

Chapter 12

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,” including “*Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks*” (draft-martini-l2circuit-encap-mpls-05.txt) and “*Transport of Layer 2 Frames Over MPLS*” (draft-martini-l2circuit-trans-mpls-11.txt), 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 on page 406

System Requirements on page 408

Terms and Acronyms on page 409

Configure Layer 2 Circuits on page 409

Example: Ethernet-Based Layer 2 Circuit Configuration on page 418

Check Your Work on page 422

Example: SONET-Based Layer 2 Circuit Configuration on page 425

Check Your Work on page 429

Example: ATM 2-Based Layer 2 Circuit Configuration on page 431

Check Your Work on page 437

Example: Layer 2 Circuit Traffic Engineering over Multiple LSPs Configuration on page 440

Check Your Work on page 449

Example: APS for Layer 2 Circuits Configuration on page 450

Check Your Work on page 451

For More Information on page 452

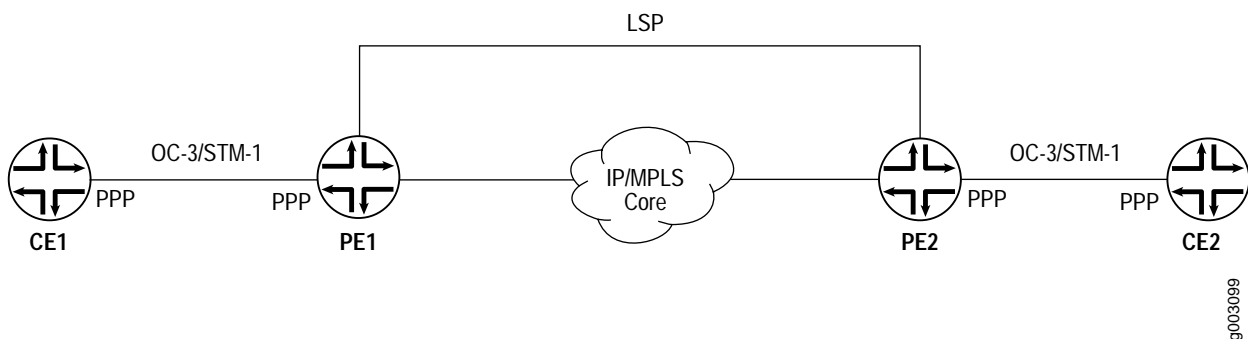
Revision History on page 453

Overview

Layer 2 circuits allow for the creation of point-to-point Layer 2 connections over an IP and 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 ATM networks, Frame Relay networks, and some portions of time division multiplexing (TDM) networks, with an IP and MPLS-based network.

In Figure 39, an OC-3/STM-1 interface encapsulated with Point to Point Protocol (PPP) on router PE1 can be connected over a Layer 2 circuit to reach an OC-3/STM-1 interface encapsulated with PPP on router PE2. For Layer 2 circuits to operate, the provider edge (PE) routers in Figure 39 must be 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 39: 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.

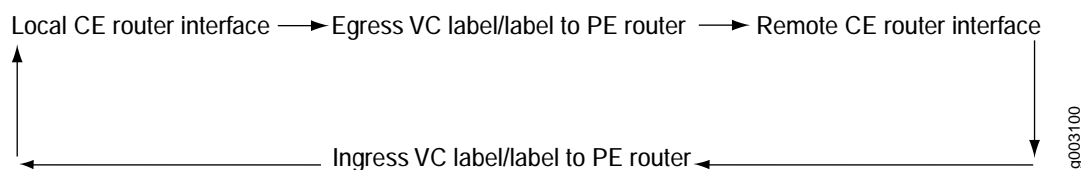
Layer 2 VPNs, like Layer 3 VPNs, require BGP for transport of traffic between provider edge (PE) routers. In contrast, Layer 2 circuits do not require BGP. Instead, Layer 2 circuits rely on LDP and MPLS for their operation. As a result, Layer 2 circuits require less configuration than Layer 2 VPNs.

