Plug & Play Data Center with *Open Optical Transponder* over Reliable *Open ROADM* Transport Network

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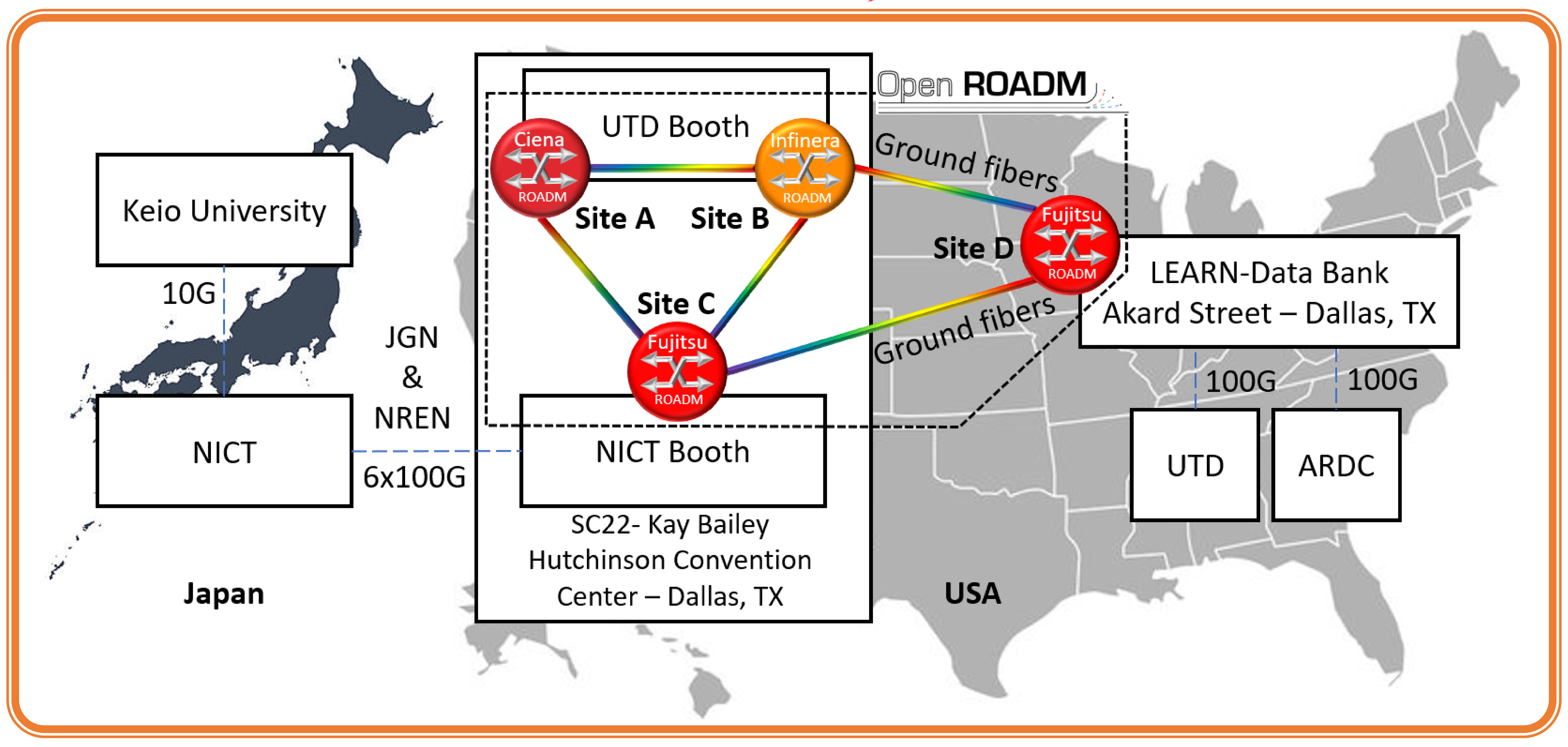


Interoperable CFP2-DCO 400G

CFP2-DCO pluggable transceivers make use of digital coherent optical signals and are designed for line-side trunk DWDM data center interconnect (DCI), metro carrier, and regional/long haul applications. This is the first public demonstration of Open ROADM compliant and interoperable CFP2-DCO 400G modules that are provided by three OEMs.

