Configuring Modular QoS Congestion Management

This chapter covers the following topics:

Congestion Management Overview

Congestion management features allow you to control congestion by determining the order in which a traffic flow (or packets) is sent out an interface based on priorities assigned to packets. Congestion management entails the creation of queues, assignment of packets to those queues based on the classification of the packet, and scheduling of the packets in a queue for transmission.

The types of traffic regulation mechanisms supported are:

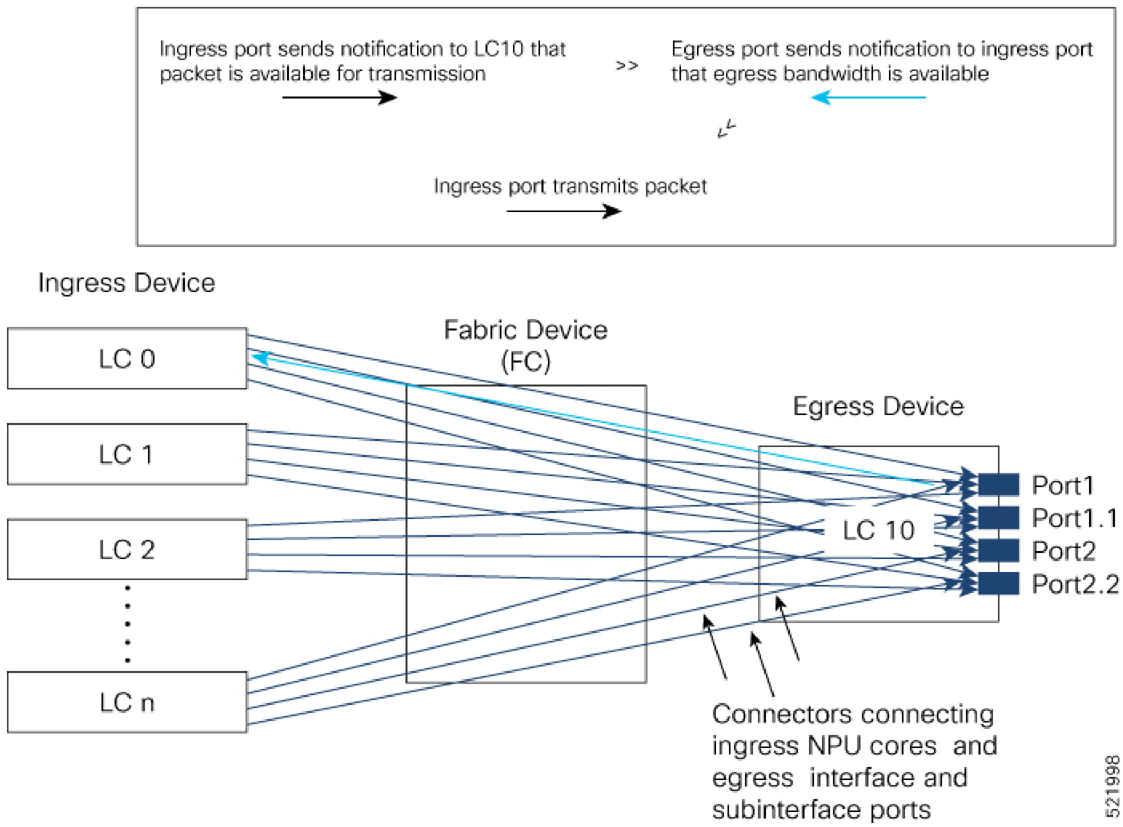
- Class-based Weighted Fair Queueing, on page 3
- Low-Latency Queuing with Strict Priority Queuing, on page 5
- Traffic Shaping, on page 10
- Traffic Policing, on page 13

Ingress Traffic Management Model

The ingress traffic management model relies on packet queueing on the egress interface using Virtual Output Queueing (VOQ) on the ingress. In this model, buffering takes place at ingress. Here’s how the VOQ process works.

Your routers support up to eight output queues per main interface or physical port. For every egress output queue, the VOQ model earmarks buffer space on every ingress pipeline. This buffer space is in the form of dedicated VOQs. These queues are called virtual because the queues physically exist on the ingress interface only when the line card actually has packets enqueued to it. To support the modular model of packet distribution, each network processing unit (NPU) core at the ingress needs connectors to every egress main interface and subinterface. The ingress traffic management model thus requires a mesh of connectors to connect the ingress NPU cores to the egress interfaces, as shown in **The Ingress Traffic Management Model**.

Figure 1: The Ingress Traffic Management Model



In the figure, every ingress interface (LC 0 through LC n) port has eight VOQs for the single egress line card LC 10.

