Evaluation of Juniper Networks IPv6 Migration Solution Functionality

Areas of Evaluation:
Network Address Translation – Protocol Translation
IPv6 Tunneling Mechanisms across IPv4 Network
Dual-Stack Support verification
Connecting IPv6 Islands using MPLS and IPv6 VPNs
Isocore Verification of Juniper Networks IPv6 Migration Solution - Summary Report

About Isocore
Isocore provides technology validation, certification and product evaluation services in emerging and next generation Internet and wireless technologies. Isocore is leading validation and interoperability of novel technologies including Carrier Ethernet, IPv6, IP Optical Integration, wireless backhauling and Layer 2/3 Virtual Private Networks (VPNs) and currently focuses on IPTV service deployment architecture validation and design. Major router and switch vendors, Service Providers, and test equipment suppliers participate in Isocore activities. Isocore has major offices in the USA (the Washington DC area), Europe (Paris, France) and Asia (Tokyo, Japan).
Executive Summary

This report summarizes the results of a recently conducted evaluation of Juniper Networks IPv6 Migration solution. The test was a result of Juniper Network commissioning Isocore for an independent third party validation of its IPv6 migration solutions portfolio for smoothing carrier transition to next generation IPv6 protocol and feature-set.

Isocore for this test put forth a set of critical requirements for this test. These requirements are derived from Isocore’s continuous and extensive experience from both vendor and service provider community interactions. The evaluation’s primary focus was to test the ability of JUNOS (Juniper's single network operating system spanning multiple product families) to transition an existing IPv4 infrastructure to a network connecting IPv6 sites using IP/MPLS transport. In addition, emphasis was placed on evaluating the feature-set that goes along in making this transition seamless. This report summarizes the key findings of the test conducted.

Besides verifying the basic IPv6 support, the testing comprehensively validated the functionality of Network Address Translation – Protocol translation (NAT-PT), IPv6 over IPv4 MPLS (6PE), MPLS based Layer 3 VPNs supporting IPv6 subscribers/sites (6VPE), and multicast forwarding for IPv6 flows. The testing is a first of its kind, which independently validates an IPv6 migration solution on both routing and switching platforms using one operating system.

Testing was conducted on a large testbed representing a true carrier class network comprising of Juniper Networks MX-Series Ethernet Service Routers (ESR), M-Series Multi-Service Edge Routers (MSER) and T-series core platform. The overall network consisted of 5 MX-Series ESRs, 3 M-Series MSERs and 1 T-Series core platform.

The tests carried out as part of this effort certifies the functionality of current Juniper Networks IP/MPLS solution to support the transportation of IPv6 subscribers, and site traffic across an existing IPv4 infrastructure. Since the focus of the test was not to verify the performance, and scaling of the solution, the functionalities demonstrated by JUNOS satisfied the requirements for IPv6 migration set forth for this test. The tests also highlighted the co-existence of dual-stack provider edge routers with real-world IPv4/IPv6 routing and multicast traffic flows. The setup presents a true case study for a service provider or any agencies that are considering transporting their IPv6 subscribers, and network islands across IPv4 core network.
Technical Overview

For this test a real-world network setup was created using 9 nodes from Juniper Networks product families. This large network offered the dynamics that exists in any live network and helped in making the test realistic in a lab environment. Since the performance measurement, and scaling was not the focus of the test, the system under test (SUT) used did not consist of fully loaded nodes in terms of physical ports. However, to confirm the functionality of the features tested multiple iterations were carried out. Furthermore, all control-plane functionality was tested with reliability of the data-plane forwarding.

The Juniper Networks IPv6 migration solution demonstrated to Isocore what it promises to deliver – supporting IPv6 islands across IPv4 MPLS core, support IPv6 sites by using other tunneling mechanisms while supporting both IPv4/IPv6 unicast and multicast traffic. The following summarizes key findings and the testbed details:

Testbed Overview:

- A total of 9 nodes used to build an IPv4 core, and dual-stack edge supporting IPv6 VPN sites, and IPv6 traffic.
- Agilent N2X test platform was used to create IPv4/IPv6 unicast and multicast traffic flows, emulated IPv4/IPv6 routing protocols and offered measuring capabilities to verify the integrity of the data plane
- All tests conducted on one comprehensive setup, although the network was split to carryout NAT-PT specific tests