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 40, 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 tunnelled 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 tunnelled through RSVP) to the local PE router from the remote PE router.

Figure 40: 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 ATM 2 interfaces

- Cisco High-Level Data Link Control (HDLC), Frame Relay, and PPP on SONET-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 listed above, 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: Map Layer 2 Protocol Control Information into a Layer 2 Circuit” on page 416.)

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 rather than unsequenced.

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 is incremented 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 5.2 or later for Ethernet-based Layer 2 circuits

JUNOS Release 5.6 or later for Frame Relay, HDLC, and PPP-based Layer 2 circuits

JUNOS Release 5.7 or later for ATM cell-relay mode or AAL5 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 6.1 or later for Automatic Protection Switching (APS) for Layer 2 circuits

Five Juniper Networks M-series Internet routers or T-series Internet 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, please see either the *JUNOS Internet Software Configuration Guide: Network Interfaces and Class of Service* or the *JUNOS Internet Software Configuration Guide: MPLS Applications*.

Control word—A 32-bit field used in Layer 2 circuits to transport sequence information, Layer 2 media control information, and padding.

Configure Layer 2 Circuits

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

Configure an Interface Encapsulation on CE-Facing Interfaces on page 410

Configure Layer 2 Circuits on page 413

Configure MPLS, LDP, and an IGP to Transport Layer 2 Circuits on page 414

Optional Layer 2 circuit configuration steps are as follows:

Option: Apply Traffic Engineering to a Layer 2 Circuit on page 415

Option: Map Layer 2 Protocol Control Information into a Layer 2 Circuit on page 416

Option: Configure APS for Layer 2 Circuits on page 417

To apply your knowledge, visit these sections:

Example: Ethernet-Based Layer 2 Circuit Configuration on page 418

Check Your Work on page 422

Example: SONET-Based Layer 2 Circuit Configuration on page 425

Check Your Work on page 429

Example: ATM 2-Based Layer 2 Circuit Configuration on page 431

Check Your Work on page 437

Example: Layer 2 Circuit Traffic Engineering over Multiple LSPs Configuration on page 440

Check Your Work on page 449

Example: APS for Layer 2 Circuits Configuration on page 450

Check Your Work on page 451

Configure an Interface Encapsulation on CE-Facing Interfaces

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

Configure CCC Encapsulation on CE-Facing Ethernet Interfaces on page 410

Configure CCC Encapsulation on CE-Facing SONET Interfaces on page 411

Configure CCC Encapsulation on CE-Facing ATM 2 Interfaces and a Layer 2 Circuit Mode on page 411

Configure 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;
    }
  }
}
```

Configure CCC Encapsulation on CE-Facing SONET Interfaces

On SONET 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;
    }
  }
}
```

Configure CCC Encapsulation on CE-Facing ATM 2 Interfaces and a Layer 2 Circuit Mode

On ATM 2 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 ATM 2 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 ATM 2 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 the 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 ATM 2 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 ATM 2 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 Internet Software Configuration Guide: MPLS Applications* or the *JUNOS Internet Software Configuration Guide: Network Interfaces and Class of Service*.

Configure 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 | nrri | connections | route) [detail];
    }
    neighbor ip-address {
      interface interface-name {
        virtual-circuit-id identifier;
        no-control-word;
        community community-name;
      }
    }
  }
}
```

Unlike Layer 2 VPNs, you do not need to specify the encapsulation type at the `[edit protocols l2circuit]` hierarchy level because it has already been specified in the interface configuration.

Configure MPLS, 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 the IETF Internet draft *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.

Both MPLS and LDP rely on an underlying IGP, such as OSPF or IS-IS. As a result, configure MPLS, 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 {
  mpls {
    interface so-0/1/0.0;
  }
  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: Apply 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-next-hop lsp lsp-name;
      accept;
    }
  }
}
community community-name members value;
}
```

