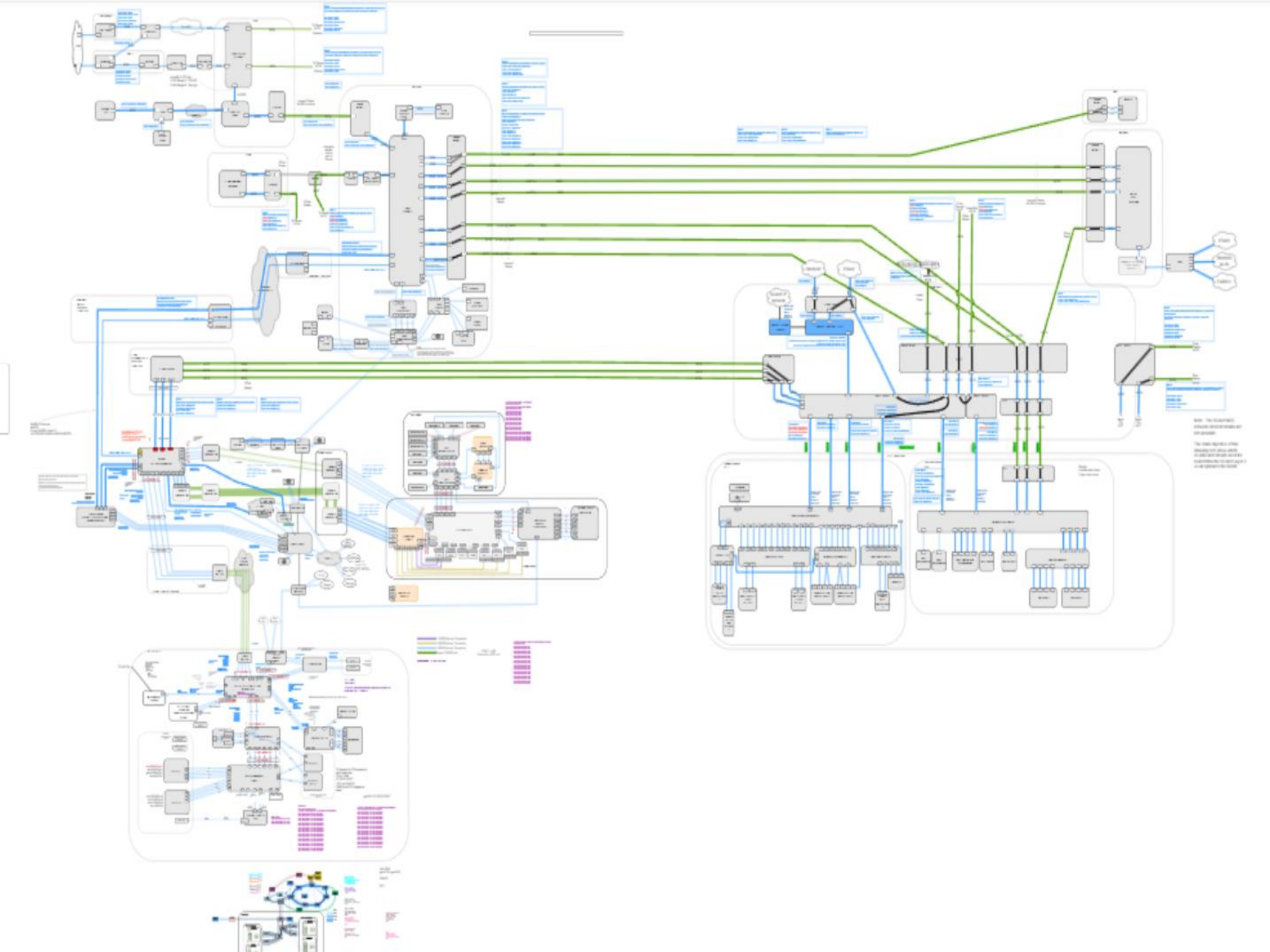
STARLIGHT SDX

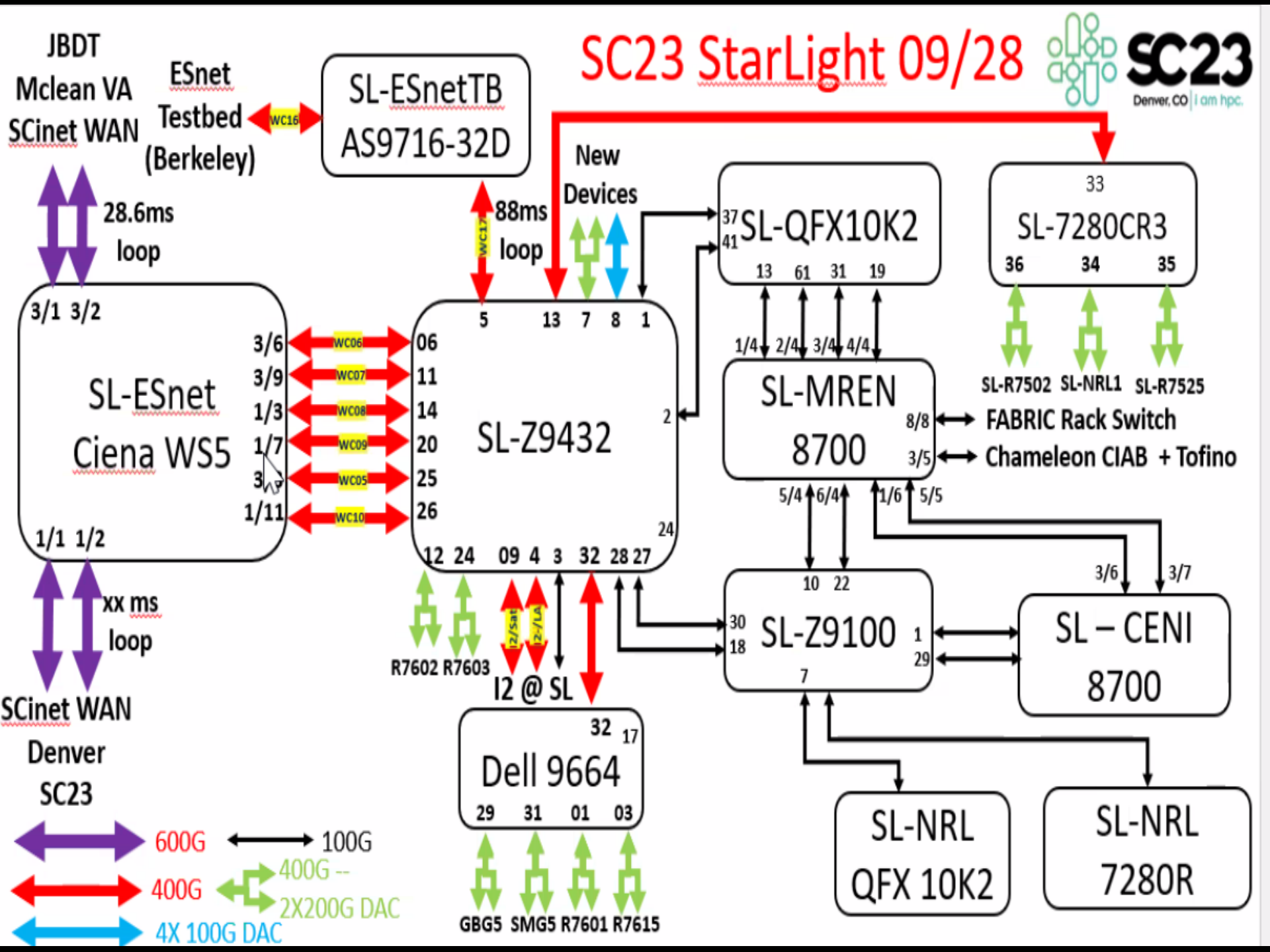
Source: Jim Chen

STARLIGHT SM

SCinet National WAN Testbed

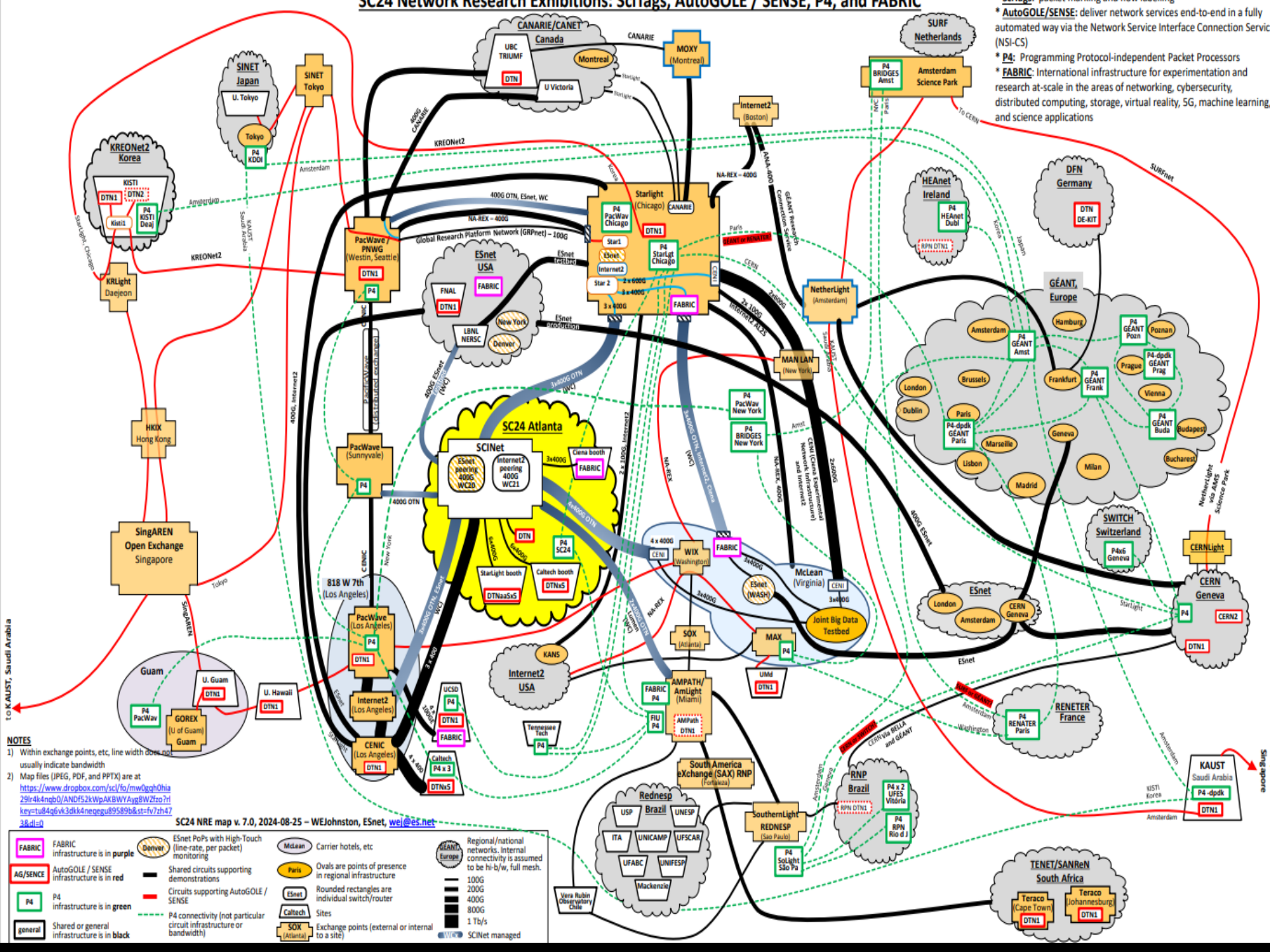
- As In Previous Years, iCAIR Supports SCinet In Designing and Implementing a National WAN Testbed
- A Key Focus Is 400, 800, and 1.2 Tbps Path Services and Interconnections, Including Direct Connections To Edge Nodes, Primarily High Performance DTNs
- The SC23 National WAN Testbed Is Being Designed and Implemented To Support Demonstrations and Experiments Of Innovations Related To Data Intensive Science

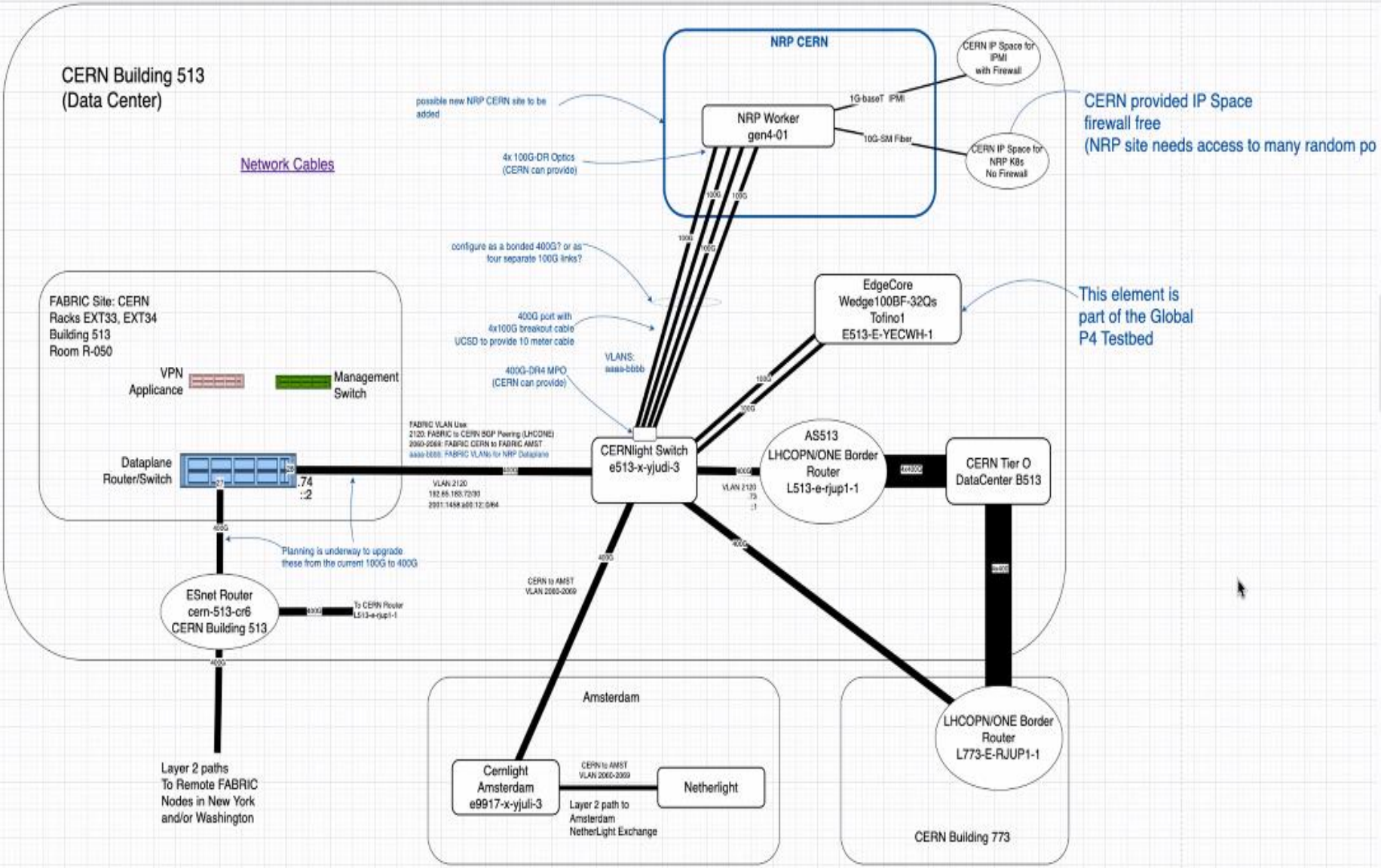



SC23 StarLight 09/28
SC23
Denver, CO | I am hpc.
JBDT
Mclean VA
SCinet WAN
ESnet
Testbed
(Berkeley)
WC16
SL-ESnetTB
AS9716-32D
New
Devices
88ms
loop
WC17
28.6ms
loop
SL-QFX10K2
37
41
13 61 31 19
33
SL-7280CR3
36 34 35
SL-R7502 SL-NRL1 SL-R7525
3/1 3/2
SL-ESnet
Ciena WS5
1/1 1/2
3/6
3/9
1/3
1/7
3
1/11
WC06
WC07
WC08
WC09
WC05
WC10
5 13 7 8 1
06
11
14
20
25
26
2
24
SL-Z9432
12 24 09 4 3 32 28 27
1/4 2/4 3/4 4/4
SL-MREN
8700
8/8
3/5
FABRIC Rack Switch
Chameleon CIAB + Tofino
5/4 6/4
1/6 5/5
3/6 3/7
10 22
30
18
SL-Z9100
1
29
7
SL – CENI
8700
xx ms
loop
SCinet WAN
Denver
SC23
R7602 R7603
I2/Sat
I2/LA
I2 @ SL
32 17
Dell 9664
29 31 01 03
SL-NRL
QFX 10K2
SL-NRL
7280R
GBG5 SMG5 R7601 R7615
600G
100G
400G
400G --
2X200G DAC
4X 100G DAC

SC24 Network Research Exhibitions: SCinet, AutoGOLE / SENSE, P4, and FABRIC

* **AutoGOLE/SENSE**: deliver network services end-to-end in a fully automated way via the Network Service Interface Connection Service (NSI-CS)
* **P4**: Programming Protocol-independent Packet Processors
* **FABRIC**: International infrastructure for experimentation and research at-scale in the areas of networking, cybersecurity, distributed computing, storage, virtual reality, 5G, machine learning, and science applications




CERN Building 513
(Data Center)
Network Cables
NRP CERN
NRP Worker
gen4-01
CERN IP Space for
IPMI
with Firewall
CERN IP Space for
NRP K8s
No Firewall
1G-baseT IPMI
10G-SM Fiber
possible new NRP CERN site to be added
4x 100G-DR Optics
(CERN can provide)
CERN provided IP Space
firewall free
(NRP site needs access to many random po
configure as a bonded 400G? or as four separate 100G links?
400G port with
4x100G breakout cable
UCSD to provide 10 meter cable
400G-DR4 MPO
(CERN can provide)
VLANS:
aaaa-bbbb
EdgeCore
Wedge100BF-32Qs
Tofino1
E513-E-YECWH-1
This element is
part of the Global
P4 Testbed
FABRIC Site: CERN
Racks EXT33, EXT34
Building 513
Room R-050
VPN
Applicance
Management
Switch
Dataplane
Router/Switch
.74
:2
FABRIC VLAN Use:
2120: FABRIC to CERN BGP Peering (LHCONE)
2060-2069: FABRIC CERN to FABRIC AMST
aaaa-bbbb: FABRIC VLANs for NRP Dataplane
VLAN 2120
CERNlight Switch
e513-x-yjudi-3
AS513
LHCOPN/ONE Border
Router
L513-e-rjup1-1
CERN Tier O
DataCenter B513
Planning is underway to upgrade these from the current 100G to 400G
ESnet Router
cern-513-cr6
CERN Building 513
To CERN Router
L513-e-rjup1-1
CERN to AMST
VLAN 2060-2069
Layer 2 paths
To Remote FABRIC
Nodes in New York
and/or Washington
Amsterdam
Cernlight
Amsterdam
e9917-x-yjuli-3
CERN to AMST
VLAN 2060-2069
Netherlight
Layer 2 path to
Amsterdam
NetherLight Exchange
LHCOPN/ONE Border
Router
L773-E-RJUP1-1
CERN Building 773