We capture the key findings here below

Key Findings:

- All IPv6 migration tests were successfully passed by JUNOS implementation
- JUNOS successfully demonstrated the NAT-PT functionality when forwarding traffic from IPv4 subscriber to and IPv6 server, or vice versa
- The edge routers in the test network successfully passed all 6PE and 6VPE tests with the following background configuration¹:
  o 200,000 BGP4+ IPv6 Routes via one BGP peer
  o 300,000 BGP IPv4 Routes via one BGP peer
  o 10K OSPF IPv4 Routes to populate the 6PE IPv4 Core
  o 250 OSPFv3 per 6PE Edge Router with a total of 1000 OSPFv3 Peers for the network
  o 4000 OSPFv3 routes per 6PE Edge Router with a total of 16,000 IPv6 routes across the network peripheral (these routes are advertized via BGP to remote edge routers)
  o 100 IPv6 VPNs with 4 sites in one VPN
  o Traffic flows to all advertized IPv6 routes, and connected routes
- All multicast forwarding tests were performed successfully along with validation of Embedded RP verification

Isocore through observed results confirm the IPv6 transition feature-set of JUNOS, and its ability to offer seamless transition from a native IPv4 MPLS network to a network that has ability to support both IPv6 and IPv4 subscribers while leveraging the investments made in the IPv4 infrastructure. Several tests were carried to confirm this capability. Even though the performance, and scalability was not the motive of the test, but to verify the ability of the system under test to adapt to realistic conditions, large number of both

¹ The baseline configuration used for all tests does not represent the scale of the SUT. The scalability, and performance was not the focus of the test. Only functionality of the implementation was checked during this exercise.
IPv4 and IPv6 routes were advertised along with large number of IGP adjacencies. The test systems demonstrated stability throughout the testing event.
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1 TEST OVERVIEW

As part of its IPv6 test program, Isocore evaluated Juniper Networks IPv6 migration and transition solution. This solution is supported on JUNOS spanning Juniper’s routing/switching platforms and promises to simplify the transition from an existing IPv4/MPLS infrastructure to a dual-stack infrastructure capable of supporting both IPv4 and IPv6 subscribers. The test during its entirety considered an MPLS enabled IPv4 core.

The test cases proposed for this event were carefully designed considering the experience gained in multi-vendor testing and Isocore carrier member interactions. Isocore and Juniper Networks considered the usage of Agilent N2X Multi-service solution for this testing for creating a realistic environment by advertising large number of routes, and adjacencies.

Table 1 provides an overview of the executed test scenarios and the associated results.

<table>
<thead>
<tr>
<th>Test Scenario</th>
<th>Observations</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>Network and Protocol translation capabilities of JUNOS under global or logical router configuration</td>
<td>Successfully demonstrated the translation of IPv6 addresses to IPv4 and vice versa while supporting stateful traffic (originated from an IPv4 or IPv6 address). Tests were executed under both logical routers, and global routing instances</td>
<td>Pass</td>
</tr>
<tr>
<td>Support for configured GRE, and IP-in-IP tunnels supporting IPv6 addressing over IPv4 core, or an MPLS enabled IPv4 core</td>
<td>Successfully passed this test with all edge nodes actively used in the setup. Full mesh of GRE/IP-in-IP tunnels was configured across a non-MPLS, and MPLS enabled IPv4 core</td>
<td>Pass</td>
</tr>
<tr>
<td>Support for dual-stack running both IPv4 and IPv6 protocol stacks on a physical router or within the context of a logical router</td>
<td>Successfully passed the tests verifying the co-existence of IPv4/IPv6 addressing, and ability of the node to pass both IPv4 and IPv6 traffic</td>
<td>Pass</td>
</tr>
<tr>
<td>Support for IPv6 over MPLS enabled IPv4 core (6PE) functionality</td>
<td>Successfully passed the tests executed for validating the 6PE functionality and transporting IPv6 traffic across an MPLS IPv4 core</td>
<td>Pass</td>
</tr>
<tr>
<td>Support for IPv6 VPNs over MPLS enabled IPv4 core (6VPE) functionality</td>
<td>Successfully passed the tests in an environment created to mimic a real-world network settings for IPv6 VPNs</td>
<td>Pass</td>
</tr>
<tr>
<td>IPv6 Multicast functionality</td>
<td>The test results verified that the system under test successfully supported the multicast traffic flows for 1000 groups</td>
<td>Pass</td>
</tr>
</tbody>
</table>