Option: Map Layer 2 Protocol Control Information into a Layer 2 Circuit

The control word is defined in the IETF draft “*Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks*” (draft-martini-l2circuit-encap-mpls-04.txt). 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 ATM 2 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 ATM 2 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: Configure APS for Layer 2 Circuits

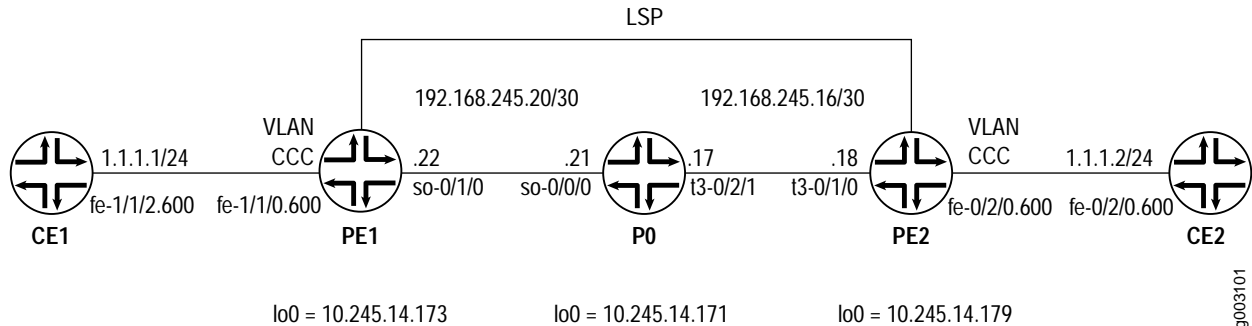
To apply Automatic Protection Switching (APS) to a Layer 2 circuit, you must configure an APS working circuit and a protect circuit on PE router interfaces that support SONET options (such as SONET, ATM, and ATM 2 interfaces) and circuit cross-connect (CCC) encapsulation types. Then, you must configure 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;
      }
    }
  }
}
```

Example: Ethernet-Based Layer 2 Circuit Configuration

Figure 41: Ethernet-Based Layer 2 Circuit Topology Diagram



In Figure 41, 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.

```

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 one advertised by 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.

```

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;
    }
  }
  fe-1/1/0 {
    description "to CE1 fe-1/1/2";
    vlan-tagging;
    encapsulation vlan-ccc; # Configure a CCC encapsulation on your CE-facing interface.
    unit 600 {
      encapsulation vlan-ccc;# You also enable this encapsulation on the logical interface.
      vlan-id 600;
    }
  }
  lo0 {
    unit 0 {
      family inet {
        address 10.245.14.173/32;
      }
    }
  }
}
protocols {
  mpls {
    interface so-0/1/0.0;
  }
  ospf {
    traffic-engineering;
    area 0.0.0.0 {
      interface so-0/1/0.0;
      interface lo0.0;
    }
  }
  ldp {
    interface so-0/1/0.0; # LDP is required as the signaling protocol for Layer 2 circuits.
    interface lo0.0; #You must include the loopback address in LDP
  }
  l2circuit {
    neighbor 10.245.14.179 { # This points to the loopback interface 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 one advertised by 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.

```

PO [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;
    }
  }
  t3-0/2/1 {
    description "to PE2 t3-0/1/0";
    unit 0 {
      family inet {
        address 192.168.245.17/30;
      }
      family mpls;
    }
  }
  lo0 {
    unit 0 {
      family inet {
        address 10.245.14.171/32;
      }
    }
  }
}
protocols {
  mpls {
    interface so-0/0/0.0;
    interface t3-0/2/1.0;
  }
  ospf {
    traffic-engineering;
    area 0.0.0.0 {
      interface so-0/0/0.0;
      interface t3-0/2/1.0;
    }
  }
  ldp {
    interface so-0/0/0.0;
    interface t3-0/2/1.0;
  }
}

```

LDP is required as the signaling protocol for Layer 2 circuits.

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.