Example SC24 SCinet Network Research Exhibitions

- Global Research Platform (GRP)
- SDX 1.2 Tbps WAN Services
- SDX E2E 400 Gbps 800 Gbps WAN Services
- 400 Gbps DTNs & Smart NICs
- Orchestration With Packet Marking (SciTags)
- ESnet High Touch Network Measurements
- NA REX Continental Backbone For Data Intensive Science
- SDX International Testbed Integration
- StarLight SDX for Petascale Science
- DTN-as-a-Service For Data Intensive Science With Scitags
- P4 Integration With Kubernetes, P4 Global Lab
- NASA Goddard Space Flight Center HP WAN Transport Services (400 G Dsk-Dsk)
- **Resilient Distributed Processing & Rapid Data Transfer**
- AutoGOLE/SENSE E2E Orchestration Net Services And Workflow Integration
- Open Science Grid Demonstrations
- National Research Platform Demonstrations
- Chameleon FABRIC/FAB Integration
- SciStream Multi Site Data Streaming Orchestration
- Distributed Pipelines Over WANs For On-Line Data Analysis
- DTNs for Research Enhanced Environments (ONION-RED ONION)
- Distributed Hybrid Quantum Computing With PQC/QKD Secured Links

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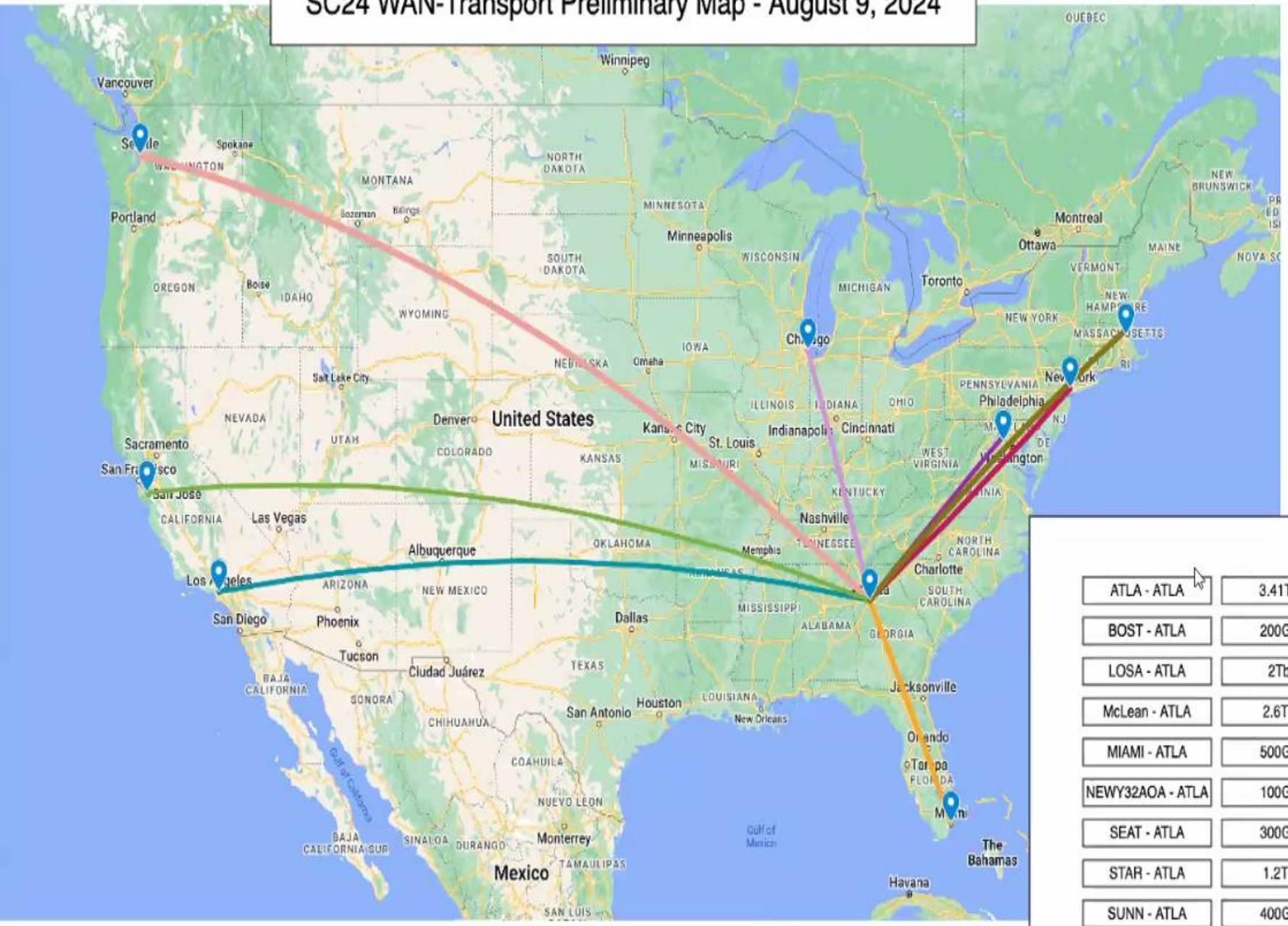
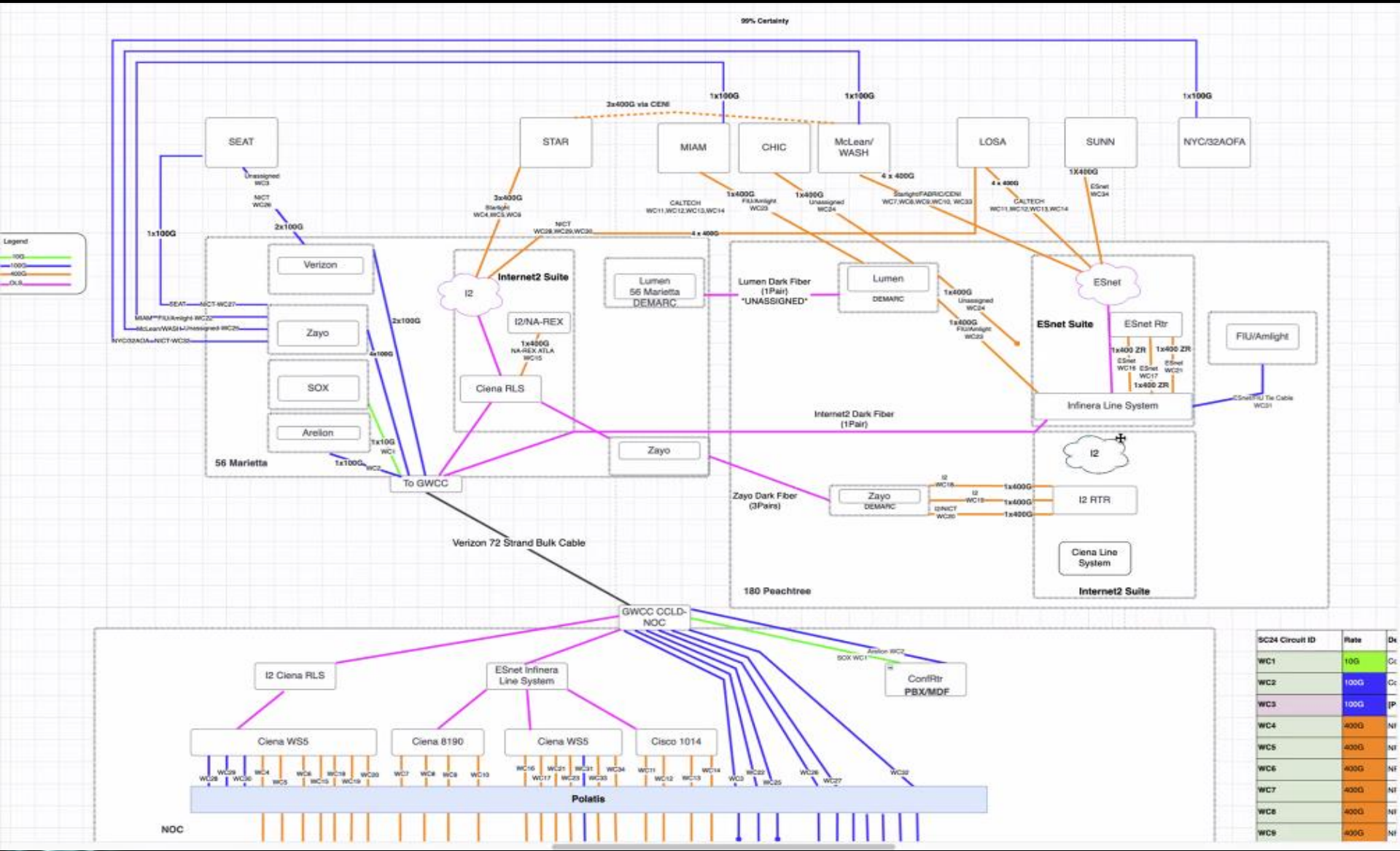
SC24 WAN-Transport Preliminary Map - August 9, 2024



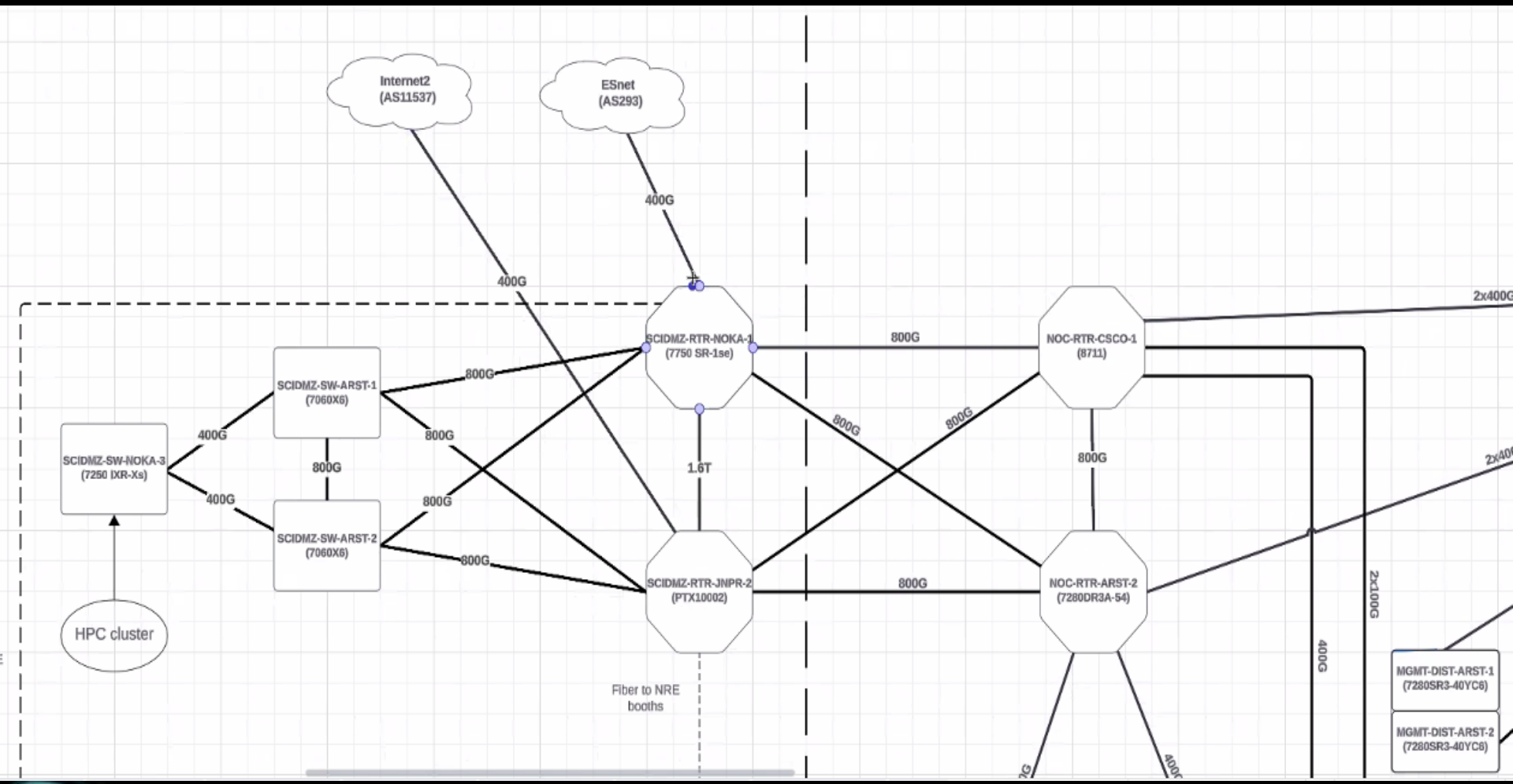
ATLA - ATLA	3.41Tbps
BOST - ATLA	200Gbps
LOSA - ATLA	2Tbps
McLean - ATLA	2.6Tbps
MIAMI - ATLA	500Gbps
NEWY32AOA - ATLA	100Gbps
SEAT - ATLA	300Gbps
STAR - ATLA	1.2Tbps
SUNN - ATLA	400Gbps

