BEN Substrate Catalog

BEN Overview

Introduction

BEN[1] is the primary platform for RENCI network research. It's a dark fiber-based, time-sharing research facility created for researchers and scientists in order to promote scientific discovery by providing the three Triangle Universities with world-class infrastructure and resources. RENCI engagement sites at the three university campuses (UNC, NCSU and Duke) in RTP area as well as RENCI Europa anchor site in Chapel Hill, NC contain BEN PoPs (Points of Presence) that form a research test bed. Fig. 1 (below) illustrates RENCI's BEN dark fiber network that's used to connect the engagement sites.

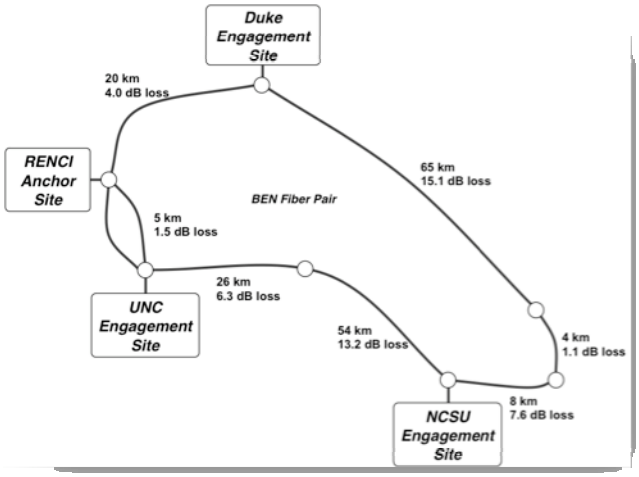

Figure 1: The diagram illustrates the BEN fiber footprint over the NCNI ring. Its touchpoints include the Duke, NCSU and UNC Engagement Sites and RENCI's anchor site, the Europa Center.

BEN Network Architecture

BEN consists of two planes – *management*, run over a mesh of secure tunnels provisioned over commodity IP and *data*, run over the dark fiber infrastructure. Access to the management plane is granted over a secure VPN. Management plane address space is private non-routable.

Each RENCI PoP shares the same network architecture that enables the following capabilities in support of regional network research:

[1] Breakable Experimental Network: https://ben.renci.org

- Reconfigurable fiber switch (layer 0) provides researcher access to fiber ports for dynamically assigning new connections, which enables different physical topologies to be generated and connect different experiments to BEN fiber
- Power and Space to place equipment for performing experiments on BEN
- RENCI additionally provides equipment to support collaborative research efforts:
    - Reconfigurable DWDM (Dense Wavelength Division Multiplexing) (layer 1) which provides access to wavelengths to configure new network connections
    - Reconfigurable switch/router (layers 2 and 3) provide packet services
    - Programmable compute platforms (3-4 server blades at each PoP)

