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Junos OS Evolved

AI-ML Data Center Feature Guide

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JUNOS EVOLVED

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The information in this document is current as of the date on the title page.

YEAR 2000 NOTICE

Juniper Networks hardware and software products are Year 2000 compliant. Junos OS has no known time-related limitations through the year 2038. However, the NTP application is known to have some difficulty in the year 2036.

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Overview

AI-ML Data Center Overview

As artificial intelligence (AI) and machine learning (ML) applications expand, the networks supporting these AI-ML applications require increased capacity to handle large data flows. This requirement is particularly true for the data centers that store AI-ML data sets. Junos® OS Evolved offers a set of innovative features for AI-ML data centers. Network administrators can use this guide to learn how to configure these features to optimize operations inside AI-ML data center fabrics.

Generative AI and ML applications such as large language models (LLMs) are based on statistical analysis of data sets: the more often the computational model finds a pattern in the data, the more it reinforces that pattern in its output. Through this repetitive pattern finding, these models are able to accomplish tasks such as convincingly imitating human speech. However, a generative AI application is only as good as the data set it is trained on. The larger the data set, the more patterns the model is able to detect. For this reason, AI and ML applications require large data sets. These data sets are stored in data centers.

To increase the speed of training, AI and ML models are often trained within the data center network through parallel computing. Graphics processing unit (GPUs) are clustered together and hosted on server nodes that are distributed across the data center. Complex computations occur simultaneously on these GPU clusters. The network must synchronize the output from the GPUs within a cluster to create a fully trained model. This synchronization requires the continuous movement of large data flows, henceforth referred to as *elephant flows*, across the back end of the network.

The elephant flows in AI-ML data centers require robust networks. When dealing with elephant flows, an insufficient network quickly encounters problems such as traffic congestion, dropped packets, and link failures. These network problems are especially unacceptable when dealing with data that requires high levels of accuracy. One robust network design ideal for AI-ML data centers is the Rail-Optimized Stripe. This AI cluster architecture minimizes network disruption by moving data to a GPU on the same rail as the destination. An IP Clos architecture is another functional AI-ML data center fabric design.

Juniper Networks® QFX Series Switches running Junos OS Evolved are ideal candidates for both Rail-Optimized Stripe architectures and IP Clos network designs. For example, the QFX5220-32CD, QFX5230-64CD, QFX5240-64OD, and QFX5240-QD switches work well in both network types as leaf, spine, and superspine devices. These switches also function well as a group of leaf-spine switches called a point of distribution (POD). To build larger AI-ML clusters in your data center, you can use a superspine layer to interconnect different PODs. You can deploy these switches as a single POD or multiple PODs for maximum flexibility and network redundancy. In addition, these devices support advanced AI-ML features that solve many load balancing and traffic management problems common in AI-ML data centers.

RELATED DOCUMENTATION

- Juniper Validated Design (JVD): AI Data Center Network with Juniper Apstra, NVIDIA GPUs, and WEKA Storage
- Designing Data Centers for AI Clusters
- AI Data Center Networking

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Upgrade

Recommended Release

IN THIS SECTION

Junos OS Evolved Release 23.4X100D20 is the first Junos Evolved release introducing the EVPN-VXLAN multi-tenancy feature-set on QFX5230 and QFX5240-64OD/64QD switches for the AI-ML data center usecase. We recommend approaching the Juniper Networks representative or partner for the latest release recommendation.

For specific features, see Feature Explorer for platform and release support.

Platform Documentation

- QFX5220
- QFX5230-64CD
- QFX5240-64OD and QFX5240-QD

Additional Resources

- Port Checker
- Software Licenses for QFX Series Switches

Unified ISSU for AI-ML Data Centers

SUMMARY

Use unified in-service software upgrade (ISSU) to minimize traffic loss during the software upgrade process.

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Overview

IN THIS SECTION

In an AI-ML data center deployment, the large data flows, also known as *elephant flows*, traveling through the network mean that even a low percentage of lost traffic can be a large number of packets. As the network administrator, you can use the unified in-service software upgrade (unified ISSU) feature to upgrade to a more recent release of Junos OS Evolved with no disruption on the control plane and minimal loss of traffic.

Benefits

- Eliminates network downtime during software image upgrades.
- Reduces operating costs while delivering higher service levels.
- Enables you to implement new features more quickly.

Configuration

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Configuration Overview

When you are planning to perform a unified ISSU, choose a time when your network is as stable as possible. As with a normal upgrade, Telnet sessions, SNMP, and CLI access are briefly interrupted.

We recommend that you read the *Unified ISSU Considerations for Junos OS Evolved* topic to anticipate any special circumstances that might affect your upgrade.

For AI-ML data center deployments, the following configurations do not roll over to the upgraded operating system with unified ISSU. You must reconfigure these features after the upgrade is complete:

- Generic routing encapsulation (GRE) tunnels
- sFlow
- Port mirroring
- Multicast Internet Group Management Protocol (IGMP) snooping and Protocol Independent Multicast (PIM)
- Virtual Router Redundancy Protocol (VRRP)
- Link Aggregation Control Protocol (LACP)
- Bidirectional Forwarding Detection (BFD) protocol

Prepare to Run the Upgrade

1. Make sure that you have sufficient disk space for the upgrade and that a backup of the system is available. Save the system configuration and the information about how the system is handling traffic.

   You can do this by following the procedure at *Before You Upgrade or Reinstall Junos OS Evolved*.

You will need the information about the system configuration and how the system is handling traffic when you verify that the upgrade was performed correctly.

2. Download the software package from the Juniper Networks Support website at https://www.juniper.net/support/ and place the package on your local server.
3. If the BGP protocol is configured on the main routing instance or a specific routing instance, then configure BGP graceful restart. Set the restart time value to greater than or equal to 300 seconds.

   NOTE: Changing the restart-time for BGP graceful restart causes the existing BGP sessions to restart, which might cause disruptions. We recommend that you perform this action during a low network usage time to avoid traffic loss.

   Configure the following on the device you are upgrading as well as its BGP peers.

   To configure BGP graceful restart and the restart-time value on the main routing instance, issue the following commands:

```
[edit]
user@host# set routing-options graceful-restart
[edit]
user@host# set protocols bgp graceful-restart restart-time 300
```

   To configure BGP graceful restart and the restart-time value on a specific routing instance, issue the following commands:

```
[edit]
user@host# set routing-instances routing-instance routing-options graceful-restart
[edit]
user@host# set routing-instances routing-instance protocols bgp graceful-restart restart-time
300
```

4. If a Spanning Tree Protocol (STP) is configured, then configure the STP-enabled ports as edge ports and enable bridge protocol data unit (BPDU) protection.

   Depending on the type of STP configured, issue the following commands:

```
[edit]
user@host# set protocols (mstp | rstp | vstp) bpdu-block-on-edge
[edit]
user@host# set protocols (mstp | rstp | vstp) interface (interface-name | all) edge
```

5. Configure the value of the Address Resolution Protocol (ARP) aging timer to the maximum value of 240 minutes. Extending the aging timer to its maximum value gives the device time to upgrade between ARP updates.

```
[edit]
user@host# set system arp aging-timer 240
```

6. On the BGP peers of the device you are upgrading, set the number of ARP retry attempts to 300. If the number of retries is too low, the peer device might stop trying to reconnect before the upgrade is complete.

```
[edit]
user@peer-device# set system arp arp-retries 300
```

7. Copy the software image to the **/var/tmp/** directory of the device running Junos OS Evolved using the `scp` command.

   For example:

```
user@host> file copy scp://junos-evo-install-qfx-ms-x86-64-22.1R1-S1.2-EVO.iso /var/tmp/junos-evo-install-qfx-ms-x86-64-22.1R1-S1.2-EVO.iso
```

8. Validate the existing configuration against the new software image to check whether it supports unified ISSU by using the `request system software validate-restart` *package-name* command.

   For example:

```
user@host> request system software validate-restart /var/tmp/junos-evo-install-qfx-ms-x86-64-22.1R1-S1.2-EVO.iso
```

Run the Upgrade

After you have completed the tasks above, run the `request system software add` *package-name* `restart` command on the device that you want to upgrade.

For example:

```
user@host> request system software add /var/tmp/junos-evo-install-qfx-ms-x86-64-22.1R1-S1.2-EVO.iso restart
```

The system restarts or reboots to load the new software image. When the upgrade is complete, the device displays the login prompt.

Verify the Upgrade Was Successful

1. At the login prompt, log in and verify the release of the installed software, using the `show system software list` command.
2. Verify that the system is running properly and correctly handling traffic by repeating the steps in the procedure in *Before You Upgrade or Reinstall Junos OS Evolved*. Compare the information about the system configuration to what you collected before you installed the software package.
3. If you need to make any changes to the configuration after the upgrade, remember to back up the software and configuration using the `request system snapshot` command. See *Back up and Recover Software with Snapshots*.
4. If the unified ISSU fails for some reason, and if the CLI is still working, you can follow the steps in *Recover from a Failed Installation Attempt If the CLI Is Working* to install the software image.
5. Reconfigure any applicable features listed in the "Configuration Overview" on page 7 above. Commit your changes.

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Unified ISSU for Junos OS Evolved

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CHAPTER

Load Balancing

Load Balancing Overview for AI-ML Data Centers

Significant load balancing challenges arise when AI-ML data centers process elephant flows. If elephant flows are not load-balanced properly across the network, they are likely to cause traffic congestion. When traffic congestion does occur, ineffective load balancing can compound the problem by inadvertently directing traffic to already congested links. Junos OS Evolved offers several types of load-balancing configurations that are optimized for the challenges of elephant flows.

