Chapter 15
Layer 2 Circuits

After the introduction and early adoption of Layer 3 virtual private networks (VPNs) based on RFC 2547bis, many customers asked their service providers to offer VPNs that would preserve data at Layer 2. One of the Layer 2 VPN options that has emerged is known as a Layer 2 circuit. It based on a series of Internet Engineering Task Force (IETF) drafts authored by Luca Martini. These so-called "Martini-drafts" include draft-martini-l2circuit-encap-mpls-07.txt, *Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks* (expires December 2004) and draft-martini-l2circuit-trans-mpls-14.txt, *Transport of Layer 2 Frames Over MPLS* (expires December 2004), and establish the basis for Juniper Networks implementation of Layer 2 circuits. This guide shows how to implement Layer 2 circuits in a variety of ways.

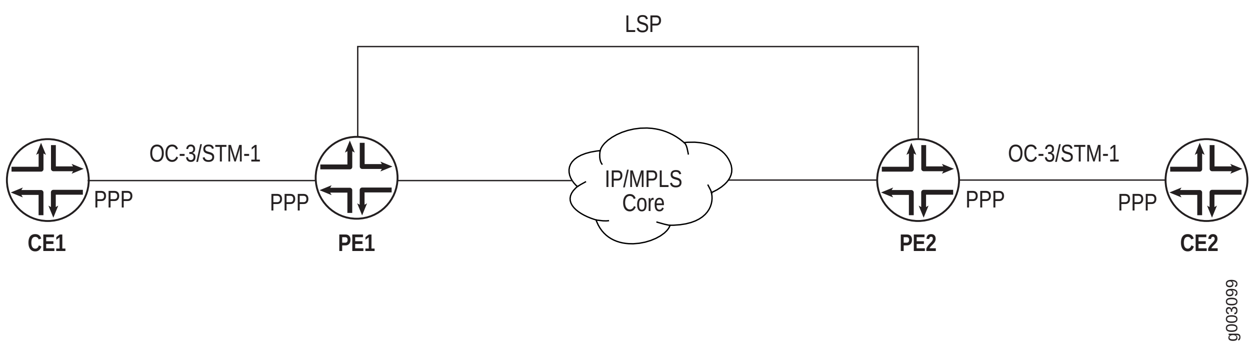
This feature guide covers these topics:

Overview

Layer 2 circuits allow for the creation of point-to-point Layer 2 connections over an IP and Multiprotocol Label Switching (MPLS)-based network. Physical circuits with the same Layer 2 encapsulations can be connected together across such a network. Layer 2 circuits can allow for the replacement of end-to-end Asynchronous Transfer Mode (ATM) networks, Frame Relay networks, and some portions of Time-Division Multiplexing (TDM) networks, with an IP and MPLS-based network.

In Figure 54, an OC3/STM1 interface encapsulated with the Point-to-Point Protocol (PPP) on Router PE1 is connected over a Layer 2 circuit to reach an OC3/STM1 interface encapsulated with PPP on Router PE2. To enable the Layer 2 circuits to operate, the provider edge (PE) routers in Figure 54 are part of an MPLS network. Routers PE1 and PE2 must also be Label Distribution Protocol (LDP) peers. Additionally, any interface on the PE routers that connects to a customer edge (CE) router must support circuit cross-connect (CCC) interface encapsulations.

Figure 54: Layer 2 Circuit Connection



Layer 2 circuits are very similar to Layer 2 VPNs. However, there are some significant differences:

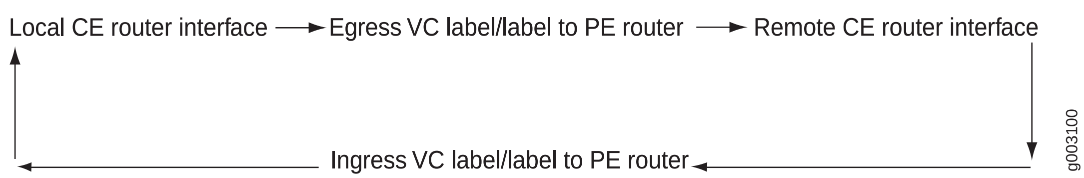
- You configure Layer 2 VPNs in a routing instance. As a result, Layer 2 VPNs have unique site and VPN identifiers. However, Layer 2 circuits do not require a routing instance configuration and instead use an alternate method of identifying circuits. Layer 2 circuit peer relationships are established with three components: a logical interface on the local PE router, the IP address of the remote PE router neighbor, and a virtual circuit identifier.
- Layer 2 VPNs, like Layer 3 VPNs, require Border Gateway Protocol (BGP) for transport of traffic between PE routers. In contrast, Layer 2 circuits do not require BGP. Instead, Layer 2 circuits rely on LDP and MPLS for their operation. As a result, Layer 2 circuits require less configuration than Layer 2 VPNs.

Layer 2 circuits are configured between two peers. The peers must use the same interior gateway protocol (IGP), such as Open Shortest Path First (OSPF) or Intermediate System-to-Intermediate System (IS-IS). Also, the peers must have a symmetrical Layer 2 configuration and belong to the same routing domain or autonomous system.

The basic building block for a Layer 2 circuit is a virtual circuit (VC). A VC is a point-to-point Layer 2 connection that is transported over MPLS or any other tunneling technology in a service provider network. A VC is similar to a CCC connection except that multiple VCs are transported over a single MPLS label-switched path (LSP) tunnel between two provider edge (PE) routers. In contrast, CCC only supports a single Layer 2 connection over a single LSP.

In Figure 55, the basic inner workings of Layer 2 circuits are explained. Two customer edge (CE) router logical interfaces, one local and one remote, are running the same Layer 2 protocol. Packets are sent from the local CE router to the remote CE router over an egress label advertised by the remote PE router. The label is transported over an LDP LSP (or LDP tunneled through RSVP) to the remote PE router that is connected to the remote CE router. Return traffic from the remote CE router is sent over an ingress label advertised by the local PE router. Once again, the label rides over an LDP LSP (or LDP tunneled through RSVP) to the local PE router from the remote PE router.

Figure 55: Layer 2 Circuit Concept



The Layer 2 circuit framework requires LDP to be used as the signaling protocol for advertising ingress labels. In most cases, it is not necessary to transport the Layer 2 encapsulation across the network; rather, the Layer 2 header can be stripped at one PE router, and reproduced at the egress PE router. Such Layer 2 information is carried in a special Layer 2 circuit header called a *control word*.

In the Layer 2 circuit IETF drafts, the control word is optional for most Layer 2 protocols, except Frame Relay and ATM AAL5 where it is required. However, in JUNOS Release 5.6 and later, a control word for all forms of Layer 2 circuits is sent by default. If you are establishing a Layer 2 circuit between a router running JUNOS Release 5.5 or earlier and a router running JUNOS Release 5.6 or later, use of the control word is negotiated automatically.

The Layer 2 protocols that are supported for Layer 2 circuits are:

- ATM cell-relay mode and ATM Adaptation Layer 5 (AAL5) mode on ATM2 intelligent queuing (IQ) interfaces
- Cisco High-Level Data Link Control (HDLC), Frame Relay, and PPP on SONET/SDH-based interfaces
- Ethernet, VLAN, and Extended VLAN on Ethernet-based interfaces

For an Ethernet 802.1q VLAN or simple Ethernet, the entire Ethernet frame without the preamble or frame check sequence (FCS) is transported. For ATM cell-relay mode, ATM cells are transported without a SAR process. For Cisco HDLC, the frame is transported in its entirety except for HDLC flags and the FCS. For PPP, the frame is transported in its entirety except for any media-specific framing information.

For most protocols, a null control word consisting of all zeroes is sent between Layer 2 circuit neighbors. However, individual bits are available in a control word that can carry Layer 2 protocol control information. The control information is mapped into the control word, which allows the header of a Layer 2 protocol to be stripped from the frame. The remaining data and control word can be sent over the Layer 2 circuit, and the frame can be reassembled with the proper control information at the egress point of the circuit.

The Layer 2 protocols that map Layer 2 control information into special bit fields in the control word are as follows:

- Frame Relay—This control word supports the transport of discard eligible (DE), forward explicit congestion notification (FECN), and backward explicit congestion notification (BECN) information. (For configuration information, see "Option: Mapping Layer 2 Protocol Control Information into a Layer 2 Circuit" on page 678.)

- ATM AAL5 mode—This control word supports the transport of sequence number processing, ATM cell loss priority (CLP), and explicit forward congestion indication (EFCI) information. When you configure an AAL5 mode Layer 2 circuit, the control information is carried by default and no additional configuration is needed.

- ATM cell-relay mode—This control word supports sequence number processing only. When you configure a cell-relay mode Layer 2 circuit, the sequence number information is carried by default and no additional configuration is needed.

The JUNOS software implementation of sequence number processing for ATM cell-relay mode and AAL5 mode is not the same as that described in Sec. 3.1.2 of the IETF draft *Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks*. The differences are as follows:

- A packet with a sequence number of 0 is treated as out of sequence.

- Any packet which does not have the next incremental sequence number is considered out of sequence.

- When out-of-sequence packets arrive, the sequence number in the Layer 2 circuit control word increments by one and becomes the expected sequence number for the neighbor.

System Requirements

To implement Layer 2 circuits, your system must meet these minimum requirements:

- JUNOS Release 7.3 or later for configuring Layer 2 circuits simultaneously over RSVP and LDP LSPs
- JUNOS Release 7.1 or later for local interface switching for Layer 2 circuits
- JUNOS Release 7.0 or later for specifying a unique maximum transmission unit (MTU) for each Layer 2 circuit
- JUNOS Release 6.4 or later for ATM2 IQ interface-based CoS and bandwidth reservation for trunks
- JUNOS Release 6.2 or later for Layer 2 circuit trunk mode on T-series and M320 routing platforms and bandwidth reservation for Layer 2 circuits
- JUNOS Release 6.1 or later for Automatic Protection Switching (APS) for Layer 2 circuits
- JUNOS Release 6.0 or later for Layer 2 circuit traffic engineering, and Frame Relay or ATM control word mapping
- JUNOS Release 5.7 or later for ATM cell-relay mode or AAL5 Layer 2 circuits
- JUNOS Release 5.6 or later for Frame Relay, HDLC, and PPP-based Layer 2 circuits
- JUNOS Release 5.2 or later for Ethernet-based Layer 2 circuits
- Five Juniper Networks M-series or T-series routing platforms

Terms and Acronyms

- **Layer 2 circuit**—A method of transporting Layer 2 frames between provider edge (PE) routers across an MPLS backbone using LDP signaling.
- **circuit cross-connect (CCC)**—A Juniper Networks method of exchanging frames between one router interface running a Layer 2 protocol and another router interface using the same Layer 2 protocol. For more information about CCC, see either the *JUNOS Network Interfaces and Class of Service Configuration Guide* or the *JUNOS MPLS Applications Configuration Guide*.
- **control word**—A 32-bit field used in Layer 2 circuits to transport sequence information, Layer 2 media control information, and padding.

Configuring Layer 2 Circuits

To implement Layer 2 circuits, you must perform the following:

- Configuring an Interface Encapsulation on CE-Facing Interfaces on page 671
- Configuring the MPLS Family on Core Interfaces on page 674
- Configuring Layer 2 Circuits on page 675
- Configuring LDP and an IGP to Transport Layer 2 Circuits on page 676

Optional Layer 2 circuit configuration steps are as follows:

- Option: Applying Traffic Engineering to a Layer 2 Circuit on page 677
- Option: Mapping Layer 2 Protocol Control Information into a Layer 2 Circuit on page 678
- Option: Configuring APS for Layer 2 Circuits on page 679
- Option: Configuring Layer 2 Circuit Trunk Mode on ATM2 IQ Interfaces on page 680
- Option: Reserving LSP Bandwidth for a Layer 2 Circuit on page 682
- Option: Selecting an MTU for a Layer 2 Circuit on page 684
- Option: Configuring Local Interface Switching for a Layer 2 Circuit on page 684
- Option: Configuring Layer 2 Circuits Simultaneously over RSVP and LDP LSPs on page 685

To apply your knowledge, visit these sections:

- Example: Ethernet-Based Layer 2 Circuit Configuration on page 686
- Checking Your Work on page 690
- Example: SONET/SDH-Based Layer 2 Circuit Configuration on page 693
- Checking Your Work on page 697
- Example: ATM2 IQ-Based Layer 2 Circuit Configuration on page 699
- Checking Your Work on page 705
- Example: Layer 2 Circuit Traffic Engineering over Multiple LSPs Configuration on page 708
- Checking Your Work on page 718
- Example: APS for a Layer 2 Circuit Configuration on page 719
- Checking Your Work on page 721

Configuring an Interface Encapsulation on CE-Facing Interfaces

When you configure Layer 2 circuits, you can use Ethernet, SONET/SDH, and ATM2 IQ interfaces on a PE router. The specific steps you must take to configure these interface types for Layer 2 circuits are described as follows:

- Configuring CCC Encapsulation on CE-Facing Ethernet Interfaces on page 671
- Configuring CCC Encapsulation on CE-Facing SONET/SDH Interfaces on page 672
- Configuring a CCC Encapsulation and a Layer 2 Circuit Mode on CE-Facing ATM2 IQ Interfaces on page 673

Configuring CCC Encapsulation on CE-Facing Ethernet Interfaces

On Ethernet-based CE-facing PE router interfaces, you must configure one of the three Ethernet CCC encapsulation types—Ethernet CCC, VLAN CCC, or Extended VLAN CCC. Use the following guidelines to configure an Ethernet-based interface CCC encapsulation:

- ethernet-ccc—Use Ethernet CCC encapsulation on Ethernet interfaces that must accept packets carrying standard Tag Protocol ID (TPID) values.
- extended-vlan-ccc—Use extended VLAN CCC encapsulation on Ethernet interfaces that have VLAN 802.1Q tagging and must accept packets carrying TPIDs 0x8100, 0x9100, and 0x9901.
- vlan-ccc—Use VLAN CCC encapsulation on Ethernet interfaces with VLAN tagging enabled. VLAN CCC encapsulation supports TPID 0x8100 only. You must configure this encapsulation type on both the physical interface and the logical interface.
- Ethernet interfaces in VLAN mode can have multiple logical interfaces. For encapsulation type vlan-ccc, VLAN IDs from 1 through 511 are reserved for normal VLANs, and VLAN IDs from 512 through 1023 are reserved for CCC VLANs. For encapsulation type extended-vlan-ccc, all VLAN IDs from 1 through 4094 are valid for CCC VLANs. VLAN ID 0 is reserved for tagging the priority of frames.