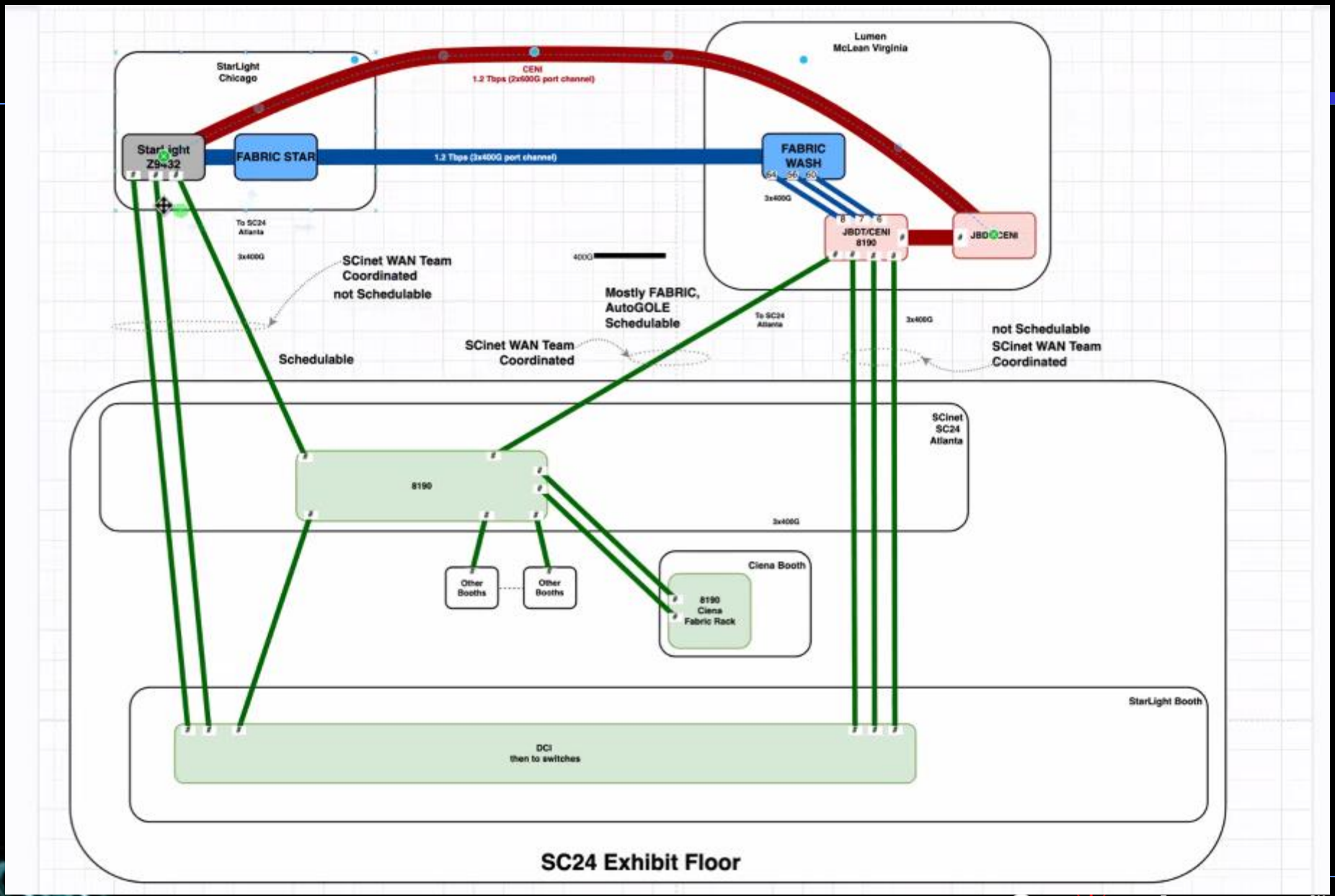
SC24 SCinet 2024

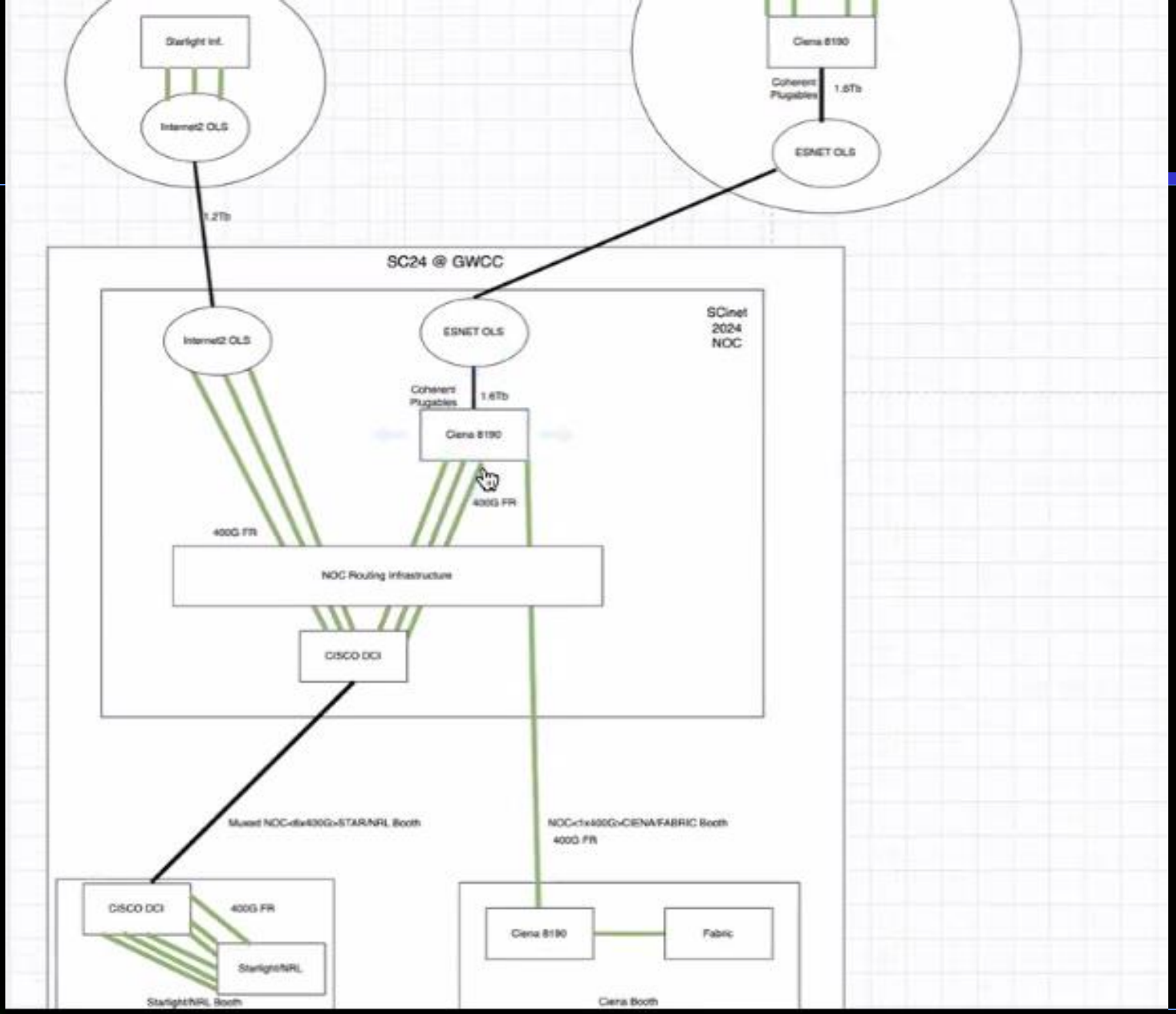


STARLIGHT SM

SCinet SC24 Venue 800 Gbps Science DMZ



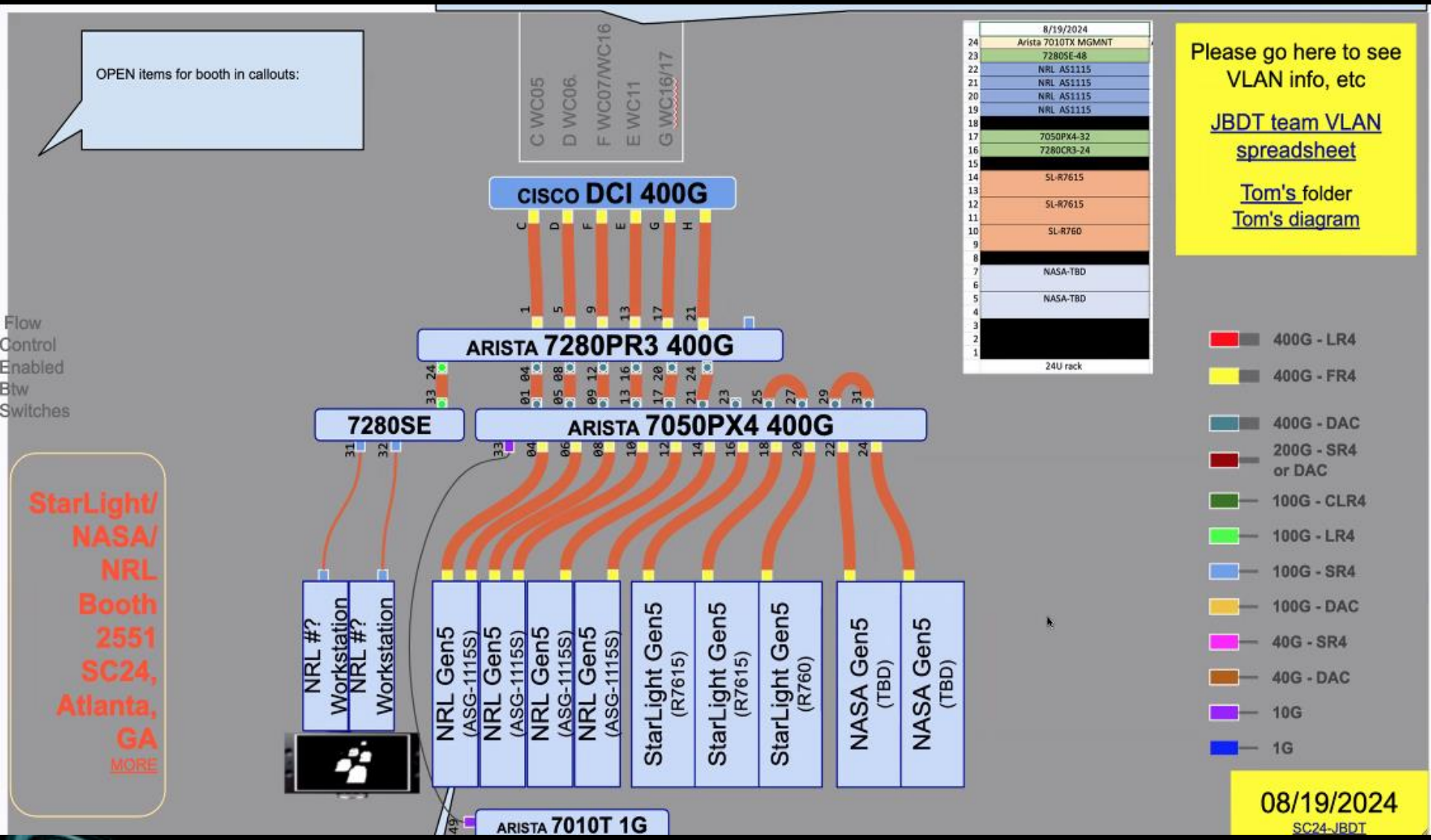

StarLight
Chicago
CENI
1.2 Tbps (2x400G port channel)
Lumen
McLean Virginia
StarLight
Z9-32
FABRIC STAR
1.2 Tbps (3x400G port channel)
FABRIC
WASH
3x400G
To SC24
Atlanta
3x400G
400G
JBDT/CENI
8190
JBD/CENI
SCinet WAN Team
Coordinated
not Schedulable
Mostly FABRIC,
AutoGOLE
Schedulable
To SC24
Atlanta
3x400G
not Schedulable
SCinet WAN Team
Coordinated
Schedulable
SCinet WAN Team
Coordinated
SCinet
SC24
Atlanta
8190
3x400G
Other
Booths
Other
Booths
Ciena Booth
8190
Ciena
Fabric Rack
StarLight Booth
DCI
then to switches
SC24 Exhibit Floor

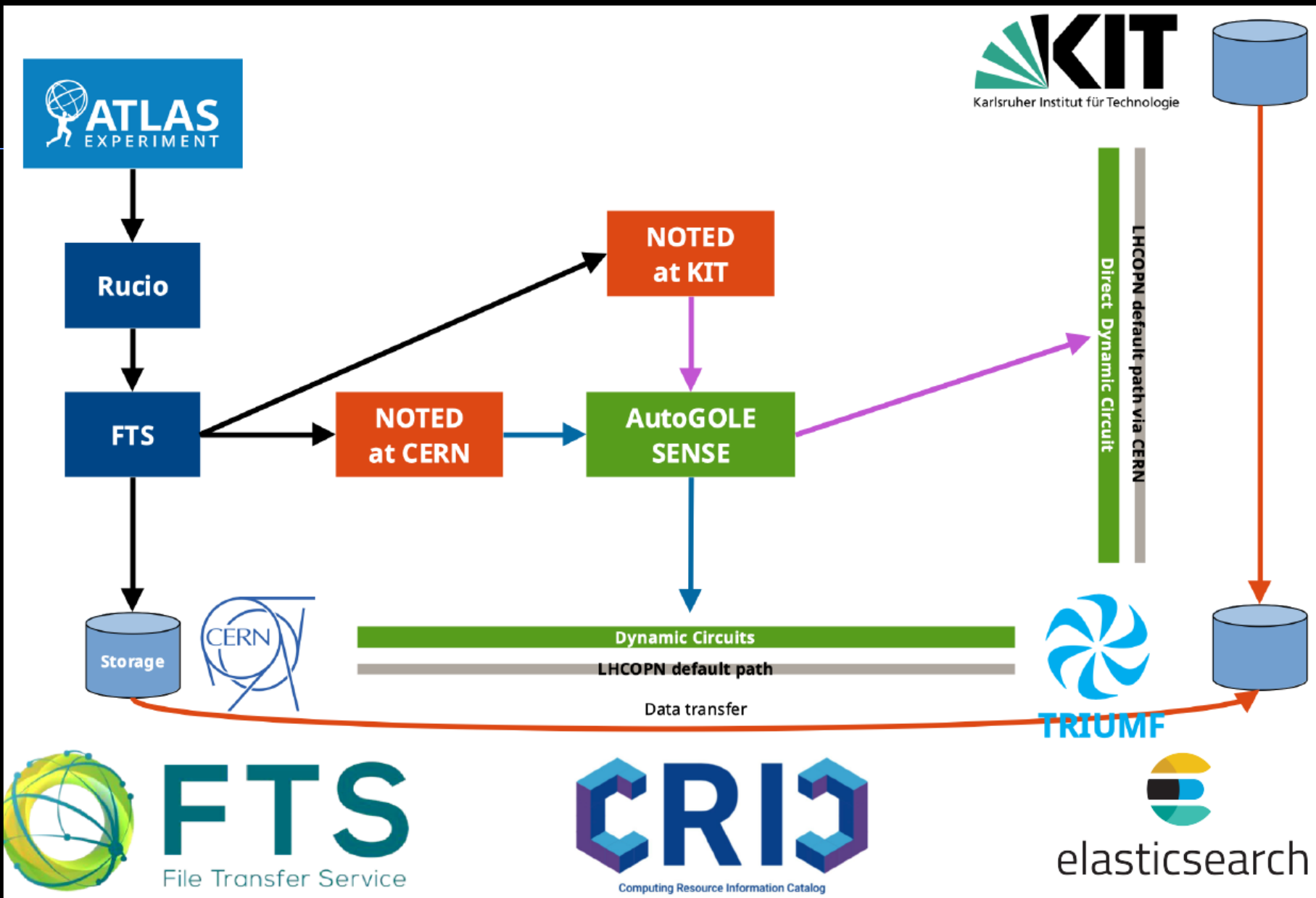


SC24 Venue: 1.2 Tbps and 400 Gbps Paths

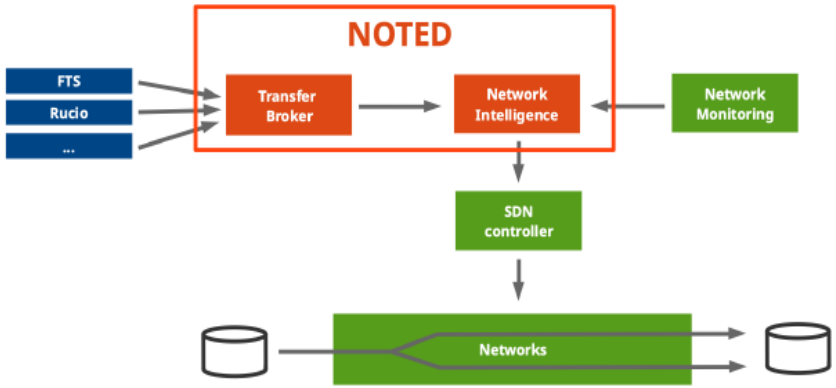
STARLIGHT SM

Planned StarLight Booth SC24, Nov Atlanta




ATLAS EXPERIMENT
Rucio
FTS
NOTED at KIT
NOTED at CERN
AutoGOLE SENSE
Direct Dynamic Circuit
LHCOPN default path via CERN
Storage
CERN
Dynamic Circuits
LHCOPN default path
Data transfer
KIT
Karlsruher Institut für Technologie
TRIUMF
FTS
File Transfer Service
CRIC
Computing Resource Information Catalog
elasticsearch

SKELETON AND ELEMENTS OF NOTED



FTS (File Transfer Service):

- Inspect and analyse data transfers to estimate if an action can be applied to optimise the network utilization → get on-going and queued transfers.

CRIC (Computing Resource Information Catalog):

- Enrichment to get an overview and knowledge of the network topology → get IPv4/IPv6 addresses, endpoints, rcsite and federation.

FLOWCHART AND DATASET STRUCTURE

- Input parameters: configuration given by the user
  - In noted/config/config.yaml → define a list of {src_rcsite, dst_rcsite}, maximum and minimum throughput threshold, SENSE/AutoGOLE VLANs UUID and user-defined email notification among others.
- Enrich NOTED with the topology of the network:
  - Query CRIC database → get endpoints that could be involved in the data transfers for the given {src_rcsite, dst_rcsite} pairs.
- Analyse on-going and upcoming data transfers:
  - Query FTS recursively → get on-going data transfers for each set of source and destination endpoints.
  - The total utilization of the network is the sum of on-going and upcoming individual data transfers for each source and destination endpoints for the given {src_rcsite, dst_rcsite} pairs.
- Network decision:
  - If NOTED interprets that the link will be congested → provides a dynamic circuit via SENSE/AutoGOLE.
  - If NOTED interprets that the link will not be be congested anymore → cancel the dynamic circuit and the traffic is routed back.

scitags.org

Network Flow and Packet Marking for Global Scientific Computing

View On **GitHub** | Download **Tech. Spec** | Join **scitags.org**

Hosted on GitHub Pages — Theme by orderedlist

Scientific network tags (scitags) is an initiative promoting identification of the science domains and their high-level activities at the network level.

It provides an open system using open source technologies that helps *Research and Education (R&E) providers* in understanding how their networks are being utilised while at the same time providing feedback to the *scientific community* on what network flows and patterns are critical for their computing.

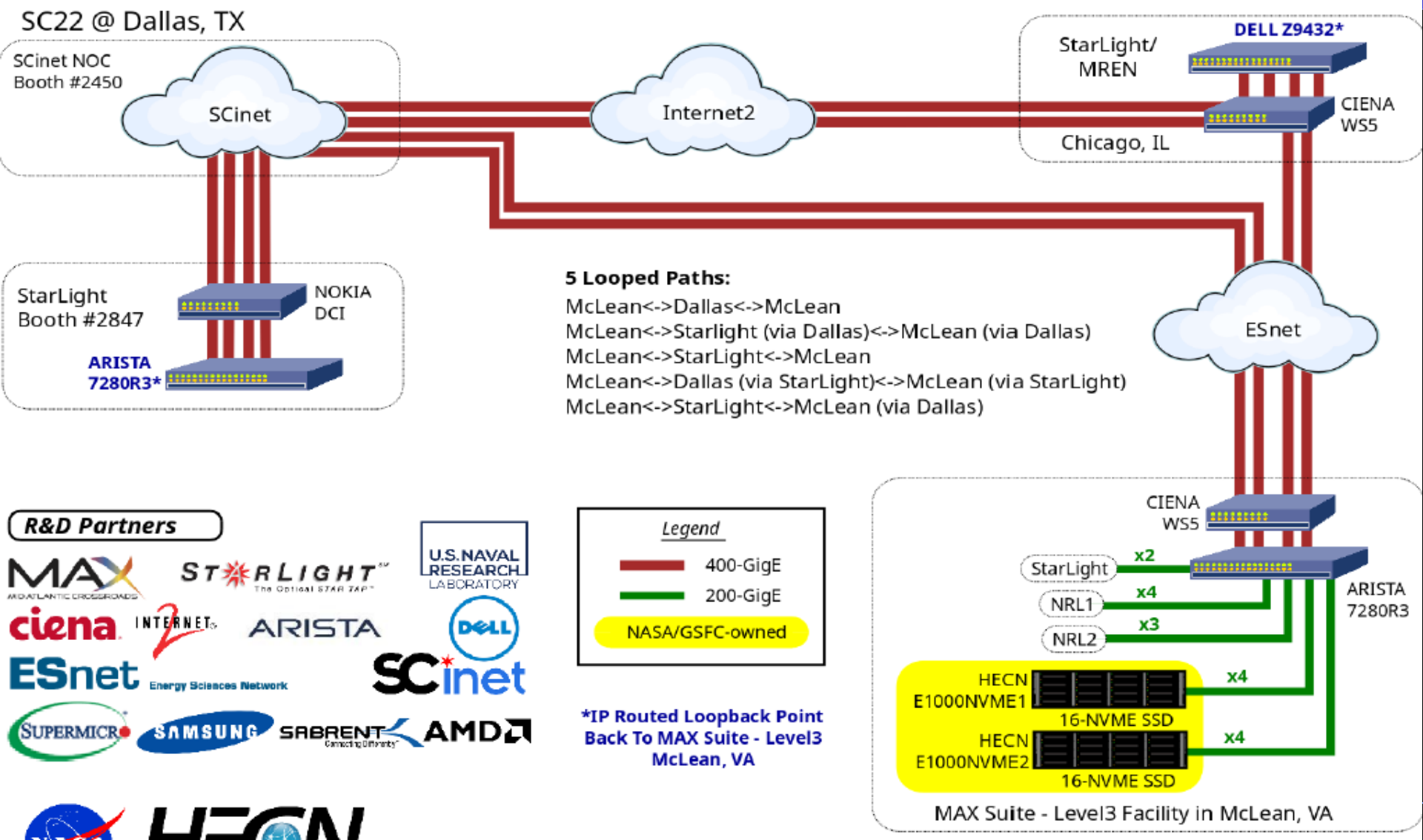
Our approach is based on a network tagging mechanism that marks network packets and/or network flows using the science domain and activity fields. These tags can then be captured by the *R&E providers* and correlated with their existing netflow data to better understand existing network patterns, estimate network usage and track activities.

The initiative offers an **open collaboration on the research and development of the packet and flow marking prototypes** and works in close collaboration with the scientific storage and transfer providers to enable the marking capability. The project is currently in the prototyping phase and is open for participation from any science domain that require or anticipate to require high throughput computing as well as any interested *R&E providers*.