As the network administrator, you can configure three main types of load balancing on your network:

- **Static load balancing (SLB)**—In SLB, you configure certain types of traffic to always use certain links. SLB is the most basic type of load balancing.
- **Dynamic load balancing (DLB)**—DLB dynamically chooses the link for a traffic flow based on the size of the traffic queue and the local link bandwidth utilization. DLB also checks the health of a link before rerouting traffic. DLB is more effective at avoiding traffic congestion than SLB.

  DLB has several modes and types that allow for customization, including:

  - **Selective DLB**—Selectively enable DLB for certain per-packet scenarios and use SLB for others.
  - **Flowlet mode**—In *flowlet mode*, DLB tracks the status of flows using an inactivity timer. When the inactivity timer expires for a particular flow, DLB rechecks whether that link is still optimal for that flow. If the link is no longer optimal, DLB selects a new egress link.
  - **Reactive path rebalancing**—Use this enhancement to DLB to move the traffic to a better quality link even when *flowlet mode* is enabled.
- **Global load balancing (GLB)**—GLB is an improvement on DLB. While DLB takes into account only the local link bandwidth utilization, GLB has visibility into the bandwidth utilization of links at the next-to-next-hop (NNH) level. GLB can reroute traffic flows to avoid traffic congestion farther out in the network than what DLB can detect.

You can use these different load balancing techniques in parallel within your AI-ML data center fabric.

RELATED DOCUMENTATION

- Load Balancing for Aggregated Ethernet Interfaces
- Managing the Elephant in the Room for AI Data Centers
- Load Balancing in the AI Data Center

Selective Dynamic Load Balancing (DLB)

IN THIS SECTION

Overview

IN THIS SECTION

In AI-ML workloads, the majority of the application traffic uses Remote Direct Memory Access (RDMA) over Converged Ethernet version 2 (RoCEv2) for transport. Dynamic load balancing (DLB) is ideal for achieving efficient load balancing and preventing congestion in RoCEv2 networks. However, static load balancing (SLB) can be more effective for some types of traffic. With *selective DLB*, you no longer have to choose between DLB and SLB for all traffic traversing your device. You can configure your preferred DLB mode at the global level, configure a default type of load balancing, and then selectively enable or disable DLB for certain kinds of traffic.

You can enable load balancing in two ways: per flow or per packet. Per-flow load balancing has been the most widely used because it handles the largest number of packets at a time. The device classifies packets that have the same 5-tuple packet headers as a single flow. The device gives all packets in the flow the same load balancing treatment. Flow-based load balancing works well for general TCP and UDP traffic because the traffic utilizes all links fairly equally. However, per-packet load balancing can reorder some packets, which can impact performance.

Many AI clusters connect the application to the network through smart network interface cards (SmartNICs) that can handle out-of-order packets. To improve performance, enable per-packet DLB on your network. Then enable DLB for only those endpoint servers that are capable of handling out-of-order packets. Your device looks at the RDMA operation codes (opcodes) in the BTH+ headers of these packets in real time. Using any firewall filter match condition, you can selectively enable or disable DLB based on these opcodes. Other flows continue to use default hash-based load balancing, also known as SLB.

Selective DLB is also useful when an elephant flow encounters links that are too small for the entire data flow. In this scenario, selective DLB can calculate the optimal use of the links' available bandwidth in the data center fabric. When you enable selective per-packet DLB for the elephant flow, the algorithm directs the packets to the best-quality link first. As the link quality changes, the algorithm directs subsequent packets to the next best-quality link.

Benefits

- Improve your network handling of large data flows.
- Use per-packet and per-flow load balancing in the same traffic stream to improve performance.
- Customize load balancing based on any firewall filter match condition.

Configuration

IN THIS SECTION

Configuration Overview

You can selectively enable DLB in two ways: disable DLB by default and selectively enable DLB on certain flows, or enable DLB globally and selectively disable DLB. In either case, you'll need to first

configure DLB in *per-packet mode*. Per-packet is the DLB mode used wherever DLB is enabled. You cannot configure DLB in per-flow and per-packet mode on the same device at the same time.

This feature is compatible with flowlet mode. You can optionally enable this feature when DLB is configured in flowlet mode.

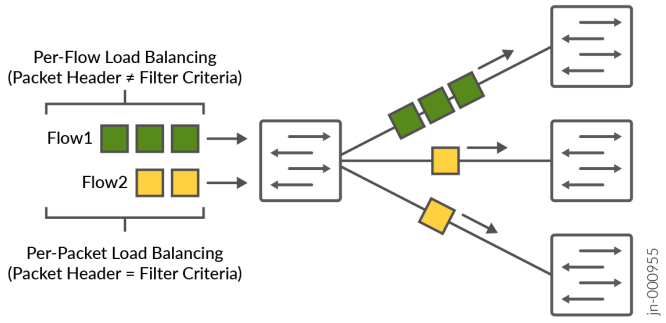
Topology

In the topology shown in Figure 1 on page 15, DLB is disabled by default. We have enabled DLB selectively on Flow2 in per-packet mode. Table 1 on page 15 summarizes the load balancing configuration on the two flows shown and the results of the load balancing applied on the flows:

Table 1: Flow Behaviors

Flow	DLB Enabled?	Result
Flow1	No	The device uses the default load balancing configuration, which is per-flow mode. The flow is directed to a single device.
Flow2	Yes	The device uses the DLB configuration, which is per-packet mode. The device splits this flow into packets. DLB assigns each packet to a path that is based on the RDMA opcode in the packet header and the corresponding filter.

Figure 1: Per-Flow and Per-Packet Load Balancing



Disable DLB Globally and Selectively Enable DLB

In cases where very few packets will require DLB, you can disable DLB at the global level and selectively enable it per flow.

1. Enable DLB per-packet mode. Whenever DLB is enabled on a flow, DLB uses this mode to direct traffic.

```
set system packet-forwarding-options firewall profiles <inet | inet6 | ethernet-switching>
udf-profile-name
set forwarding-options enhanced-hash-key ecmp-dlb per-packet
```

2. Disable DLB globally by turning it off for all Ethernet types. By default, all packets will get hash-based load balancing (SLB).

```
set forwarding-options enhanced-hash-key ecmp-dlb ether-type none
```

3. Configure a firewall filter to match a specific RDMA opcode within the BTH+ header.

   This example matches based on `rdma-opcode` 10.

```
set firewall family inet filter filter-name term term-name from rdma-opcode 10
```

4. Enable per-packet DLB within that firewall filter to only apply DLB to those packets with the chosen RDMA opcode in the BTH+ header.

```
set firewall family inet filter filter-name term term-name then dynamic-load-balance enable
```

5. Other packets get the default load balancing method, which is SLB.

```
set firewall family inet filter filter-name term default then accept
```

Enable DLB Globally and Selectively Disable DLB

In cases where most packets will benefit from DLB, enable DLB at the global level for all packets and selectively disable it per packet.

1. Configure DLB at the global level in per-packet mode for all flows.

```
set system packet-forwarding-options firewall profiles <inet | inet6 | ethernet-switching>
udf-profile-name
set forwarding-options enhanced-hash-key ecmp-dlb per-packet
```

2. Configure a firewall filter to match a specific RDMA opcode within the BTH+ header.

   This example matches based on `rdma-opcode` 10.

```
set firewall family inet filter filter-name term term-name from rdma-opcode 10
```

3. Disable per-packet DLB within that firewall filter for packets with the chosen RDMA opcode in the BTH+ header.

```
set firewall family inet filter filter-name term term-name then dynamic-load-balance disable
```

4. Other packets get the default load balancing method, which is DLB.

```
set firewall family inet filter filter-name term default then accept
```

Verification

Verify DLB is enabled as you expected using the following commands:

```
show forwarding-options enhanced-hash-key
```

```
show pfe filter hw profile-info
```

Example: Selectively Enable DLB with a Firewall Filter Match Condition

One of the benefits of selective DLB is that you can customize load balancing based on any firewall filter match condition. This example shows how to enable DLB based on a firewall filter that matches with RDMA queue pairs. Use this example to enable per-packet DLB only for those flows terminating on a network interface card (NIC) that supports packet reordering.

In a network that uses RoCEv2 for application traffic transport, an RDMA connection sends traffic on a send queue and receives traffic on a receive queue. These queues form the RDMA connection. Together, the send queue and receive queue are referred to as a queue pair. Each queue pair has an identifiable prefix. In this example, we use queue pair prefixes to control when DLB is enabled.

This example is configured on a QFX5240-64QD switch.

1. Create a user-defined field in a firewall for matching packets that is destined for a specific RDMA destination queue pair. Select a queue pair you know terminates on an NIC that is capable of reordering packets.

   We named our firewall filter `sDLB`. The term `QP-match` matches on incoming packets with a destination queue pair with the following characteristics.

   ```
   set firewall family inet filter sDLB term QP-match from flexible-match-range match-start
   layer-4
   set firewall family inet filter sDLB term QP-match from flexible-match-range byte-offset 13
   set firewall family inet filter sDLB term QP-match from flexible-match-range bit-length 24
   set firewall family inet filter sDLB term QP-match from flexible-match-range range 0x64
   ```

2. Configure the firewall filter to enable per-packet DLB on the queue pairs that match the filter.

   If the queue pair is not a match, the device uses the default load balancing type of SLB for that packet.

   ```
   set firewall family inet filter sDLB term QP-match then dynamic-load-balance enable
   ```

3. Configure a counter that increments each time there is a match.

   The counter `QP-match-count` tracks how many packets were load balanced with DLB. You can use this information when troubleshooting.