To configure CCC interface encapsulation, include the encapsulation statement at the [edit interfaces *ethernet-interface-fpc/pic/port*] hierarchy level and select ethernet-ccc, vlan-ccc, or extended-vlan-ccc as the encapsulation type. If you select the VLAN CCC encapsulation, also include the vlan-ccc statement at the [edit interfaces *ethernet-interface-fpc/pic/port* unit *unit-number* encapsulation] logical interface hierarchy level. When using either VLAN CCC or extended VLAN CCC encapsulations, include the vlan-tagging statement at the [edit interfaces *ethernet-interface-fpc/pic/port*] hierarchy level.

```
[edit]
interfaces {
    fe-0/1/0 {
        vlan-tagging;
        encapsulation vlan-ccc;
        unit 0 {
            encapsulation vlan-ccc;
            vlan-id 600;
        }
    }
}
```

Configuring CCC Encapsulation on CE-Facing SONET/SDH Interfaces

On SONET/SDH interfaces in a PE router, you can use Frame Relay CCC, Cisco HDLC CCC, or PPP CCC encapsulation for Layer 2 circuits:

- To configure Frame Relay CCC interface encapsulation, include the encapsulation statement at the [edit interfaces so-*fpc/pic/port*] hierarchy level and select frame-relay-ccc as the encapsulation type. To enable Frame Relay CCC at the logical interface level, include the encapsulation frame-relay-ccc statement at the [edit interfaces so-*fpc/pic/port* unit *unit-number*] hierarchy level.

- To configure Cisco HDLC CCC interface encapsulation, include the encapsulation statement at the [edit interfaces so-*fpc/pic/port*] hierarchy level and select cisco-hdlc-ccc as the encapsulation type.

- To configure PPP CCC interface encapsulation, include the encapsulation statement at the [edit interfaces so-*fpc/pic/port*] hierarchy level and select ppp-ccc as the encapsulation type.

```
[edit]
interfaces {
    so-0/0/0 {
        encapsulation (frame-relay-ccc | cisco-hdlc-ccc | ppp-ccc);
        unit 0 {
            encapsulation frame-relay-ccc;
        }
    }
}
```

Configuring a CCC Encapsulation and a Layer 2 Circuit Mode on CE-Facing ATM2 IQ Interfaces

On ATM2 IQ interfaces in a PE router, you need to configure two encapsulations to enable Layer 2 circuits: one at the [edit interfaces at-*fpc/pic/port*] hierarchy level and the other at the [edit chassis fpc *fpc-slot* pic *pic-slot*] hierarchy level. There are two types of ATM2 IQ Layer 2 circuits: cell-relay mode and ATM Adaptation Layer 5 (AAL5) mode. For both modes, you must specify the Physical Interface Card (PIC) type with the pic-type atm2 statement at the [edit interfaces at-*fpc/pic/port* atm-options] hierarchy level. You can configure only one mode per PIC at a time. If you need to enable both ATM2 IQ Layer 2 circuit modes in the same router, you must configure the different modes on different PICs.

To configure a cell-relay mode Layer 2 circuit, include the atm-l2circuit-mode cell statement at the [edit chassis fpc *fpc-slot* pic *pic-slot*] hierarchy level and the encapsulation atm-ccc-cell-relay statement at both the [edit interfaces at-*fpc/pic/port*] physical hierarchy level and the [edit interfaces at-*fpc/pic/port* unit *unit-number*] logical hierarchy level.

```
[edit]
chassis {
    fpc 0 {
      pic 1 {
        atm-l2circuit-mode {
          cell;
        }
      }
    }
}
interfaces {
    at-0/1/0 {
      encapsulation atm-ccc-cell-relay;
      atm-options {
        cell-bundle-size 4;
        pic-type atm2;
        vpi 0;
      }
      unit 0 {
        encapsulation atm-ccc-cell-relay;
        vci 32;
        cell-bundle-size 10;
      }
    }
}
```

For ATM2 IQ Layer 2 circuit cell-relay mode only, you can adjust the cell bundle size at the physical interface level and the logical interface level. To configure, include the cell-bundle-size statement at either the [edit interfaces at-*fpc/pic/port* atm-options] physical interface hierarchy level or the [edit interfaces at-*fpc/pic/port* unit *unit-number*] logical interface hierarchy level. If the statement is included at both levels, the logical interface setting takes precedence. The default value for cell bundle size is 1 and the maximum value is 190. If you configure the cell bundle size statement, you should configure the same value on all ATM2 IQ neighbors.

To configure an AAL5 mode Layer 2 circuit, include the atm-l2circuit-mode aal5 statement at the [edit chassis fpc *fpc-slot* pic *pic-slot*] hierarchy level and the encapsulation atm-ccc-vc-mux statement at the [edit interfaces at-*fpc/pic/port*] hierarchy level:

```
[edit]
chassis {
    fpc 1 {
        pic 2 {
            atm-l2circuit-mode {
                aal5;
            }
        }
    }
}
interfaces {
    at-1/2/0 {
        atm-options {
            pic-type atm2;
            vpi 0;
        }
        unit 0 {
            encapsulation atm-ccc-vc-mux;
            vci 32;
        }
    }
}
```

For more information on how to configure interfaces with CCC encapsulation types,
see the *JUNOS MPLS Applications Configuration Guide* or the *JUNOS Network Interfaces and Class of Service Configuration Guide*.

Configuring the MPLS Family on Core Interfaces

Because LDP is used as the signaling protocol to transport MPLS labels across the core of the network, you must include the family mpls statement at the [edit interfaces *interface-name* unit *logical-unit-number*] hierarchy level. Include the statement on all router interfaces in the path from the local PE router to the remote PE router across the core network that transports the Layer 2 circuit traffic.

```
[edit]
interfaces {
    interface-name {
        unit logical-unit-number {
            family inet {
                address ip-address/prefix;
            }
            family mpls;
        }
    }
}
```

Configuring Layer 2 Circuits

After you enable the PE router interfaces with the proper encapsulations, you then configure Layer 2 circuits (also referred to as VCs) between two or more PE router neighbors. To configure a Layer 2 circuit, include the l2circuit statement at the [edit protocols] hierarchy level.

Each Layer 2 circuit is represented by a logical interface on the local PE router, the IP address of the remote PE router neighbor, and a virtual circuit identifier. The logical interface connects the local PE router to the local CE router. The loopback address and router ID of the PE neighbor is commonly the neighbor's IP address. This address is also the destination end-point of the LSP tunnel, which transports the Layer 2 circuit to the neighbor. The virtual circuit ID uniquely identifies the VC to a specific neighbor.

This combination of logical interface, neighbor address, and virtual circuit ID is used to map a particular LDP forwarding equivalence class (FEC) received from a specific neighbor to a local VC. The egress label is added to a table and is used for sending traffic on that VC between the CE routers.

Both ends of a Layer 2 circuit must use the same Layer 2 technology because the Layer 2 encapsulation type is carried in the LDP FEC. The encapsulation type from a received FEC is matched against the local encapsulation type of the VC. If there is a mismatch, the VC is not established.

To add the IP address of the remote PE router neighbor into a Layer 2 circuit, include the neighbor *ip-address* statement at the [edit protocols l2circuit] hierarchy level. To map the remote neighbor to the local interface that connects to the CE router, include the interface statement at the [edit protocols l2circuit neighbor *ip-address*] hierarchy level. To select the identifier for the virtual circuit, include the virtual-circuit-identifier statement at the [edit protocols l2circuit neighbor *ip-address* interface *interface-name*] hierarchy level. To disable default control word processing, include the no-control-word statement at the [edit protocols l2circuit neighbor *ip-address* interface *interface-name*] hierarchy level. Finally, to assign the Layer 2 circuit to a community, include the community *community-name* statement at the [edit protocols l2circuit neighbor *ip-address* interface *interface-name*] hierarchy level.

```
[edit]
protocols {
    l2circuit {
      traceoptions {
        file name [replace] [size size] [files files] [nostamp];
        flag (error | topology | nlri | connections | route) [detail];
      }
      neighbor ip-address {
        interface interface-name {
          virtual-circuit-id identifier;
          no-control-word;
          community community-name;
        }
      }
    }
}
```

You do not need to specify the encapsulation type at the [edit protocols l2circuit] hierarchy level because it is already specified in the interface configuration.

Configuring LDP and an IGP to Transport Layer 2 Circuits

LDP is used as the signaling protocol to advertise the ingress MPLS label to the remote PE router. For this purpose, a remote LDP neighbor is established using the extended discovery mechanism described in RFC 3036, *LDP Specification*, and a session is established.

No new configuration is necessary in LDP because the LDP protocol recognizes the Layer 2 circuit configuration and initiates extended neighbor discovery for all Layer 2 circuit neighbors on the remote PE routers. This is very similar to the behavior of LDP when it is tunneled over RSVP. However, you must configure LDP on the lo0.0 interface for extended neighbor discovery to function correctly.

LDP relies on an underlying IGP, such as OSPF or IS-IS. Therefore, configure LDP and your IGP on all routers in the path from the local PE router to the remote PE router across the service provider backbone.

```
[edit]
protocols {
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/1/0.0;
            interface lo0.0;
        }
    }
    ldp {
        interface so-0/1/0.0;
        interface lo0.0;
    }
}
```

Option: Applying Traffic Engineering to a Layer 2 Circuit

To traffic engineer Layer 2 circuits over multiple LSPs, you must create a community, assign a set of Layer 2 circuits to that community, define a policy to send the community traffic over a desired LSP, and apply the policy to the forwarding table.

To create a community, include the community *community-name* statement at the [edit policy-options] hierarchy level. To assign a Layer 2 circuit to a community, include the community *community-name* statement at the [edit protocols l2circuit neighbor *ip-address* interface *interface-name*] hierarchy level. To create a policy that sends community traffic over a specific LSP, include the community *community-name* statement at the [edit policy-options policy-statement *policy-name* term *term-name* from] hierarchy level and the install-next-hop lsp *lsp-name* statement at the [edit policy-options policy-statement *policy-name* term *term-name* then] hierarchy level. To apply the policy to the forwarding table, include the export *policy-name* statement at the [edit routing-options forwarding-table] hierarchy level.

```
[edit]
routing-options {
      forwarding-table {
         consistency-checking {
            enable;
            period 1000;
         }
         export policy-name;
      }
}
protocols {
      l2circuit {
         neighbor ip-address {
            interface interface-name {
               virtual-circuit-id identifier;
               community community-name;
            }
         }
      }
}
policy-options {
      policy-statement policy-name {
         from community community-name;
         then {
            install-nexthop lsp lsp-name;
            accept;
            }
         }
      }
      community community-name members value;
}
```

Option: Mapping Layer 2 Protocol Control Information

into a Layer 2 Circuit

The control word is defined in Internet draft draft-martini-l2circuit-encap-mpls-07.txt, *Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks*. It is a set of fields that carry Layer 2 control information across a Layer 2 circuit. The following control word support is available for PE routers:

- Frame Relay—To carry Frame Relay FECN/BECN information in a Layer 2 circuit control word, include the translate-fecn-and-becn statement at the [edit interfaces *interface-name* encapsulation frame-relay-ccc unit *unit-number* encapsulation frame-relay-ccc family ccc] hierarchy level. To carry Frame Relay DE information in a Layer 2 circuit control word, include the translate-discard-eligible statement at the [edit interfaces *interface-name* encapsulation frame-relay-ccc unit *unit-number* encapsulation frame-relay-ccc family ccc] hierarchy level.

```
[edit]
interfaces {
    interface-name {
        encapsulation frame-relay-ccc;
        unit 0 {
            encapsulation frame-relay-ccc;
            point-to-point;
            dlci 512;
            family ccc {
                translate-fecn-and-becn;
                translate-discard-eligible;
            }
        }
    }
}
```

- ATM AAL5 mode—For ATM2 IQ interfaces, the ATM AAL5 control word contains bit fields to carry sequence numbers, ATM cell loss priority (CLP), and early forward congestion indication (EFCI) information. When you configure ATM Layer 2 circuits, the control word carries the sequence number, CLP, and EFCI information by default. No additional configuration is necessary.