All tests were performed under a completely independent environment with support from the Juniper Networks engineers. Isocore in this effort performed an in-depth analysis of areas listed in the table 1 and performed the tests on the network testbed shown in figure 1. The test offers several options, which could be adopted by carriers, or other agencies considering transition part of their networks to IPv6 without performing much of the fork lift upgrade of their existing IPv4 infrastructure. The test results confirm that an IPv6 transition can be performed without impacting existing IPv4 services/subscribers.

The overall results of the tests confirmed that the JUNOS IPv6 migration techniques could be readily deployed for connecting IPv6 islands, or supporting IPv6 VPNs. Juniper Networks IPv6 solution offers flexibility in supporting IPv6 services across an MPLS or an IPv4 network and support both IPv4 and IPv6 subscribers using the address and protocol translation capabilities.
In summary, the observations confirm that JUNOS passed all tests set forth during this test and demonstrated how a typical IPv4 network can be transitioned to offer both IPv4/IPv6 services.

1.1 TEST ENVIRONMENT AND SETUP

Figure 1 provides an overview of the test network setup that was used for this evaluation. The setup used a total of 9 nodes, which included 5 MX-Series ESRs, 3 M-Series MSERs and 1 T-Series core platform. The testbed was primarily constructed by using only 1-gigabit Ethernet interfaces. The device under test were populated with other interfaces, however only the interfaces shown in the figure 1 were actually used for the testbed creation.

In the testbed, the core network was created using two Juniper Networks routers, one M-series, and one T-series. Both core routers were connected via a 10-gigabit Ethernet link. MX-series Ethernet service routers were used to create provider edge supporting dual-stack IPv4/IPv6 routing and responsible for supporting IPv6 subscriber traffic across IPv4/MPLS transport. All edge nodes (labeled as NPE1-5, and ASBR1, 2) were connected to Agilent N2X emulating the access terminations and IPv6 customers. Only Gigabit Ethernet ports were used on the N2X platform for this test. No triple-play type of traffic was configured during this test, since performance measurement was not the focus of this test. The setup shown in Figure 1 was used for the entire testing. For simplicity, and ease of referencing in the report the nodes are labeled as shown in the figure 1. This convention is however different from the host names used in the actual test.

Isocore tested Juniper Networks IPv6 transition solution with JUNOS 9.1 baseline on all the nodes except when which was configured with JUNOS 9.2 baseline.
2 TESTING DETAILS AND RESULTS

This section provides the details of the Isocore’s evaluation and testing of Juniper Networks IPv6 migration solution. Isocore in this test focused readiness of JUNOS implementation and the deployability of the solution. For this Juniper Networks offered 3 product families to be considered for this evaluation. Although large number of nodes was used for the evaluation, but scaling and performance was not focus of this test and is planned for the forthcoming reports.

Isocore’s evaluation mainly focused on the following JUNOS capabilities:

1. NAT-PT capability verification
2. IPv6 tunneling through an IPv4 network
3. Dual-stack support verification
4. IPv6 and IPv6 VPN support over MPLS

2.1 NAT-PT CAPABILITY VERIFICATION

The objective of these tests was to verify the functionality of JUNOS IPv6 address management and NAT-PT for IPv6/IPv4 subscribers. NAT-PT is considered as an important migration tool and integral part of any IPv6 migration solution that helps carriers to use a protocol translator between IPv6 and IPv4 allowing direct communication between two endpoints using different network protocol. Isocore test plan included several test cases, which confirmed the functionality of the NAT-PT. JUNOS successfully passed the following tests:

1. Test to verify the translation of IPv6 address to IPv4 using NAT-PT
2. Verify the bi-directional traffic between an IPv6 and IPv4 host
3. Confirm the functionality of OAM tools including traceroute, and ping from an IPv6 or IPv4 hosts
4. Verify the forwarding for both IPv4 and IPv6 hosts using a mix of UDP and TCP traffic

All nodes involved in these tests successfully passed all the tests, and no traffic loss was observed. JUNOS correctly enforced the stateful-firewall rules on all the flows pushed through the SUT, and displayed the NAT IPv4 source relationship with the NAT IPv6 destination address.