Here’s how packet transmission takes place:

1. When a packet arrives at ingress port (say on LC 0), the forwarding lookup on ingress line card points to the egress interface. Based on the egress interface (say it is on LC10), the packet is enqueued to the VOQ of LC 10. The egress interface is always mapped to a physical port.
2. Once egress bandwidth is available, the LC 10 ports ready to receive the packets (based on the packet marking and distribution model) send grants to the ingress ports via the connectors. (The figure shows a separate line for the grant for the sake of visual representation. In reality, the same connector is used for requests, grants, and transmission between an NPU core at the ingress and the egress port on LC 10.)
3. The ingress ports respond to this permission by transmitting the packets via FC to the LC 10 ports. (The time it takes for the ingress ports to request for egress port access, the egress port to grant access, and the packet to travel across FC is the round-trip time.)

The VOQ model thus operates on the principle of storing excess packets in buffers at ingress until bandwidth becomes available. Based on the congestion that builds up and the configured threshold values, packets begin to drop at the ingress itself, instead of having to travel all the way to the egress interface and then getting dropped.

Class-based Weighted Fair Queueing

Class-based Weighted Fair Queueing (CBWFQ) allows definition of traffic classes based on customer match criteria. With CBWFQ you can define traffic classes and assign guaranteed amount of minimum bandwidth to them. CBWFQ also allows for a strict priority queue for delay-sensitive traffic.

Bandwidth Remaining

The CBWFQ algorithm derives the weight for each class from the bandwidth remaining value allocated to the class. The **bandwidth remaining** option specifies a weight for the class to the CBWFQ . After the priority-queue is serviced, the leftover bandwidth is distributed as per bandwidth remaining ratio (BWRR) or percentage. If you do not configure this command for any class, the default value of the BWRR is considered as 1 (one). In the case of **bandwidth remaining percent**, the remaining bandwidth is equally distributed among other classes, to make it 100 percentage (100%).

Restrictions

- The **bandwidth remaining** command is supported only for egress policies.

Configure Minimum Bandwidth and Bandwidth Remaining

Guidelines

- The **priority** command cannot be configured along with **bandwidth**, **bandwidth remaining** commands, but can be configured with **shaping**, **queue-limit** and **random-detect** commands in the same class. Also see Restrictions for Configuring H-QoS.

Configuration Example

You have to accomplish the following to complete the minimum bandwidth and bandwidth remaining configuration:

1. Creating or modifying a policy-map that can be attached to one or more interfaces
2. Specifying the traffic class whose policy has to be created or changed
3. Allocating the minimum bandwidth and leftover bandwidth for the class
4. Attaching the policy-map to an output interface

```
Router# configure
Router(config)# policy-map test-bw-bw-rem
Router(config-pmap)# class qos-6
Router(config-pmap-c)# bandwidth percent 60
Router(config-pmap-c)# bandwidth remaining percent 60
```

```
Router(config-pmap-c# exit
Router(config-pmap)# exit
Router(config)# interface HundredGigE 0/6/0/18
Router(config-if)# service-policy output test-bw-bw-rem
Router(config-if)# commit
```

Running Configuration

```
policy-map test-bw-bw-rem
 class qos-6
  bandwidth percent 60
  bandwidth remaining percent 60
 !
 class qos-5
  bandwidth percent 20
  bandwidth remaining percent 40
 !
 class class-default
 !
 end-policy-map
!

interface HundredGigE0/6/0/18
 service-policy input 100g-s1-1
 service-policy output test-bw-bw-rem
!
```

Verification

```
Router# show qos interface HundredGigE 0/6/0/18 output

NOTE:- Configured values are displayed within parentheses
Interface HundredGigE0/6/0/18 ifh 0x3000220  -- output policy
NPU Id:                        3
Total number of classes:       3
Interface Bandwidth:           100000000 kbps
VOQ Base:                      11176
VOQ Stats Handle:              0x88550ea0
Accounting Type:               Layer1 (Include Layer 1 encapsulation and above)
------------------------------------------------------------------------------
Level1 Class                             =   qos-6
Egressq Queue ID                         =   11182 (LP queue)
Queue Max. BW.                           =   100824615 kbps (default)
Queue Min. BW.                           =   60494769 kbps (60 %)
Inverse Weight / Weight                  =   2 (60%)
Guaranteed service rate                  =   71881188 kbps
TailDrop Threshold                       =   90177536 bytes / 10 ms (default)
WRED not configured for this class

Level1 Class                             =   qos-5
Egressq Queue ID                         =   11181 (LP queue)
Queue Max. BW.                           =   100824615 kbps (default)
Queue Min. BW.                           =   20164923 kbps (20 %)
Inverse Weight / Weight                  =   3 (40%)
Guaranteed service rate                  =   27920792 kbps
TailDrop Threshold                       =   35127296 bytes / 10 ms (default)
WRED not configured for this class

Level1 Class                             =   class-default
```

```
Egressq Queue ID                        =   11176 (Default LP queue)
Queue Max. BW.                          =   101803495 kbps (default)
Queue Min. BW.                          =   0 kbps (default)
Inverse Weight / Weight                 =   120 (BWR not configured)
Guaranteed service rate                 =   198019 kbps
TailDrop Threshold                      =   247808 bytes / 10 ms (default)
WRED not configured for this class
```