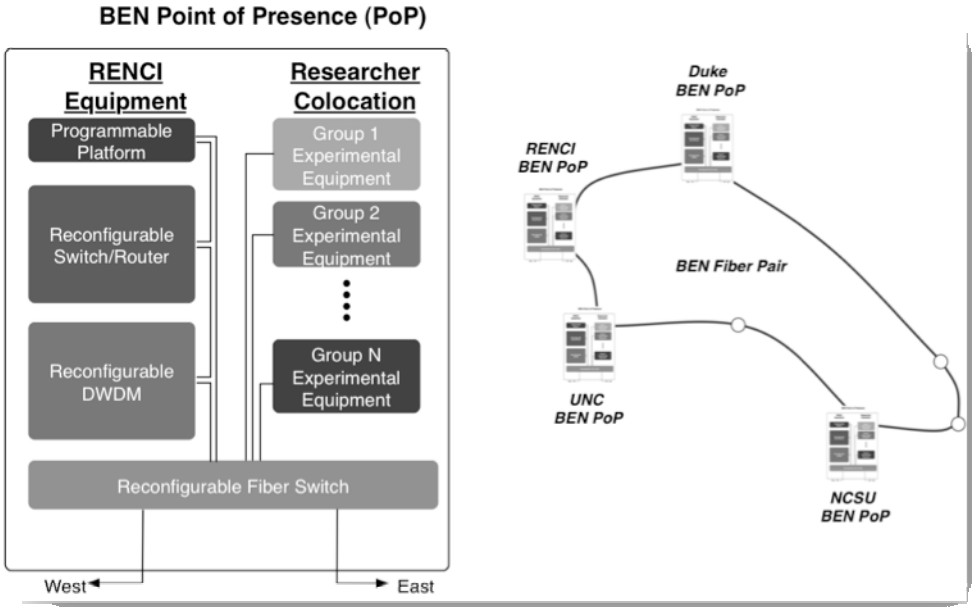

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Figure 2: Fig. (a) provides a functional diagram of a RENCI BEN PoP. The nodal architecture indicates various types of equipment and power and space for researchers to collocate their experimental equipment. Fig (b) provides a systems level network architecture perspective that illustrates network connectivity between PoPs.

As shown in Figure 2 each BEN PoP is capable of accommodating equipment for several experiments that can use the dark fiber exclusively in a time-shared fashion, or, at higher layers, run concurrently.

BEN External Connectivity

BEN is an experimental testbed that is designed to allow running networking experiments in isolation. However some experiments may require external connectivity to national backbones or other resources. BEN external connectivity is achieved through an interface between BEN's Cisco 6509 and a production Cisco 7609 router at RENCI's Europa anchor site. This router allows interconnecting

BEN's data plane with either a regional provider (NCREN) or national backbones (NLR or, via NCREN, I2). Due to the production nature of the Cisco 7609, which also serves to support RENCI's global connectivity, as well as due to security concerns, connections from BEN to the outside world are currently done by special arrangements.

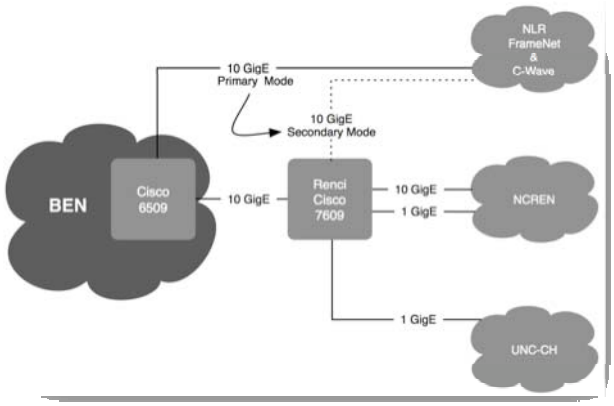

Figure 3: BEN external connectivity diagram – access to BEN occurs directly through Renci's 10 GigE NLR FrameNet connection and through Renci's production router that's used for commodity Internet, Internet2 and NLR connectivity (via NCREN).

Figure 3 and Table 1 summarize the possibilities for external connections to BEN data plane.

Table 1: BEN External connectivity

Connection	Type	Interface	Purpose
BEN	IP	10 GigE	Enables remote access to BEN through directly connected IP interface on Renci's 7609 router
NCREN	IP/BGP	10 GigE	Primary connectivity to commodity Internet and R&E networks (Internet2 and NLR PacketNet); can be used for layer 2 connectivity to Internet2's Dynamic Circuit Network (DCN)
NLR FrameNet	Ethernet	10 GigE	Experimental connectivity to national layer 2 switch fabric - FrameNet; it can also be used to implement layer 2 point-to-point connections through NLR, as well as connectivity to C-Wave

BEN Operational Overview

BEN is a regional networking resource that is shared by the NC research community. BEN operates in a time-shared fashion with individual experiments scheduling time

on BEN exclusively, or, when possible, concurrently. Currently BEN scheduling is manual. Our plans for automatic scheduling and provisioning are centered on adapting Duke's ORCA framework to BEN to become its de facto scheduling solution. Researchers are represented in BEN by their projects and allocation of time on BEN is done on a per-project basis. Each project has a representative in the BEN Experimenter Group (BEN EG), and the EG is the body that is responsible for managing BEN time allocations and resolving conflicts.