SC22
Joint Big Data Testbed

Demonstrations of 400 Gbps Disk-to-Disk WAN File Transfers using NVMe-oF/TCP

An SC22 Collaborative Initiative Among NASA and Several Partners



R&D Partners

MAX MID-ATLANTIC CROSSROADS · STARLIGHT The Optical STAR TAP · U.S. NAVAL RESEARCH LABORATORY · ciena · INTERNET2 · ARISTA · DELL · ESnet Energy Sciences Network · SCinet · SUPERMICRO · SAMSUNG · SABRENT · AMD

Legend

400-GigE

200-GigE

NASA/GSFC-owned

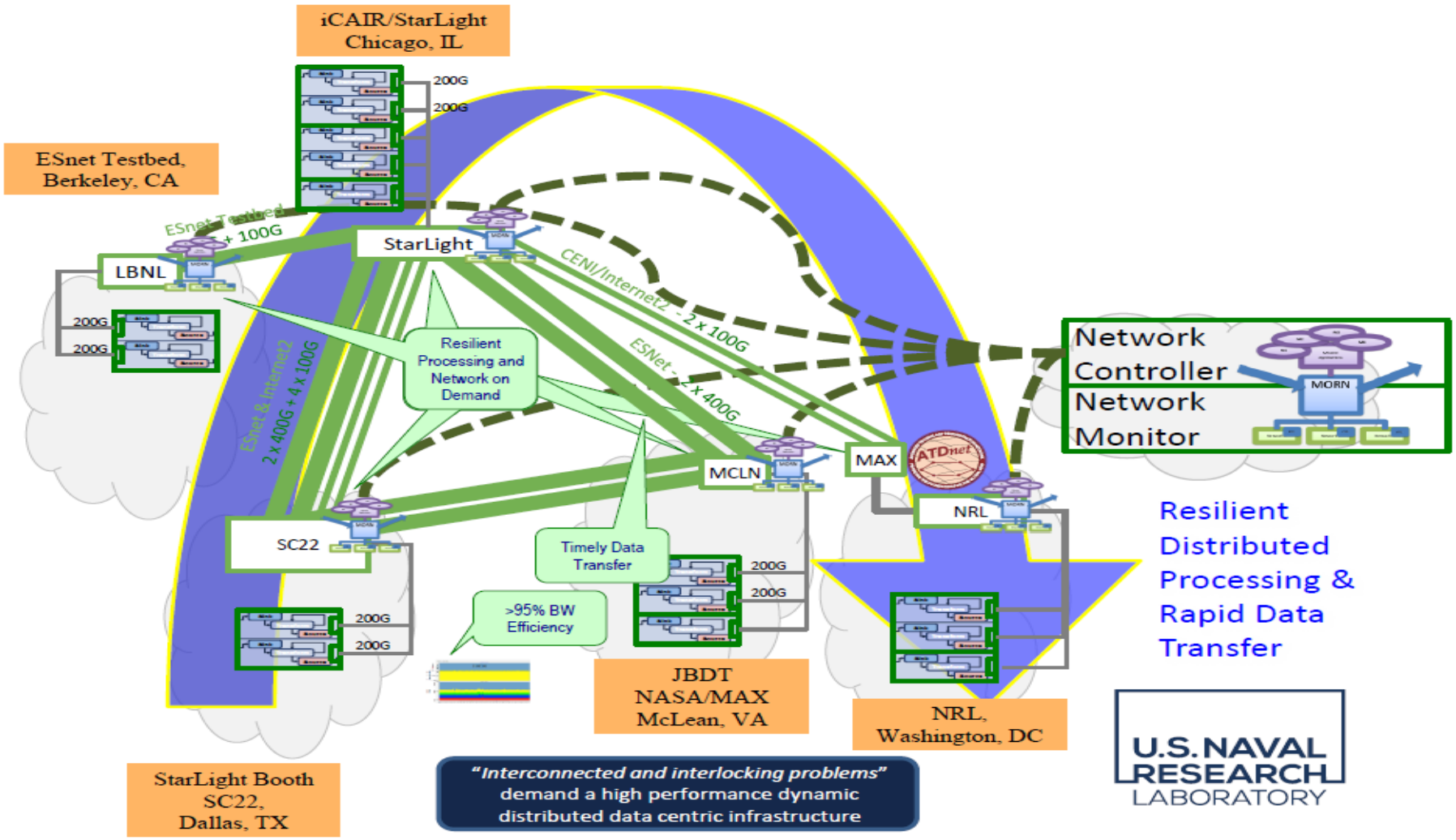
***IP Routed Loopback Point Back To MAX Suite - Level3 McLean, VA**

NASA · HECN High End Computer Networking

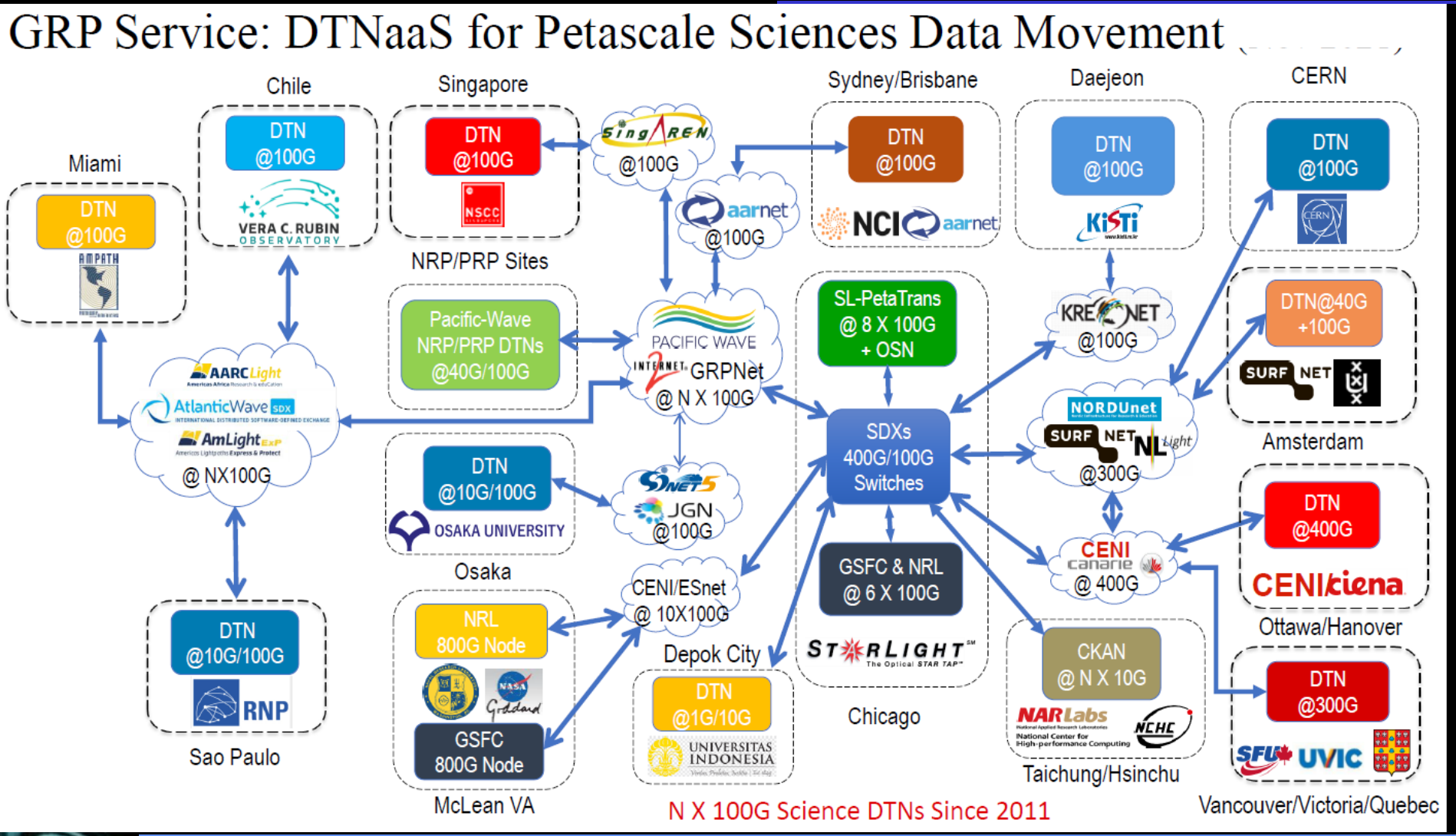
In memory of Paul Lang and Pat Gary

NASA/GSFC High End Computer Networking (HECN) Team
Diagram by Bill Fink - 10/20/2022

Resilient Disributed Processing & Rapid Data Transfer



GRP DTNaaS For Petascale Science



DTN-as-a-Service – Demonstrated At SC22

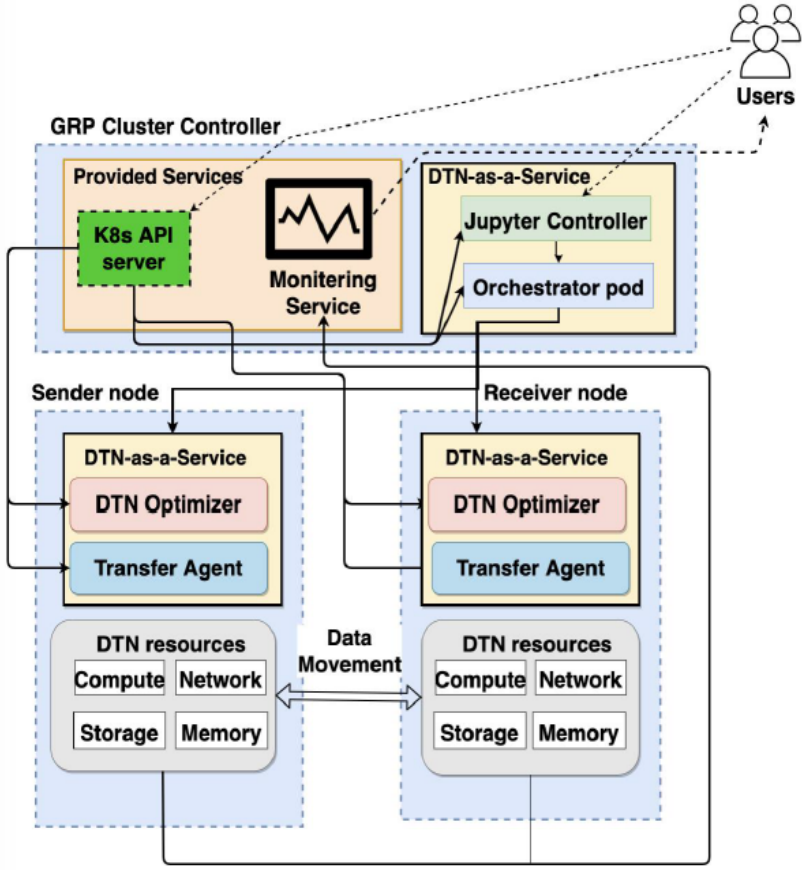
GRP Cluster with DTN-as-a-Service

DTN-as-a-Service(DTNaaS) provides a data movement workflow in GRP k8s cluster:

1. Deploy DTNaaS workloads via k8s API server
2. Use Jupyter to optimize and run transfers
3. Observe performance from monitoring service

GRP DTNaaS Components:

- Orchestrator: controller of DTNaaS to manage agent and optimizer pods via REST API.
- Transfer Agent: run transfer jobs
- DTN Optimizer: optimize the DTN resources for workflow
- Jupyter: web interface to run DTNaaS interactively