Related Topics

- Bandwidth Remaining, on page 3

Associated Commands

- bandwidth
- bandwidth remaining

Low-Latency Queuing with Strict Priority Queuing

The Low-Latency Queuing (LLQ) feature brings strict priority queuing (PQ) to the CBWFQ scheduling mechanism. Priority queuing (PQ) in strict priority mode ensures that one type of traffic is sent, possibly at the expense of all others. For PQ, a low-priority queue can be detrimentally affected, and, in the worst case, never allowed to send its packets if a limited amount of bandwidth is available or the transmission rate of critical traffic is high.

Configuring Low Latency Queuing with Strict Priority queuing

Configuring low latency queuing (LLQ) with strict priority queuing (PQ) allows delay-sensitive data such as voice to be de-queued and sent before the packets in other queues are de-queued.

Guidelines

- Only priority level 1 to 7 is supported, with 1 being the highest priority and 7 being the lowest. However, the default CoSQ 0 has the lowest priority among all.
- Priority level 1 to 7 is supported for non-H-QoS profiles, with 1 being the highest priority and 7 being the lowest. For H-QoS profiles, priority level 1 to 4 is supported. For all profiles, however, the class default is CoSQ 0 and has the lowest priority among all.
- Egress policing is not supported. Hence, in the case of strict priority queuing, there are chances that the other queues do not get serviced.
- You can configure **shape average** and **queue-limit** commands along with **priority**.
- A Priority Queue (PQ) can oversubscribe bandwidth when other queues do not utilize the entire port bandwidth. However, oversubscription of traffic is supported only with a single priority level.

Configuration Example

You have to accomplish the following to complete the LLQ with strict priority queuing:

1. Creating or modifying a policy-map that can be attached to one or more interfaces
2. Specifying the traffic class whose policy has to be created or changed.
3. Specifying priority to the traffic class
4. (Optional) Shaping the traffic to a specific bit rate
5. Attaching the policy-map to an output interface

```
Router# configure
Router(config)#class-map qos-1
Router(config-cmap)#match traffic-class 1
Router(config-cmap)#commit

Router(config)#class-map qos-2
Router(config-cmap)#match traffic-class 2
Router(config-cmap)#commit

Router(config)# policy-map test-priority-1
Router(config-pmap)# class qos1
Router(config-pmap-c)# priority level 7
Router(config-pmap-c)# shape average percent 2
Router(config-pmap-c)# class qos-2
Router(config-pmap-c)# priority level 6
Router(config-pmap-c)# shape average percent 1
Router(config-pmap-c)# commit
Router(config-pmap-c# exit
Router(config-pmap)# exit

Router(config)# interface HundredGigE 0/0/0/20
Router(config-if)# service-policy output test-priority-1
Router(config-if)# commit
```

Running Configuration

```
policy-map test-priority-1
 class qos-1
  priority level 7
  shape average percent 2
 !
 class qos-2
  priority level 6
  shape average percent 1
 !
 class class-default
 !
 end-policy-map
!

interface HundredGigE0/0/0/20
 service-policy output test-priority-1
!
```

Verification

```
Router#  show qos int hundredGigE 0/0/0/20 output
```

```
NOTE:- Configured values are displayed within parentheses
Interface HundredGigE0/0/0/20 ifh 0x38  -- output policy
NPU Id:                        0
Total number of classes:       3
Interface Bandwidth:           100000000 kbps
Policy Name:                   test-priority-1
VOQ Base:                      1184
Accounting Type:               Layer1 (Include Layer 1 encapsulation and above)
------------------------------------------------------------------------------
Level1 Class (HP7)                       =   qos-1
Egressq Queue ID                         =   1185 (HP7 queue)
Queue Max. BW.                           =   2000000 kbps (2 %)
Guaranteed service rate                  =   2000000 kbps
Peak burst                               =   36864 bytes (default)
TailDrop Threshold                       =   2499840 bytes / 10 ms (default)
WRED not configured for this class

Level1 Class (HP6)                       =   qos-2
Egressq Queue ID                         =   1186 (HP6 queue)
Queue Max. BW.                           =   1000000 kbps (1 %)
Guaranteed service rate                  =   1000000 kbps
Peak burst                               =   36864 bytes (default)
TailDrop Threshold                       =   1249792 bytes / 10 ms (default)
WRED not configured for this class

Level1 Class                             =   class-default
Egressq Queue ID                         =   1184 (Default LP queue)
Queue Max. BW.                           =   no max (default)
Queue Min. BW.                           =   0 kbps (default)
Inverse Weight / Weight                  =   1 / (BWR not configured)
Guaranteed service rate                  =   97000000 kbps
Peak burst                               =   36864 bytes (default)
TailDrop Threshold                       =   121249792 bytes / 10 ms (default)
WRED not configured for this class
```