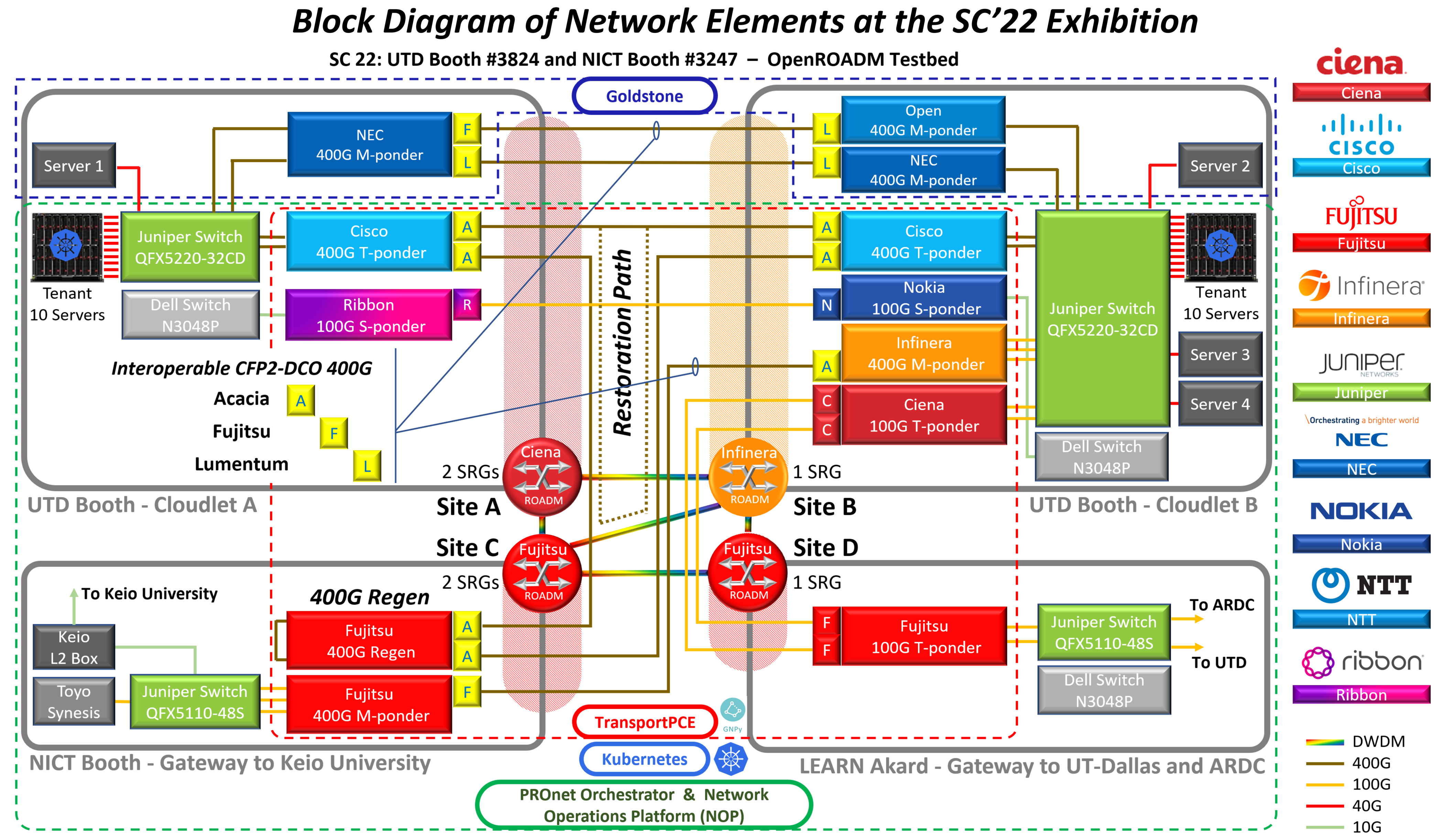
Interoperable CFP2-DCO 400G Optics

Introduction

Open ROADM MSA has been defining interoperability specifications for disaggregated optical transport networks. These specifications, which also include YANG data models, address Reconfigurable Optical Add/Drop Multiplexers (ROADM), transponder, and pluggable optics. Multi-vendor Open ROADM compliant equipment can be integrated into the same network solution and controlled by the open-source *Transport PCE* (TPCE) software defined networking (SDN) controller. This open software and disaggregated hardware approach is enabling new architectures, such as the Open All-Photonic Network (APN). The Open APN architecture interconnects medium-scale decentralized data centers by creating high-speed and low-latency direct DWDM wave services between communication endpoints (compute servers) and achieves end-to-end communication with deterministic performance.