```

PE2 [edit]
interfaces {
  t3-0/1/0 {
    description "PO t3-0/2/1";
    unit 0 {
      family inet {
        address 192.168.245.18/30;
      }
      family mpls;
    }
  }
  fe-0/2/0 {
    description "to CE2 fe-0/2/0";
    vlan-tagging;
    encapsulation vlan-ccc; # Configure a CCC encapsulation on your CE-facing interface.
    unit 600 {
      encapsulation vlan-ccc; # You also enable this encapsulation on the logical interface.
      vlan-id 600;
    }
  }
  lo0 {
    unit 0 {
      family inet {
        address 10.245.14.179/32;
      }
    }
  }
}
protocols {
  mpls {
    interface t3-0/1/0.0;
  }
  ospf {
    traffic-engineering;
    area 0.0.0.0 {
      interface t3-0/1/0.0;
      interface lo0.0;
    }
  }
  ldp {
    interface t3-0/1/0.0; # LDP is required as the signaling protocol for Layer 2 circuits.
    interface lo0.0; # You must include the loopback address in LDP.
  }
  l2circuit {
    neighbor 10.245.14.173 { # This points to the loopback interface 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 one advertised by 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.

```
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 one advertised by your CE neighbor.
      family inet {
        address 1.1.1.2/24;
      }
    }
  }
}
```

Check Your Work

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

```
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:

PE1 Status on page 423

P0 Status on page 424

PE2 Status on page 424

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
```

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

```

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

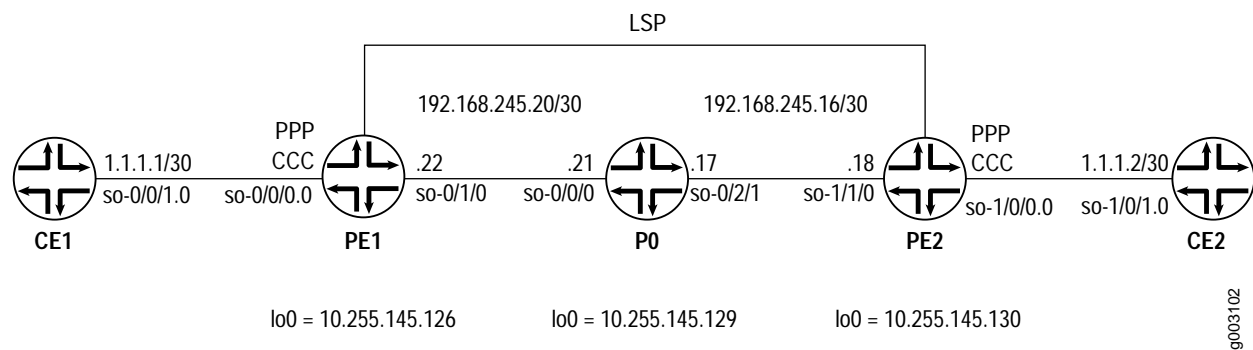
Input label database, 10.245.14.179:0-10.245.14.173:0
Label      Prefix
          3     10.245.14.173/32
100008     10.245.14.171/32
100009     10.245.14.179/32
100007     L2CKT VLAN VC 5

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-Based Layer 2 Circuit Configuration

Figure 42: SONET-Based Layer 2 Circuit Topology Diagram



In this second Layer 2 circuit example, you configure a Layer 2 circuit for a SONET interface encapsulated with PPP.

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

```

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.

```

PE1 [edit]
interfaces {
  so-0/0/0 {
    description "to CE1 so-0/0/1";
    encapsulation ppp-ccc; # Configure a CCC encapsulation on your CE-facing interface.
  }
  so-0/1/0 {
    description "to P0 so-0/0/0";
    unit 0 {
      family inet {
        address 192.168.245.22/30;
      }
      family mpls;
    }
  }
}
lo0 {
  unit 0 {
    family inet {
      address 10.255.145.126/32;
    }
  }
}
}

```

```

protocols {
  mpls {
    interface so-0/1/0.0;
  }
  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 interface 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 one advertised by 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.