- ATM cell-relay mode—For ATM2 IQ interfaces, the ATM cell-relay control word supports sequence number processing only. Once you configure a cell-relay mode Layer 2 circuit, the sequence number information is carried by default. No additional configuration is necessary.

Option: Configuring APS for Layer 2 Circuits

To apply Automatic Protection Switching (APS) to a Layer 2 circuit, you must configure an APS working circuit and a protect circuit on PE router interfaces that support SONET options (such as SONET/SDH, ATM, and ATM2 IQ interfaces) and circuit cross-connect (CCC) encapsulation types. Then, you must configure the working circuit as the primary Layer 2 circuit interface and the protect circuit as the protected Layer 2 circuit interface. Note that APS only protects the PE-CE link and not the entire Layer 2 circuit.

To configure an APS working circuit, include the working-circuit statement at the [edit interfaces *interface-name* sonet-options aps] hierarchy level. To configure an APS protect circuit, include the protect-circuit statement at the [edit interfaces *interface-name* sonet-options aps] hierarchy level. To configure the primary Layer 2 circuit interface, include the interface statement at the [edit protocols l2circuit neighbor *ip-address*] hierarchy level. To configure the protected Layer 2 circuit interface, include the protect-interface statement at the [edit protocols l2circuit neighbor *ip-address* interface *interface-name*] hierarchy level.

```
[edit]
interfaces {
    at-0/0/1 {
        description “APS protect circuit”;
        encapsulation CCC-encapsulation-type;
        sonet-options {
            aps {
                protect-circuit name;
            }
        }
    }
    at-1/3/1 {
        description “APS working circuit”;
        encapsulation CCC-encapsulation-type;
        sonet-options {
            aps {
                working-circuit name;
            }
        }
    }
}
protocols {
    l2circuit {
        neighbor ip-address {
            interface at-1/3/1.0 {
                protect-interface at-0/0/1.0;
                virtual-circuit-id number;
            }
        }
    }
}
```

Option: Configuring Layer 2 Circuit Trunk Mode

on ATM2 IQ Interfaces

When you configure Layer 2 circuits on CE-facing ATM2 IQ interfaces in a PE router that connects to some vendors' ATM switches, you can create a trunk. The trunk bundles several ATM cell streams into one LSP, preserves the cell loss priority (CLP) and class-of-service (CoS) information of the cells within the experimental (EXP) bits of the MPLS header, and provides network-to-network interface (NNI) or user-to-network interface (UNI) information within a proprietary header. A physical interface supports a total of 32 logical trunks in NNI mode and 8 logical trunks when you use the UNI option. To configure a trunk, include the trunk statement at the [edit chassis fpc *fpc-slot* pic *pic-slot* atm-l2circuit-mode] hierarchy level, select NNI or UNI mode with the nni or uni statement, and specify a number of bits in the ATM header that will carry an identifier with the id-width statement. You can choose a value from 1 through 8 for the identifier width.

```
[edit]
chassis {
    fpc fpc-slot {
        pic pic-clot {
            atm-l2circuit-mode {
                trunk {
                    (nni | uni) {
                        id-width number;
                    }
                }
            }
        }
    }
}
```

You can also configure several trunk options at the [edit interfaces at-*fpc/pic/port* unit *unit-number*] hierarchy level:

- To specify an ATM interface as the control channel for a Layer 2 circuit trunk, include the control-channel statement at the [edit interfaces at-*fpc/pic/port* unit *unit-number*] hierarchy level.
- To specify a trunk identifier, include the trunk-id statement at the [edit interfaces at-*fpc/pic/port* unit *unit-number*] hierarchy level. Trunk ID values range from 0 through 31.
- To configure the amount of bandwidth reserved for the trunk, include the trunk-bandwidth statement at the [edit interfaces at-*fpc/pic/port* unit *unit-number*] hierarchy level and specify a value from 1,000,000 bps (1 Mbps) through 542,526,792 bps.
- To apply a CoS scheduler map to the trunk, include the atm-scheduler-map statement at the [edit interfaces at-*fpc/pic/port* unit *unit-number*] hierarchy level. This statement must reference an ATM2 IQ interface-based scheduler map at the [edit interfaces at-*fpc/pic/port* atm-options scheduler-maps *map-name*] hierarchy level.

```
interfaces {
    at-fpc/pic/port {
        atm-options {
            pic-type atm2;
            scheduler-maps {
                map-name {
                    ...
            }
        }
        unit unit-number {
            atm-scheduler-map map-name;
            control-channel;
            trunk-id id-number;
            trunk-bandwidth bandwidth;
        }
    }
}
```

You can configure a variety of CoS-related statements for an ATM2 IQ interface-based scheduler map. To select the CoS mode used for virtual circuits, include the vc-cos-mode statement at the [edit interfaces at-*fpc/pic/port* atm-options scheduler-maps *map-name*] hierarchy level. To specify forwarding class settings, include the priority, transmit-weight, and epd-threshold statements at the [edit interfaces at-*fpc/pic/port* atm-options scheduler-maps *map-name* forwarding-class *class-name*] hierarchy level. For more information about CoS, see the *JUNOS Network Interfaces and Class of Service Configuration Guide*.

```
[edit]
interfaces {
    at-fpc/pic/port {
        atm-options {
            pic-type atm2;
            scheduler-maps {
                map-name {
                    vc-cos-mode (alternate | strict);
                    forwarding-class class-name {
                        priority (high | low);
                        transmit-weight (cells number-of-cells | percent percentage);
                        epd-threshold plp0-threshold plp1 plp1-threshold;
                    }
                }
            }
        }
    }
}
```

Option: Reserving LSP Bandwidth for a Layer 2 Circuit

You can specify the amount of bandwidth in bytes per second that must be available on an LSP for a specific Layer 2 circuit. By using a bandwidth constraint for a Layer 2 circuit, the router performs a type of call admission control. If an LSP exists that contains the required bandwidth, the Layer 2 circuit is established. If the bandwidth is not available on an LSP, the Layer 2 circuit is not established.

To configure bandwidth requirements for a Layer 2 circuit, include the bandwidth statement at the [edit protocols mpls label-switched-path *lsp-name*] hierarchy level and the [edit protocols l2circuit neighbor *ip-address* interface *interface-name*] hierarchy level.

```
[edit]
protocols {
    mpls {
        label-switched-path lsp-name {
            bandwidth traffic-class bytes-per-second;
        }
    }
    l2circuit {
        neighbor ip-address {
            interface interface-name {
                bandwidth bytes-per-second;
            }
        }
    }
}
```

You can also assign minimum bandwidth requirements for class-of-service (CoS) queues within a Layer 2 circuit and its corresponding LSP. Class type (CT) queues 0, 1, 2, and 3 in a Layer 2 circuit or LSP correspond to the standard four CoS queues available on M-series and T-series routing platforms. To enable mapping of class type queues to the standard CoS queues, include the bandwidth-model statement at the [edit protocols mpls diffserv-te] hierarchy level. To assign specific bandwidth requirements to each class type queue, include the ct0, ct1, ct2, and ct3 statements at the [edit protocols mpls label-switched-path *lsp-name* bandwidth] hierarchy level and the [edit protocols l2circuit neighbor *ip-address* interface *interface-name* bandwidth] hierarchy level.

```
[edit]
protocols {
    mpls {
        diffserv-te {
            bandwidth-model extended-mam;
        }
        label-switched-path lsp-name {
            bandwidth {
                ct0 100m;
                ct1 100m;
                ct2 50m;
                ct3 5m;
            }
        }
    }
    l2circuit {
        neighbor ip-address {
            interface interface-name {
                bandwidth {
                    ct0 100m;
                    ct1 100m;
                    ct2 50m;
                    ct3 5m;
                }
            }
        }
    }
}
```

For more information about class of service, see the *JUNOS Network Interfaces and Class of Service Configuration Guide*.

Option: Selecting an MTU for a Layer 2 Circuit

To configure the MTU for each individual Layer 2 circuit, include the mtu statement at the [edit protocols l2circuit neighbor *ip-address* interface *interface-name*] hierarchy level. If the MTU setting between Layer 2 circuit neighbors does not match, the Layer 2 circuit is torn down.

NOTE: If you configure an MTU value for an ATM cell relay interface on an ATM2 PIC and simultaneously configure an MTU value for a Layer 2 circuit that uses the same ATM2 PIC, the MTU value for the Layer 2 circuit takes precedence when calculating the cell bundle size and is advertised to Layer 2 circuit neighbors.

Option: Configuring Local Interface Switching for a Layer 2 Circuit

You can terminate a Layer 2 circuit locally on an ingress PE router. To configure a locally terminated circuit, include the local-switching statement at the [edit protocols l2circuit] hierarchy level. Select the Layer 2 circuit interfaces you want to connect locally, specify any APS protect interfaces, and configure an end interface. To select the Layer 2 circuit interfaces that are connected locally, include the interface statement at the [edit protocols l2circuit local-switching] hierarchy level. To configure an end interface, include the end-interface statement at the [edit protocols l2circuit local-switching interface *interface-name*] hierarchy level. To specify APS protect interfaces, include the protect-interface statement at the [edit protocols l2circuit local-switching interface *interface-name*] or [edit protocols l2circuit local-switching interface *interface-name* end-interface *interface-name*] hierarchy levels.

```
[edit]
protocols {
    l2circuit {
        local-switching {
            interface interface1 {
                protect-interface interface2;
                end-interface interface3 {
                    protect-interface interface4;
                }
            }
            interface interface5 {
                protect-interface interface6;
                end-interface interface7 {
                    protect-interface interface8;
                }
            }
        }
    }
}
```

Option: Configuring Layer 2 Circuits Simultaneously

over RSVP and LDP LSPs

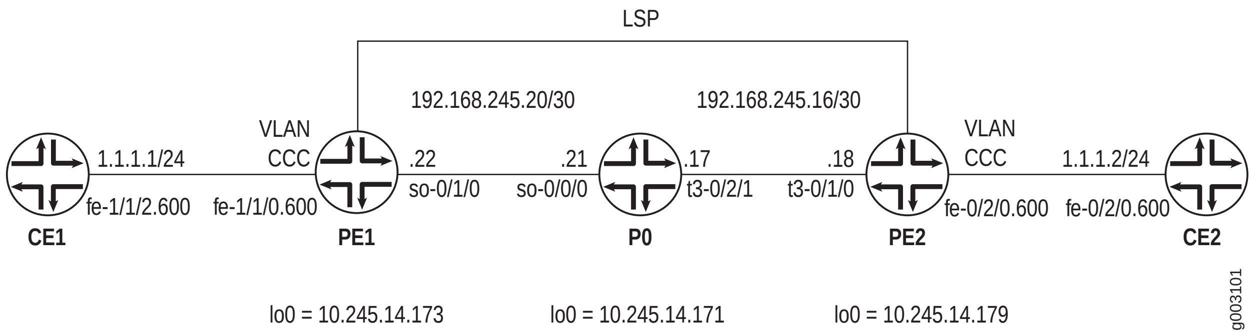
You can configure a Layer 2 circuit simultaneously over an RSVP LSP and an LDP LSP between the same two routing platforms. To accomplish this, do the following:

- Configure two loopback addresses—a primary and a secondary loopback.
- Configure the RSVP LSP using the primary loopback address.
- Configure the LDP LSP using the secondary loopback address. You can accomplish this by advertising the secondary loopback address as a forwarding equivalence class (FEC) in LDP.
- Configure the transport tunnel endpoint (also known as a packet-switched network [PSN] tunnel endpoint in the IETF drafts) to be used for transporting the Layer 2 circuit traffic. To configure the tunnel endpoint, include the psn-tunnel-endpoint statement at the [edit protocols l2circuit] hierarchy level. By default, the tunnel endpoint is the same as the address of the Layer 2 circuit neighbor.

To verify that your configuration is operational, issue the show l2circuit connections command. This command has been enhanced to display tunnel endpoints. For more information about configuring Layer 2 circuits simultaneously over RSVP and LDP LSPs, see the *JUNOS VPNs Configuration Guide*.

Example: Ethernet-Based Layer 2 Circuit Configuration

Figure 56: Ethernet-Based Layer 2 Circuit Topology Diagram



In Figure 56, a Layer 2 circuit is established between routers PE1 and PE2 to deliver Layer 2 traffic between customer routers CE1 and CE2. A Layer 2 circuit VC connection is configured on the PE routers only. No special configuration is required on the CE routers, and the provider core P0 router only requires MPLS and LDP on the appropriate interfaces to enable labels to be shared between the PE routers.

On Router CE1, configure the Fast Ethernet interface to handle VLAN traffic. Be sure to use the same VLAN ID both here and on the Fast Ethernet interface of Router CE2.