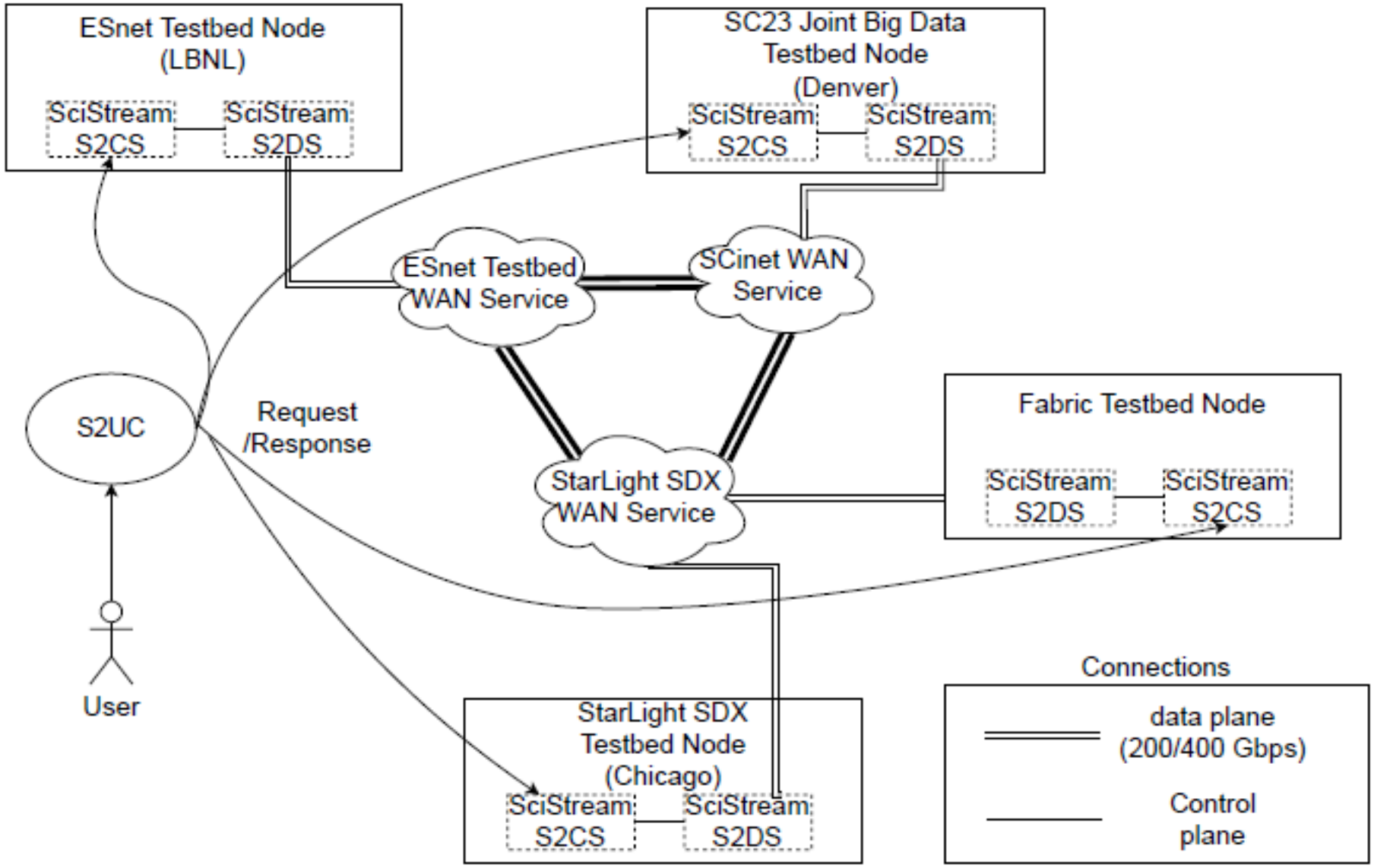


iCAIR

STARLIGHT SDX

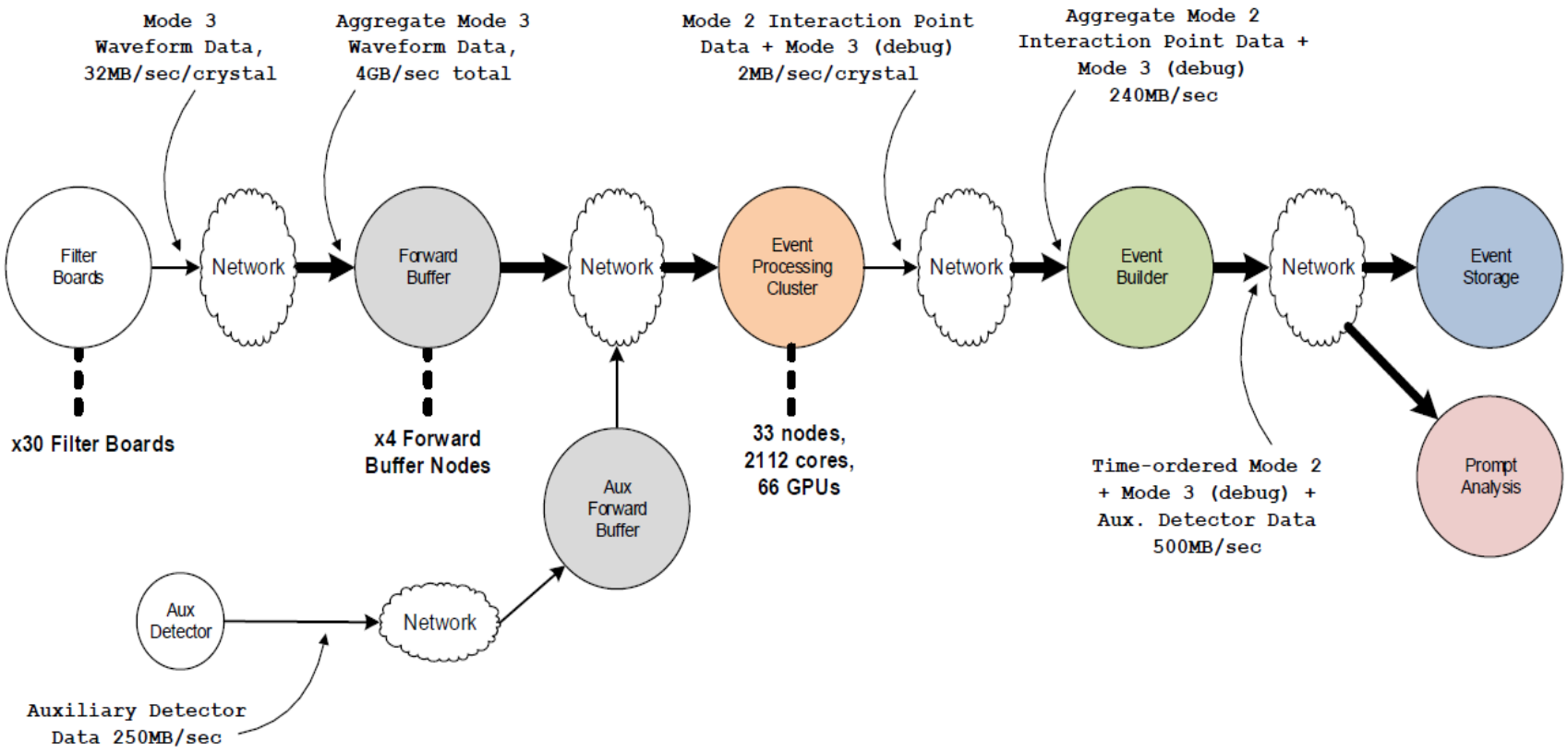
STARLIGHT

SC23 NRE-010: Multi-site data streaming orchestration with SciStream



ESnet Gamma Ray Energy Tracking Array (GRETA) Prototype

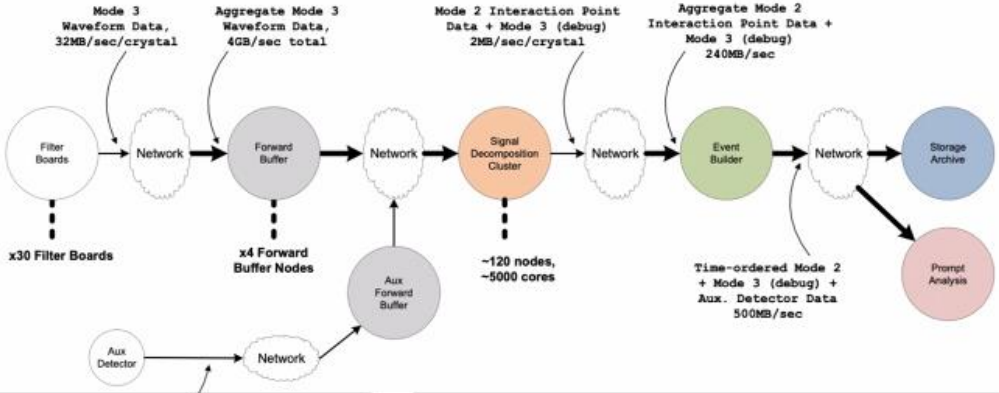
GRETA Data Pipeline



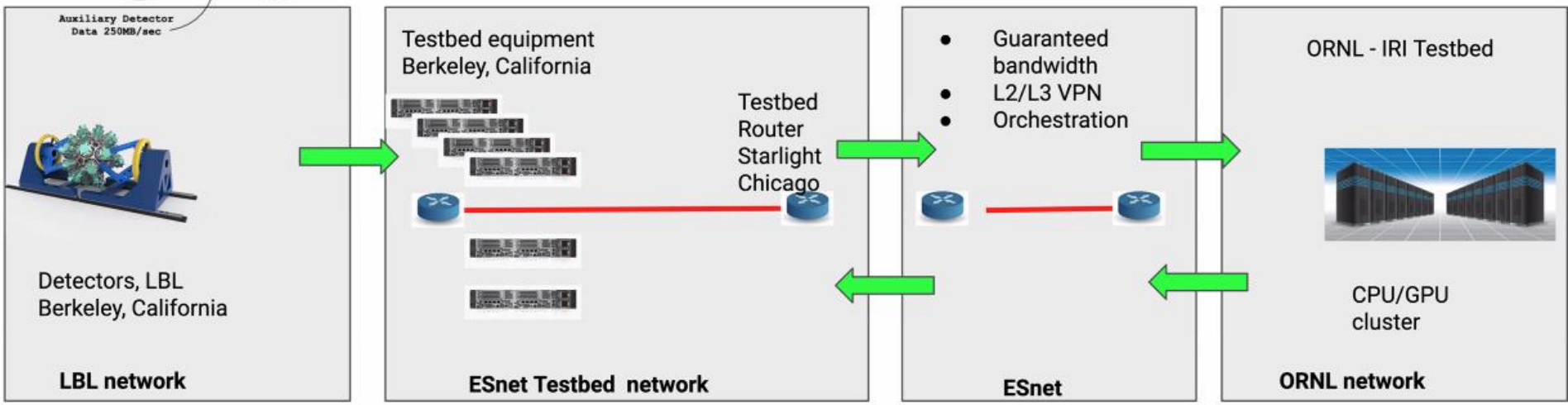
Source: ESnet Testbed

STARLIGHT SM

GRETA to DELERIA



Impact: scaling up online processing using user facilities

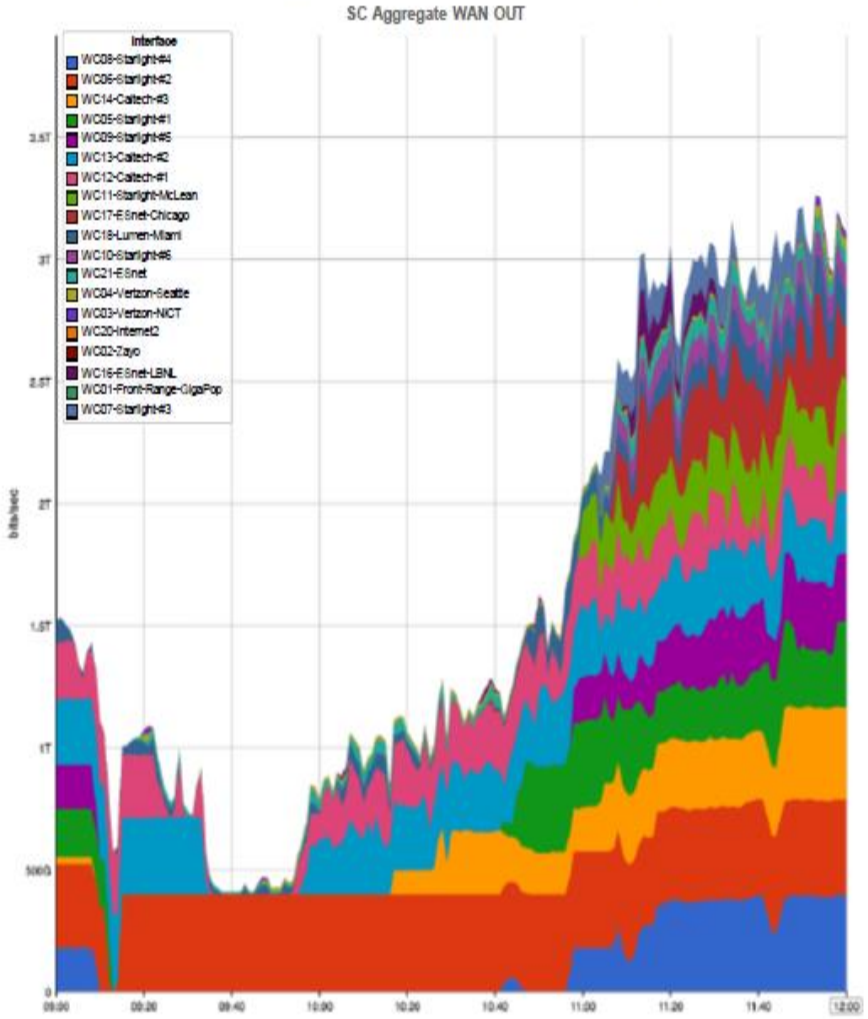


Source: ESnet Testbed

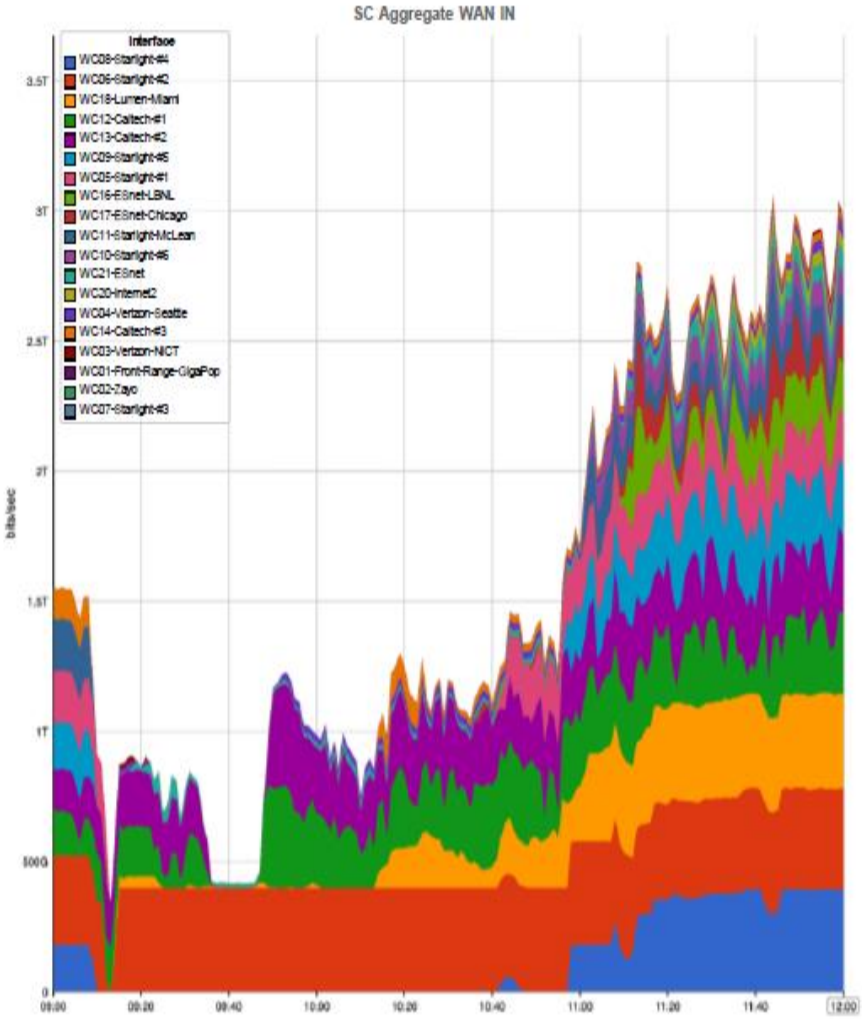
STARLIGHT SM

SC23 Bandwidth Challenge

StarLight contributes 4 of Top 5

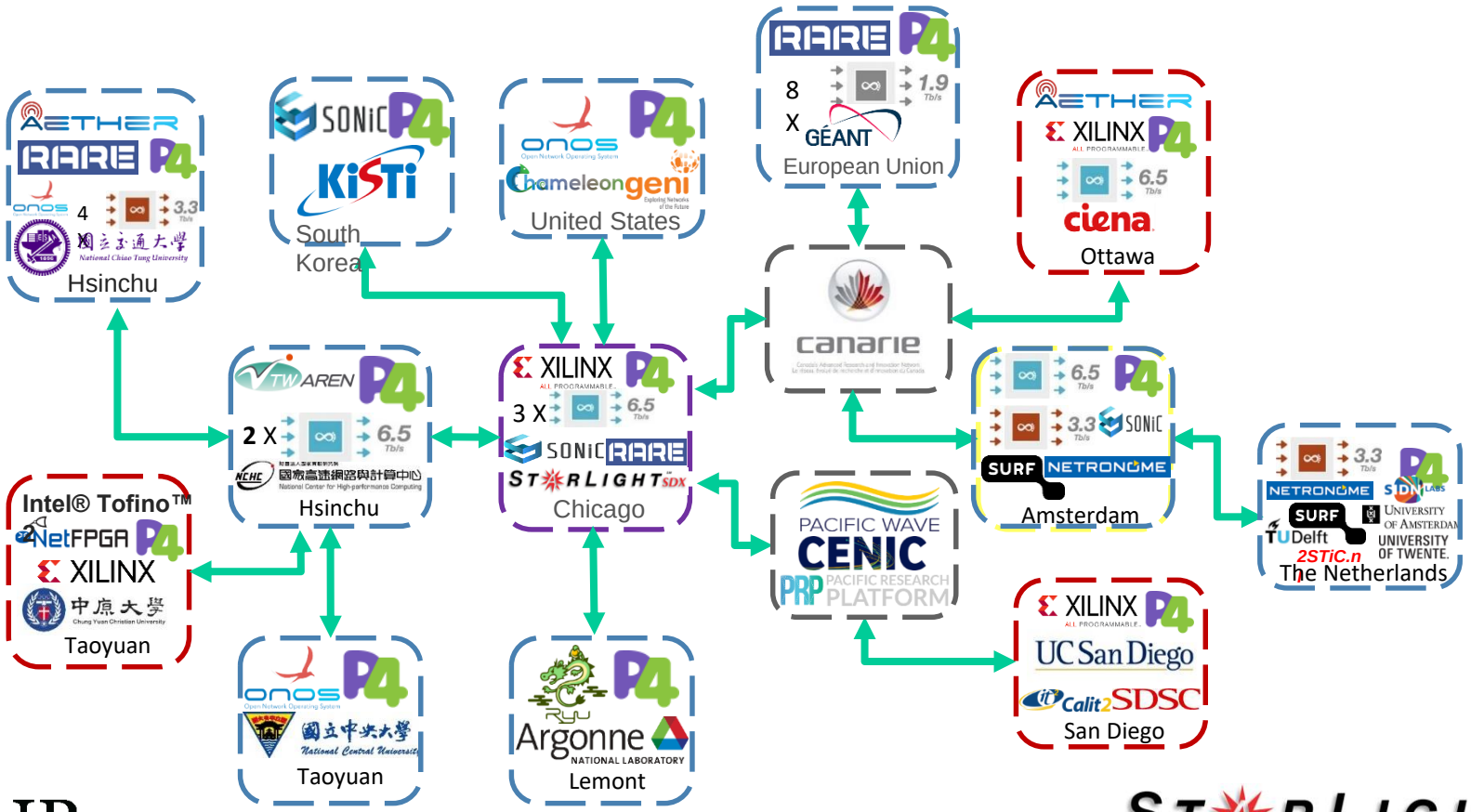


StarLight contributes 2 of Top 5



International P4 Testbed Showcase at SC23

GRP Service: International P4 Experimental Networks (iP4EN)



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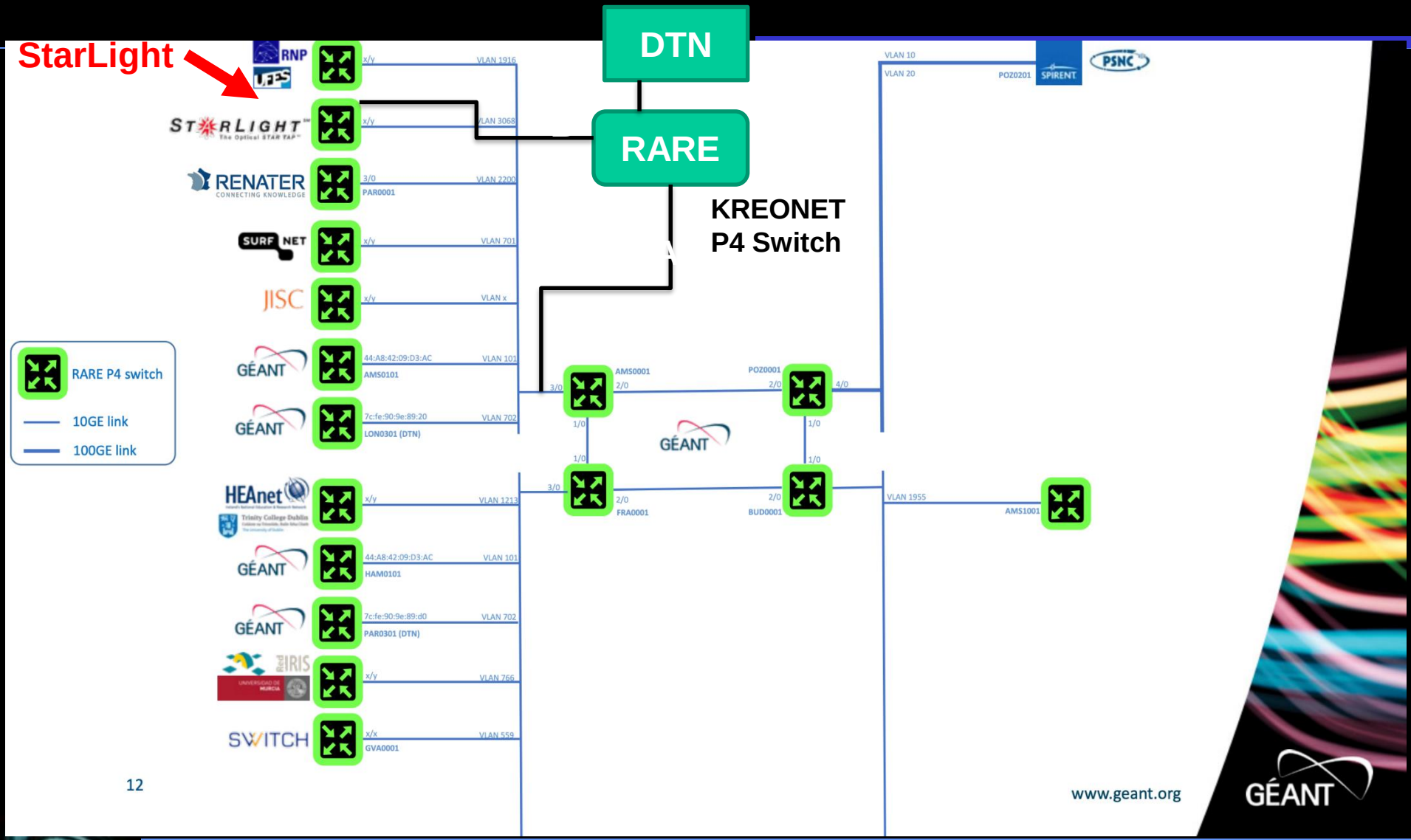
STARLIGHT SDX

Integration With GEANT P4 Testbed



Chameleon

www.chameleoncloud.org

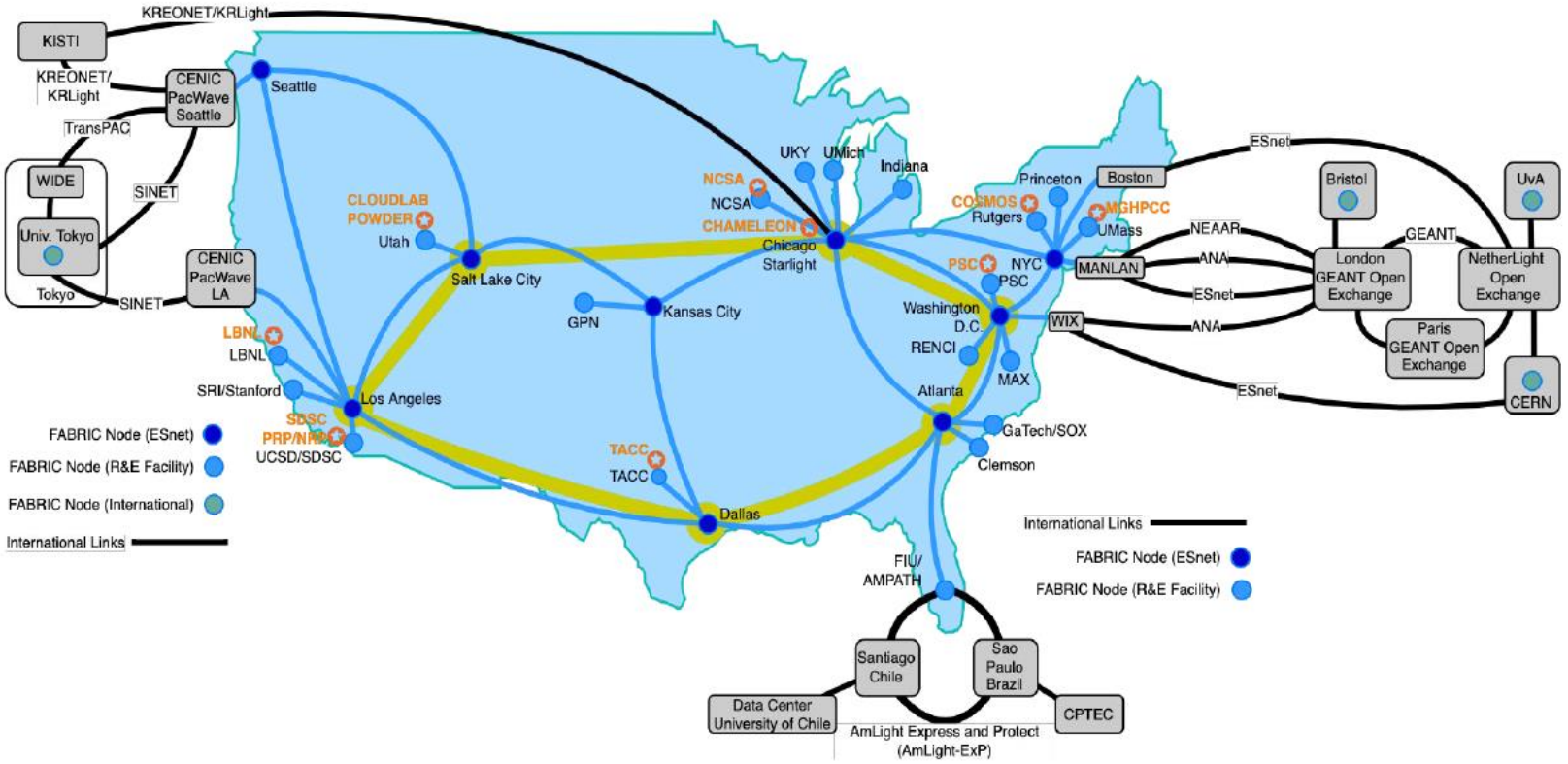
CHAMELEON: A LARGE SCALE, RECONFIGURABLE EXPERIMENTAL INSTRUMENT FOR COMPUTER SCIENCE