```

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;
    }
  }
  so-0/2/1 {
    description "to PE2 so-1/1/0";
    unit 0 {
      family inet {
        address 192.168.245.17/30;
      }
      family mpls;
    }
  }
  lo0 {
    unit 0 {
      family inet {
        address 10.255.145.129/32;
      }
    }
  }
}

```

```

protocols {
  mpls {
    interface so-0/0/0.0;
    interface so-0/2/1.0;
  }
  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.

```

PE2 [edit]
interfaces {
  so-1/0/0 {
    description "to CE1 so-1/0/1";
    encapsulation ppp-ccc; # Configure a CCC encapsulation on your CE-facing interface.
  }
  so-1/1/0 {
    description "to P0 so-0/2/1";
    unit 0 {
      family inet {
        address 192.168.245.18/30;
      }
      family mpls;
    }
  }
  lo0 {
    unit 0 {
      family inet {
        address 10.255.145.130/32;
      }
    }
  }
}

```

```

protocols {
  mpls {
    interface so-1/1/0.0;
  }
  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 interface 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 one advertised by your PE neighbor.
      }
    }
  }
}

```

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

```

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;
      }
    }
  }
}

```

Check Your Work

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

```
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: ATM 2-Based Layer 2 Circuit Configuration

Figure 43: ATM 2-Based Layer 2 Circuit Topology Diagram

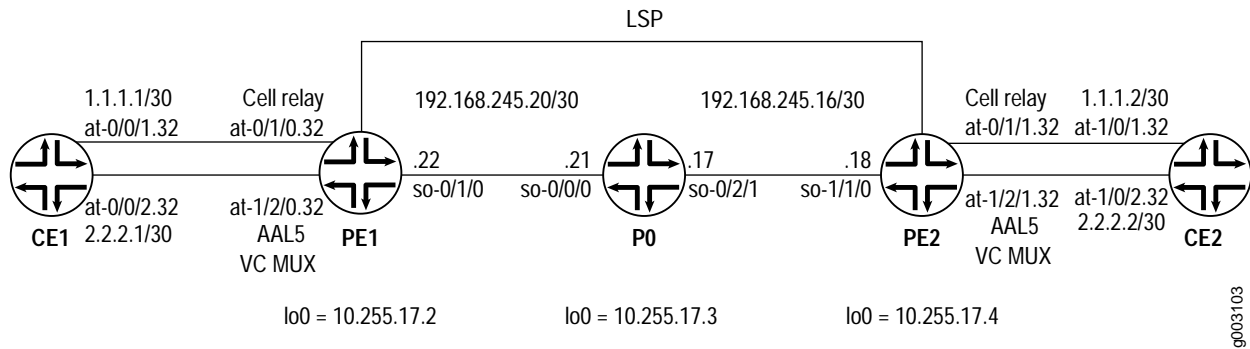


Figure 43 shows a similar network topology to our previous two examples. In this example, Routers PE1 and PE2 use ATM cell-relay mode on a CE-facing interface and ATM AAL5 mode on a second CE-facing interface.

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

```

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 ATM 2 interfaces.
      vpi 0;
    }
    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 ATM 2 interfaces.
      vpi 0;
    }
    unit 0 {
      encapsulation atm-vc-mux;
      vci 32;
      family inet {
        address 2.2.2.1/30;
      }
    }
  }
}

```

On router PE1, configure the ATM 2-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.