Router CE1

```
[edit]
interfaces {
    fe-1/1/2 {
        description "to PE1 fe-1/1/0";
        vlan-tagging;
        unit 600 {
            vlan-id 600; # Be sure this VLAN ID matches the VLAN ID of your CE neighbor.
            family inet {
                address 1.1.1.1/24;
            }
        }
    }
}
```

On Router PE1, configure the Ethernet-based CE-facing interface with the CCC encapsulation type of your choice. If you use VLAN CCC, include the vlan-tagging statement at the [edit interfaces *ethernet-interface-fpc/pic/port*] hierarchy level. Also, include the encapsulation vlan-ccc statement at both the [edit interfaces *ethernet-interface-fpc/pic/port*] and [edit interfaces *ethernet-interface-fpc/pic/port* unit *unit-number*] hierarchy levels.

Establish your Layer 2 circuit with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (usually the loopback address of the neighbor), the interface connected to the CE router, and a virtual circuit identifier for this VC. Then, configure MPLS, LDP, and an IGP (such as OSPF) to enable signaling for your Layer 2 circuit.

Router PE1

```
[edit]
interfaces {
    so-0/1/0 {
      description "to P0 so-0/0/0";
      unit 0 {
        family inet {
          address 192.168.245.22/30;
        }
        family mpls; # Include the MPLS family on core-facing interfaces.
      }
    }
    fe-1/1/0 {
      description "to CE1 fe-1/1/2";
      vlan-tagging;
      encapsulation vlan-ccc; # Configure CCC encapsulation on CE-facing interfaces.
      unit 600 {
        encapsulation vlan-ccc; # Enable this encapsulation on the logical interface.
        vlan-id 600;
      }
    }
    lo0 {
      unit 0 {
        family inet {
          address 10.245.14.173/32;
        }
      }
    }
}
```

```
protocols {
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/1/0.0;
            interface lo0.0;
        }
    }
    ldp {                  # LDP is required as the signaling protocol for Layer 2 circuits.
        interface so-0/1/0.0;
        interface lo0.0;          # You must include the loopback address in LDP.
    }
    l2circuit {
        neighbor 10.245.14.179 { # This points to the loopback of the PE neighbor.
            interface fe-1/1/0.600 { # Here you include the local CE-facing interface.
                virtual-circuit-id 5; # Be sure this ID matches the ID of your PE neighbor.
            }
        }
    }
}
```

On Router P0, configure LDP, MPLS, and OSPF on the interfaces connected to the PE routers. The core router provides the MPLS backbone needed to tunnel Layer 2 traffic from the ingress PR router to the egress PE router.

Router P0

```
[edit]
interfaces {
    so-0/0/0 {
        description "to PE1 so-0/1/0";
        unit 0 {
            family inet {
                address 192.168.245.21/30;
            }
            family mpls; # Include the MPLS family on core interfaces.
        }
    }
    t3-0/2/1 {
        description "to PE2 t3-0/1/0";
        unit 0 {
            family inet {
                address 192.168.245.17/30;
            }
            family mpls; # Include the MPLS family on core interfaces.
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 10.245.14.171/32;
            }
        }
    }
}
```

```
protocols {
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/0/0.0;
            interface t3-0/2/1.0;
        }
    }
    ldp {              # LDP is required as the signaling protocol for Layer 2 circuits.
        interface so-0/0/0.0;
        interface t3-0/2/1.0;
    }
}
```

On Router PE2, complete the Layer 2 circuit by configuring statements to match those previously set on Router PE1. Configure the Ethernet-based CE-facing interface with CCC encapsulation. Again, you must include the vlan-tagging statement at the [edit interfaces *ethernet-interface-fpc/pic/port*] hierarchy level when you use VLAN CCC. Also, include the encapsulation vlan-ccc statement at both the [edit interfaces *ethernet-interface-fpc/pic/port*] and [edit interfaces *ethernet-interface-fpc/pic/port* unit *unit-number*] hierarchy levels.

Establish your Layer 2 circuit with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (Router PE1), the virtual circuit identifier previously configured on Router PE1, and the interface connected to the CE router. Finally, configure MPLS, LDP, and OSPF to enable signaling for your Layer 2 circuit.

Router PE2

```
[edit]
interfaces {
    t3-0/1/0 {
        description "P0 t3-0/2/1";
        unit 0 {
            family inet {
                address 192.168.245.18/30;
            }
            family mpls; # Include the MPLS family on core-facing interfaces.
        }
    }
    fe-0/2/0 {
        description "to CE2 fe-0/2/0";
        vlan-tagging;
        encapsulation vlan-ccc; # Configure CCC encapsulation on CE-facing interfaces.
        unit 600 {
            encapsulation vlan-ccc; # Enable this encapsulation on the logical interface.
            vlan-id 600;
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 10.245.14.179/32;
            }
        }
    }
```

```
}
protocols {
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface t3-0/1/0.0;
            interface lo0.0;
        }
    }
    ldp {               # LDP is required as the signaling protocol for Layer 2 circuits.
        interface t3-0/1/0.0;
        interface lo0.0;            # You must include the loopback address in LDP.
    }
    l2circuit {
        neighbor 10.245.14.173 { # This points to the loopback of the PE neighbor.
            interface fe-0/2/0.600 { # Here you include the local CE-facing interface.
                virtual-circuit-id 5; # Be sure this ID matches the ID of your PE neighbor.
            }
        }
    }
}
```

On Router CE2, configure the Fast Ethernet interface to handle VLAN traffic. Be sure to use the same VLAN ID on this interface as the one seen on the Fast Ethernet interface of Router CE1.

Router CE2

```
[edit]
interfaces {
    fe-0/2/0 {
        description "to PE2 fe-0/2/0";
        vlan-tagging;
        unit 600 {
            vlan-id 600; # Be sure this VLAN ID matches the VLAN ID of your CE neighbor.
            family inet {
                address 1.1.1.2/24;
            }
        }
    }
}
```

Checking Your Work

To verify proper operation of Layer 2 circuits, use the following commands:

- ping mpls l2circuit interface *interface-name*
- ping mpls l2circuit virtual-circuit *virtual-circuit-id* neighbor *ip-address*
- show l2circuit connections
  - Options: [brief] | [down] | [extensive] | [history] | [instance] | [local-site] | [remote-site] |[status] | [summary] | [up] | [up-down]
- show ldp database

In addition to displaying bindings for IP prefixes, the show ldp database command also displays the bindings for the Layer 2 FECs.

The following sections show the output of these commands used with the configuration example:

- Router PE1 Status on page 691
- Router P0 Status on page 691
- Router PE2 Status on page 692

Router PE1 Status

```
user@PE1> show l2circuit connections
Layer-2 Circuit Connections:

Legend for connection status (St)   Legend for interface status
EI -- encapsulation invalid         UP -- operational
MM -- mtu mismatch                  Dn -- down
EM -- encapsulation mismatch        NP -- no present
OL -- no outgoing label             DS -- disabled
Dn -- down                          WE -- wrong encapsulation
VC-Dn -- Virtual circuit Down       UN -- uninitialized
UP -- operational
XX -- unknown

Neighbor: 10.245.14.179
    Interface                 Type  St     Time last up          # Up trans
    fe-1/1/0.600 (vc 5)       rmt   Up     Nov 30 00:54:55 2001           1
      Local interface: fe-1/1/0.600, Status: Up, Encapsulation: VLAN
      Remote PE: 10.245.14.179, Negotiated control-word: Yes (Null)
      Incoming label: 100007, Outgoing label: 100000

user@PE1> show ldp database

Input label database, 10.245.14.173:0-10.245.14.171:0
  Label     Prefix
 100019     10.245.14.173/32
 100020     10.245.14.179/32
      3     10.245.14.171/32

Output label database, 10.245.14.173:0-10.245.14.171:0
  Label     Prefix
 100009     10.245.14.179/32
      3     10.245.14.173/32
 100008     10.245.14.171/32

Input label database, 10.245.14.173:0-10.245.14.179:0
  Label     Prefix
 100001     10.245.14.171/32
 100002     10.245.14.173/32
      3     10.245.14.179/32
 100000     L2CKT VLAN VC 5

Output label database, 10.245.14.173:0-10.245.14.179:0
  Label     Prefix
 100009     10.245.14.179/32
      3     10.245.14.173/32
 100008     10.245.14.171/32
 100007     L2CKT VLAN VC 5
```

Router P0 Status

```
user@P0> show ldp database
```

```
Input label database, 10.245.14.171:0-10.245.14.173:0
  Label     Prefix
      3     10.245.14.173/32
 100009     10.245.14.179/32
 100008     10.245.14.171/32

Output label database, 10.245.14.171:0-10.245.14.173:0
  Label     Prefix
 100019     10.245.14.173/32
 100020     10.245.14.179/32
      3     10.245.14.171/32

Input label database, 10.245.14.171:0-10.245.14.179:0
  Label     Prefix
 100001     10.245.14.171/32
      3     10.245.14.179/32
 100002     10.245.14.173/32

Output label database, 10.245.14.171:0-10.245.14.179:0
  Label     Prefix
 100019     10.245.14.173/32
 100020     10.245.14.179/32
      3     10.245.14.171/32
```

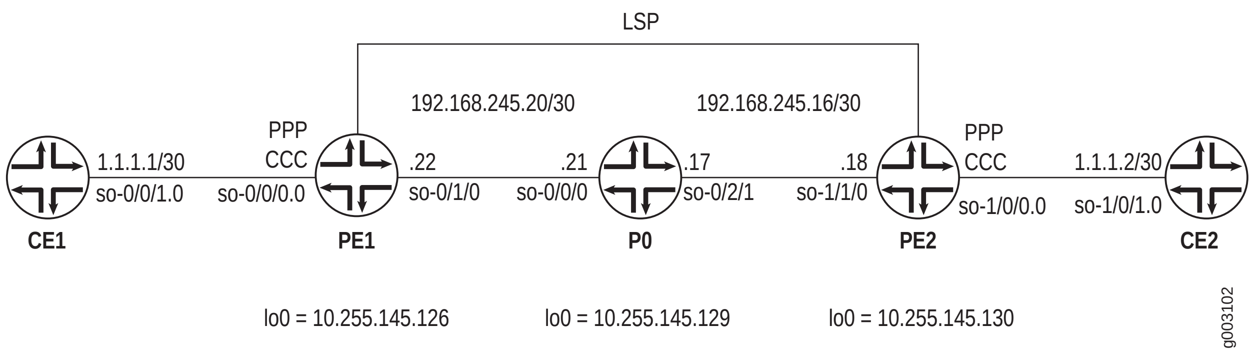
Router PE2 Status

```
user@PE2> show l2circuit connections
Layer-2 Circuit Connections:

Legend for connection status (St)   Legend for interface status
EI -- encapsulation invalid         UP -- operational
MM -- mtu mismatch                  Dn -- down
EM -- encapsulation mismatch        NP -- no present
OL -- no outgoing label             DS -- disabled
Dn -- down                          WE -- wrong encapsulation
VC-Dn -- Virtual circuit Down       UN -- uninitialized
UP -- operational
XX -- unknown

Neighbor: 10.245.14.173
    Interface                 Type  St     Time last up          # Up trans
    fe-0/2/0.600 (vc 5)       rmt   Up     Nov 30 00:54:54 2001           1
      Local interface: fe-0/2/0.600, Status: Up, Encapsulation: VLAN
      Remote PE: 10.245.14.173, Negotiated control-word: Yes (Null)
      Incoming label: 100000, Outgoing label: 100007

user@PE2> show ldp database

Input label database, 10.245.14.179:0-10.245.14.171:0
  Label     Prefix
 100019     10.245.14.173/32
      3     10.245.14.171/32
 100020     10.245.14.179/32

Output label database, 10.245.14.179:0-10.245.14.171:0
  Label     Prefix
 100001     10.245.14.171/32
 100002     10.245.14.173/32
      3     10.245.14.179/32

Input label database, 10.245.14.179:0-10.245.14.173:0
  Label     Prefix
```

```
      3      10.245.14.173/32
 100008      10.245.14.171/32
 100009      10.245.14.179/32
 100007      L2CKT VLAN VC 5

Output label database, 10.245.14.179:0-10.245.14.173:0
  Label      Prefix
 100001      10.245.14.171/32
 100002      10.245.14.173/32
      3      10.245.14.179/32
 100000      L2CKT VLAN VC 5
```

Example: SONET/SDH-Based Layer 2 Circuit Configuration

Figure 57: SONET/SDH-Based Layer 2 Circuit Topology Diagram



In this second Layer 2 circuit example shown in Figure 57, you configure a Layer 2 circuit for a SONET/SDH interface encapsulated with PPP.

On Router CE1, configure the SONET/SDH interface to handle PPP traffic. Be sure to use the same IP address prefix both here and on the SONET/SDH interface of Router CE2.

Router CE1

```
[edit]
interfaces {
    so-0/0/1 {
      description "to PE1 so-0/0/0";
      encapsulation ppp;
      unit 0 {
        family inet {
          address 1.1.1.1/30;
        }
      }
    }
}
```

On Router PE1, configure the PPP-based CE-facing interface with PPP CCC encapsulation. Establish your Layer 2 circuit with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (usually the loopback address of the neighbor), the interface connected to the CE router, and a virtual circuit identifier for this VC. Then, configure MPLS, LDP, and an IGP (such as OSPF) to enable signaling for your Layer 2 circuit.