Kate Keahey

Joe Mambretti, Pierre Riteau, Paul Ruth, Dan Stanzione

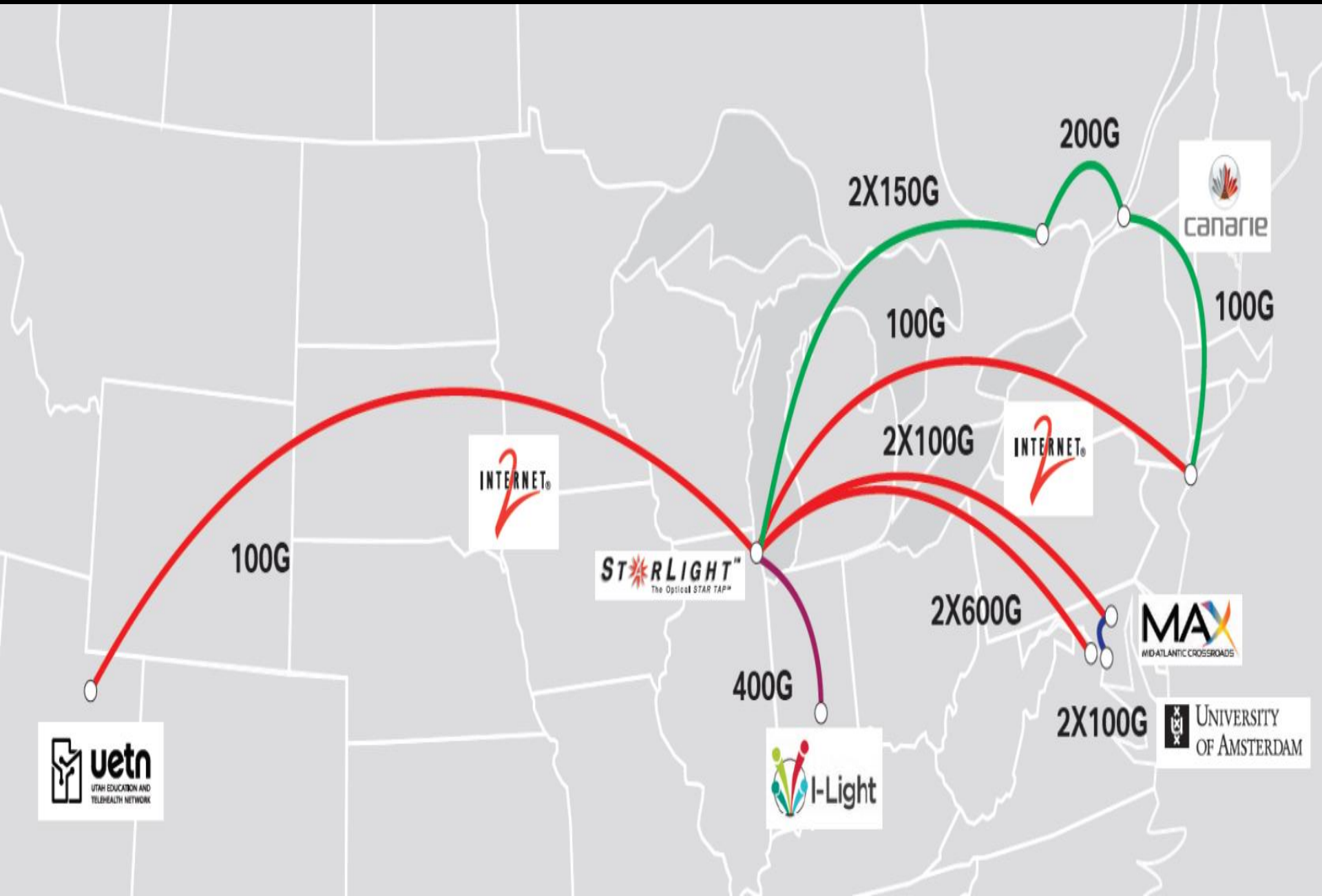
THE UNIVERSITY OF CHICAGO TACC renci NORTHWESTERN UNIVERSITY NSF

FABRIC Testbed (+FAB)

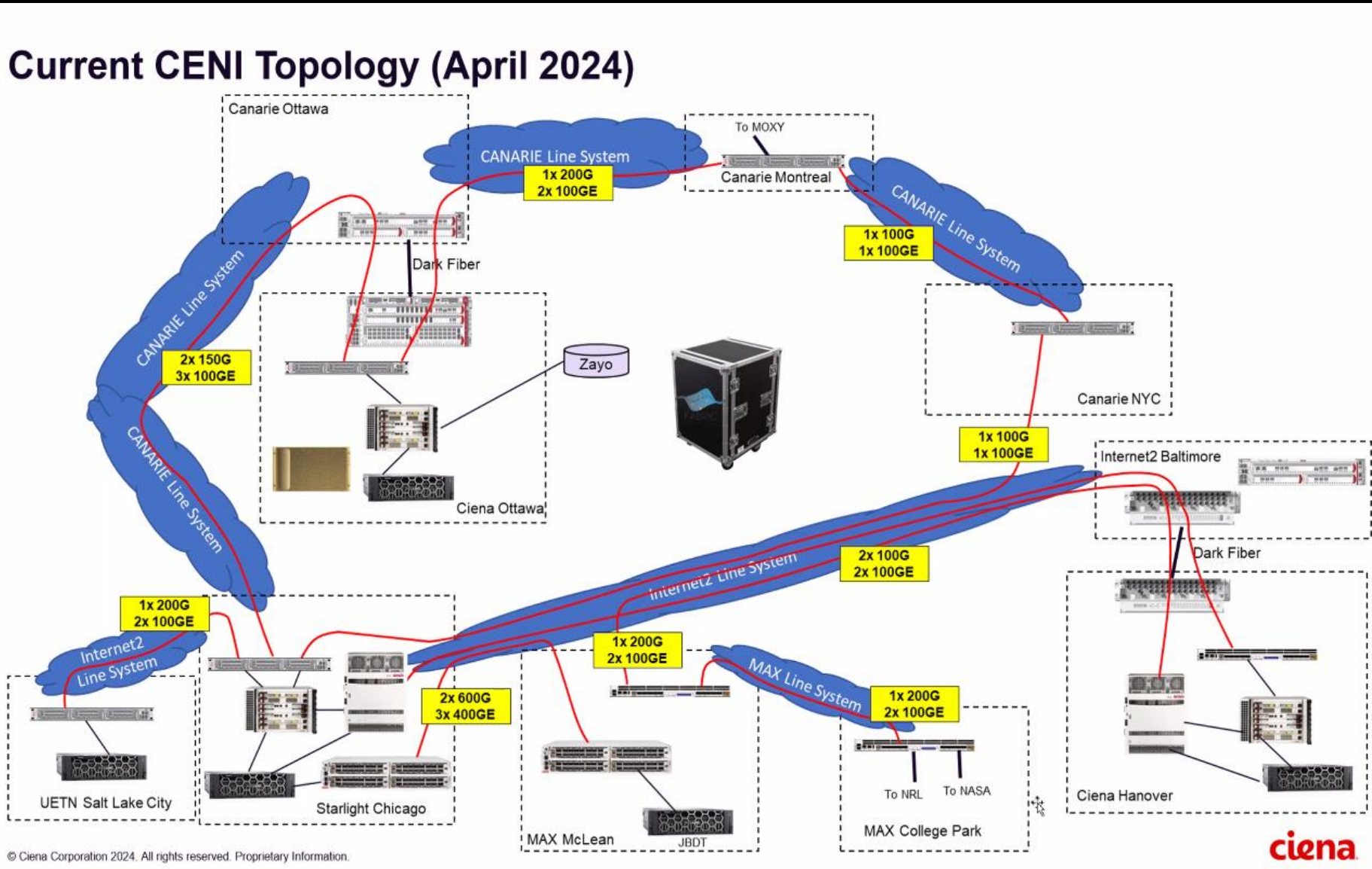


FABRIC Topology - with FAB Sites

Ciena CENI


200G
2X150G
canarie
100G
100G
2X100G
INTERNET2
INTERNET2
100G
STARLIGHT
The Optical STAR TAP
2X600G
MAX
MID-ATLANTIC CROSSROADS
400G
2X100G
UNIVERSITY OF AMSTERDAM
uetn
UTAH EDUCATION AND TELEHEALTH NETWORK
I-Light

Ciena CENI



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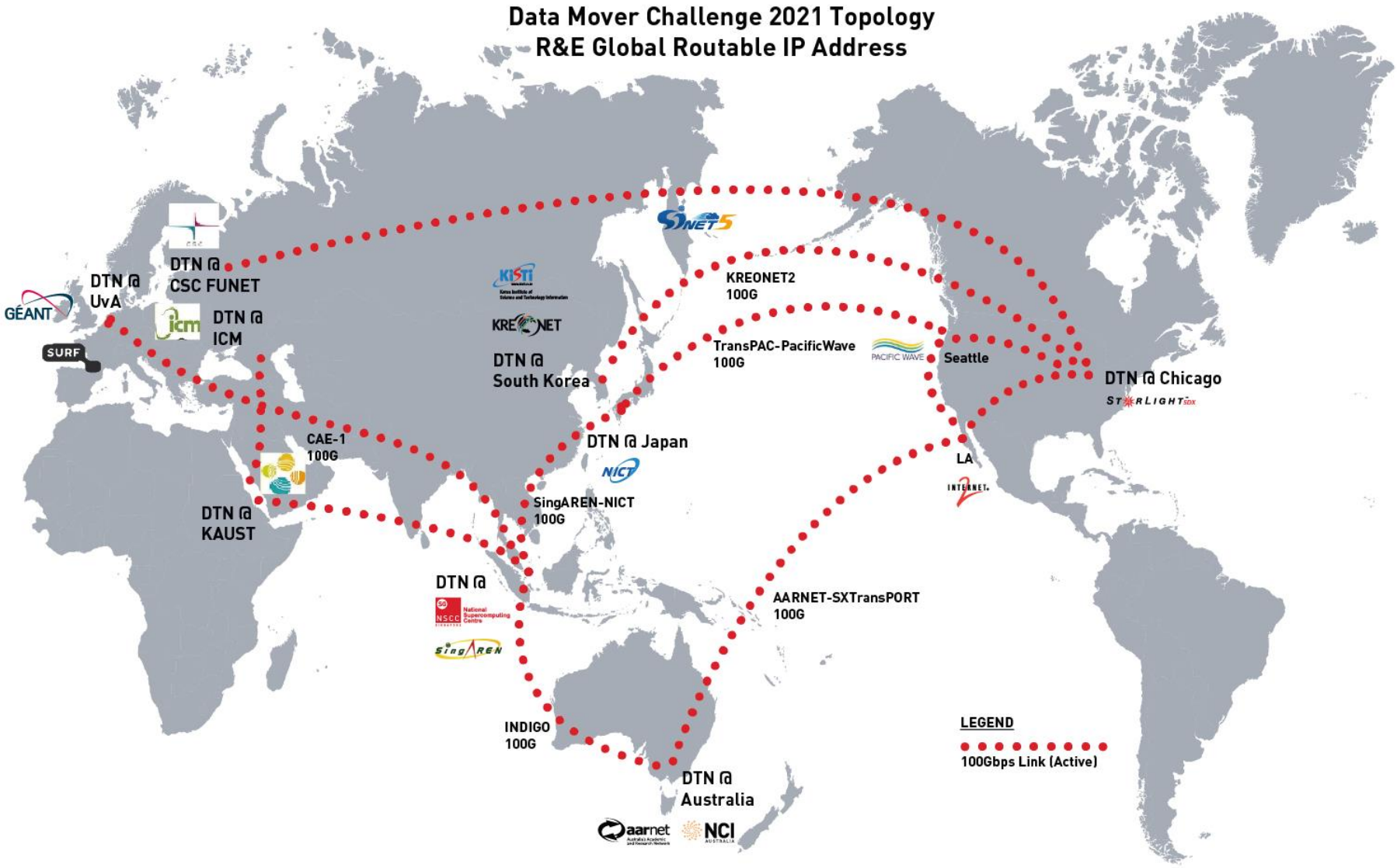
FabFed

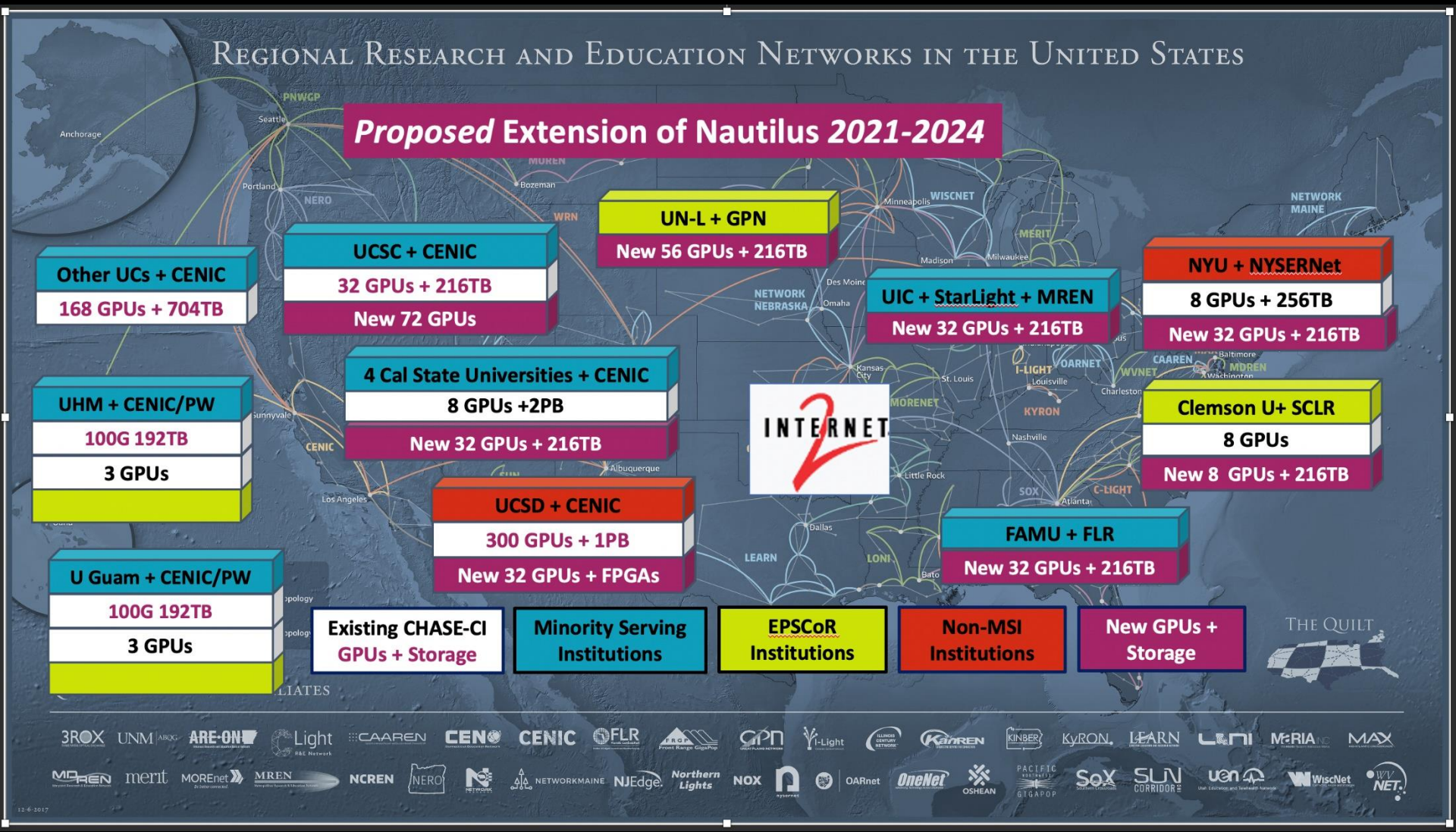
FABRIC Federation Software Extension (FabFed)

- Goals
  - Provide a software stack for FABRIC users to run experiment with tool-based federation across multiple testbeds and providers
  - Integrate external network and cloud resources into a FABRIC slice in an automated and orchestrated fashion
  - Explore a "testbed of testbeds" paradigm for the future
- Targets
  - NSF Cloud Testbeds (Chameleon & CloudLab)
  - Internet2 AL2S L2, L3 and Cloud Connect Services
  - Public Cloud (AWS, GCP, Azure)
  - AutoGOLE/SENSE Testbed (most regional and international RENs)
  - Other NSF Testbeds such as POWDER, and more

StarLight: Founding Partner Of Supercomputing Asia DMC International Testbed



National Research Platform



+ Open Science Grid & Open Science Data Grid

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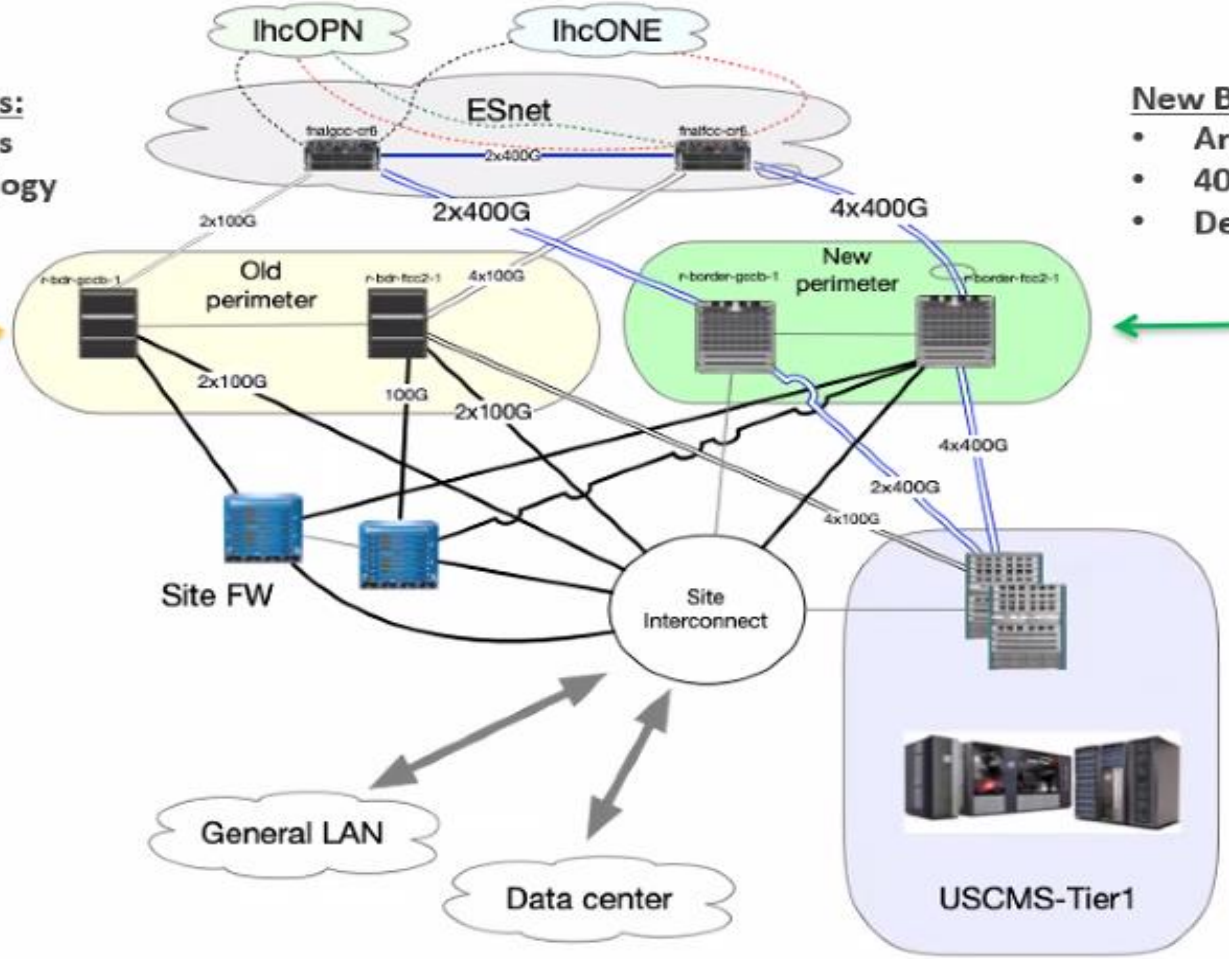
WAN Connectivity Transition! (to 2.4Tb/s...)