```

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 mode requires CCC 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 ATM 2 interfaces.
      vpi 0;
    }
    unit 0 {
      encapsulation atm-ccc-cell-relay; # Configure this encapsulation on 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 ATM 2 interfaces.
      vpi 0;
    }
    unit 0 {
      encapsulation atm-ccc-vc-mux; # AAL5 mode requires CCC VC MUX encapsulation.
      vci 32;
    }
  }
}

```

```

so-0/1/0 {
  description "to PO so-0/0/0";
  unit 0 {
    family inet {
      address 192.168.245.22/30;
    }
    family mpls;
  }
}
lo0 {
  unit 0 {
    family inet {
      address 10.255.17.2/32;
    }
  }
}
}
protocols {
  mpls {
    interface so-0/1/0.0;
  }
  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 interface 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 one advertised by your PE neighbor.
      }
    }
    neighbor 10.255.17.4 { # This points to the loopback interface 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 one advertised by 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.

```

PO [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;
    }
  }
  so-0/2/1 {
    description "to PE2 so-1/1/0";
    unit 0 {
      family inet {
        address 192.168.245.17/30;
      }
      family mpls;
    }
  }
  lo0 {
    unit 0 {
      family inet {
        address 10.255.17.3/32;
      }
    }
  }
}
protocols {
  mpls {
    interface so-0/0/0.0;
    interface so-0/2/1.0;
  }
  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 ATM 2-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.

```

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 mode requires CCC 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 ATM 2 interfaces.
      vpi 0;
    }
    unit 0 {
      encapsulation atm-ccc-cell-relay; # Also configure this 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 ATM 2 interfaces.
      vpi 0;
    }
    unit 0 {
      encapsulation atm-ccc-vc-mux; # AAL5 mode requires CCC VC MUX encapsulation.
      vci 32;
    }
  }
  so-1/1/0 {
    description "to PO so-0/2/1";
    unit 0 {
      family inet {
        address 192.168.245.18/30;
      }
      family mpls;
    }
  }
}

```

```

lo0 {
  unit 0 {
    family inet {
      address 10.255.17.4/32;
    }
  }
}
}
protocols {
  mpls {
    interface so-1/1/0.0;
  }
  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 interface 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 one advertised by your PE neighbor.
      }
    }
    neighbor 10.255.17.2 { # This points to the loopback interface 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 one advertised by your PE neighbor.
      }
    }
  }
}
}

```

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

```

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 ATM 2 interfaces.
      vpi 0;
    }
    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 ATM 2 interfaces.
    vpi 0;
  }
  unit 0 {
    encapsulation atm-vc-mux;
    vci 32;
    family inet {
      address 2.2.2.2/30;
    }
  }
}
}

```

Check Your Work

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

```
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 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 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 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 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 44: Layer 2 Circuit Traffic Engineering Topology Diagram