Router PE1

```
[edit]
interfaces {
    so-0/0/0 {
        description "to CE1 so-0/0/1";
        encapsulation ppp-ccc; # Configure CCC encapsulation on CE-facing interfaces.
        unit 0;
    }
    so-0/1/0 {
        description "to P0 so-0/0/0";
        unit 0 {
            family inet {
                address 192.168.245.22/30;
            }
            family mpls; # Include the MPLS family on core-facing interfaces.
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 10.255.145.126/32;
            }
        }
    }
}
protocols {
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/1/0.0;
            interface lo0.0;
        }
    }
    ldp {            # LDP is required as the signaling protocol for Layer 2 circuits.
        interface so-0/1/0.0;
        interface lo0.0;
    }
    l2circuit {
        neighbor 10.255.145.130 { # This points to the loopback of the PE neighbor.
            interface so-0/0/0.0 { # Here you include the local CE-facing interface.
                virtual-circuit-id 1; # Be sure this ID matches the ID of your PE neighbor.
            }
        }
    }
}
```

On Router P0, configure LDP, MPLS, and OSPF on the interfaces connected to the PE routers. The core router provides the MPLS backbone needed to tunnel Layer 2 traffic from the ingress PR router to the egress PE router.

Router P0

```
[edit]
interfaces {
    so-0/0/0 {
      description "to PE1 so-0/1/0";
      unit 0 {
        family inet {
          address 192.168.245.21/30;
        }
        family mpls; # Include the MPLS family on core interfaces.
      }
    }
    so-0/2/1 {
      description "to PE2 so-1/1/0";
      unit 0 {
        family inet {
          address 192.168.245.17/30;
        }
        family mpls; # Include the MPLS family on core interfaces.
      }
    }
    lo0 {
      unit 0 {
        family inet {
          address 10.255.145.129/32;
        }
      }
    }
}
protocols {
    ospf {
      traffic-engineering;
      area 0.0.0.0 {
        interface so-0/0/0.0;
        interface so-0/2/1.0;
      }
    }
    ldp {           # LDP is required as the signaling protocol for Layer 2 circuits.
      interface so-0/0/0.0;
      interface so-0/2/1.0;
    }
}
```

On Router PE2, complete the Layer 2 circuit by configuring statements to match those previously set on Router PE1. Configure the PPP-based CE-facing interface with PPP CCC encapsulation. Complete your Layer 2 circuit with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (Router PE1), the interface connected to the CE router, and a virtual circuit identifier for this VC. Then, configure MPLS, LDP, and an IGP (such as OSPF) to enable signaling for your Layer 2 circuit.

Router PE2

```
[edit]
interfaces {
    so-1/0/0 {
        description "to CE1 so-1/0/1";
        encapsulation ppp-ccc; # Configure CCC encapsulation on CE-facing interfaces.
        unit 0;
    }
    so-1/1/0 {
        description "to P0 so-0/2/1";
        unit 0 {
            family inet {
                address 192.168.245.18/30;
            }
            family mpls; # Include the MPLS family on core-facing interfaces.
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 10.255.145.130/32;
            }
        }
    }
}
protocols {
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-1/1/0.0;
            interface lo0.0;
        }
    }
    ldp {           # LDP is required as the signaling protocol for Layer 2 circuits.
        interface so-1/1/0.0;
        interface lo0.0;
    }
    l2circuit {
        neighbor 10.255.145.126 { # This points to the loopback of the PE neighbor.
            interface so-1/0/0.0 { # Here you include the local CE-facing interface.
                virtual-circuit-id 1; # Be sure this ID matches the ID of your PE neighbor.
            }
        }
    }
}
```

On Router CE2, configure the SONET/SDH interface to handle PPP traffic. Be sure to use the same IP address prefix both here and on the SONET/SDH interface of Router CE1.

Router CE2

```
[edit]
interfaces {
    so-1/0/1 {
        description "to PE2 so-1/0/0";
        encapsulation ppp;
        unit 0 {
            family inet {
                address 1.1.1.2/30;
            }
        }
    }
}
```

Checking Your Work

To verify proper operation of Layer 2 circuits, use the following commands:

- ping mpls l2circuit interface *interface-name*
- ping mpls l2circuit virtual-circuit *virtual-circuit-id* neighbor *ip-address*
- show l2circuit connections
  - Options: [brief] | [down] | [extensive] | [history] | [instance] | [local-site] | [remote-site] |[status] | [summary] | [up] | [up-down]
- show ldp database
- show route table

The following section shows the output of these commands used with the configuration example:

```
user@PE1> show l2circuit connections
Layer-2 Circuit Connections:

Legend for connection status (St)
EI -- encapsulation invalid      NP -- interface not present
MM -- mtu mismatch               Dn -- down
EM -- encapsulation mismatch     VC-Dn -- Virtual circuit Down
CM -- control-word mismatch      Up -- operational
OL -- no outgoing label          XX -- unknown
NC -- intf encaps not CCC/TCC

Legend for interface status
Up -- operational
Dn -- down

Neighbor: 10.255.145.130
     Interface                 Type  St     Time last up          # Up trans
     so-0/0/0.0 (vc 1)         rmt   Up     Jan 26 14:13:54 2003           1
       Local interface: so-0/0/0.0, Status: Up, Encapsulation: PPP
       Remote PE: 10.255.145.130, Negotiated control-word: Yes (Null)
       Incoming label: 100000, Outgoing label: 100000
```

```
user@PE1> show ldp database l2circuit
Input label database, 10.255.145.126:0--10.255.145.130:0
   Label     Prefix
  100000     L2CKT CtrlWord PPP VC 1

Output label database, 10.255.145.126:0--10.255.145.130:0
   Label     Prefix
  100000     L2CKT CtrlWord PPP VC 1

user@PE1> show ldp database l2circuit detail
Input label database, 10.255.145.126:0--10.255.145.130:0
   Label     Prefix
  100000     L2CKT CtrlWord PPP VC 1
             State: Active
             Age: 5:37

Output label database, 10.255.145.126:0--10.255.145.130:0
   Label     Prefix
  100000     L2CKT CtrlWord PPP VC 1
             State: Active
             Age: 5:37

user@PE1> show route table mpls.0

mpls.0: 7 destinations, 7 routes (7 active, 0 holddown, 0 hidden)
Restart Complete
+ = Active Route, - = Last Active, * = Both
0                  *[MPLS/0] 00:05:04, metric 1
                       Receive
1                  *[MPLS/0] 00:05:04, metric 1
                       Receive
2                  *[MPLS/0] 00:05:04, metric 1
                       Receive
100000             *[L2VPN/7] 00:04:50
                     > via so-0/0/0.0, Pop       Offset: 4
100016             *[LDP/9] 00:04:52, metric 1
                     > via so-0/1/0.0, Pop
100016(S=0)        *[LDP/9] 00:04:52, metric 1
                     > via so-0/1/0.0, Pop
so-0/0/0.0         *[L2VPN/7] 00:04:50
                     > via so-0/1/0.0, Push 100000 Offset: -4
```

Example: ATM2 IQ-Based Layer 2 Circuit Configuration

Figure 58: ATM2 IQ-Based Layer 2 Circuit Topology Diagram

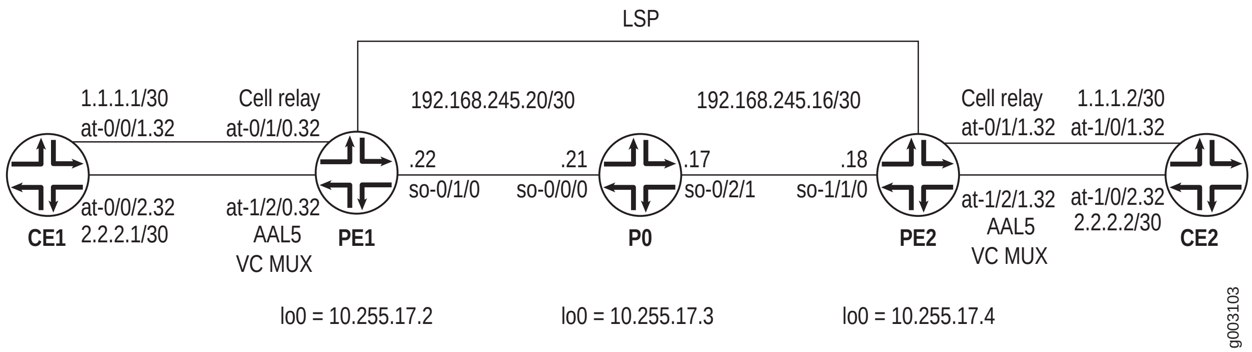


Figure 58 shows a similar network topology to our previous two examples. In this example, Routers PE1 and PE2 use ATM cell-relay mode on a CE-facing interface and ATM AAL5 mode on a second CE-facing interface.

On Router CE1, configure the ATM2 IQ interfaces to handle ATM traffic. Interface at-0/0/1 handles standard ATM traffic while interface at-0/0/2 handles AAL5 traffic.

Router CE1

```
[edit]
interfaces {
    at-0/0/1 {
        description "to PE1 at-0/1/0";
        atm-options {
            pic-type atm2;             # Layer 2 circuits are compatible with
            vpi 0;                     # ATM2 IQ interfaces.
        }
        unit 0 {
            vci 32;
            family inet {
                address 1.1.1.1/30;
            }
        }
    }
    at-0/0/2 {
        description "to PE1 at-1/2/0";
        atm-options {
            pic-type atm2;             # Layer 2 circuits are compatible with
            vpi 0;                     # ATM2 IQ interfaces.
        }
        unit 0 {
            encapsulation atm-vc-mux;
            vci 32;
            family inet {
                address 2.2.2.1/30;
            }
        }
    }
}
```

On Router PE1, configure the ATM2 IQ-based CE-facing interfaces: one with ATM cell-relay mode CCC encapsulation and the other with ATM VC multiplexing CCC encapsulation. Also enable the corresponding Layer 2 circuit modes at the [edit chassis] hierarchy level. In this case, you must configure cell-relay mode on Physical Interface Card (PIC) 1 in Flexible PIC Concentrator (FPC) 0 and AAL5 mode on PIC 2 in FPC 1.

Establish your Layer 2 circuit with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (usually the loopback address of the neighbor), the interfaces connected to the CE router, and a virtual circuit identifier for each VC. In this case, you will establish one VC for cell-relay mode traffic and a second VC for AAL5 traffic. Then, configure MPLS, LDP, and an IGP (such as OSPF) to enable signaling for your Layer 2 circuit.

Router PE1

```
[edit]
chassis {
    fpc 0 {
        pic 1 {
            atm-l2circuit-mode {
                cell;                   # This dedicates FPC 0 PIC 1 to cell-relay mode.
            }
        }
    }
    fpc 1 {
        pic 2 {
            atm-l2circuit-mode {
                aal5;                   # This dedicates FPC 1 PIC 2 to AAL5 mode.
            }
        }
    }
}
interfaces {
    at-0/1/0 {
        description "to CE1 at-0/0/1";
        encapsulation atm-ccc-cell-relay; # Cell-relay requires cell-relay encapsulation.
        atm-options {
            cell-bundle-size 4;         # This sets the cell bundle size for the interface.
            pic-type atm2;              # Layer 2 circuits are compatible with
            vpi 0;                      # ATM2 IQ interfaces.
        }
        unit 0 {
            encapsulation atm-ccc-cell-relay; # Encapsulation for the logical interface.
            vci 32;
            cell-bundle-size 10; # The cell bundle size for the logical interface overrides
        }                       # the physical interface setting.
    }
```

```
        at-1/2/0 {
            description "to CE1 at-0/0/2";
            atm-options {
                pic-type atm2;              # Layer 2 circuits are compatible with
                vpi 0;                      # ATM2 IQ interfaces.
            }
            unit 0 {
                encapsulation atm-ccc-vc-mux; # AAL5 requires CCC VC MUX encapsulation.
                vci 32;
            }
        }
        so-0/1/0 {
            description "to P0 so-0/0/0";
            unit 0 {
                family inet {
                    address 192.168.245.22/30;
                }
                family mpls; # Include the MPLS family on core-facing interfaces.
            }
        }
        lo0 {
            unit 0 {
                family inet {
                    address 10.255.17.2/32;
                }
            }
        }
    }
    protocols {
        ospf {
            traffic-engineering;
            area 0.0.0.0 {
                interface so-0/1/0.0;
                interface lo0.0;
            }
        }
        ldp {           # LDP is required as the signaling protocol for Layer 2 circuits.
            interface so-0/1/0.0;
            interface lo0.0;
        }
        l2circuit {
            neighbor 10.255.17.4 {   # This points to the loopback of the PE neighbor.
                interface at-0/1/0.32 { # Here you include the local CE-facing interface.
                    virtual-circuit-id 1; # Be sure this ID matches the ID of your PE neighbor.
                }
            }
            neighbor 10.255.17.4 {   # This points to the loopback of the PE neighbor.
                interface at-1/2/0.32 { # Here you include the local CE-facing interface.
                    virtual-circuit-id 2; # Be sure this ID matches the ID of your PE neighbor.
                }
            }
        }
    }
```

On Router P0, configure LDP, MPLS, and OSPF on the interfaces connected to the PE routers. The core router provides the MPLS backbone needed to tunnel Layer 2 traffic from the ingress PR router to the egress PE router.