   ```
   set firewall family inet filter sDLB term QP-match then count QP-match-count
   ```

4. Enable your firewall filter on the relevant interface.

   ```
   set interfaces et-0/0/5 unit 0 family inet filter input sDLB
   ```

5. Verify your firewall filter term is matching on packets coming through the device.

The QP-match-count counter shows the number of bytes and packets that the firewall filter has redirected for load balancing with DLB.

```
user@device> show firewall

Filter: sDLB
Counters:
Name                                Bytes              Packets
QP-match-count                 176695488320            552173401
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Dynamic Load Balancing
- dynamic-load-balance
- rdma-opcode

Customize Egress Port Link Quality Metrics for DLB

IN THIS SECTION

Overview

IN THIS SECTION

Dynamic load balancing (DLB) selects an optimal link based on the quality of the link so that traffic flows are evenly distributed across your network. You (the network administrator) can customize the way DLB assigns quality metrics of egress ports so that DLB selects the optimal link.

DLB assigns each egress port that is part of equal-cost multipath (ECMP) to a quality band. Quality bands are numbered from 0 through 7, where 0 is the lowest quality and 7 is the highest quality. DLB tracks two metrics on each of the ports, and it uses these metrics to compute the link quality:

- Port load metric: The amount of traffic recently transmitted over each ECMP link, measured in bytes.
- Port queue metric: The amount of traffic enqueued on each ECMP link for transmission, measured in number of cells.

Based on the member port load and queue size, DLB assigns one of the quality bands to the member port. The port-to-quality band mapping changes based on the instantaneous port load and queue size metrics.

By default, DLB weighs the port load metric and port queue metric equally when evaluating link quality. You can configure DLB to base the link quality more heavily on the port load than the port queue, or vice versa. Configure the amount of weight DLB places on the port load using the `rate-weightage` statement at the `[edit forwarding-options enhanced-hash-key ecmp-dlb egress-quantization]` hierarchy level. DLB assigns the remaining weight percentage to the port queue. For example, if you configure the `rate-weightage` value to be 80, DLB places 80% weight on the port load and 20% weight on the port queue when evaluating the quality of a link.

You can also configure port load thresholds that determine the upper and lower quality bands. The thresholds are percentages of the total port load that you configure using the `min` and `max` options. DLB assigns any egress port with a port load falling below this minimum to the highest quality band (7). Any port load larger than the maximum threshold falls into the lowest quality band (0). DLB divides the remaining port load quantities among quality bands 1 through 6.

For example, if you configure the minimum to be 10 and the maximum to be 70, DLB assigns any egress port with a port load that takes up less than 10 percent (%) of the total port load to quality band 7. DLB assigns any egress port with a port load taking up more than 70% of the total port load to quality band

0. DLB then assigns egress ports with port loads taking up 10% through 70% of the total port load to quality bands 1 through 6.

Benefits

- Optimize load balancing based on port activity that is determined by both port load size and queues.
- Configure link quality parameters that best suit your network needs.
- Allow DLB to flexibly assign ports to quality bands based on real-time metrics.

Configuration

Configure the egress port quality metric.

1. Configure how much weight DLB puts on the port load metric, or amount of traffic, when determining the link quality.

   Range of `rate-weightage`: 0 through 100, where 100 means that DLB bases link quality 100% on the port load.

   When the rate weightage changes, the device repairs all ECMP DLB groups with the new egress quantization values for each of their egress links. During the transition between configurations, traffic can drop.

   ```
   set forwarding-options enhanced-hash-key ecmp-dlb egress-quantization rate-weightage rate-weightage
   ```

2. Configure the minimum port load in percentage.

   DLB assigns any egress port with a port load falling below this minimum to the highest quality band (7). Range of `min`: 1 through 100 (percent).

   ```
   set forwarding-options enhanced-hash-key ecmp-dlb egress-quantization min min
   ```

3. Configure the maximum port load in percentage.

DLB assigns any egress port with a port load above this maximum to the lowest quality band (0). Range of `max`: 1 through 100 (percent).

```
set forwarding-options enhanced-hash-key ecmp-dlb egress-quantization max max
```

4. Verify the configuration was successful.

```
show forwarding-options enhanced-hash-key
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Dynamic Load Balancing
- enhanced hash-key
- show forwarding-options enhanced-hash-key

Configure Flowset Table Size in DLB Flowlet Mode

IN THIS SECTION

Overview

IN THIS SECTION

Dynamic load balancing (DLB) is a load balancing technique that selects an optimal egress link based on link quality so that traffic flows are evenly distributed. You (the network administrator) can configure DLB in *flowlet mode*.

In flowlet mode, DLB tracks the flows by recording the last seen timestamp and the egress interface that DLB selected based on the optimal link quality. DLB records this information in the flowset table allocated to each ECMP group. The DLB algorithm maintains a given flow on a particular link until the last seen timestamp exceeds the inactivity timer. When the inactivity timer expires for a particular flow, DLB rechecks whether that link is still optimal for that flow. If the link is no longer optimal, DLB selects a new egress link and updates the flowset table with the new link and the last known timestamp of the flow. If the link continues to be optimal, the flowset table continues to use the same egress link.

You (the network administrator) can increase the flowset table size to change the distribution of the flowset table entries among the ECMP groups. The more entries an ECMP group has in the flowset table, the more flows the ECMP group can accommodate. In environments such as AI-ML data centers that must handle large numbers of flows, it is particularly useful for DLB to use a larger flowset table size. When each ECMP group can accommodate a large number of flows, DLB achieves better flow distribution across the ECMP member links.

The flowset table holds 32,768 total entries, and these entries are divided equally among the DLB ECMP groups. The flowset table size for each ECMP group ranges from 256 through 32,768. Use the following formula to calculate the number of ECMP groups:

```
32,768/(flowset size) = Number of ECMP groups
```

By default, the flowset size is 256 entries, so by default there are 128 ECMP groups.

Benefits

- Improve load distribution over egress links.

- Group flows to minimize how many calculations DLB has to make for each flow.
- Customize flowset table entry allocation for maximum efficiency.
- Increase the efficiency of flowlet mode.

Configuration

Be aware of the following when configuring the flowset table size:

- When you change the flowset size, the scale of ECMP DLB groups also changes. Allocating a flowset table size greater than 256 reduces the number of DLB-capable ECMP groups.
- When you commit this configuration, traffic can drop during the configuration change.
- DLB is not supported when a link aggregation group (LAG) is one of the egress members of ECMP.
- Only underlay fabrics support DLB.
- QFX5240 switch ports with a speed less than 50 Gbps do not support DLB.

1. Configure DLB in flowlet mode. See Configuring Dynamic Load Balancing.
2. Configure the flowset table size.

```
set forwarding-options enhanced-hash-key ecmp-dlb flowlet flowset-table-size value
```