BEN will be represented in the GENI effort by RENCI. Following the established operational model, GENI will become a project on BEN and RENCI personnel will serve as an interface between BEN and the external research community for the purposes of setup, operational support and scheduling. This will allow for the use of RENCI owned resources on BEN, such as Infinera's DTN platforms, Cisco 6509 and Juniper routers etc. If other groups within the NC research community desire to contribute equipment to GENI, their equipment can be accommodated at BEN PoPs and connected to BEN.

BEN Equipment Descriptions

Polatis 32 fiber Reconfigurable Optical Switch

Purpose

The Polatis Fiber Switch enables connectivity between individual fibers in an automated fashion. Renci is developing a graphical user interface with multiple views (based on credentials) to operate the switch. The optical switch permits various scenarios for connecting the different pieces of equipment in a BEN PoP. In a traditional implementation, layer 2-3 devices will connect to layer 1 WDM equipment that connects to the optical switch. Alternatively, a layer 2-3 switch/router or experimental equipment can connect directly to the fiber switch. With the appropriate optics, it's entirely possible to directly connect end systems into the optical fiber switch for network connectivity to end systems located in other BEN PoPs.

Technology

- Polatis implements beam-steering technology to collimate opposite interfaces from an input array to an output array of optical ports
- Voltage signals control the alignment of the optical interfaces on both sides of the array
- Fully reconfigurable switch allows connectivity form any port to any other port on the switch
- Optical power monitors are inserted to accurately measure the strength of optical signals through the switch

Specification

- 32 fibers

- Full non-blocking and completely reconfigurable: e.g. any fiber may be connected to another fiber without needing to reconfigure existing optical fiber connections
- Switch unit is optically transparent and fully bidirectional
- Switch uinit front panel comprising 32 LC/UPC type connectors
- Switch unit height 1RU
- Switch unit to fit into a standard 19" rack
- Ethernet interface and a serial RS-232 interface
- Support for SNMP and TL1
- See fiber switch data sheet for detailed specification of optical performance - http://www.polatis.com/datasheets/vst%20303-07-0-s%20aug%202007.pdf
    - Base loss through switch core < 1.4 dB (See Performance Category H on OST data sheet – excludes additional loss from optical power monitors, OPM)
    - Additional loss for a single OPM in connected path < 0.2 dB (See Performance Category K-300 on fiber switch data switch)
    - Additional loss for two OPMs in connected path < 0.3 dB (See performance category K-500 on fiber switch data switch)
    - Additional loss for three OPMs in connected path < 0.5 dB
    - Additional loss for four OPMs in connection path < 0.6 dB
    -

Optical Power Monitoring specifications:

20 directional optical power monitors (OPM) as specified in the table below

Fiber #	Input OPM?	Output OPM?	Fiber #	Input OPM?	Output OPM?
1	Yes	Yes	17	Yes	Yes
2	Yes	Yes	18	Yes	Yes
3	Yes		19		Yes
4	Yes		20		Yes
5	Yes		21		Yes
6	Yes		22		Yes
7	Yes		23		Yes
8	Yes		24		Yes
9			25		
10			26		
11			27		
12			28		
13			29		
14			30		
15			31		
16			32		

- Input optical power monitors measure light entering the switch

- Output optical power monitors measure light exiting the switch
- No optical power monitors on fibers 9-16 and 25-32

Experimenter interface

TL1 and SNMP for configuration and status.

Infinera Digital Transport Node (DTN)

Purpose

The Infinera DTN (Digital Transport Node) delivers advanced WDM infrastructure capabilities for the purpose of supporting network and application research. Dedicated to promote experimentation in BEN, the DTN is fully reconfigurable to aid investigators in advancing network science. Within a BEN node, the DTN can accept a variety of client side signals through the fiber switch to enable direct connectivity to experimental systems or other commercial network equipment to facilitate new proof-of-concept demonstrations. Reconfigurability at layer 1 in a non-production, pro-research testbed facility encourages fresh looks at network architectures by incorporating dynamic signaling of the DTN in new networking paradigms and integrating it's functionality in novel approaches to exploring network phenomena.