Router P0

```
[edit]
interfaces {
    so-0/0/0 {
        description "to PE1 so-0/1/0";
        unit 0 {
            family inet {
                address 192.168.245.21/30;
            }
            family mpls; # Include the MPLS family on core interfaces.
        }
    }
    so-0/2/1 {
        description "to PE2 so-1/1/0";
        unit 0 {
            family inet {
                address 192.168.245.17/30;
            }
            family mpls; # Include the MPLS family on core interfaces.
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 10.255.17.3/32;
            }
        }
    }
}
protocols {
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/0/0.0;
            interface so-0/2/1.0;
        }
    }
    ldp {           # LDP is required as the signaling protocol for Layer 2 circuits.
        interface so-0/0/0.0;
        interface so-0/2/1.0;
    }
}
```

On Router PE2, complete the Layer 2 circuit by configuring statements to match those previously set on Router PE1.

Configure the ATM2 IQ-based CE-facing interfaces: one with ATM cell-relay mode CCC encapsulation and the other with ATM VC multiplexing CCC encapsulation. Also enable the corresponding Layer 2 circuit modes at the [edit chassis] hierarchy level. In this case, you must configure cell-relay mode on PIC 1 in FPC 0 and AAL5 mode on PIC 2 in FPC 1.

Complete your Layer 2 circuit with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (Router PE1), the interfaces connected to the CE router, and a virtual circuit identifier for each VC. In this case, you will establish one VC for cell-relay mode traffic and a second VC for AAL5 traffic. Then, configure MPLS, LDP, and an IGP (such as OSPF) to enable signaling for your Layer 2 circuit.

Router PE2

```
[edit]
chassis {
    fpc 0 {
        pic 1 {
            atm-l2circuit-mode {
                cell;                  # This dedicates FPC 0 PIC 1 to cell-relay mode.
            }
        }
    }
    fpc 1 {
        pic 2 {
            atm-l2circuit-mode {
                aal5;                  # This dedicates FPC 1 PIC 2 to AAL5 mode.
            }
        }
    }
}
interfaces {
    at-0/1/1 {
        description "to CE2 at-1/0/1";
        encapsulation atm-ccc-cell-relay; # Cell-relay requires cell-relay encapsulation.
        atm-options {
            cell-bundle-size 4;  # This sets the cell bundle size for the physical interface.
            pic-type atm2;            # Layer 2 circuits are compatible with
            vpi 0;                    # ATM2 IQ interfaces.
        }
        unit 0 {
            encapsulation atm-ccc-cell-relay; # Also configure the encapsulation
            vci 32;                           # on the logical interface.
            cell-bundle-size 10; # The cell bundle size for the logical interface overrides
        }                        # the physical interface setting.
    }
```

```
        at-1/2/1 {
            description "to CE2 at-1/0/2";
            atm-options {
                pic-type atm2;              # Layer 2 circuits are compatible with
                vpi 0;                      # ATM2 IQ interfaces.
            }
            unit 0 {
                encapsulation atm-ccc-vc-mux; # AAL5 requires CCC VC MUX encapsulation.
                vci 32;
            }
        }
        so-1/1/0 {
            description "to P0 so-0/2/1";
            unit 0 {
                family inet {
                    address 192.168.245.18/30;
                }
                family mpls; # Include the MPLS family on core-facing interfaces.
            }
        }
        lo0 {
            unit 0 {
                family inet {
                    address 10.255.17.4/32;
                }
            }
        }
    }
    protocols {
        ospf {
            traffic-engineering;
            area 0.0.0.0 {
                interface so-1/1/0.0;
                interface lo0.0;
            }
        }
        ldp {           # LDP is required as the signaling protocol for Layer 2 circuits.
            interface so-1/1/0.0;
            interface lo0.0;
        }
        l2circuit {
            neighbor 10.255.17.2 {   # This points to the loopback of the PE neighbor.
                interface at-0/1/1.32 { # Here you include the local CE-facing interface.
                    virtual-circuit-id 1; # Be sure this ID matches the ID of your PE neighbor.
                }
            }
            neighbor 10.255.17.2 {   # This points to the loopback of the PE neighbor.
                interface at-1/2/1.32 { # Here you include the local CE-facing interface.
                    virtual-circuit-id 2; # Be sure this ID matches the ID of your PE neighbor.
                }
            }
        }
    }
```

On Router CE2, configure the ATM2 IQ interfaces to handle ATM traffic. Interface at-1/0/1 handles standard ATM traffic while interface at-1/0/2 handles AAL5 traffic.

Router CE2

```
[edit]
interfaces {
    at-1/0/1 {
        description "to PE2 at-0/1/1";
        atm-options {
            pic-type atm2;              # Layer 2 circuits are compatible with
            vpi 0;                      # ATM2 IQ interfaces.
        }
        unit 0 {
            vci 32;
            family inet {
                address 1.1.1.2/30;
            }
        }
    }
    at-1/0/2 {
        description "to PE2 at-1/2/1";
        atm-options {
            pic-type atm2;              # Layer 2 circuits are compatible with
            vpi 0;                      # ATM2 IQ interfaces.
        }
        unit 0 {
            encapsulation atm-vc-mux;
            vci 32;
            family inet {
                address 2.2.2.2/30;
            }
        }
    }
}
```

Checking Your Work

To verify proper operation of Layer 2 circuits, use the following commands:

- ping mpls l2circuit interface *interface-name*
- ping mpls l2circuit virtual-circuit *virtual-circuit-id* neighbor *ip-address*
- show l2circuit connections
    - Options: [brief] | [down] | [extensive] | [history] | [instance] | [local-site] | [remote-site] |[status] | [summary] | [up] | [up-down]
- show interfaces
- show route table l2circuit.0
- show ldp database l2circuit detail

This is what the operational command output looks like for cell-relay mode on Router PE1:

```
user@PE1> show l2circuit connections
Layer-2 Circuit Connections:

Legend for connection status (St)
EI -- encapsulation invalid      NP -- interface not present
MM -- mtu mismatch               Dn -- down
EM -- encapsulation mismatch     VC-Dn -- Virtual circuit Down
CM -- control-word mismatch      Up -- operational
OL -- no outgoing label          XX -- unknown
NC -- intf encaps not CCC/TCC

Legend for interface status
Up -- operational
Dn -- down

Neighbor: 10.255.17.4
    Interface                 Type  St     Time last up          # Up trans
    at-0/1/0.0 (vc 32)        rmt   Up     Jan 22 15:15:52 2003           1
      Local interface: at-0/1/0.0, Status: Up, Encapsulation: ATM CELL (VC Mode)
      Remote PE: 10.255.17.4, Negotiated control-word: Yes (Non-null)
      Incoming label: 100000, Outgoing label: 100000

user@PE1> show route table l2circuit.0 detail

l2circuit.0: 2 destinations, 2 routes (2 active, 0 holddown, 0 hidden)
10.255.17.4:CtrlWord:9:32:Local/96 (1 entry, 1 announced)
        *L2CKT  Preference: 7
                Next hop: via so-0/2/0.0 weight 1, selected
                Label-switched-path PE1-PE2
                Protocol next hop: 10.255.17.4 Indirect next hop: 85135e8 367
                State: <Active Int>
                Local AS:    69
                Age: 2:34
                Task: l2 circuit
                Announcement bits (1): 0-LDP
                AS path: I
                VC Label 100000, MTU 0, cell-bundle size 80

10.255.17.4:CtrlWord:9:32:Remote/96 (1 entry, 1 announced)
        *LDP    Preference: 9
                Next hop type: Discard
                State: <Active Int>
                Local AS:    69
                Age: 28:11
                Task: LDP
                Announcement bits (1): 1-l2 circuit
                AS path: I
                VC Label 100000, MTU 0, cell-bundle size 80

user@PE1> show interfaces at-0/1/0.0 extensive
  Logical interface at-0/1/0.0 (Index 66) (SNMP ifIndex 40) (Generation 4)
    Flags: Point-To-Point SNMP-Traps Encapsulation: ATM-CCC-Cell-Relay
    L2 circuit cell bundle size: 10, bundle timeout: 125 usec, timeout count: 0
    L2 circuit out-of-sequence count: 0
    Traffic statistics:
[...]
```

```
user@PE1> show interfaces media at-0/1/0
Physical interface: at-0/1/0, Enabled, Physical link is Up
 Interface index: 154, SNMP ifIndex: 50
 Link-level type: ATM-CCC-Cell-Relay, MTU: 4482, Clocking: Internal, SONET mode,
 L2 circuit mode: Cell, Speed: OC12, Loopback: None
[...]

user@PE1> show ldp database l2circuit detail
Input label database, 10.255.17.2:0--10.255.17.4:0
    Label     Prefix
   100000     L2CKT CtrlWord ATM CELL (VC Mode) VC 32
              Cell bundle size: 80
              State: Active
              Age: 9:48

Output label database, 10.255.17.2:0--10.255.17.4:0
    Label     Prefix
   100000     L2CKT CtrlWord ATM CELL (VC Mode) VC 32
              Cell bundle size: 80
              State: Active
              Age: 9:48
```

This is what the operational command output looks like on Router PE1 if AAL5 mode is used:

```
user@PE1> show l2circuit connections
Layer-2 Circuit Connections:

Legend for connection status (St)
EI -- encapsulation invalid      NP -- interface not present
MM -- mtu mismatch               Dn -- down
EM -- encapsulation mismatch     VC-Dn -- Virtual circuit Down
CM -- control-word mismatch      Up -- operational
OL -- no outgoing label          XX -- unknown
NC -- intf encaps not CCC/TCC

Legend for interface status
Up -- operational
Dn -- down

Neighbor: 10.255.17.4
    Interface                 Type  St     Time last up          # Up trans
    at-1/2/0.0 (vc 32)        rmt   Up     Feb 18 18:00:00 2003           1
      Local interface: at-1/2/0.0, Status: Up, Encapsulation: ATM AAL5
      Remote PE: 10.255.17.4, Negotiated control-word: Yes (Non-null)
      Incoming label: 100016, Outgoing label: 100032

user@PE1> show interfaces media at-0/1/0
Physical interface: at-0/1/0, Enabled, Physical link is Up
 Interface index: 154, SNMP ifIndex: 50
 Link-level type: ATM-PVC, MTU: 4482, Clocking: Internal, SONET mode,
 L2 circuit mode: AAL5, Speed: OC12, Loopback: None, Payload scrambler: Enabled
[...]

user@PE1> show interfaces at-1/2/0.0 extensive
  Logical interface at-1/2/0.0 (Index 68) (SNMP ifIndex 40) (Generation 38)
    Flags: Point-To-Point SNMP-Traps Encapsulation: ATM-CCC-VCMUX
    L2 circuit out-of-sequence count: 0
    Traffic statistics:[...]
```

Example: Layer 2 Circuit Traffic Engineering over Multiple LSPs Configuration

Figure 59: Layer 2 Circuit Traffic Engineering Topology Diagram

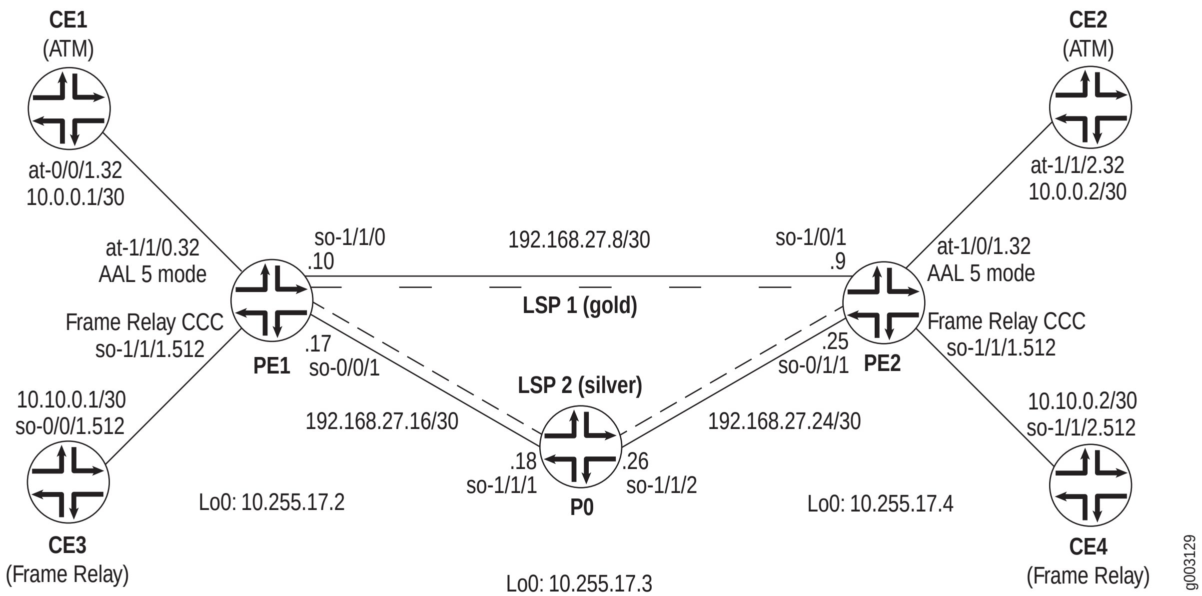


Figure 59 shows a network topology designed to traffic engineer different Layer 2 circuits over select LSPs. Across provider edge routers PE1 and PE2, an ATM AAL5 mode Layer 2 circuit connects customer edge routers CE1 and CE2, and a Frame Relay Layer 2 circuit connects routers CE3 and CE4. To maintain traffic separation, the ATM traffic is mapped onto LSP1 with a community named gold, and the Frame Relay traffic is mapped onto LSP2 with a community named silver. LSP1 takes the direct route between routers PE1 and PE2, while LSP2 travels from Router PE1 to PE2 through Router P0.