Figure 3 shows the output confirming the protocol and address translation on one of the node involved in the test. The case shown in the figure was captured when UDP traffic was sent from an IPv6 source and was translated to an IPv4 destination and bi-directional TCP traffic. The test configuration involved defining a rule v6-v4 under the NAT configuration, and configuring the IPv4-IPv6 address range pool for both source, and destination. This policy is then applied to the interface.
The data plane verification was performed by transmitting the IPv4 and IPv6 traffic from the test ports on the Agilent N2X platform. No line rate performance measurements were performed but the however no traffic loss was observed during the test.

### 2.2 IPV6 TUNNELING THROUGH AN IPV4 NETWORK

JUNOS supports manual configuration of IPv6 tunnels across an existing IPv4 network infrastructure. The manual IPv6 tunnel was configured by using the IPv6 address on the tunnel and the IPv4 addresses were manually configured at the tunnel source and the tunnel destination.

Isocore included this in the scope of this test to verify the ability of JUNOS to support IPv6 overlay tunneling techniques for integrating IPv6 services using an IPv4 network topology. This also allows carriers to offer IPv6 Internet, IPv6 subscribers for gaming, chatting, and other hosting applications without incurring much capital upgrade expenses.

To comprehensively evaluate this capability, following tests were successfully executed:

1. Verifying the support for manually configured IPv6 tunnels (IPv4 or IPv4/MPLS core)
2. Verifying the support for configured IPv6 tunnels over GRE tunnels (with or without MPLS core)

Figure 3 and figure 4 illustrates the configuration of manual IPv6 tunnels. Figure 3 shows the configuration that was used to create GRE tunnel using the IPv4 source and destination address, with tunnel interface address configured for IPv6. The above configuration was verified for GRE tunnels for both IP and MPLS enabled core.

```
MX240-VineyardHaven-re0# show interfaces gr-1/0/0
unit 0 {
  tunnel {
    source 5.5.5.5;
    destination 3.3.3.3;
  }
  family iso;
  family inet6 {
    address beef::1:2/126;
  }
}
inet6.0: 40 destinations, 55 routes (40 active, 0 holddown, 0 hidden)
@ = Routing Use Only, # = Forwarding Use Only
+ = Active Route, - = Last Active, * = Both
::3.3.3.3/128  *[OSPF/150] 5d 20:49:30, metric 0, tag 0
  >via gr-1/0/0.0
::a1aa::/64  *[OSPF/150] 5d 20:49:30, metric 0, tag 0
  > via gr-1/0/0.0
```

Figure 3: Configured IPv6 manual GRE tunnel configuration on one of the PE MX-series nodes

Figure 4 illustrates the configuration that was used to create IP tunnels using IPv4 source and destination address, with tunnel interface configured for IPv6.
Both above tests were carried out with and without MPLS enabled in the core and the functionality of IPv6 tunneling through an IPv4 network was successfully verified. The data-plane integrity was verified by forwarding traffic on configured tunnels, and ensuring that no traffic loss was observed. As expected IPv6 traffic was pushed successfully with no traffic loss through a mesh of IPv6 manually configured tunnels initiated from MX-series routers part of AS-1 as shown in the figure 1.

2.3 DUAL-STACK SUPPORT VERIFICATION

Dual-stack node is a single network node, which is configured to operate with both IPv4 or IPv6 addressing on the same or different network interface. In addition to translation (ability to covert IPv6 packets into IPv4 and vice versa), and tunneling (ability to transport IPv6 packets across IPv4 network) dual-stack is an important transition mechanism that should be supported by a solution claiming to provide transition to an IPv6 network. Isocore carefully evaluated the configurations, and functionality of the dual-stack capability within the context of both OSPF, and IS-IS. Following tests were successfully executed with observed results meeting Isocore’s expectations.

1. Verify the support for dual-stack capability and forwarding to IPv4/IPv6 destinations
2. Verify the support of OSPF and OSPFv3 on the same
3. Verify the support of IS-IS for both IPv4 and IPv6

All above test cases were executed on the physical router, as well as in a logical-router configuration. Juniper networks define logical routers as nodes that perform a subset of the actions of physical router and have their own interfaces, routing tables, policies and routing instances.