3. Verify the configuration was successful.

```
show forwarding-options enhanced-hash-key
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Dynamic Load Balancing

Reactive Path Rebalancing

IN THIS SECTION

Overview

IN THIS SECTION

Dynamic load balancing (DLB) is an important tool for handling the large data flows (also known as elephant flows) inherent in AI-ML data center fabrics. *Reactive path rebalancing* is an enhancement to existing DLB features.

In the flowlet mode of DLB, you (the network administrator) configure an inactivity interval. The traffic uses the assigned outgoing (egress) interface until the flow pauses for longer than the inactivity timer. If the outgoing link quality deteriorates gradually, the pause within the flow might not exceed the configured inactivity timer. In this case, classic flowlet mode does not reassign the traffic to a different link, so the traffic cannot utilize a better-quality link. Reactive path rebalancing addresses this limitation by enabling the user to move the traffic to a better-quality link even when flowlet mode is enabled.

The device assigns a quality band to each equal-cost multipath (ECMP) egress member link that is based on the traffic flowing through the link. The quality band depends on the port load and the queue buffer. The port load is the number of egress bytes transmitted. The queue buffer is the number of bytes waiting to be transmitted from the egress port. You can customize these attributes based on the traffic pattern flowing through the ECMP.

Benefits

- Scalable solution to link degradation
- Optimal use of bandwidth for large data flows
- Avoidance of load balancing inefficiencies due to long-lived flows

Configuration

IN THIS SECTION

Configuration Overview

Quality bands are numbered from 0 through 7, where 0 is the lowest quality and 7 is the highest quality. Based on the member port load and queue size, DLB assigns a quality band value to the member port. The port-to-quality band mapping changes based on instantaneous port load and queue size.

When both of the following conditions are met, reactive path rebalancing reassigns a flow to a higher-quality member link:

- A better-quality member link is available whose quality band is equal to or greater than the current member's quality band plus the configured reassignment *quality delta* value. The quality delta is the difference between the two quality bands. Configure the quality delta value using the `quality-delta` statement.
- The packet random value that the system generates is lower than the reassignment *probability threshold* value. Configure the probability threshold value using the `prob-threshold` statement.

Be aware of the following when using this feature:

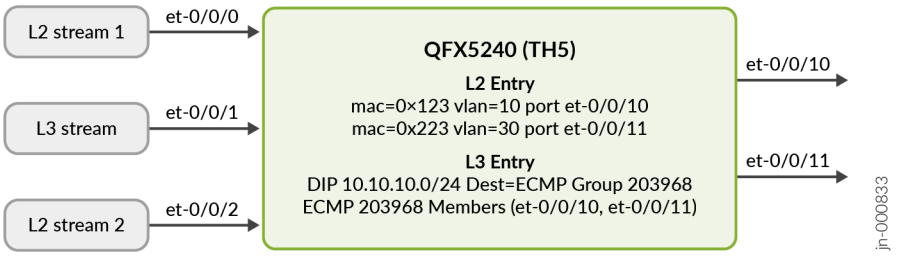
- Reactive path rebalancing is a global configuration and applies to all ECMP DLB configurations in the system.
- You can configure egress quantization in addition to reactive path rebalancing to control the flow reassignment.

- Packet reordering can occur when the flow moves from one port to another. Configuring reactive path rebalancing can cause momentary out-of-order issues when the flow is reassigned to the new link.

Topology

In this topology, the device has three ingress ports and two egress ports. Two of the ingress streams are Layer 2 (L2) traffic and one is Layer 3 (L3) traffic. The figure shows the table entries forwarding the traffic to each of the egress ports. All the ingress and egress ports are of the same speed.

Figure 2: Reactive Path Rebalancing



In this topology, reactive path rebalancing works as follows:

1. Quality delta of 2 is configured.
2. L2 stream 1 (`mac 0x123`) enters ingress port et-0/0/0 with a rate of 10 percent. It exits through et-0/0/10. The egress link utilization of et-0/0/10 is 10 percent and the quality band value is 6.
3. The L3 stream enters port et-0/0/1 with a rate of 50 percent. It exits through et-0/0/11 and selects the optimal link from the ECMP member list. The egress link utilization of et-0/0/11 is 50 percent with a quality band value of 5.
4. L2 stream 2 (`mac 0x223`) enters port et-0/0/2 with a rate of 40 percent. It also exits through et-0/0/11. This further degrades the et-0/0/11 link quality band value to 4. Now the difference in the quality band values of both ECMP member links is 2.
5. The reactive path balancing algorithm now becomes operational because the difference in quality band values for ports et-0/0/10 and et-0/0/11 is equal to or higher than the configured quality delta of 2. The algorithm moves the L3 stream from et-0/0/11 to a better-quality member link, which in this case is et-0/0/10.
6. After the L3 steam moves to et-0/0/10, the et-0/0/10 link utilization increases to 60 percent with a decrease in quality band value to 5. L2 stream 2 continues to exit through et-0/0/11. The et-0/0/11 link utilization remains at 40 percent with an increase in quality band value to 5.

Configure Reactive Path Rebalancing

1. Configure DLB in flowlet mode. See Configuring Dynamic Load Balancing.
2. Configure the required difference (delta) in quality between the current stream member and the member available for reassignment.

   Optimal selection of the quality delta is very important. An incorrect delta can result in continuous reassignment of flow from one link to another.

   The range of the `quality-delta` statement is 0 through 8. Set it to 0 to disable reassignment of the flows.

   ```
   set forwarding-options enhanced-hash-key ecmp-dlb flowlet reassignment quality-delta reassign-quality-delta
   ```

3. Set the probability threshold that reactive path rebalancing uses to reassign the existing flow to a better available member link.

   Note the following when configuring the probability threshold:

   - When `quality-delta` is configured, `prob-threshold` defaults to 100.
   - The range of `prob-threshold` is 0 through 255. Set it to 0 to disable reassignment of the flows.
   - A lower probability threshold value means that flows move to a higher-quality member link at a slower rate. For example, flows move to a higher-quality link more quickly with a probability threshold value of 200 than with a probability threshold value of 50.

   ```
   set forwarding-options enhanced-hash-key ecmp-dlb flowlet reassignment prob-threshold reassign-prob-threshold
   ```

4. Verify the configuration was successful.

   ```
   show forwarding-options enhanced-hash-key
   ```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Dynamic Load Balancing
- enhanced hash-key
- show forwarding-options enhanced-hash-key

Global Load Balancing (GLB)

IN THIS SECTION

Overview

IN THIS SECTION

NOTE: This is an evolving feature for early adopters. More enhancements are planned in a future release.

AI-ML data centers have less entropy and larger data flows than other networks. Because hash-based load balancing does not always effectively load-balance this type of traffic, dynamic load balancing (DLB) is often used instead. However, DLB takes into account only the local link bandwidth utilization. For this reason, DLB can effectively mitigate traffic congestion only on the immediate next hop. Global load balancing (GLB) is an enhancement to DLB that has visibility into congestion at the next-to-next-hop (NNH) level. GLB more effectively load-balances large data flows by taking traffic congestion on remote links into account.

Classic load balancing mechanisms use a hashing algorithm to decide the egress interface through which to send traffic. These algorithms operate the hash function on five tuples of the received packet. However, the algorithms do not consider the real-time utilization of the links through which they send packets. Even in DLB, the decision is completely local and the algorithm is unable to globally detect link utilization. If a node farther out is congested, that node might drop the packet.

GLB takes into account the link utilization of remote links before deciding on the egress interface. Similarly to DLB, when one multipath leg experiences congestion, GLB can offload traffic to alternative legs to mitigate the congestion. Unlike DLB, GLB can reroute traffic flows on leaf devices to avoid traffic congestion on the spine level.

Benefits

- Reduces packet loss due to congestion and remote link failures
- Effectively load-balances large data flows in Clos topologies end-to-end to avoid congestion
- Is particularly useful in AI-ML deployments where large data flows increase the likelihood of traffic congestion

Configuration

IN THIS SECTION

Considerations

Keep the following in mind when configuring GLB:

- GLB is supported only in a 3-Clos (leaf-spine-leaf) topology.
- All the devices in the 3-Clos topology must support GLB before you can configure GLB.
- The 3-Clos topology can have a maximum of 64 leaf devices when it supports GLB.
- GLB supports only one link between the same pair of devices (for example, a spine device and leaf device).

GLB does not support the following features:

- Integrated routing and bridging (IRB) interfaces between top-of-rack (ToR) and spine devices
- Multihomed servers
- GLB for overlay routes (IPv4 or IPv6)
- GLB for BGP routes learned in routing instances

Configure GLB

1. Configure DLB.

   The DLB configuration on each device in the fabric must be identical. See Dynamic Load Balancing for how to configure DLB.

2. Configure a node ID for each node.

   Each node must have a node ID. Keep the following in mind when configuring the node ID:

   - Configure the node ID at one of these hierarchy levels:

     ```
     [edit routing-optons router-id router-id]
     [edit protocols bgp bgp-identifier bgp-identifier]
     ```

   - If you configure the `bgp-identifier` statement, you must configure it globally, not at a `group` or `neighbor` hierarchy level.
   - The BGP identifier for each node must be unique within the fabric.

3. On spine devices, configure GLB in `helper-only` mode.

   In `helper-only` mode, BGP sends the NNH node (NNHN) capability for the route it advertises. BGP instructs the GLB application to monitor the link qualities of all local links with EBGP sessions and

flood that information to all direct neighbors. Configure this option on the spine devices in a 3-Clos architecture.

```
set protocols bgp global-load-balancing helper-only
set forwarding-options enhanced-hash-key ecmp-dlb <flowlet | per-packet>
```

4. On leaf devices, configure GLB in `load-balancer-only` mode.

   In `load-balancer-only` mode, BGP does not send the NNHN capability for the route it advertises. The switch receives link qualities from neighboring nodes. It uses the combined link quality of next hops and NNHs to make load balancing decisions. Configure this option on the leaf devices of any Clos architecture.

   ```
   set protocols bgp global-load-balancing load-balancer-only
   set forwarding-options enhanced-hash-key ecmp-dlb <flowlet | per-packet>
   ```

5. Selectively disable GLB.

   After you globally configure GLB using the `global-load-balancing` statement, you can selectively disable it on a particular BGP group or peer. To selectively disable GLB, use the `no-global-load-balancing` statement at either of these hierarchy levels:

   ```
   [edit protocols bgp group group-name]
   ```

   ```
   [edit protocols bgp group group-name neighbor address]
   ```

   For example:

   ```
   set protocols bgp group group-name no-global-load-balancing
   ```

6. Verify the configuration was successful using the following commands:

   - **show bgp global-load-balancing**
   - **show bgp global-load-balancing path**
   - **show bgp global-load-balancing path-monitor**
   - **show bgp global-load-balancing profile**

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- enhanced hash-key
- Dynamic Load Balancing

CHAPTER 4

Traffic Management

Traffic Management Overview for AI-ML Data Centers

Traffic management is a reactive technique to handle traffic congestion as it occurs. One of the key types of traffic management for AI-ML data centers is priority-based flow control (PFC). Before configuring AI-ML traffic management features, configure class-of-service (CoS) features on your device. Read on to learn about the AI-ML traffic management features that Junos OS Evolved offers.

RELATED DOCUMENTATION

- CoS Support on QFX Series Switches and EX4600 Line of Switches
- Understanding CoS Flow Control (Ethernet PAUSE and PFC)

PFC Watchdog

IN THIS SECTION

Overview

IN THIS SECTION

In a lossless AI Ethernet fabric, priority-based flow control (PFC) allows independent flow control for each class of service to ensure that congestion does not result in frame loss. PFC pause frames instruct the link partner to halt packet transmission. These frames can propagate through the network, causing traffic on the PFC streams to stop in what is known as a *PFC pause storm*. Use the *PFC watchdog* to detect and to resolve PFC pause storms.

The PFC watchdog monitors PFC-enabled ports for PFC pause storms. The PFC watchdog intervenes when a PFC-enabled port receives PFC pause frames for an extended period of time and is unable to schedule any of the data packets on PFC-enabled queues. The PFC watchdog mitigates the situation by disabling the queue where the PFC pause storm was detected for a set length of time. This length of time, called the recovery time, is configurable. After the recovery time passes, the PFC watchdog reenables the affected queue.

The PFC watchdog plays a critical role with its three key functions: detection, mitigation, and restoration.

Benefits

- Quickly detect and resolve PFC pause storms.
- Maintain lossless traffic links.
- Improve link quality.

Configuration

The watchdog recovery is a global setting, so it requires the same action on all ports to function. When you configure the PFC watchdog on multiple ports, make sure all ports are configured with the same type of action (drop or forward). By default, all ports use the drop action.

You can enable the PFC watchdog on all PFC-enabled queues.

The device logs PFC watchdog detection and recovery events in the system log with a timestamp.

1. Enable PFC watchdog.

```
set class-of-service congestion-notification-profile cnp-name pfc-watchdog
```

2. The PFC watchdog checks the status of PFC queues at regular intervals. Configure this interval in milliseconds.

```
set class-of-service congestion-notification-profile cnp-name pfc-watchdog watchdog-interval
<1/10/100>
```

3. Configure how many polling intervals the PFC watchdog waits before it mitigates the stalled traffic.