Through a collaborative effort we showcase for the first time a number of hardware and software functionalities that enable Open APN to become a reality. These functionalities include interoperability of CFP2-DCO 400G devices from three OEMs, an open 400G muxponder architecture defined by a service provider, an Open ROADM compliant 400G single-node 3R regenerator, an automated path restoration mechanism at the physical layer implemented in the open-source TPCE, and a number of network monitoring techniques for both optical and data packet transport layer. These demonstrations are carried out over a single testbed composed of multiple network elements provided by seven Original Equipment Manufacturers (OEMs).

Block Diagram of Network Elements at the SC'22 Exhibition



400G Open Muxponder

We envision data center operators that make use of open-source operational applications to perform zero-touch provisioning and fault detection using streaming telemetry. This SC'22 demo showcases **open optical transponder** that complies with global standards and offers validated interoperability. Operators can therefore manage both compute servers and transponders using the same open-source software eco-system, while at the same time leverage Open ROADM transport network functionalities.

This demo concurrently features:

- Hardware and software disaggregation in compliance with TIP Phoenix and MUST
- Multi-vendor and multi-generation transceivers
- Open ROADM MSA compliant CFP2-DCO
- Staircase FEC and oFEC
- Signal tunneling through alien wavelength between two Open ROADM nodes that are MSA compliant
- Containerized applications using Kubernetes

400G Signal Regenerator

When the optical signal's quality of transmission falls below a desired threshold a 3R (re-amplification, re-shaping, and re-timing) regenerator device is required along the transmission path. In this year's SC demo, an Open ROADM-compliant regenerator with a bidirectional, single-node (all optical) design is demonstrated for the first time. A two-hop 400G signal is routed through Site-A, Site-C, and Site-B, while 3R regeneration is applied in Site-C. The CD ROADM in Site-C requires two SRGs to handle the two signals (one from Site-A and one from Site-B) that must be regenerated in each direction of propagation. In this single-node design, only network interfaces are specified (e.g., OTSI, OTSI-group, OTUC4, and ODUC4 for 400G). Reliable high-data rate connections are achievable over multi-hop and/or long distance physical routes.

Retrieving Optical Network Performance Metrics

The UT Dallas Network Operations Platform (NOP) is enhanced in two areas. **First** is the capture, storage, and presentation of NETCONF-based Open ROADM Performance Metrics (PMs), including OTS optical input and output power and transponder pre-FEC corrected block counts. These PMs are graphed live in a UI console and stored in a "data lake" for data analysis. The pre-FEC correct block count is important as it is proportional to the bit error rate (BER) when signal rate and FEC overhead is taken into account. **Second** is the presentation of Kafka-based messaging related to state transitions performed by the TPCE SDN controller during the "path restoration" mechanism referred to elsewhere on this poster.

Reconfigurable In-Network Security Sensor (REINS)

As defined by the Keio University team, "Reconfigurable Probes" are distributed across the network and can be configured on-demand to forward mirrored data packets to a remote NOC via dedicated DWDM channels created across the Open ROADM transport network. Optionally, packet payloads can be removed by the **Keio Privacy Control BOX** and replaced by "0" values before being forwarded to the remote NOC (in Japan in this demo), where advanced data traffic analysis is performed.

T-PCE Automated Path Restoration

Automated path restoration is a newly implemented feature in the open-source Transport PCE (T-PCE) controller. For any created service that is labeled as "restorable" the T-PCE controller triggers a restoration mechanism at the physical layer as soon as its signal is subject to a severe power degradation (e.g., a fiber cut). Any critical signal degradation of the signal power level that is monitored at each ROADM node generates a notification through subscription to a NETCONF stream of the Open ROADM device. Upon receiving a change notification of the ROADM degree OTS (optical transmission section) interface operational state, T-PCE computes a new candidate path that avoids the problematic degree and moves the wave service over the new path. Automated path restoration improves the reliability of Open ROADM networks.

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