In addition to traffic engineering, you can send Layer 2 control information in the control word of a Layer 2 circuit. In this case, Frame Relay discard eligible (DE), forward explicit congestion notification (FECN), and backward explicit congestion notification (BECN) information is mapped into the control word. Likewise, ATM cell loss priority (CLP) and explicit forward congestion indicator (EFCI) information is mapped into the control word.

To traffic engineer Layer 2 circuits over multiple LSPs, you assign a set of Layer 2 circuits to a community and then apply a policy to send the community traffic over a desired LSP. To create communities, include the community *community-name* statement at the [edit policy-options] hierarchy level. To assign a Layer 2 circuit to a community, include the community *community-name* statement at the [edit protocols l2circuit neighbor *neighbor-id* interface *interface-name*] hierarchy level. To send community traffic over a specific LSP, include the community *community-name* statement at the [edit policy-options policy-statement *policy-name* term *term-name* from] hierarchy level and the install-next-hop lsp *lsp-name* statement at the [edit policy-options policy-statement *policy-name* term *term-name* then] hierarchy level.

On Router CE1, configure the ATM2 IQ interface at-0/0/1.32 to handle ATM AAL5 traffic:

Router CE1

```
[edit]
interfaces {
    at-0/0/1 {
      description "to PE1 at-1/1/0";
      atm-options {
        pic-type atm2;              # Layer 2 circuits are compatible with
        vpi 0;                      # ATM2 IQ interfaces.
      }
      unit 0 {
        encapsulation atm-vc-mux; # Use ATM VC MUX encapsulation on the CE.
        point-to-point;
        vci 0.32;
        family inet {
          address 10.0.0.1/30;
        }
      }
    }
```

On Router CE3, configure the SONET/SDH interface at so-0/0/1 to handle Frame Relay traffic:

Router CE3

```
[edit]
interfaces
    so-0/0/1 {
      description “to PE1 so-1/1/1”
      encapsulation frame-relay; # Use Frame Relay encapsulation on the CE router.
      unit 0 {
        encapsulation frame-relay;
        point-to-point;
        dlci 512;
        family inet {
          address 10.10.0.1/30;
        }
      }
    }
}
```

On Router PE1, configure the ATM2 IQ-based CE1-facing interface at-1/1/0 with ATM VC multiplexing CCC encapsulation on the logical interface. Also enable the corresponding Layer 2 circuit modes at the [edit chassis] hierarchy level. In this case, you must configure AAL5 mode on PIC 1 in FPC 1. Once you configure the ATM2 IQ-based Layer 2 circuit, the CLP and EFCI bits are mapped to the control word by default.

Next, configure the Frame Relay interface so-1/1/1 with Frame Relay CCC encapsulation on both the physical and logical interface. Map the DE, FECN, and BECN bits to the control word with the translate-fecn-and-becn and translate-discard-eligible statements at the [edit interfaces so-*fpc/pic/port* unit *unit-number* family ccc] hierarchy level.

Establish your Layer 2 circuits with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (usually the loopback address of the neighbor), the interfaces connected to the CE router, and a virtual circuit identifier for each VC. In this case, you will establish one VC for ATM AAL5 traffic and a second VC for Frame Relay traffic. Then, configure MPLS, LDP, and an IGP (such as OSPF) to enable signaling for your Layer 2 circuit. Two LSPs are established for the ATM and Frame Relay traffic: LSP1 for ATM traffic going directly to Router PE2 and LSP 2 for Frame Relay traffic going through Router P0 before going on to Router PE2.

Finally, configure a community for traffic separation for the ATM and Frame Relay Layer 2 circuits. Assign community gold to the ATM VC and community silver to the Frame Relay VC. Remember to give the communities numerical values and configure a routing policy to match the communities to specific LSPs. This policy is applied as an export policy for the forwarding table at the [edit routing-options] hierarchy level.

Router PE1

```
[edit]
chassis {
    fpc 1 {
        pic 1 {
            atm-l2circuit-mode {
                aal5;                    # This dedicates FPC 1 PIC 1 to AAL5 mode.
            }
        }
    }
}
interfaces {
    at-1/1/0 {
        description "to CE1 at-0/0/2";
        atm-options {
            pic-type atm2;               # Layer 2 circuits are compatible with
            vpi 0;                       # ATM2 IQ interfaces.
        }
        unit 0 {
            encapsulation atm-ccc-vc-mux; # CLP/EFCI bits are mapped to control word.
            vci 0.32;
        }
    }
```

```
        so-0/1/0 {
            description "to P0 so-0/0/0";
            unit 0 {
                family inet {
                    address 192.168.27.17/30;
                }
                family mpls; # Include the MPLS family on core-facing interfaces.
            }
        }
        so-1/1/0 {
            description "to PE2 so-1/0/1";
            unit 0 {
                family inet {
                    address 192.168.27.10/30;
                }
                family mpls; # Include the MPLS family on core-facing interfaces.
            }
        }
        so-1/1/1 {
            description "to CE3 so-0/0/1";
            dce;
            encapsulation frame-relay-ccc;
            unit 0 {
                encapsulation frame-relay-ccc;
                point-to-point;
                dlci 512;
                family ccc {
                    translate-fecn-and-becn;  # Option to map FECN/BECN bits to control word.
                    translate-discard-eligible; # Option to map DE bit to control word.
                    }
            }
        }
        lo0 {
            unit 0 {
                family inet {
                    address 10.255.17.2/32;
                }
            }
        }
}
routing-options {
        forwarding-table {
            consistency-checking {
                enable;
                period 1000;
            }
            export layer2communities; # This applies communities to the Layer 2 circuits.
        }
}
```

```
protocols {
    mpls {
        label-switched-path lsp1 { # ATM LSP 1 goes directly to PE2.
            to 10.255.17.4;
            primary direct;
        }
        label-switched-path lsp2 { # Frame Relay LSP 2 goes through P0.
            to 10.255.17.4;
            primary thruP0;
        }
        path direct {
            192.168.27.9 strict;
        }
        path thruP0 {
            192.168.27.18 strict;
            192.168.27.25 strict;
        }
        interface so-0/0/1.0;
        interface so-1/1/0.0;
    }
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/0/1.0;
            interface so-1/1/0.0;
            interface lo0.0;
        }
    }
    ldp {           # LDP is required as the signaling protocol for Layer 2 circuits.
        interface so-0/0/1.0;
        interface so-1/1/0.0;
        interface lo0.0;
    }
    l2circuit {
        neighbor 10.255.17.4 {   # This points to the loopback of the PE neighbor.
            interface at-1/1/0.32 { # Here you include the local CE-facing interface.
                virtual-circuit-id 1; # Be sure this ID matches the ID of your PE neighbor.
                community gold;    # Assigns the ATM Layer 2 circuit to the gold
community.
            }
        }
        neighbor 10.255.17.4 {   # This points to the loopback of the PE neighbor.
            interface so-1/1/1.512 { # Here you include the local CE-facing interface.
                virtual-circuit-id 2; # Be sure this ID matches the ID of your PE neighbor.
                community silver; # Assigns the Frame Relay Layer 2 circuit to silver.
            }
        }
    }
}
```

```
policy-options {
    policy-statement layer2communities { # Here you map the communities to LSPs.
      term 10 {
        from community gold;           # Apply community gold to LSP 1.
        then {
          install-nexthop lsp lsp1;
          accept;
        }
      term 20 {
        from community silver;         # Apply community silver to LSP 2.
        then {
          install-nexthop lsp lsp2;
          accept;
        }
    community gold members 103:1; # Assign numerical value to community gold.
    community silver members 103:2; # Assign numerical value to community silver.
```

On Router P0, configure LDP, MPLS, and OSPF on the interfaces connected to the PE routers. The core router provides the MPLS backbone needed to tunnel Layer 2 traffic from the ingress PR router to the egress PE router. Only LSP 2 for Frame Relay passes through Router P0.

Router P0

```
[edit]
interfaces {
    so-1/1/1 {
      description "to PE1 so-0/0/1";
      unit 0 {
        family inet {
          address 192.168.27.18/30;
        }
        family mpls; # Include the MPLS family on core interfaces.
      }
    }
    so-1/1/2 {
      description "to PE2 so-0/1/1";
      unit 0 {
        family inet {
          address 192.168.27.26/30;
        }
        family mpls; # Include the MPLS family on core interfaces.
      }
    }
    lo0 {
      unit 0 {
        family inet {
          address 10.255.17.3/32;
        }
      }
    }
}
```

```
protocols {
    mpls {
        interface so-1/1/1.0;
        interface so-1/1/2.0;
    }
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-1/1/1.0;
            interface so-1/1/2.0;
        }
    }
    ldp {          # LDP is required as the signaling protocol for Layer 2 circuits.
        interface so-1/1/1.0;
        interface so-1/1/2.0;
    }
}
```

On Router PE2, complete the Layer 2 circuit by configuring statements to match those previously set on Router PE1.

Establish your Layer 2 circuits with configuration of the l2circuit statement at the [edit protocols] hierarchy level. Remember to include in your Layer 2 circuit configuration the IP address of your remote PE neighbor (usually the loopback address of the neighbor), the interfaces connected to the CE router, and a virtual circuit identifier for each VC. In this case, you will establish one VC for ATM AAL5 traffic and a second VC for Frame Relay traffic. Then, configure MPLS, LDP, and an IGP (such as OSPF) to enable signaling for your Layer 2 circuit. Two LSPs are established for the ATM and Frame Relay traffic: LSP1 for ATM traffic going directly to Router PE2 and LSP 2 for Frame Relay traffic going through Router P0 before going on to Router PE2.

Finally, configure a community for traffic separation for the ATM and Frame Relay Layer 2 circuits. The ATM VC has community gold and the Frame Relay VC has community silver. Remember to give the communities numerical values and configure a routing policy to match the communities to specific LSPs. This policy is applied as an export policy for the forwarding table at the [edit routing-options] hierarchy level.

Router PE2

```
[edit]
chassis {
    fpc 1 {
        pic 0 {
            atm-l2circuit-mode {
                aal5;                # This dedicates FPC 1 PIC 0 to AAL5 mode.
            }
        }
    }
}
```

```
interfaces {
    at-1/0/1 {
        description "to CE2 at-1/1/2";
        atm-options {
            pic-type atm2;          # Layer 2 circuits are compatible with
            vpi 0;                  # ATM2 IQ interfaces.
        }
        unit 0 {
            encapsulation atm-ccc-vc-mux; # CLP and EFCI appear in the control word.
            vci 0.32;
        }
    }
    so-0/1/1 {
        description "to P0 so-1/1/2";
        unit 0 {
            family inet {
                address 192.168.27.25/30;
            }
            family mpls; # Include the MPLS family on core-facing interfaces.
        }
    }
    so-1/0/1 {
        description "to PE1 so-1/1/0";
        unit 0 {
            family inet {
                address 192.168.27.9/30;
            }
            family mpls; # Include the MPLS family on core-facing interfaces.
        }
    }
    so-1/1/1 {
        description "to CE4 so-1/1/2";
        dce;
        encapsulation frame-relay-ccc;
        unit 0 {
            encapsulation frame-relay-ccc;
            point-to-point;
            dlci 512;
            family ccc {
                translate-fecn-and-becn;  # Option to map FECN/BECN bits to control word.
                translate-discard-eligible; # Option to map DE bit to control word.
                }
        }
    }
    lo0 {
        unit 0 {
            family inet {
                address 10.255.17.4/32;
            }
        }
    }
}
```

```
routing-options {
    forwarding-table {
      consistency-checking {
        enable;
        period 1000;
      }
      export layer2communities; # This maps communities to the Layer 2 circuits.
    }
}
protocols {
    mpls {
      label-switched-path lsp1 { # ATM LSP 1 goes directly to Router PE2.
        to 10.255.17.2;
        primary direct;
      }
      label-switched-path lsp2 { # Frame Relay LSP 2 goes through Router P0.
        to 10.255.17.2;
        primary thruP0;
      }
      path direct {
        192.168.27.10 strict;
      }
      path thruP0 {
        192.168.27.26 strict;
        192.168.27.17 strict;
      }
      interface so-0/1/1.0;
      interface so-1/0/1.0;
    }
    ospf {
      traffic-engineering;
      area 0.0.0.0 {
        interface so-0/1/1.0;
        interface so-1/0/1.0;
        interface lo0.0;
      }
    }
    ldp {             # LDP is required as the signaling protocol for Layer 2 circuits.
      interface so-0/1/1.0;
      interface so-1/0/1.0;
      interface lo0.0;
    }
    l2circuit {
      neighbor 10.255.17.2 {   # This points to the loopback of the PE neighbor.
        interface at-1/0/1.32 { # Here you include the local CE-facing interface.
          virtual-circuit-id 1; # Be sure this ID matches the ID of your PE neighbor.
          community gold;    # Assigns the ATM Layer 2 circuit to the gold
community.
        }
      }
      neighbor 10.255.17.2 {   # This points to the loopback of the PE neighbor.
        interface so-1/1/1.512 { # Here you include the local CE-facing interface.
          virtual-circuit-id 2; # Be sure this ID matches the ID of your PE neighbor.
          community silver; # Assigns the Frame Relay Layer 2 circuit to silver.
        }
      }
    }
```

```
}
policy-options {
    policy-statement layer2communities { # Here you map communities to LSPs.
      term 10 {
        from community gold;          # Apply community gold to LSP 1.
        then {
          install-nexthop lsp lsp1;
          accept;
        }
      term 20 {
        from community silver;        # Apply community silver to LSP 2.
        then {
          install-nexthop lsp lsp2;
          accept;
        }
    community gold members 103:1; # Assign numerical value to community gold.
    community silver members 103:2; # Assign numerical value to community silver.
```

On Router CE2, configure the ATM2 IQ interfaces to handle ATM traffic. Interface at-1/0/1 handles AAL5 traffic.