```
set class-of-service congestion-notification-profile cnp-name pfc-watchdog detection polling-
interval
```

4. Specify the action that the PFC watchdog takes to mitigate the traffic congestion.

```
set class-of-service congestion-notification-profile cnp-name pfc-watchdog watchdog-action
<drop/forward>
```

5. Configure how long the PFC watchdog disables the affected queue for before it restores PFC.

```
set class-of-service congestion-notification-profile cnp-name pfc-watchdog recovery time in
milliseconds
```

6. Verify you have configured the PFC watchdog correctly.

```
show class-of-service congestion-notification-profile cnp-name
```

7. Monitor the number of PFC pause storms that have been detected and recovered, as well as the number of packets that have been dropped, on a particular interface.

```
show interfaces interface-name extensive
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- PFC Watchdog
- congestion-notification-profile

PFC Using DSCP at Layer 3 for Untagged Traffic

IN THIS SECTION

Overview

IN THIS SECTION

AI and ML applications are rapidly expanding in data centers. When dealing with AI and ML workloads and large data sets, one critical challenge is handling the size of the data. Offloading the computation to

graphics processing units (GPUs) can significantly speed up this task. However, the data size and the model, especially with large language models (LLMs), often exceed the memory capacity of a single GPU. As a result, you commonly require multiple GPUs to achieve reasonable job completion times, especially for training.

The performance of an AI data center depends on the number of GPUs that are used and the efficiency of the network that connects them. Slowdowns in the network can lead to underutilization of GPUs and longer job completion times. Ethernet-based networks are becoming more popular as an alternative to InfiniBand for AI data center networking. One solution is the Remote Direct Memory Access (RDMA) over Converged Ethernet version 2 (RoCEv2) network.

RoCEv2 involves encapsulating RDMA protocol packets within UDP packets for transport over Ethernet networks. The RoCEv2 protocol utilizes priority-based flow control (PFC) to establish a drop-free network, while *data center quantized congestion notification* (DCQCN) provides end-to-end congestion control for RoCEv2. Junos OS Evolved supports DCQCN by combining explicit congestion notification (ECN) and PFC to enable end-to-end lossless AI Ethernet networking.

To support lossless IPv6 traffic across Layer 3 (L3) connections to Layer 2 (L2) subnetworks, you can configure PFC to operate using 6-bit Differentiated Services code point (DSCP) values from L3 headers of untagged VLAN traffic. You can use PFC with DSCP as an alternative to IEEE 802.1p priority values in L2 VLAN-tagged packet headers. You need DSCP-based PFC to support RoCEv2.

Benefits

- Utilize Ethernet-based networks for AI-ML data center networking.
- Improve network efficiency for large data sets.
- Enable end-to-end lossless AI-ML Ethernet networking.

Configuration

IN THIS SECTION

Enable DSCP-Based PFC

1. Map a forwarding class (FC) to a PFC priority using the `pfc-priority` statement.

```
set class-of-service forwarding-classes class class-name pfc-priority pfc-priority
set class-of-service forwarding-classes class class-name queue-num queue-num
set class-of-service forwarding-classes class class-name no-loss
```

2. Define a congestion notification profile to enable PFC on traffic specified by a 6-bit DSCP value. Map the `code-point` configuration to no-loss queues.

```
set class-of-service congestion-notification-profile cnp input dscp code-point dscp-value pfc
```

3. Set up a classifier for the DSCP value and the PFC-mapped FC.

```
set class-of-service classifiers dscp classifier-name forwarding-class class-name loss-
priority <low/medium-high/high> code-points dscp-value
```

Verify the Configuration

1. Check the ingress port.

```
show interfaces interface-name extensive | match Priority
```

2. Check the ingress port.

```
show interfaces queue interface-name
```

3. Display the DSCP-based input CNP.

```
show class-of-service congestion-notification-profile cnp name
```

4. Display which FCs are mapped to each PFC priority.

```
show class-of-service forwarding-classes
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Configuring DSCP-based PFC for Layer 3 Untagged Traffic

Customize PFC X-ON Threshold and Per-Queue Alpha Values

IN THIS SECTION

Overview

IN THIS SECTION

When you configure a congestion notification profile on an ingress port, lossless traffic is mapped to lossless priority groups. You configure these priority groups with priority-based flow control (PFC) *X-OFF* and *X-ON* thresholds. In case of congestion at an egress port, these priority groups ensure that the ingress port generates the PFC frames toward the peer based on the configured thresholds. When the shared occupancy or receive buffer on an ingress priority group reaches its PFC X-OFF limit, the corresponding priority group transmits the PFC pause frame to the egress peer. The peer temporarily stops transmitting packets to give the device time to resolve the traffic congestion.

The X-ON threshold is a buffer limit that is shared by the priority group. When the buffer usage on the ingress priority group drops below this PFC X-ON limit, the priority group sends a PFC message to the peer so it can resume packet transmission. Make sure the device has enough time to resolve the congestion. You must also ensure that traffic is not paused for long enough to cause disruption to your network. To optimize the downtime during a PFC pause storm, adjust the X-ON threshold through the congestion notification profile (CNP).

You can globally adjust the limit of buffers that each queue can consume from the shared buffer pool. The shared buffer pool is based on a dynamic threshold setting called the alpha value. You can configure a scheduler with different dynamic buffer threshold values for different queues, thereby controlling the shared buffer access by individual queues.

Benefits

- Ensure that the device has enough time to resolve traffic congestion without disrupting your network.
- Customize device responses to PFC pause storms.
- Globally adjust the limits of buffers for ease of configuration.

Configuration

1. Enable PFC.

   Map the `code-point` configuration to no-loss queues.

   ```
   set class-of-service congestion-notification-profile profile-name input dscp code-point code-point-bits pfc
   ```

2. Specify the number of X-ON threshold offset cells before the peer resumes transmission from the dynamic shared buffer.

The range is 0 through 100000:

```
set class-of-service congestion-notification-profile profile-name input dscp code-point code-point-bits xon value
```

3. Configure the per-queue alpha value through a scheduler.

   Per-queue alpha values are not supported for lossless queues. The range of the threshold for the maximum buffer share for a queue at the egress buffer partition is 0 through 10:

```
set class-of-service schedulers scheduler-name buffer-dynamic-threshold value
```

4. Verify the shared buffer configuration.

```
show class-of-service shared-buffer
```

5. Verify the buffer profile configuration.

```
show class-of-service dedicated-buffer-profile
```

6. Verify the configuration on the interface.

```
show class-of-service interface interface-name
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- PFC
- xon (Input Congestion Notification)
- buffer-dynamic-threshold

Increase Shared Buffer Pool by Reducing Dedicated Buffer

IN THIS SECTION

Overview

IN THIS SECTION

Each device that supports this feature partitions its buffer into dedicated and shared buffers. The dedicated buffer is exclusive to each port, and only that port can use its dedicated buffer. The shared buffer is shared across all ports. When ports have little traffic, their dedicated buffer space is unused. Ports with a lot of traffic cannot use that unused buffer space as long as it is dedicated to other ports. You can effectively increase the global shared buffer space, and therefore the buffer of busy ports, by decreasing the dedicated buffer space from the default value.

You can also define a dedicated buffer profile to increase or decrease the dedicated buffer that is allocated to an individual port. Buffer profiles for individual ports are particularly useful for decreasing dedicated buffer space on unused or down ports, thereby increasing dedicated buffer space available to active ports.

Benefits

- Allow the device to allocate buffer space more efficiently among ports.
- Increase the buffer space available to active ports.
- Busy traffic ports can use more of the buffer space according to their dynamic-threshold value.

Configuration

> **NOTE**: Modify the dedicated buffer settings with caution to prevent traffic loss due to buffer misconfiguration.

1. Configure the dedicated buffer.

   To avoid all ports contending with the shared buffers and to address line-rate traffic, you cannot reduce dedicated buffers below 15 percent of the default value.

   Range of `percent`: 15 through 100 (percent).

   ```
   set class-of-service dedicated-buffer ingress percent percent
   set class-of-service dedicated-buffer egress percent percent
   ```

2. Configure the dedicated buffer profile.

   If the dedicated buffer configured as part of the `dedicated-buffer-profile` statement exceeds the total available dedicated buffers, the configuration is not effective. The configuration commits but the device logs a system logging error and does not program the configuration in the hardware.

   Range of `buffer-size`: 20 through 50,000 (absolute value in cells).