Figure 4: Configured IPv6 manual tunnel configuration on one of the PE MX-series nodes

Figure 5: Status of a dual-stack interface

Figure 5 illustrates interface configuration of a dual-stack interface.
Figure 6 presents the screen captures of one of the edge node (MX-series) from the testbed shown in figure 1. The figure shows the status of the IGP adjacencies for both IPv4 and IPv6 routing protocols. However, the IPv6 neighbor adjacencies for OSPF, and IS-IS were established over GRE tunnels, and IPv4 IGP neighbor adjacencies were established over physical interfaces. No issues were observed during the both network protocol IGP neighbor sessions setup for both OSPF, and IS-IS.

![Image of screen captures from a node from the testbed showing IGP neighbor status](image)

No IPv4 or IPv6 traffic loss was observed when traffic destined for both network protocols was pushed through the SUT simultaneously or individually. Also, no change in network wide latency was observed when IPv6 flows were added to the mix, while SUT was forwarding IPv4 flows. All forwarding tests were performed with 512 byte layer 3 packets. No variation in the in the behavior of the JUNOS was observed when the above tests were executed on physical router or on the logical router configured on a physical router. In figure 1, all nodes in AS-1, except two core nodes (M120, and T640) were configured for dual-stack configuration and only node was configured with logical router.

2.4 VALIDATING IPV6 OVER MPLS AND IPV6 VPN OVER MPLS SOLUTION

One of the main focus of this testing evaluation was to use MPLS core in addition to IPv4 core to provide seamless service to IPv6 enabled domains. Service providers are looking for solution in which they could leverage their IPv4/MPLS core to offers IPv6 services, and layer 3 VPNs supporting the pure IPv6 or dual-stack sites. The two types of services are more commonly referred to as - connecting IPv6 islands with MPLS and BGP or 6PE and IPv6 VPNs over MPLS or 6VPE. The intent for the testing was to verify both of these functionalities while supporting large number of both IPv4 and IPv6 routes. This configuration created a realistic environment for validating the deploybility of the JUNOS IPv6 integration into an IPv4 MPLS network. For this test, the baseline configuration was enabled only 4 edge nodes (NPE1, NPE 2, NPE5, and ASBR1) shown in figure 1. The 100 IPv6 VPNs were configured on all these nodes making these nodes as provider edge routers for 4 sites. Isocore considered following baseline load on the network before any test was executed:

The network configuration using testbed configuration illustrated in figure 1:

- 200,000 BGP4+ IPv6 Routes via one BGP peer
- 300,000 BGP IPv4 Routes via one BGP peer
- 10K OSPF IPv4 Routes to populate the 6PE IPv4 Core
- 250 OSPFv3 per 6PE Edge Router with a total of 1000 OSPFv3 Peers for the network
• 4000 OSPFv3 routes per 6PE Edge Router with a total of 16,000 IPv6 routes across the network peripheral (these routes are advertised via BGP to remote edge routers)
• 100 IPv6 VPNs with 4 sites in one VPN
• Traffic flows to all advertised IPv6 routes, and connected routes
• IPv6 Multicast forwarding and replication in both intra- and inter-AS environment for 1,000 channels
• No Traffic loss observed during the data forwarding verification

Isocore confirmed the results of the following tests with the baseline configuration listed above:

1. Verify the support for 6PE functionality and successful transport of IPv6 traffic across an IPv4 MPLS core
2. Evaluate the impact of large number of IPv4 and IPv6 routes on the functionality of the 6PE and 6VPE
3. Verify the functionality of the IPv6 VPNs over MPLS and co-existence with 6PE configuration
4. Verify the support for IPv6 multicast in both intra- and inter-AS setup and verify the traffic replication ability

The observations from the execution of the above tests suggested that the JUNOS implementation of both 6PE and 6VPE functionality is robust, and stable. The functionality and forwarding of IPv6 routing is not impacted as the number of routes, and load increased on the edge nodes. Even though the scalability was not the scope of the test stress was imposed on the network due to flapping of large number of routes, and re-configurations, the system under test did not show any anomaly in the functionality of any test executed as part of this effort. While no forwarding performance benchmarking was done, however for 6VPE test 100 IPv6 VPNs were created and the no-packet drops were seen when flows were sent across 4 sites configured within each of the 100 VPNs configured.