Router CE2

```
[edit]
interfaces {
    at-1/1/2 {
      description "to PE2 at-1/0/1";
      atm-options {
        pic-type atm2;            # Layer 2 circuits are compatible with
        vpi 0;                    # ATM2 IQ interfaces.
      }
      unit 0 {
        encapsulation atm-vc-mux; # Use ATM VC MUX encapsulation on the CE.
        point-to-point;
        vci 0.32;
        family inet {
          address 10.0.0.2/30;
        }
      }
    }
```

On Router CE4, configure the SONET/SDH interface at so-1/1/2 to handle Frame Relay traffic:

Router CE3

```
[edit]
interfaces {
    so-1/1/2 {
      description "to PE2 so-1/1/1";
      encapsulation frame-relay-ccc; # Use Frame Relay encapsulation on the CE.
      unit 0 {
        encapsulation frame-relay-ccc;
        point-to-point;
        dlci 512;
        family inet {
          address 10.10.0.2/30;
        }
      }
    }
}
```

Checking Your Work

To verify proper operation of traffic engineered Layer 2 circuits, use the following command:

show route table mpls.0 detail

On Router PE1, you can see that ATM traffic is part of the gold community that has a value of 103:1 and is associated with LSP 1. Likewise, Frame Relay traffic is part of the silver community that has a value of 103:2 and is associated with LSP 2:

```
user@PE1> show route table mpls.0 detail

mpls.0: 2 destinations, 2 routes (2 active, 0 holddown, 0 hidden)
at-1/1/0.32 (1 entry, 1 announced)
         *L2CKT  Preference: 7
                 Next hop: 192.168.27.9 via so-1/1/0.0 weight 1, selected
                 Label-switched-path lsp1
                 Label operation: Push 100032 Offset: -4
                 Next hop: via so-0/0/1.0 weight 1
                 Label-switched-path lsp2
                 Label operation: Push 100032 Offset: -4
                 Protocol next hop: 10.255.17.4
                 Push 100032 Offset: -4
                  Indirect next hop: 8576bd0 300
                 State: <Active Int>
                 Age: 7:18
                 Task: Common L2 VC
                 Announcement bits (2): 0-KRT 1-Common L2 VC
                 AS path: I
                 Communities: 103:1          # This is the gold community.

so-1/1/1.512 (1 entry, 1 announced)
         *L2CKT  Preference: 7
                 Next hop: 192.168.27.9 via so-1/1/0.0 weight 1
                 Label-switched-path lsp1
                 Label operation: Push 100048 Offset: -4
                 Next hop: via so-0/0/1.0 weight 1, selected
                 Label-switched-path lsp2
                 Label operation: Push 100048 Offset: -4
                 Protocol next hop: 10.255.17.4
                 Push 100048 Offset: -4
                  Indirect next hop: 860f1f8 293
                 State: <Active Int>
                 Age: 5:15
                 Task: Common L2 VC
                 Announcement bits (2): 0-KRT 1-Common L2 VC
                 AS path: I
                 Communities: 103:2          # This is the silver community.
```

Example: APS for a Layer 2 Circuit Configuration

Figure 60: APS for a Layer 2 Circuit Topology Diagram

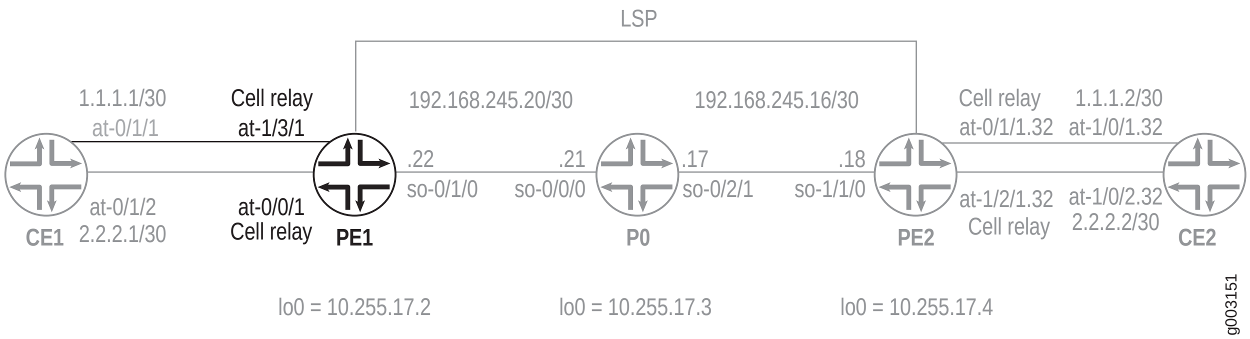


Figure 60 shows that APS is configured on a PE router to protect a PE-CE link in a Layer 2 circuit. This example shows only the PE router configuration and assumes that you have preconfigured a full Layer 2 circuit topology. For more information about configuring Layer 2 circuits, see "Configuring Layer 2 Circuits" on page 670.

On Router PE1, configure ATM2 IQ interface at-0/0/1 as an APS protect circuit and ATM2 IQ interface at-1/3/1 as a working circuit. Also, configure the working circuit interface as the primary interface for your Layer 2 circuit and configure the protect circuit interface as the protected interface for your Layer 2 circuit.

Router PE1

```
[edit]
chassis {
    fpc 0 {
        pic 0 {
            atm-l2circuit-mode {
                cell;                    # This dedicates FPC 0 PIC 0 to cell-relay mode.
            }
        }
    }
    fpc 1 {
        pic 3 {
            atm-l2circuit-mode {
                cell;                    # This dedicates FPC 1 PIC 3 to cell-relay mode.
            }
        }
    }
}
```

```
interfaces {
    at-0/0/1 {
        description "To CE1 at-0/1/2";
        encapsulation atm-ccc-cell-relay;
        sonet-options {
            aps {
                protect-circuit TEST;      # This interface is the APS protect circuit.
            }
        }
        atm-options {
            pic-type atm2;
            promiscuous-mode;
        }
        unit 0 {
            allow-any-vci;
        }
    }
    at-1/3/1 {
        description "To CE1 at-0/1/1";
        encapsulation atm-ccc-cell-relay;
        sonet-options {
            aps {
                working-circuit TEST;      # This interface is the APS working circuit.
            }
        }
        atm-options {
            pic-type atm2;
            promiscuous-mode;
        }
        unit 0 {
            allow-any-vci;
        }
    }
}
protocols {
    l2circuit {
        neighbor 10.255.17.4 {
            interface at-1/3/1.0 { # The Layer 2 circuit interface is the working circuit.
                protect-interface at-0/0/1.0; # The protect-interface is the protect circuit.
                virtual-circuit-id 100;
            }
        }
    }
}
```

Checking Your Work

To verify proper operation of APS for Layer 2 circuits, use the following command:

show l2circuit connections

After you configure the Layer 2 circuit and the APS working and protect circuits, you can see which APS circuit is active for the Layer 2 circuit with the show l2circuit connections command. The first local interface that is displayed is always the active circuit. If the second local interface field indicates Protect-Inactive, the working circuit is active, as shown in this output sample.

```
user@PE0> show l2circuit connections
Layer-2 Circuit Connections:

Legend for connection status (St)
EI -- encapsulation invalid      NP -- interface h/w not present
MM -- mtu mismatch               Dn -- down
EM -- encapsulation mismatch     VC-Dn -- Virtual circuit Down
CM -- control-word mismatch      Up -- operational
OL -- no outgoing label          XX -- unknown
NC -- intf encaps not CCC/TCC
CB -- rcvd cell-bundle size bad

Legend for interface status
Up -- operational
Dn -- down

Neighbor: 10.255.17.4
Interface                 Type  St     Time last up          # Up trans
 at-1/3/1.0(vc 100)        rmt   Up     Sep  3 17:48:25 2003          1
   Local interface: at-1/3/1.0, Status: Up, Encapsulation: ATM CELL (PORT Mode)
   Remote PE: 10.255.17.4, Negotiated control-word: Yes (Null)
   Incoming label: 100368, Outgoing label: 100112
   Local interface: at-0/0/1.0, Status: Dn, Encapsulation: ATM CELL (PORT Mode),
   Protect-Inactive
```

Conversely, if the first local interface is marked with the Protect-Active indicator, and the second local interface indicates Primary-Inactive, the protect circuit is active, as shown here:

```
user@PE0> show l2circuit connections
Layer-2 Circuit Connections:

Legend for connection status (St)
EI -- encapsulation invalid      NP -- interface h/w not present
MM -- mtu mismatch               Dn -- down
EM -- encapsulation mismatch     VC-Dn -- Virtual circuit Down
CM -- control-word mismatch      Up -- operational
OL -- no outgoing label          XX -- unknown
NC -- intf encaps not CCC/TCC
CB -- rcvd cell-bundle size bad

Legend for interface status
Up -- operational
Dn -- down

Neighbor: 10.255.17.4
 Interface                 Type  St     Time last up          # Up trans
 at-1/3/1.0(vc 100)        rmt   Up     Sep  3 17:51:06 2003           2
   Local interface: at-0/0/1.0, Status: Up, Encapsulation: ATM CELL (PORT Mode),
   Protect-Active
   Remote PE: 10.255.17.4, Negotiated control-word: No
   Incoming label: 100368, Outgoing label: 100112
   Local interface: at-1/3/1.0, Status: Dn, Encapsulation: ATM CELL (PORT Mode),
   Primary-Inactive
```

For More Information

For additional information about Layer 2 circuits, see the following:

- *JUNOS Network Interfaces and Class of Service Configuration Guide*
- *JUNOS VPNs Configuration Guide*
- RFC 3036, *LDP Specification*
- Internet draft draft-martini-atm-encap-mpls-01.txt, *Encapsulation Methods for Transport of ATM Cells/Frame Over IP and MPLS Networks* (expires December 2002)
- Internet draft draft-martini-l2circuit-encap-mpls-07.txt, *Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks* (expires December 2004)
- Internet draft draft-martini-l2circuit-trans-mpls-14.txt, *Transport of Layer 2 Frames Over MPLS* (expires December 2004)
- Internet draft draft-kompella-ppvpn-l2vpn-03.txt, *Layer 2 VPNs Over Tunnels* (expires October 2003)

Revision History

13 June 2005—Added support for configuring Layer 2 circuits simultaneously over RSVP and LDP LSPs, 7.3R1 Release. Richard Hendricks.

5 April 2005—7.2R1 Release. Richard Hendricks.

2 February 2005—Added local interface switching for Layer 2 circuits, 7.1R1 Release. Richard Hendricks.

6 October 2004—Added support for specifying a unique MTU for each Layer 2 circuit, 7.0R1 Release. Richard Hendricks.

6 July 2004—Added ATM2 IQ interface-based CoS and additional trunk-related statements, 6.4R1 Release. Richard Hendricks.

5 April 2004—Added ping mpls l2circuit commands, 6.3R1 Release. Richard Hendricks.

22 December 2003—Added Layer 2 circuit trunk mode and bandwidth reservation for Layer 2 circuits, 6.2R1 Release. Richard Hendricks.

22 September 2003—Added APS for Layer 2 circuits information and updated the traffic engineering example, 6.1R1 Release. Richard Hendricks.

30 June 2003—Added traffic engineering and control word mapping for Frame Relay and ATM2, 6.0R1 Release. Walter Goralski.

2 April 2003—Added PPP, HDLC, ATM Cell Mode, and AAL5 information, 5.7R1 Release. Richard Hendricks.

10 July 2002—Reformatted document. Richard Hendricks.

21 November 2001—Initial document written. Bill Nowak.