   ```
   set class-of-service dedicated-buffer-profile profile-name ingress buffer-size (none |
   absolute-value-in-cells)
   set class-of-service dedicated-buffer-profile profile-name egress buffer-size (none |
   absolute-value-in-cells)
   ```

3. Configure the dedicated buffer profile on a specific interface.

You can configure this feature only on physical interfaces. You cannot attach dedicated buffer profiles to aggregated Ethernet parent ports.

```
set class-of-service interface interface-name dedicated-buffer-profile profile-name
```

4. Verify the configuration is correct.

```
show class-of-service dedicated-buffer-profile
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Configuring Ingress and Egress Dedicated Buffers
- dedicated-buffer
- dedicated-buffer-profile

ECN Packets per Queue

IN THIS SECTION

Overview

IN THIS SECTION

Explicit congestion notification (ECN) enables two endpoint devices on TCP/IP-based networks to send end-to-end congestion notifications to each other. Without ECN, devices respond to network congestion by dropping TCP/IP packets. The dropped packets signal the occurrence of network congestion. In contrast, ECN marks packets to signal network congestion without dropping the packets. ECN reduces packet loss by making the sending device decrease the transmission rate until the congestion clears.

Packets may be delayed as the device decreases the transmission rate until congestion clears. To account for how many packets are delayed, you can use the `show interfaces queue` command to view the amount of ECN congestion experienced (CE) traffic in the queue.

Benefits

- Identify the packets that have experienced congestion.
- Helps in identifying if traffic is going to reach the queue buffer limits.
- Enables quick troubleshooting of network congestion points.

Configuration

1. Configure ECN.

   ECN is disabled by default. For how to configure ECN, see Example: Configuring ECN.
2. Enable ECN on both endpoints and on all of the intermediate devices between the endpoints.

   ECN must be enabled this way for ECN to work properly. Any device in the transmission path that does not support ECN breaks the end-to-end ECN functionality.
3. Use the `show interfaces queue` command to view the amount of traffic that has experienced congestion.

   The `ECN-CE packets` field shows the number of packets that have experienced congestion, while the `ECN-CE bytes` field shows the number of total bytes in those packets.

The per-queue ECN counters `ECN-CE packets` and `ECN-CE bytes` only count packets that experienced congestion on the local switch.

For example:

```
show interfaces queue et-0/0/5 forwarding-class network-control1

Physical interface: et-0/0/5, up, Physical link is Up
  Interface index: 1262, SNMP ifIndex: 974
Forwarding classes: 12 supported, 9 in use
Egress queues: 12 supported, 9 in use
Queue: 3, Forwarding classes: network-control1
  Queued:
    Packets              :              15239998               856158 pps
    Bytes                :            2225039708            999992904 bps
  Transmitted:
    Packets              :              15239998               856158 pps
    Bytes                :            2225039708            999992904 bps
    Tail-dropped packets :                     0                    0 pps
    Tail-dropped bytes   :                     0                    0 bps
    RED-dropped packets  :                     0                    0 pps
    RED-dropped bytes    :                     0                    0 bps
    ECN-CE packets       :               8577686               482043 pps
    ECN-CE bytes         :            1252342156             70378315 bps
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Example: Configuring ECN
- Understanding CoS Explicit Congestion Notification
- show interfaces queue

5
CHAPTER

BGP

BGP Overview for AI-ML Data Centers

SUMMARY

Learn the benefits of BGP for an AI-ML data center deployment.

BGP is an exterior gateway protocol (EGP) that routers in different autonomous systems (ASs) use to exchange routing information. BGP routing information includes the complete route to each destination. BGP uses the routing information to maintain a database of network reachability information, which it exchanges with other BGP systems. BGP uses the network reachability information to construct a graph of AS connectivity. This AS connectivity graph enables BGP to remove routing loops and enforce policy decisions at the AS level.

BGP enables policy-based routing (PBR). You can use routing policies to choose among multiple paths to a destination and to control the redistribution of routing information.

In AI-ML data center deployments, you can use BGP to effectively exchange equal-cost multipath (ECMP) link or load balancing-related control plane information between layers of the Clos network. The features described in this guide use this information to improve the performance of your AI-ML data center network.

RELATED DOCUMENTATION

- BGP Configuration Overview

BGP Link-Bandwidth Community

IN THIS SECTION

Overview

IN THIS SECTION

Within a BGP implementation, a link-bandwidth extended community encodes the bandwidth of a given next hop. BGP assists in load-balancing traffic by communicating the speeds of BGP links to remote peers. When you (the network administrator) combine a link-bandwidth community with multipath, the load-balancing algorithm of your choice distributes traffic flows across the set of next hops proportional to their relative bandwidths.

When the BGP link-bandwidth extended community is a transitive attribute across autonomous systems (ASs), the BGP group advertises the link-bandwidth extended community to neighboring ASs. You can choose to use the BGP link-bandwidth community as a nontransitive attribute so routers drop the link-bandwidth community at the AS boundary. The BGP group does not advertise nontransitive link-bandwidth communities to external BGP (EBGP) neighbors.

You can also configure BGP to automatically sense the bandwidth and import the community at a group or neighbor level. Using this link-bandwidth autosense feature, your network can automatically set the link-bandwidth value to the speed of the interface over which the device received the BGP route.

Only per-packet load balancing supports the BGP link-bandwidth community.

Benefits

- With multipath enabled, link-bandwidth provides weighted equal-cost multipath (WECMP) for unequal load balancing.
- Ensures high-bandwidth links carry more flows than low-bandwidth links.
- Reduces the likelihood of traffic congestion.

Configuration

IN THIS SECTION

Bandwidth

By default, the link-bandwidth community is transitive. You can use either of these statements to configure the link-bandwidth community as transitive:

```
set policy-options community name members bandwidth:value
```

```
set policy-options community name members bandwidth-transitive:value
```

To make it nontransitive, use the following configuration:

```
set policy-options community policy-name members bandwidth-non-transitive:value
```

Nontransitive Override

You can override a nontransitive configuration so that a BGP group sends the link-bandwidth extended community over an EBGP session even when link-bandwidth is nontransitive. To send the nontransitive link-bandwidth community across an EBGP neighbor, include the following configuration:

```
set protocols bgp group group-name send-non-transitive-link-bandwidth
```

The send-non-transitive-link-bandwidth statement does not differentiate between the originated link-bandwidth community and one that has been received and readvertised. When you enable this option, BGP advertises all nontransitive link-bandwidth communities to the EBGP neighbor.

Aggregate Bandwidth

By default, the aggregate link-bandwidth community is transitive. You can use either of these statements to configure the link-bandwidth community as transitive:

```
set policy-options policy-statement name then aggregate-bandwidth
```

```
set policy-options policy-statement name then aggregate-bandwidth transitive
```

To make it nontransitive, use the following configuration:

```
set policy-options policy-statement policy-name then aggregate-bandwidth non-transitive
```

To divide the total link-bandwidth by the number of peers in the advertising group, enable the divide-equal statement:

```
set policy-options policy-statement policy-name then aggregate-bandwidth divide-equal
```

Autosense

You can only enable autosense for single-hop EBGP sessions.

1. Configure autosense for the BGP group.

   Configure the auto-sense statement at the neighbor hierarchy to detect and store the bandwidth toward that BGP neighbor. Configure it at the group hierarchy to detect and store the bandwidth for all neighbors under that BGP group:

   ```
   set protocols bgp group group-name link-bandwith auto-sense
   set protocols bgp group group-name neighbor link-bandwith auto-sense
   ```

2. Configure the import policy with `auto-link-bandwidth` set to `transitive` or `non-transitive`. If you do not specify, by default `auto-link-bandwidth` is transitive:

```
set protocols bgp group group-name import policy-name
set policy-options policy-statement policy-name then auto-link-bandwidth non-transitive
```

3. (Optional) To suppress frequent changes in the link-bandwidth value when bandwidth increases, you can configure the autosense hold-down timer. The hold-down timer is only triggered when the bandwidth increases. By default, the timer is set to 60 seconds:

```
set protocols bgp group group-name link-bandwith auto-sense hold-down time-in-seconds
```

Verification

Verify the configuration was successful using the following commands:

- **show route receive-protocol bgp *peer-ip-address* extensive**
- **show route advertising-protocol bgp *peer-ip-address* extensive**
- **show route *address* extensive**
- **show bgp neighbor *address***

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- auto-sense
- group (Protocols BGP)
- policy-statement
- Load Balancing for a BGP Session

- Advertising Aggregate Bandwidth Across External BGP Links for Load Balancing Overview

Improve Network Resiliency Using Multiple ECMP BGP Peers

IN THIS SECTION

Overview

IN THIS SECTION

Equal-cost multipath (ECMP) is a network routing strategy that allows for traffic of the same session, or flow, to be transmitted across multiple paths of equal cost. A flow is traffic with the same source and destination. The ECMP process identifies routers that are legitimate equal-cost next hops toward the flow's destination. The device then uses load balancing to evenly distribute traffic across these multiple equal-cost next hops. ECMP is a mechanism that enables you (the network administrator) to load-balance traffic and increase bandwidth by fully utilizing otherwise unused bandwidth on links to the same destination.

You often use ECMP with BGP. Each BGP route can have multiple ECMP next hops. The BGP export policy determines whether to advertise the BGP route to these next hops. As the network administrator,

you can control the advertisement and withdrawal of BGP prefixes to and from these ECMP peers. The BGP export policy determines whether to advertise a BGP prefix based on the number of ECMP BGP peers the policy receives the prefix from.

You can configure the BGP export policy to withdraw a BGP route unless it receives the BGP route prefix from a minimum number of ECMP BGP peers. Requiring the BGP route to have multiple ECMP BGP peers creates better resiliency in case of link failures.

Benefits

- Improves resiliency of your network
- Prevents accidental overloading of links
- Assists with load balancing

Configuration

The BGP export policy compares the number of ECMP next hops for the BGP route against the value you configure with the `from nexthop-ecmp` statement at either of these hierarchies: `[edit policy-options policy-statement` *`policy-name`*`]` or `[edit policy-options policy-statement` *`policy-name`* `term` *`term-name`*`]`.

The options for this statement are:

- *`value`*: The exact number of ECMP gateways (1 through 512) required to meet the condition.
- `equal`: The number of gateways must be equal to the configured value.
- `greater-than`: The number of gateways must be greater than the configured value.
- `greater-than-equal`: The number of gateways must be greater than or equal to the configured value.
- `less-than`: The number of gateways must be less than the configured value.
- `less-than-equal`: The number of gateways must be less than or equal to the configured value.

1. Configure the BGP export policy to compare the number of ECMP next hops for the BGP route against the value you configure with the `from nexthop-ecmp` statement.

   In this example, the policy term `min-ecmp` finds a match when a route has less than two ECMP BGP peers.