Old Border Routers:
- Brocade MLXes
- 100GE technology

New Border Routers:
- Arista 7808R3s
- 400-800GE technology
- Deep buffers

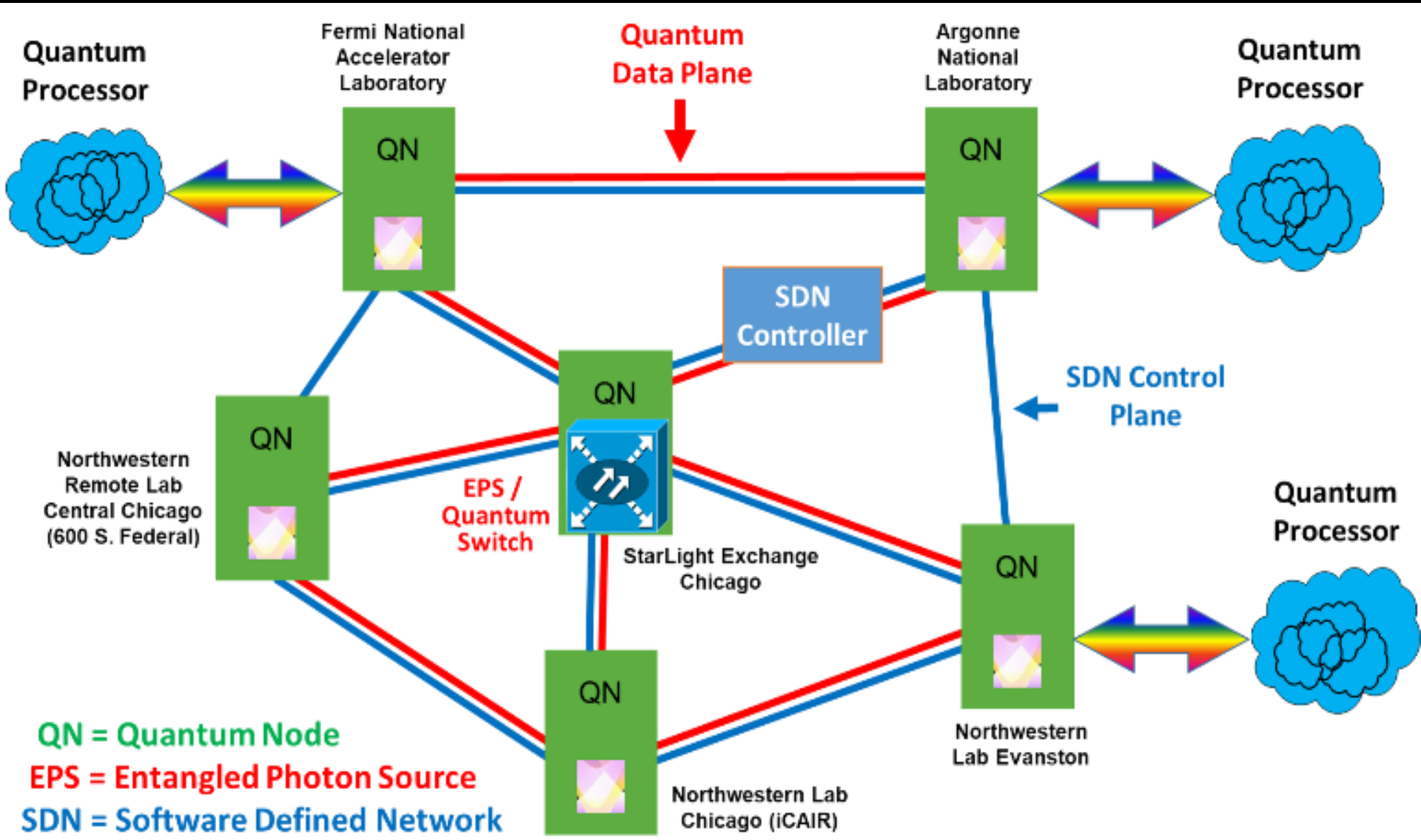


Also: Large Scale Network Research Testbed On Site

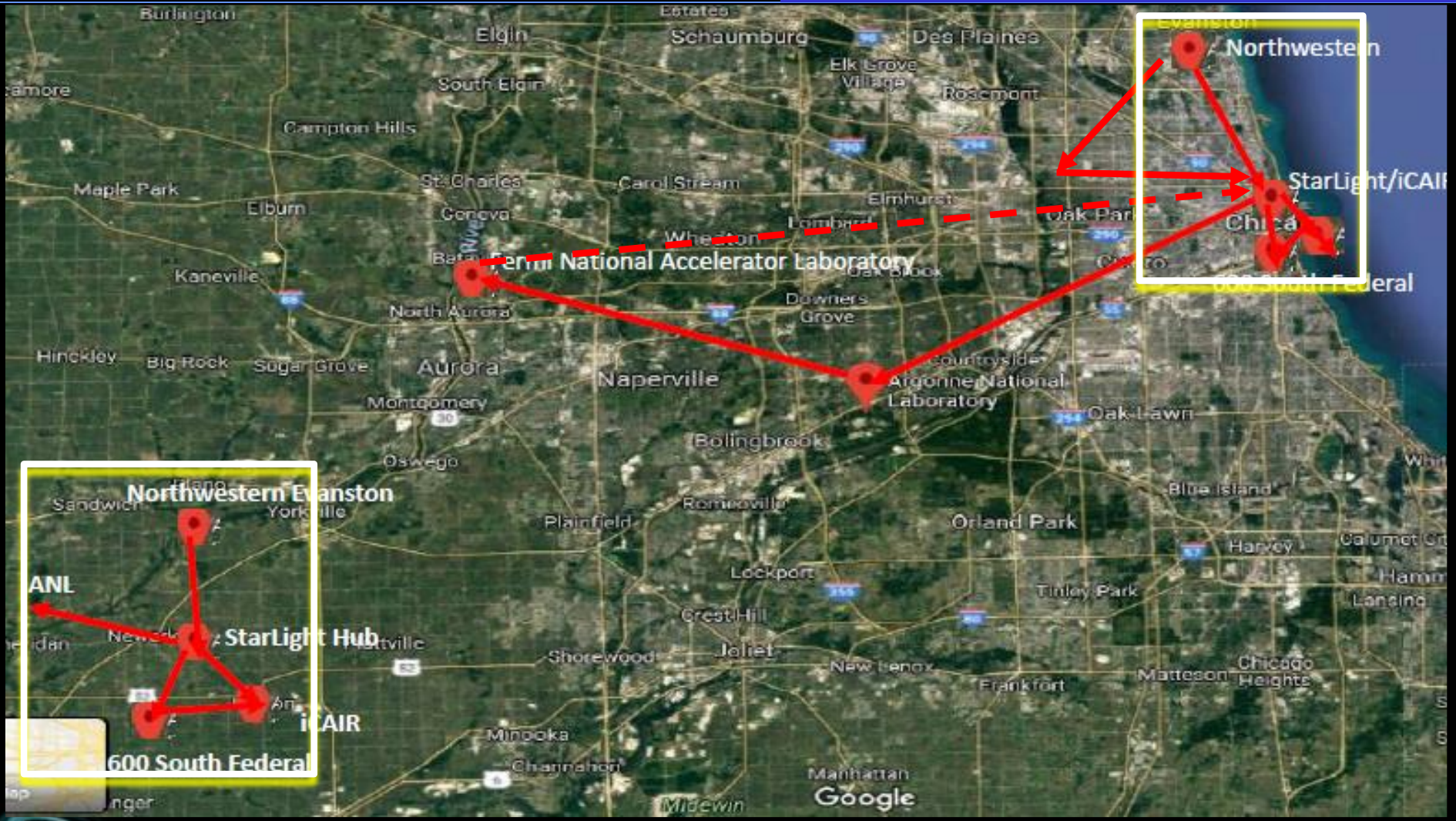
Quantum Communications And Networks: Motivation

- **Quantum Enables Many New Applications**
  - **Security – e.g., Quantum Key Distribution (QKD), Highly Secure Information Transmission, Quantum Encryption**
  - **Quantum Sensors**
  - **Quantum – e.g., Precise Clocks**
  - **New Applications Derived From Unique Properties (e.g., Superposition) And Novel Quantum Devices**
  - **Communications Among Quantum Computers, e.g., To Address Complex Computational Science Problems Through Distributed Quantum Environments (iCAIR's Quantum Research Focus)**

Emerging Chicago Quantum Exchange Testbed



Energing IEQnet Testbed Topology



Illinois Express Quantum Network

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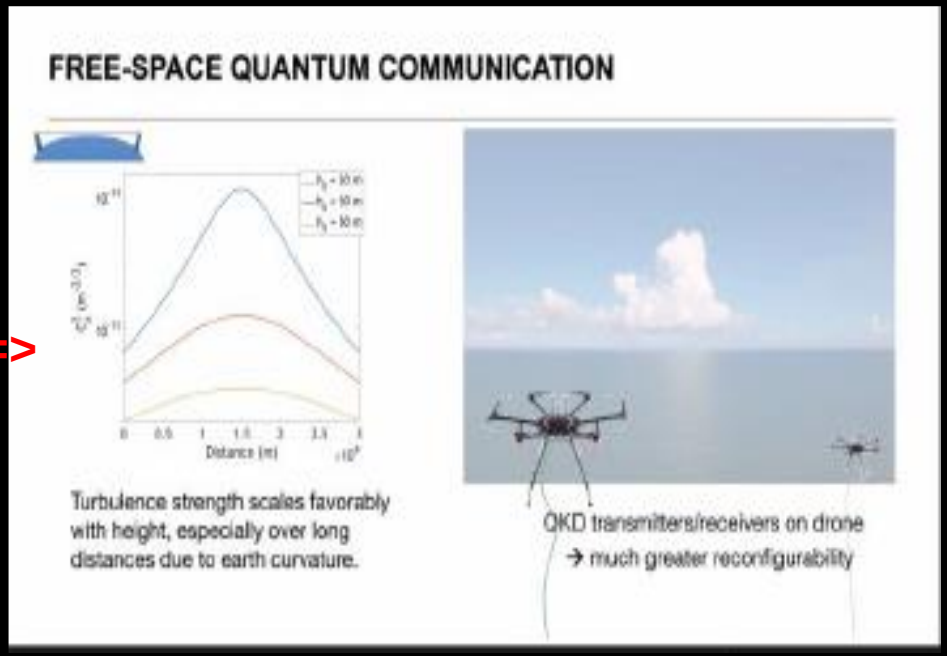
IQUIST Quantum Network Testbed: QUIUC-NET

(Hyper)Entangled Sources
Photon Detectors
Quantum Memories
Processing Nodes
Net Aps
Protocols
Distributed Processing
Sensing Net Verification
Repeater Enhanced Quantum Links
Free Space Quantum Communications=>



Source: Paul Kwiat, Director, IQUIST

UIUC

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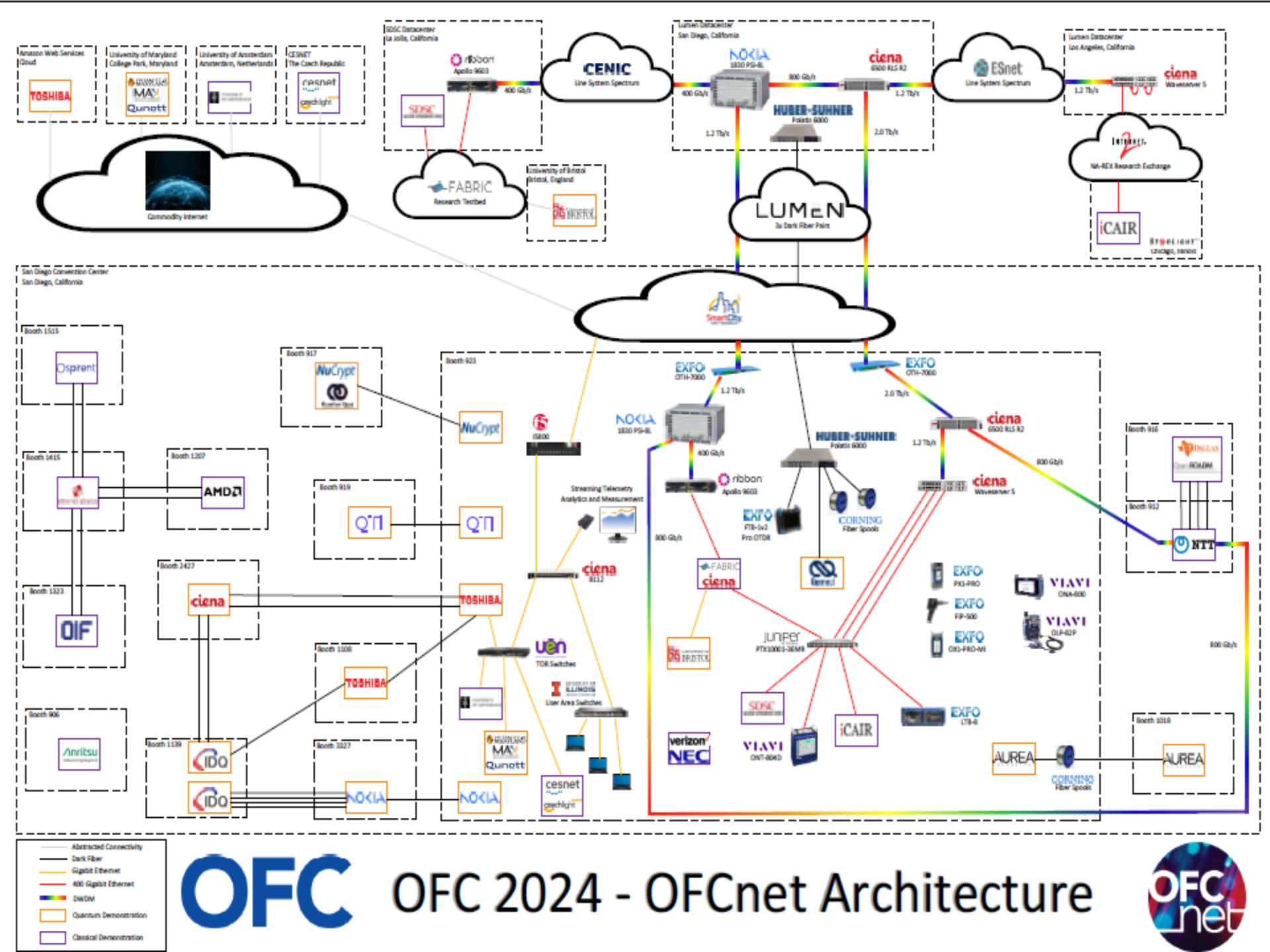
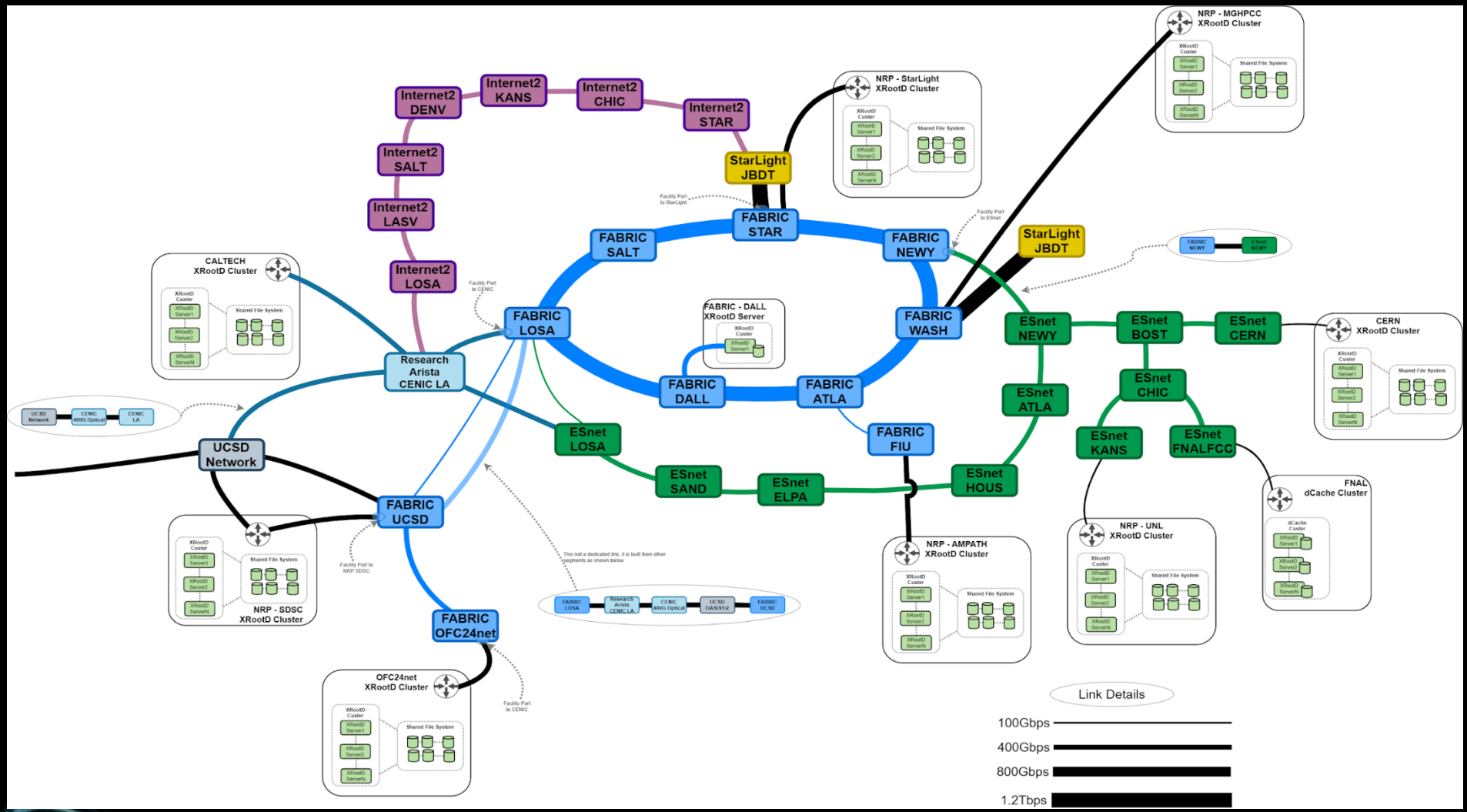
ECOC Teleportation Paper