Technology

- Infinera utilizes Photonic Integrated Circuits (PICs) implemented in Indium Phosphide as a substrate to integrate opto-electronic functions
- Each DTN node introduces an OEO operation, which provides signal clean-up, digital power monitoring, sub-wavelength grooming, muxing and add/drop
- The DTN architecture simplifies link engineering and service provisioning
- GMPLS control plane enables end-to-end services and topology auto-discovery across an Infinera DTN network

Specifications

Experimenter interface

TL1, SNMP and proprietary XML for configuration and status. GMPLS UNI support for service provisioning.

Cisco Catalyst 6509-E

Purpose

The Cisco 6509 provides a well-understood platform to support the high performance networking needs and network research requirements at Renci. Its support for nearly all standardized routing and switching protocols make it advantageous for implementing different testbed scenarios and for customized experimentation over BEN. The 6509 enables collaboration between Renci's engagement sites by integrating various computing, visualization and storage technologies.

Technology

- Support for Cisco's Internetwork Operating System (IOS)
- Each 6509 equipped with multiple 10 gigabit and 1 gigabit Ethernet interfaces
- Redundant Supervisor Engine 720 (3BXL)
- Catalyst 6500 Distributed Forwarding Card (3BXL)

Specifications

http://www.cisco.com/en/US/prod/collateral/modules/ps2797/ps5138/product_data_sheet09186a00800ff916_ps708_Products_Data_Sheet.html

Experimenter interface

CLI and SNMP for configuration and status.

Juniper 24-port EX 3200 Series Switch

Purpose

The Juniper EX switch provides a programmatic API that can be used to externally communicate with and control the switch through the use of XML. The advantage of having this capability is it enables another device, that's separate from the switch, to control its behavior for separation of the control and forwarding planes.

Technology

- Support for the Juniper Operating System (JUNOS)
- XML application to facilitate programmatic API for the switch
- 24-port 10/100/1000 Ethernet interfaces

Specifications

http://www.juniper.net/products_and_services/ex_series/index.html

Experimenter interface

CLI, published XML interface for configuration and status.

BEN Equipment Catalog

Duke (status: operational)

Polatis 32 Fiber Reconfigurable Optical Switch

- Non-blocking, optically transparent and fully bi-directional, LC connectors
- Supports optical power measurement

Infinera Digital Transport Node (DTN) – 23" chassis

- Band Multiplexing Module - C-band Only, OCG 1/3/5/7, Type 1 (Qty: 2)
- Digital Line Module - C-band, OCG 1, Type 2 (Qty: 2)
- Tributary Adaptor Module - 2-port, 10GR with Ethernet PM (Qty: 2)
- Tributary Optical Module - 10G SR-1/I64.1 & 10GBase-LR/LW (Qty: 3)

Cisco Catalyst 6509 Enhanced 9-slot chassis, 15RU

- Supervisor 720 Fabric MSFC3 PFC3BXL (Qty: 2)

- 48-port 10/100/1000 Ethernet Module, RJ-45, DFC-3BXL (Qty: 1)
- 8-port 10 Gigabit Ethernet Module, X2, DFC-3BXL (Qty: 1)

Juniper EX Switch, 1U

- 24-port 10/100/1000 Ethernet interface, RJ-45

Dell PowerEdge 860 Server (Qty: 3)

- 2.8GHz/256K Cache,Celeron533MHz
- 2GB DDR2, 533MHZ, 2x1G, Dual Ranked DIMMs
- 80GB, SATA, 3.5-inch 7.2K RPM Hard Drive
- DRAC 4 Dell Remote Management PCI Card; 8X DVD

NCSU (status: under construction, due on-line 01/09)

Polatis 32 Fiber Reconfigurable Optical Switch

- Non-blocking, optically transparent and fully bi-directional, LC connectors
- Supports optical power measurement

Infinera Digital Transport Node (DTN) – 23" chassis

- Band Multiplexing Module - C-band Only, OCG 1/3/5/7 (Qty: 2)
- Digital Line Module - C-band, OCG 1 (Qty: 2)
- Tributary Adaptor Module - 2-port, 10GR with Ethernet PM (Qty: 2)
- Tributary Optical Module - 10G SR-1/I64.1 & 10GBase-LR/LW (Qty: 3)