   ```
   set policy-options policy-statement policy-name term min-ecmp from nexthop-ecmp less-than 2
   ```

2. Configure the BGP export policy to stop advertising BGP route prefixes if the number of ECMP next hops doesn't match the conditions you configured.

```
set policy-options policy-statement policy-name term min-ecmp then reject
set policy-options policy-statement policy-name term default then accept
```

3. Apply the policy to routes being exported from the routing table into BGP.

```
set protocols bgp group group-name export policy-name
```

4. Confirm that you have configured the number of required BGP ECMP peers in the policy.

```
show policy policy-name
```

5. Check whether the BGP route has been advertised to or withdrawn from the desired upstream BGP peer.

```
show route advertising-protocol bgp peer-advertised [detail]
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Configuring Consistent Load Balancing for ECMP Groups

6
CHAPTER

EVPN-VXLAN

EVPN-VXLAN for AI-ML Data Centers

IN THIS SECTION

Overview of EVPN-VXLAN for AI-ML Data Centers

IN THIS SECTION

This document covers the steps necessary to configure Ethernet VPN-Virtual Extensible LAN (EVPN-VXLAN) in an artificial intelligence (AI) and machine learning (ML) data center fabric.

Features and Benefits of an AI-ML Data Center

- Improve scalability: You can enable multitenancy within the same data center using an IP fabric overlay.
- Improve productivity: You can run different AI workloads (multiple large language models (LLMs) for different tenants) in the same data center.
- Improve security: You can isolate L2 at the local top-of-rack (ToR) level with multiple MAC-VRF instances, or L3 at the ToR level with multiple EVPN Type 5 routing instances (IP-VRF-to-IP-VRF model). See the configuration section for examples of these use cases.
- Reduce configuration efforts: You can extend the tenants' logical context between different ToR switches in different points of delivery (PODs) without changing the configuration of the intermediate spine or superspine devices.

Configuration

IN THIS SECTION

Configuration Overview

We'll look at two use cases relevant to this topic. The first use case is running two MAC-VRF instances on the same device in a data center. The second use case is running two EVPN Type 5 VRF instances on the same device in a data center.

Use Case #1: Two MAC-VRF instances on the same device:

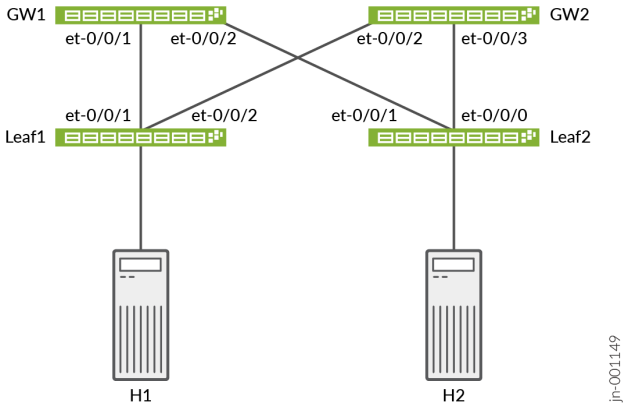
- Separate MAC-VRF instances help to isolate the AI data center tenants at the L2 level, and extend this isolation using the EVPN-VXLAN overlay.
- The intermediate AI data center spine and superspine devices don't require provisioning each new AI data center tenant.
- The L2 connectivity is closer to the actual service connection.
- AI data center tenants can be in the same MAC-VRF L2 EVPN instance (EVI) when you configure the tenants with the `vlan-aware` EVPN service type.

Use Case #2: Two EVPN Type 5 IP-VRF instances on the same device:

- Multiple EVPN Type 5 routing instances can isolate the AI data center tenants at the L3 routing level. Pure Type 5 routing can also extend the context within a POD or between PODs.
- EVPN signaling exchanges between the ToR switches of the AI data center automatically establish VXLAN tunnels for Type 5 routes.

Topology

The topology for these examples uses QFX5240-64QD switches for both the spine and leaf layers. The network is an edge-routed bridging (ERB) architecture.



How to Configure Two MAC-VRFs

Use the following steps as a guide to configure two MAC-VRF instances on the same leaf node. We use actual values for example purposes. You should customize these steps with relevant values for your implementation.

1. Configure a MAC-VRF routing instance.

```
set routing-instances myMACVRF101 instance-type mac-vrf
```

2. Configure the EVPN protocol with VXLAN encapsulation and supporting statements.

```
set routing-instances myMACVRF101 protocols evpn encapsulation vxlan
set routing-instances myMACVRF101 protocols evpn default-gateway no-gateway-community
set routing-instances myMACVRF101 protocols evpn extended-vni-list 5101
```

3. Configure a virtual tunnel endpoint (VTEP) interface.

```
set routing-instances myMACVRF101 vtep-source-interface lo0.0
```

4. Configure a service type. We use `vlan-aware` for this example. `vlan-aware` allows configuring more than one VLAN.

```
set routing-instances myMACVRF101 service-type vlan-aware
```

5. Configure an interface for the routing instance.

```
set routing-instances myMACVRF101 interface et-0/0/4.0
```

6. Configure a route distinguisher (RD) and a VRF target.

```
set routing-instances myMACVRF101 route-distinguisher 10.203.113.10:101
set routing-instances myMACVRF101 vrf-target target:1:9101
```

7. Configure one or more VLANs.

```
set routing-instances myMACVRF101 vlans vlan101 vlan-id 101
set routing-instances myMACVRF101 vlans vlan101 l3-interface irb.101
set routing-instances myMACVRF101 vlans vlan101 vxlan vni 5101
```

8. Configure a second MAC-VRF routing instance. The full configuration is displayed. Note the differences in VLANs, RD, VRF-target, and interfaces. This routing instance uses the `vlan-based` service type, limiting the configuration to a single VLAN. Either `vlan-based` or `vlan-aware` are valid choices.

```
set routing-instances myMACVRF102 instance-type mac-vrf
set routing-instances myMACVRF102 protocols evpn encapsulation vxlan
set routing-instances myMACVRF102 protocols evpn default-gateway no-gateway-community
set routing-instances myMACVRF102 protocols evpn extended-vni-list 5102
set routing-instances myMACVRF102 vtep-source-interface lo0.0
set routing-instances myMACVRF102 service-type vlan-based
set routing-instances myMACVRF102 interface et-0/0/5.0
set routing-instances myMACVRF102 route-distinguisher 10.203.113.10:102
set routing-instances myMACVRF102 vrf-target target:1:9102
set routing-instances myMACVRF102 vlans vlan102 vlan-id 102
set routing-instances myMACVRF102 vlans vlan102 l3-interface irb.102
set routing-instances myMACVRF102 vlans vlan102 vxlan vni 5102
```

Verification

Verify that routing is working as expected. Note that verification requires other network devices to be configured, and your outputs will vary.

```
user@device> show route table myMACVRF101.evpn.0 active-path

myMACVRF101.evpn.0: 10 destinations, 15 routes (10 active, 0 holddown, 0 hidden)
+ = Active Route, - = Last Active, * = Both

2:10.203.113.10:101::5101::00:10:94:00:00:05/304 MAC/IP
                   *[EVPN/170] 04:43:28
                       Indirect
2:10.203.113.10:101::5101::6c:62:fe:b9:3b:3d/304 MAC/IP
                   *[EVPN/170] 05:23:00
                       Indirect
2:10.203.113.11:101::5101::00:10:94:00:00:06/304 MAC/IP
                   *[BGP/170] 04:36:14, localpref 100, from 10.203.113.14
                      AS path: 65101 64513 I, validation-state: unverified
                       to 192.0.2.11 via et-0/0/1.0, Push 5101
                       to 192.0.2.9 via et-0/0/0.0, Push 5101
                    >  to 192.0.2.13 via et-0/0/2.0, Push 5101
2:10.203.113.11:101::5101::6c:62:fe:b9:22:3d/304 MAC/IP
                   *[BGP/170] 04:36:26, localpref 100, from 10.203.113.13
                      AS path: 65101 64513 I, validation-state: unverified
                       to 192.0.2.11 via et-0/0/1.0, Push 5101
                       to 192.0.2.9 via et-0/0/0.0, Push 5101
                    >  to 192.0.2.13 via et-0/0/2.0, Push 5101
```

```
user@device> show mac-vrf forwarding vlans

Routing instance        VLAN name             Tag          Interfaces
default-switch          default               1

myMACVRF101             vlan101               101
                                                           et-0/0/4.0*
                                                           vtep-53.32773*
myMACVRF102             vlan102               102
```

```
                                                    et-0/0/5.0
                                                    vtep-54.32773*
```

```
user@device> show ethernet-switching table vlan-id 101

MAC flags (S - static MAC, D - dynamic MAC, L - locally learned, P - Persistent static, C -
Control MAC
           SE - statistics enabled, NM - non configured MAC, R - remote PE MAC, O - ovsdb MAC,
           B - Blocked MAC)


Ethernet switching table : 3 entries, 3 learned
Routing instance : myMACVRF101
   Vlan                MAC                 MAC       GBP    Logical                SVLBNH/
Active
   name                address             flags     tag    interface              VENH Index
source
   vlan101             00:10:94:00:00:05   D                etet-0/0/4.0
   vlan101             00:10:94:00:00:06   DR               vtep-53.32773
10.203.113.11
   vlan101             6c:62:fe:b9:22:3d   DRP              vtep-53.32773
10.203.113.11
```

How to Configure Two Type 5 IP-VRFs

Use the following steps as a guide to configuring two Type 5 IP-VRFs on the same leaf node. We use actual values for example purposes. You should customize these steps with relevant values for your implementation.

1. Configure a VRF routing instance.

```
set routing-instances RT5-IPVRF1 instance-type vrf
```

2. Configure the EVPN protocol with Type 5 support.

```
set routing-instances RT5-IPVRF1 protocols evpn ip-prefix-routes advertise direct-nexthop
set routing-instances RT5-IPVRF1 protocols evpn ip-prefix-routes encapsulation vxlan
set routing-instances RT5-IPVRF1 protocols evpn ip-prefix-routes vni 1100
set routing-instances RT5-IPVRF1 protocols evpn ip-prefix-routes export my-t5-export-vrf1
```

3. Configure routing options.