- ***Quantum Teleportation Over Optical Fibers Carrying Conventional Classical Communications Traffic***
- **Jordan M. Thomas, Gregory S. Kanter, Fei I. Yeh, Jim Hao Chen, Joe J. Mambretti, Scott J. Kohlert, Prem Kumar**



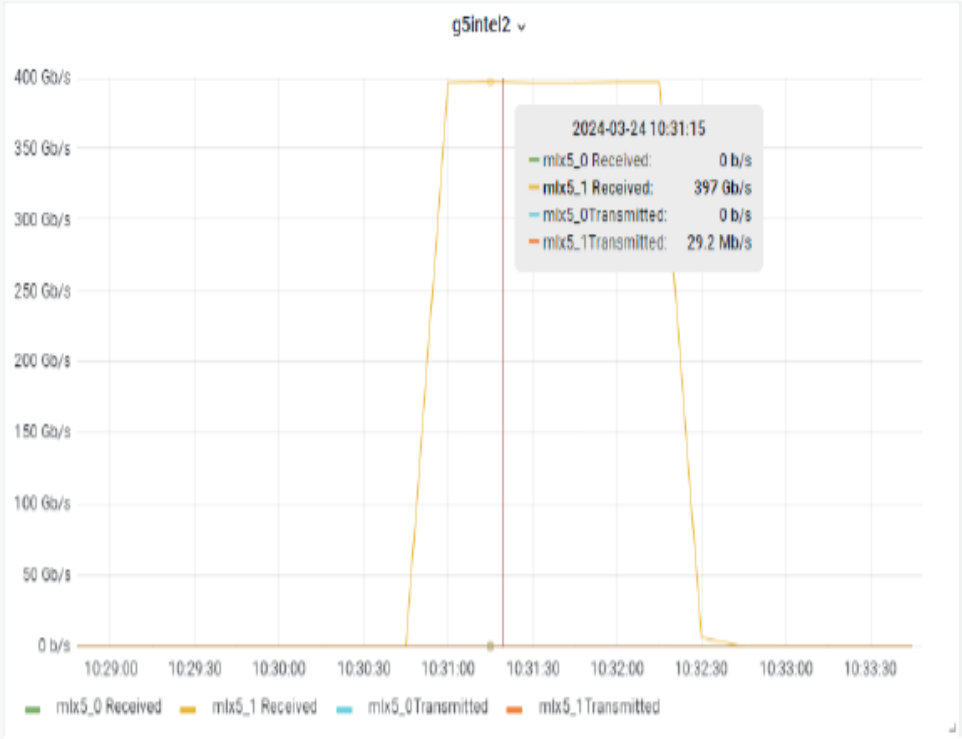
OFC 2024 - OFCnet Architecture

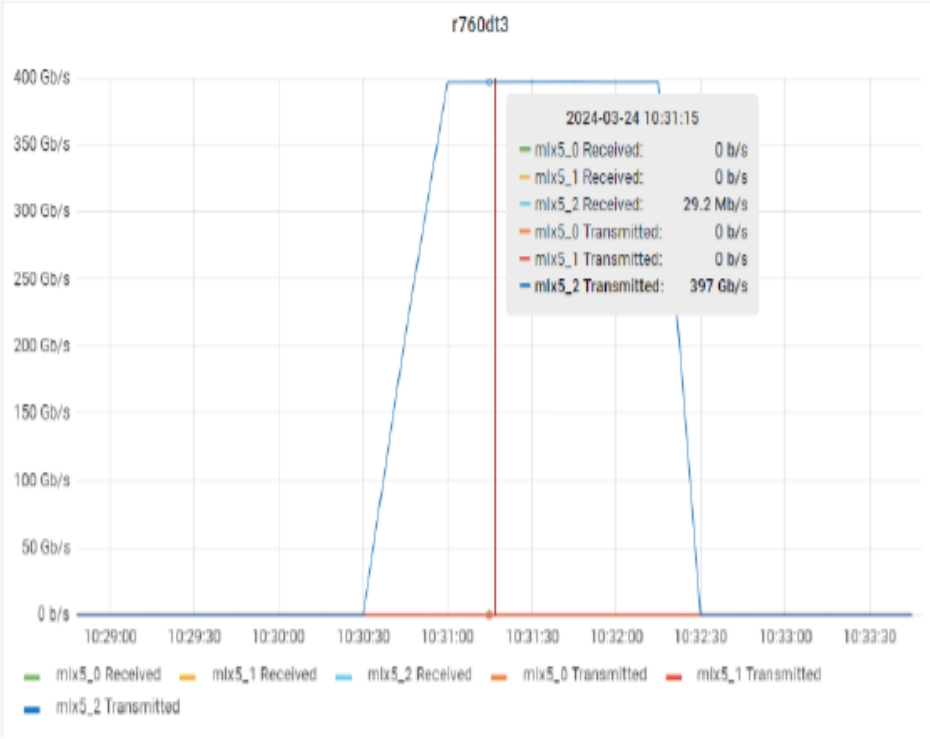

Internet2 DENV
Internet2 KANS
Internet2 CHIC
Internet2 STAR
Internet2 SALT
Internet2 LASV
Internet2 LOSA
StarLight JBDT
NRP - StarLight XRootD Cluster
NRP - MGHPCC XRootD Cluster
FABRIC STAR
FABRIC SALT
FABRIC NEWY
StarLight JBDT
CALTECH XRootD Cluster
FABRIC LOSA
FABRIC - DALL XRootD Server
FABRIC WASH
ESnet NEWY
ESnet BOST
ESnet CERN
CERN XRootD Cluster
Research Arista CENIC LA
FABRIC DALL
FABRIC ATLA
ESnet ATLA
ESnet CHIC
UCSD Network
ESnet LOSA
FABRIC FIU
ESnet KANS
ESnet FNALFCC
ESnet SAND
ESnet ELPA
ESnet HOUS
FABRIC UCSD
NRP - SDSC XRootD Cluster
NRP - AMPATH XRootD Cluster
NRP - UNL XRootD Cluster
FNAL dCache Cluster
FABRIC OFC24net
OFC24net XRootD Cluster
Link Details
100Gbps
400Gbps
800Gbps
1.2Tbps

Extending Data Center Services Over 400G WAN

Prototype Solution Initial Results:

Single Stream RDMA/RoCE Over 400G Network





StarLight-San Diego OFCnet loopback: Rtt 96.4 ms, Peak @ 397G

iCAIR

March 24, 2024

STARLIGHT SDX

Exploring OFCnet-land

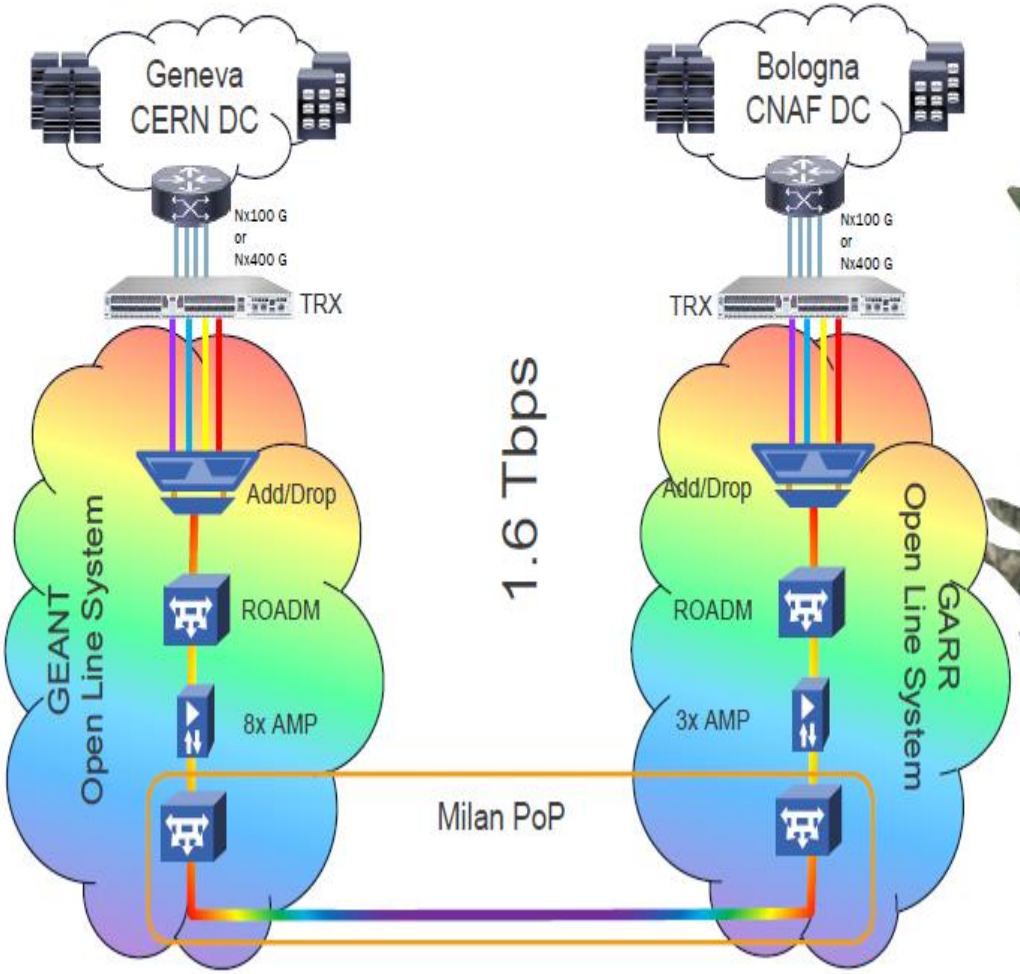
397 Gbps

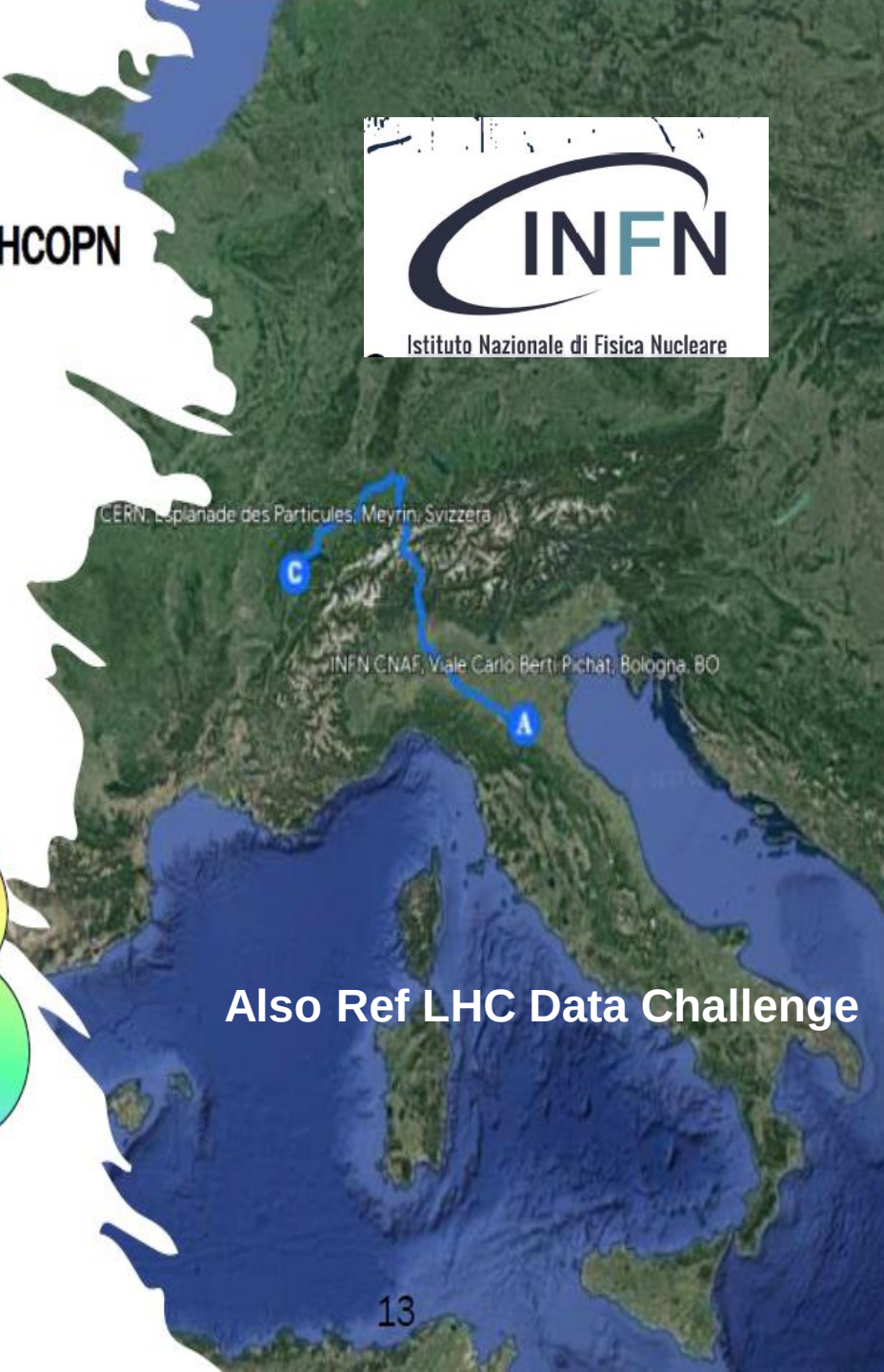
OFC 2025 San Francisco

- OFC 50 – Celebrating 50 Years Of Optical Networking and Communications
- Moscone Center, San Francisco, California
- Technical Conference: 30 March – 03 April 2025
- Exhibition: 01 – 03 April 2025
- Expected: Over 13,500 Registrants From 83+ Countries, Showcase of More Than 700 Exhibiting Global Companies
- Topics: 1.6 Terabit, AI, Coherent PON, Linear Pluggable Optics (LPO), Multicore Fiber, Data Center Technology, Quantum Networking, etc.
- OFCnet – Supported By CENIC, et al

CERN – CNAF DCI

As presented last year we have a pilot link based on multidomain Spectrum sharing Connection.
We managed to activate a **4x100Gbps to be used as LHCOPN link for INFN-T1 during the Data Challenge 2024**





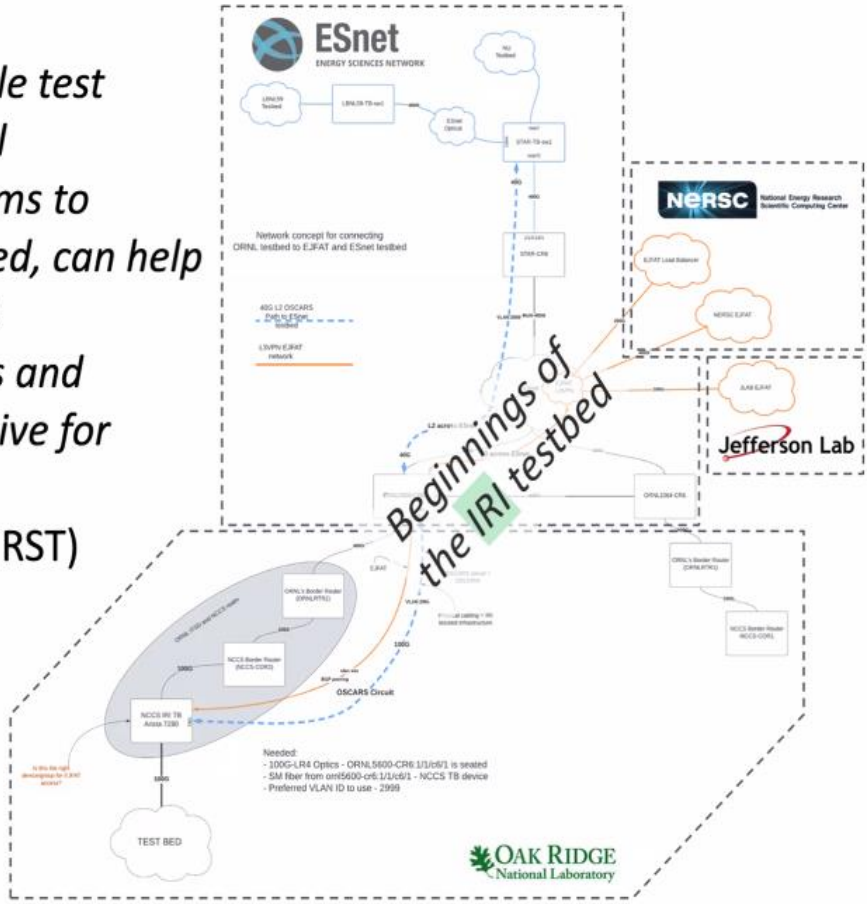
Also Ref LHC Data Challenge

IRI Testbed - A shared playground for IRI developers and pilot applications will accelerate transition to operations

"A best practice in systems design is to create an at-scale test environment in which to build, assess, and improve tool functionality before transitioning technology and systems to production. Such a common test environment, or testbed, can help the broader complex move swiftly to realize an IRI built on a collectively strong set of tools and functionality already shown effective for science."

- Federated IRI Science Testbed (FIRST) report

I. Monga, M. Shankar, C. Guok, "Federated IRI Science Testbed (FIRST): A Concept Note", December 2023, doi:10.2172/2205149, <https://doi.org/10.2172/2205149>



www.startap.net/starlight

**Thanks to the NSF, DOE, NASA, NIH, DARPA
Universities, National Labs, International & Industrial Partners,
and Other Supporters**

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