Cisco Catalyst 6509 Enhanced 9-slot chassis, 15RU

- Supervisor 720 Fabric MSFC3 PFC3BXL (Qty: 2)
- 48-port 10/100/1000 Ethernet Module, RJ-45, DFC-3BXL (Qty: 1)
- 8-port 10 Gigabit Ethernet Module, X2, DFC-3BXL (Qty: 1)
- 4-port 10 Gigabit Ethernet Module, XENPAK, DFC-3BXL (Qty:1)

Juniper EX Switch, 1U

- 24-port 10/100/1000 Ethernet interface, RJ-45

Dell PowerEdge 860 Server (Qty: 3)

- 2.8GHz/256K Cache,Celeron533MHz
- 2GB DDR2, 533MHZ, 2x1G, Dual Ranked DIMMs
- 80GB, SATA, 3.5-inch 7.2K RPM Hard Drive
- DRAC 4 Dell Remote Management PCI Card; 8X DVD

UNC (status: operational)

Polatis 32 Fiber Reconfigurable Optical Switch

- Non-blocking, optically transparent and fully bi-directional, LC connectors
- Supports optical power measurement

Infinera Digital Transport Node (DTN) – 23" chassis

- Band Multiplexing Module - C-band Only, OCG 1/3/5/7 (Qty: 2)

- Digital Line Module - C-band, OCG 1 (Qty: 2)
- Tributary Adaptor Module - 2-port, 10GR with Ethernet PM (Qty: 2)
- Tributary Optical Module - 10G SR-1/I64.1 & 10GBase-LR/LW (Qty: 4)

Cisco Catalyst 6509 Enhanced 9-slot chassis, 15RU

- Supervisor 720 Fabric MSFC3 PFC3BXL (Qty: 2)
- 48-port 10/100/1000 Ethernet Module, RJ-45, DFC-3BXL (Qty: 2)
- 8-port 10 Gigabit Ethernet Module, X2, DFC-3BXL (Qty: 2)

Juniper EX Switch, 1U

- 24-port 10/100/1000 Ethernet interface, RJ-45

Dell PowerEdge 860 Server (Qty: 3)

- 2.8GHz/256K Cache,Celeron533MHz
- 2GB DDR2, 533MHZ, 2x1G, Dual Ranked DIMMs
- 80GB, SATA, 3.5-inch 7.2K RPM Hard Drive
- DRAC 4 Dell Remote Management PCI Card; 8X DVD

Renci (status: operational)

Polatis 32 Fiber Reconfigurable Optical Switch

- Non-blocking, optically transparent and fully bi-directional, LC connectors
- Supports optical power measurement

Infinera Digital Transport Node (DTN) – 23" chassis

- Band Multiplexing Module - C-band Only, OCG 1/3/5/7 (Qty: 2)
- Digital Line Module - C-band, OCG 1 (Qty: 2)
- Tributary Adaptor Module - 2-port, 10GR with Ethernet PM (Qty: 4)
- Tributary Optical Module - 10G SR-1/I64.1 & 10GBase-LR/LW (Qty: 8)

Cisco Catalyst 6509 Enhanced 9-slot chassis, 15RU

- Supervisor 720 Fabric MSFC3 PFC3BXL (Qty: 2)
- 48-port 10/100/1000 Ethernet Module, RJ-45, DFC-3BXL (Qty: 2)
- 8-port 10 Gigabit Ethernet Module, X2, DFC-3BXL (Qty: 2)

Juniper EX Switch, 1U

- 24-port 10/100/1000 Ethernet interface, RJ-45

Dell PowerEdge 860 Server (Qty: 3)

- 2.8GHz/256K Cache,Celeron533MHz
- 2GB DDR2, 533MHZ, 2x1G, Dual Ranked DIMMs
- 80GB, SATA, 3.5-inch 7.2K RPM Hard Drive
- DRAC 4 Dell Remote Management PCI Card; 8X DVD