```
set routing-instances RT5-IPVRF1 routing-options static route 192.168.10.10/32 discard
set routing-instances RT5-IPVRF1 routing-options multipath
```

4. Configure interfaces, RD, and VRF target.

```
set routing-instances RT5-IPVRF1 interface irb.101
set routing-instances RT5-IPVRF1 interface lo0.1
set routing-instances RT5-IPVRF1 route-distinguisher 10.203.113.10:200
set routing-instances RT5-IPVRF1 vrf-target target:1100:1100
set routing-instances RT5-IPVRF1 vrf-table-label
```

5. Configure a second Type 5 IP-VRF on the same leaf node. The full configuration is displayed. Note the differences in VLANs, RD, VRF-target, and interfaces.

```
set routing-instances RT5-IPVRF2 instance-type vrf
set routing-instances RT5-IPVRF2 routing-options static route 192.168.20.20/32 discard
set routing-instances RT5-IPVRF2 routing-options multipath
set routing-instances RT5-IPVRF2 protocols evpn ip-prefix-routes advertise direct-nexthop
set routing-instances RT5-IPVRF2 protocols evpn ip-prefix-routes encapsulation vxlan
set routing-instances RT5-IPVRF2 protocols evpn ip-prefix-routes vni 2100
set routing-instances RT5-IPVRF2 protocols evpn ip-prefix-routes export my-t5-export-vrf2
set routing-instances RT5-IPVRF2 interface irb.102
set routing-instances RT5-IPVRF2 interface lo0.2
set routing-instances RT5-IPVRF2 route-distinguisher 10.203.113.10:202
set routing-instances RT5-IPVRF2 vrf-target target:2100:2100
set routing-instances RT5-IPVRF2 vrf-table-label
```

6. The routing policy supporting each VRF is shown here.

```
set policy-options policy-statement loopback-advertise term loo from route-filter
10.203.113.10/32 exact
set policy-options policy-statement loopback-advertise term loo then accept

set policy-options policy-statement my-t5-export-vrf1 term term1 from route-filter
192.168.10.10/32 exact
set policy-options policy-statement my-t5-export-vrf1 term term1 then accept
set policy-options policy-statement my-t5-export-vrf1 term term2 from route-filter
10.10.101.0/24 orlonger
```

```
set policy-options policy-statement my-t5-export-vrf1 term term2 from route-filter
192.168.101.1/32 exact
set policy-options policy-statement my-t5-export-vrf1 term term2 then accept

set policy-options policy-statement my-t5-export-vrf2 term term1 from route-filter
192.168.20.20/32 exact
set policy-options policy-statement my-t5-export-vrf2 term term1 then accept
set policy-options policy-statement my-t5-export-vrf2 term term2 from route-filter
10.10.102.0/24 orlonger
set policy-options policy-statement my-t5-export-vrf2 term term2 from route-filter
192.168.102.1/32 exact
set policy-options policy-statement my-t5-export-vrf2 term term2 then accept

set policy-options policy-statement pplb then load-balance per-packet
```

Verification

Verify that routing is working as expected. Note that verification requires other network devices to be configured, and your outputs will vary.

```
user@device> show bgp summary

Threading mode: BGP I/O
Default eBGP mode: advertise - accept, receive - accept
Groups: 3 Peers: 6 Down peers: 1
Table          Tot Paths  Act Paths Suppressed    History Damp State    Pending
inet.0
                     11         11          0          0          0          0
bgp.evpn.0
                     34         17          0          0          0          0
Peer                     AS      InPkt     OutPkt    OutQ   Flaps Last Up/Dwn State|#Active/
Received/Accepted/Damped...
192.0.2.9            65534        713        699       0       0     5:17:25 Establ
  inet.0: 4/4/4/0
192.0.2.11           65534        709        699       0       0     5:17:25 Establ
  inet.0: 3/3/3/0
192.0.2.13           65534        713        699       0       0     5:17:25 Establ
  inet.0: 4/4/4/0
198.51.100.5         65512         18         24       0       1     5:40:07 Idle
10.203.113.13         65101        724        705       0       0     5:13:39 Establ
  bgp.evpn.0: 14/17/17/0
  myMACVRF101.evpn.0: 3/5/5/0
```

```
  myMACVRF102.evpn.0: 3/3/3/0
  __default_evpn__.evpn.0: 0/0/0/0
  RT5-IPVRF1.evpn.0: 4/5/5/0
  RT5-IPVRF2.evpn.0: 4/4/4/0
10.203.113.14          65101        687        679       0       0     5:04:10 Establ
  bgp.evpn.0: 3/17/17/0
  myMACVRF101.evpn.0: 2/5/5/0
  myMACVRF102.evpn.0: 0/3/3/0
  __default_evpn__.evpn.0: 0/0/0/0
  RT5-IPVRF1.evpn.0: 1/5/5/0
  RT5-IPVRF2.evpn.0: 0/4/4/0
```

```
user@device> show route table RT5-IPVRF1.evpn.0

RT5-IPVRF1.evpn.0: 10 destinations, 15 routes (10 active, 0 holddown, 0 hidden)
+ = Active Route, - = Last Active, * = Both

5:10.203.113.10:200::0::10.10.101.0::24/248
                   *[EVPN/170] 05:28:52
                       Fictitious
5:10.203.113.10:200::0::10.10.101.1::32/248
                   *[EVPN/170] 05:28:52
                       Fictitious
5:10.203.113.10:200::0::10.10.101.10::32/248
                   *[EVPN/170] 04:49:20
                       Fictitious
5:10.203.113.10:200::0::192.168.10.10::32/248
                   *[EVPN/170] 05:32:20
                       Fictitious
5:10.203.113.10:200::0::192.168.101.1::32/248
                   *[EVPN/170] 05:32:20
                       Fictitious
5:10.203.113.11:200::0::10.10.101.0::24/248
                   *[BGP/170] 04:42:18, localpref 100, from 10.203.113.13
                      AS path: 65101 64513 I, validation-state: unverified
                    >  to 192.0.2.11 via et-0/0/1.0, Push 1100
                       to 192.0.2.9 via et-0/0/0.0, Push 1100
                       to 192.0.2.13 via et-0/0/2.0, Push 1100
                    [BGP/170] 04:42:06, localpref 100, from 10.203.113.14
                      AS path: 65101 64513 I, validation-state: unverified
                    >  to 192.0.2.11 via et-0/0/1.0, Push 1100
```

```
                    to 192.0.2.9 via et-0/0/0.0, Push 1100
                    to 192.0.2.13 via et-0/0/2.0, Push 1100
```

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- Understanding EVPN with VXLAN Data Plane Encapsulation

CHAPTER 7

Authentication

802.1X Authentication on Layer 2 Interfaces

IN THIS SECTION

Overview

IN THIS SECTION

The IEEE 802.1X standard for port-based network access control (PNAC) provides a mechanism to authenticate users of devices attached to a LAN port. The 802.1X standard verifies the user's credentials in a local or remote user database. The authentication mechanism allows only users with the correct credentials to access the network. It denies access for all other users, thereby controlling network access.

The three basic components of a network with 802.1X authentication are:

- Authenticator port access entity (PAE): A switch or router port to which a client connects. Authenticator PAEs form the control gate that blocks all traffic to and from the clients until 802.1X authenticates the clients.
- Supplicants: Clients that are trying to access the network and need to be authenticated. Supplicants connect to authenticator PAEs.

- Authentication server: The back-end database containing information about the users that are allowed to connect to the network. When a supplicant attempts to log in, 802.1X sends the supplicant's credentials to this server for authentication.

After the authentication server authenticates the supplicant's credentials, the device stops blocking access on the PAE. The device opens the interface to the supplicant and allows it to access the network. You (the network administrator) can configure 802.1X on Layer 2 (L2) interfaces.

The 802.1X IEEE standard allows you to use any authentication server for client authentication. RADIUS servers are most commonly used because those servers are easy to configure. RADIUS servers also provide the option to define proprietary, or vendor-specific, attributes. The device and the server can exchange these attributes.

Benefits

- Authenticate users.
- Prevent bad actors from accessing your network.
- Control network access.

Configuration

1. Configure the L2 interface.

   For example:

```
set interfaces et-0/0/0 unit 0 family ethernet-switching interface-mode access
set interfaces et-0/0/0 unit 0 family ethernet-switching vlan members v10
set vlans v10 vlan-id 10
```

2. Enable 802.1X authentication.

   a. Single-supplicant mode:

```
set protocols dot1x authenticator interface et-0/0/0.0 supplicant single
```

   b. Single-secure-supplicant mode:

```
set protocols dot1x authenticator interface et-0/0/0.0 supplicant single-secure
```

c. Multiple-supplicant mode:

```
set protocols dot1x authenticator interface et-0/0/0.0 supplicant multiple
```

3. Create the 802.1X profiles and associate the profiles to 802.1X, the RADIUS authentication server, and the RADIUS accounting server.

   For example:

```
set access profile dot1x-auth-profile authentication-order radius
set access profile dot1x-auth-profile radius authentication-server address
set access profile dot1x-auth-profile radius accounting-server address
set protocols dot1x authenticator authentication-profile-name dot1x-auth-profile
set access profile dot1x-accounting authentication-order radius
set access profile dot1x-accounting accounting order radius
```

4. Configure the RADIUS authentication server.

   For example:

```
set access radius-server address port 1812
set access radius-server address secret secret
set access radius-server address timeout 3
set access radius-server address retry 3
set access radius-server address source-address source-address
```

5. Verify the configuration using the following commands.

   - **show vlans**
   - **show ethernet-switching table**
   - **show mac-vrf forwarding mac-table**
   - **show dot1x interface detail**

Platform Support

See Feature Explorer for platform and release support.

Related Documentation

- 802.1X Authentication
- authenticator