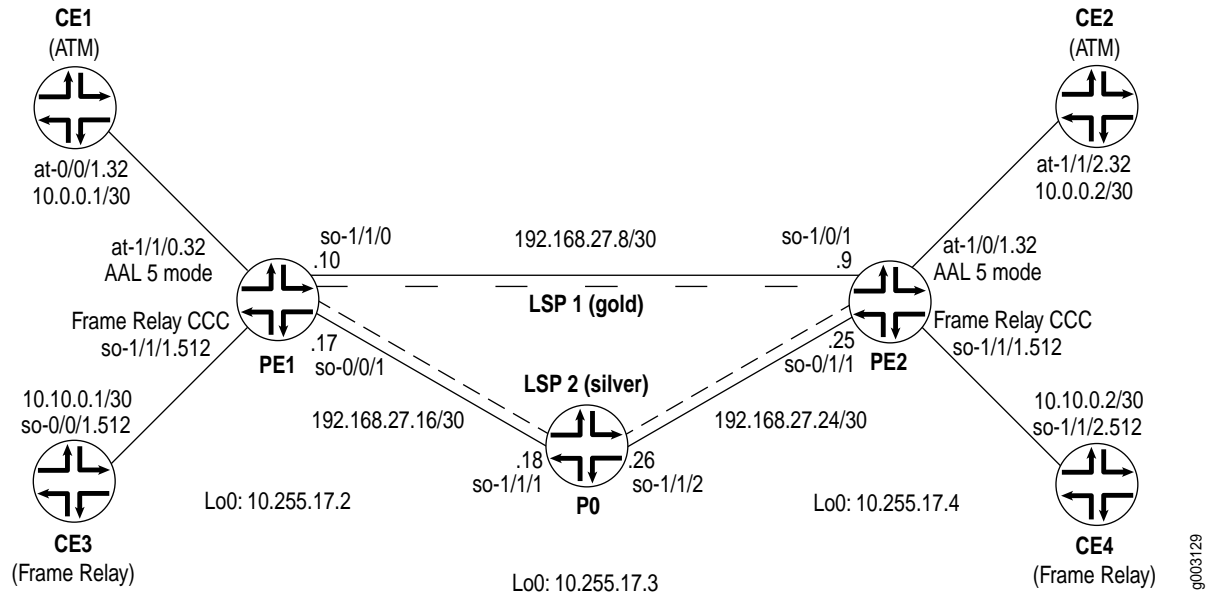


Figure 44 shows a network topology designed to traffic engineer different Layer 2 circuits over select LSPs. Across provider edge routers PE1 and PE2, an ATM AAL5 mode Layer 2 circuit connects customer edge routers CE1 and CE2, and a Frame Relay Layer 2 circuit connects routers CE3 and CE4. To maintain 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 ATM 2 interface at-0/0/1.32 to handle ATM AAL5 traffic:

```
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 ATM 2 interfaces.
    vpi 0;
  }
  unit 0 {
    encapsulation atm-vc-mux; # Use standard ATM VC MUX encapsulation on the CE router.
    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:

```

CE3 [edit]
interfaces
  so-0/0/1 {
    description "to PE1 so-1/1/1"
    encapsulation frame-relay; # Use standard 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 ATM 2-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 ATM 2-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.

```

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 ATM 2 interfaces.
      vpi 0;
    }
    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;
    }
  }
  so-1/1/0 {
    description "to PE2 so-1/0/1";
    unit 0 {
      family inet {
        address 192.168.27.10/30;
      }
      family mpls;
    }
  }
  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 the 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 PO.
      to 10.255.17.4;
      primary thruPO;
    }
    path direct {
      192.168.27.9 strict;
    }
    path thruPO {
      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 interface 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 one advertised by your PE neighbor.
      community gold; # This assigns the ATM Layer 2 circuit to the gold community.
    }
  }
  neighbor 10.255.17.4 { # This points to the loopback interface 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 one advertised by your PE neighbor.
      community silver; # This assigns the Frame Relay Layer 2 circuit to community silver.
    }
  }
}
policy-options {
  policy-statement layer2communities { # Here you match the communities with desired 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.

```

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;
    }
  }
  so-1/1/2 {
    description "to PE2 so-0/1/1";
    unit 0 {
      family inet {
        address 192.168.27.26/30;
      }
      family mpls;
    }
  }
}

```

```

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.

```

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 ATM 2 interfaces.
      vpi 0;
    }
    unit 0 {
      encapsulation atm-ccc-vc-mux; # CLP and EFCI bits are mapped into the control word.
      vci 0.32;
    }
  }
  so-0/1/1 {
    description "to PO so-1/1/2";
    unit 0 {
      family inet {
        address 192.168.27.25/30;
      }
      family mpls;
    }
  }
  so-1/0/1 {
    description "to PE1 so-1/1/0";
    unit 0 {
      family inet {
        address 192.168.27.9/30;
      }
      family mpls;
    }
  }
  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 applies the 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 PO.
      to 10.255.17.2;
      primary thruPO;
    }
    path direct {
      192.168.27.10 strict;
    }
    path thruPO {
      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 interface 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 one advertised by your PE neighbor.
        community gold; # This assigns the ATM Layer 2 circuit to the gold community.
      }
    }
    neighbor 10.255.17.2 { # This points to the loopback interface 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 one advertised by your PE neighbor.
        community silver; # This assigns the Frame Relay Layer 2 circuit to community silver.
      }
    }
  }
}

```

```

policy-options {
  policy-statement layer2communities {# Here you match the communities with desired 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 ATM 2 interfaces to handle ATM traffic. Interface at-1/0/1 handles AAL5 traffic.