Figure 7: MLD joins status on NPE-1, and MLD version configuration on ASBR-1 (Source NPE)
For IPv6 multicast forwarding test 1,000 joins were sent from NPE1, 2 and 5. NPE-1 received 1,000 MLD joins for different group ranges. The idea here was to verify replication for 1 and many receivers. The IPv6 multicast traffic source was attached to the ASBR-1 causing three times replication on ASBR-1 for one of the multicast groups. During the test functionality of embedded-RP (Rendez-vous Point) was also verified for inter-domain IPv6 multicast routing, which allows embedding the RP address in an IPv6 multicast address. For confirm this functionality, an IPv6 multicast host was also attached to ASBR-2 to verify the multicast traffic is received across the AS boundaries. Figure 7 illustrates the state of the multicast joins on one of the edge node, and figure 8 shows the embedded-RP configuration on the ASBR-2 connected to the host, and NPE-2 connected to the source.

**Figure 8: Embedded-RP configuration used in the tests**

### 3 CONCLUSION

Isocore’s evaluation of Juniper Networks IPv6 migration strategy is an industry first test effort. This test series compressively evaluates the functionality of IPv6 solution offered by Juniper Networks in their operating system (JUNOS) across variety of product lines. Based on this evaluation, it is clear that Juniper Networks IPv6 migration solution addresses service provider requirements who are trying to transition their existing IPv4 infrastructure or are planning to use the same infrastructure to offer IPv6
services while supporting their existing IPv4 service portfolio. All requirements that were set forth at the beginning of the test by Isocore were comfortably met by the SUT. To ensure the readiness of the solution, Isocore considered a large test network and created real-world conditions in terms of IPv4 and IPv6 routes further confirming deployability of the tested solution. During the entire evaluation, no performance degradation was observed, and the behavior was consistent across all the platforms used in the testbed.

Isocore for the entire test considered both control plane verification and no-loss traffic as the basis before any test is declared as a pass. Throughout the test cycle, Isocore placed emphasis on assuring that all executed test cases are relevant to the real-world environment and scrutinize the stability and reliability of the SUT. Hence all features tested in this report are very critical to any IPv6 deployment that builds upon an existing MPLS enabled IPv4 network. Juniper Networks through this test demonstrates the ability to support network and protocol translation along with smooth IGP migration in a dual-stack environment assuring the network readiness to migrate from IPv4 to IPv6.

To summarize, Isocore feels comfortable in stating that the IPv6 migration feature-set offered by Juniper Networks brings together all necessary components required for a seamless transition and concurrent support of both IPv4 and IPv6 services.

Additional IPv6 functionality supported in JUNOS beyond the migration feature-set tested here, including areas such as security, supplemental multicast routing capabilities, subscriber management, network management features, and mobility were not considered in the scope of this test but may be validated separately in the future.

4 LIST OF ABBREVIATIONS

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<tr>
<td>MPLS</td>
<td>Multiprotocol Label Switching</td>
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<tr>
<td>6VPE</td>
<td>IPv6 VPN over MPLS</td>
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<tr>
<td>JUNOS</td>
<td>Juniper Operating Systems</td>
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<td>6PE</td>
<td>IPv6 over MPLS</td>
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<tr>
<td>IGP</td>
<td>Interior Gateway Protocol</td>
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<tr>
<td>IPv6</td>
<td>Internet Protocol version 6</td>
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<tr>
<td>IPv4</td>
<td>Internet Protocol version 4</td>
</tr>
<tr>
<td>RP</td>
<td>Rendez-vous Point</td>
</tr>
<tr>
<td>MLD</td>
<td>Multicast Listener Discovery for IPv6</td>
</tr>
<tr>
<td>PIM</td>
<td>Protocol Independent Multicast</td>
</tr>
<tr>
<td>ASBR</td>
<td>Autonomous System Border Router</td>
</tr>
<tr>
<td>LSP</td>
<td>Label Switched Path</td>
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<tr>
<td>NPE</td>
<td>Network Provider Edge (Routers)</td>
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