```

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 ATM 2 interfaces.
      vpi 0;
    }
    unit 0 {
      encapsulation atm-vc-mux; # Use standard ATM VC MUX encapsulation on the CE router.
      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:

```

CE3 [edit]
interfaces {
  so-1/1/2 {
    description "to PE2 so-1/1/1"
    encapsulation frame-relay-ccc; # Use standard Frame Relay encapsulation on the CE router.
    unit 0 {
      encapsulation frame-relay-ccc;
      point-to-point;
      dlci 512;
      family inet {
        address 10.10.0.2/30;
      }
    }
  }
}

```

Check 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: 8601f8 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 Layer 2 Circuits Configuration

Figure 45: APS for Layer 2 Circuits Topology Diagram

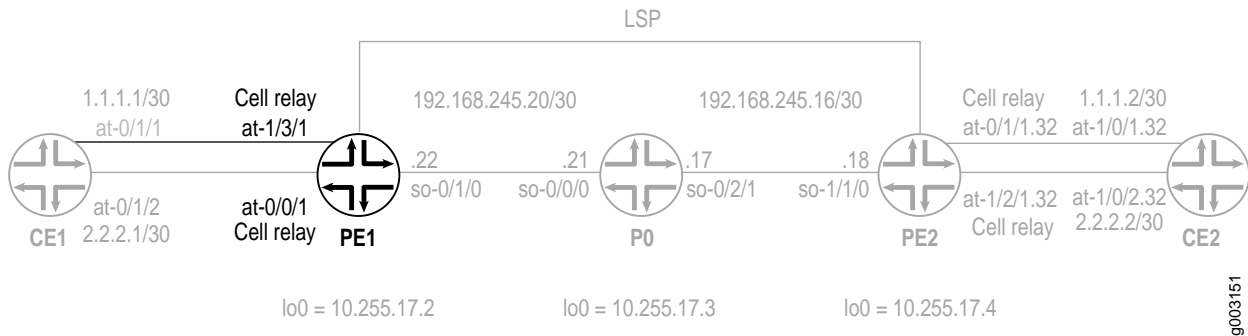


Figure 45 shows that APS is configured on a PE router to protect a PE-CE link in a Layer 2 circuit. This example shows only the PE router configuration and assumes that you have preconfigured a full Layer 2 circuit topology. For more information about configuring Layer 2 circuits, see “Configure Layer 2 Circuits” on page 409.

On router PE1, configure ATM 2 interface at-0/0/1 as an APS protect circuit and ATM 2 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.

```

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 also the APS working circuit.
      protect-interface at-0/0/1.0; # The protect-interface is also the APS protect circuit.
      virtual-circuit-id 100;
    }
  }
}
}

```

Check 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, please see the following:

JUNOS Internet Software Configuration Guide: Network Interfaces and Class of Service

JUNOS Internet Software Configuration Guide: VPNs

L. Andersson, et. al., "LDP Specification," RFC 3036, January 2001

L. Martini, et. al., "Encapsulation Methods for Transport of ATM Cells/Frame Over IP and MPLS Networks," Internet draft, draft-martini-atm-encap-mpls-01.txt, June 2002

L. Martini, et. al., "Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks," Internet draft, draft-martini-l2circuit-encap-mpls-05.txt, April 2003

L. Martini, et. al., “*Transport of Layer 2 Frames Over MPLS*,” Internet draft, draft-martini-l2circuit-trans-mpls-11.txt, April 2003

K. Kompella, et. al., “*Layer 2 VPNs Over Tunnels*,” Internet draft, draft-kompella-ppvnp-l2vpn-03.txt, April 2003

Revision History

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.