Related Topics

- Congestion Management Overview, on page 1
- Configure Traffic Shaping, on page 10
- Bandwidth Remaining, on page 3

Associated Commands

- priority

Overhead Accounting

Traffic shapers and policers use packet traffic descriptors to ensure adherence to the service level agreement in QoS. However, when traffic flows from one hop to another in a network, headers added or removed at interim hops affect the packet bytes being accounted for by QoS at each hop. When your end-user network measures the packet bytes to ensure they receive the payload as agreed, these additional header bytes cause a discrepancy.

QoS overhead accounting provides the flexibility to operators to decide which header bytes can be excluded by the traffic shaper and policer and which can be included, depending on the end user's requirements and device capabilities, to meet the committed payload in units of bytes.

For example, if the QoS commitment includes the additional header bytes, the overhead accounting feature allows your router to account for this overhead and reduces the traffic policing and shaping rates accordingly. This is also called a **positive accounting overhead**.

If however, the committed rate doesn't include the additional bytes, overhead accounting allows your router to adjust the core stream traffic such that the traffic policing and shaping rates are increased. This is also called a **negative accounting overhead**.

To summarize, QoS overhead accounting enables the router to account for packet overhead when shaping and policing traffic to a specific rate. This accounting ensures that the router runs QoS features on the actual bandwidth that the subscriber traffic consumes.

Any interface that supports QoS policies supports overhead accounting.

> **Note** You can enable user overhead accounting using the optional configuration of **accounting user-defined** ***<overhead size in bytes>*** while attaching the service policy on the egress interface.

Guidelines and Restrictions

- Overhead accounting for ingress shaping is not supported.

The following restrictions apply for routers that have Cisco NC57 line cards installed and operate in native and compatibility modes.

- More than one compensation value can be programmed, provided you configure egress policy maps on different egress ports.
- You must configure a unique compensation value for a main interface and all sub-interfaces belonging to that main interface. You can't program different compensation values on different sub-interfaces sharing a common main interface.
- You can configure different compensation values on different sub-interfaces if they belong to other main interfaces.
- Compensation value programmed on egress queues (but not on VoQs) will remain active until the last egress policy map (with header compensation) is removed from main or sub-interfaces. This may impact traffic flow on main and sub-interfaces even though no compensation is set for them.

The following restrictions apply for routers that have line cards other than Cisco NC57 line cards.

- You can't program more than one compensation value per NPU or router, even if they're on different egress ports.
- You can configure the same egress compensation for different egress ports.
- NPUs can have different compensation values configured on different line cards in a modular system.
- Compensation value programmed on egress queues (but not on VoQs) will remain active until the last egress policy map (with header compensation) is removed from main or sub-interfaces. This may impact traffic flow on main and sub-interfaces even though no compensation is set for them.

Configuring for Overhead Accounting

To configure overhead accounting, you must:

1. Create a policy map and configure QoS actions for that map.
2. Configure overhead accounting and attach the map to an interface.

```
/* create QoS policy */
Router#configure terminal
Router(config)#policy-map policer
Router(config-pmap)#class class-default
Router(config-pmap-c)#police rate percent 10
Router(config-pmap-c-police)#commit

/* configure account overhead value while attaching the QoS policy to interface */
Router(config)#int hundredGigE 0/0/0/2
Router(config-if)#service-policy input policer account user-defined 12
Router(config-if)#commit
Router(config-if)#root
Router(config)#end
```

Running Configuration

```
Router#sh run int hundredGigE 0/0/0/2
interface HundredGigE0/0/0/2
service-policy input policer account user-defined 12
!
```

The following example shows how to **configure a negative overhead accounting value**:

```
Router#conf
Router(config)#int hundredGigE 0/0/0/2
Router(config-if)#service-policy input policer account user-defined -12
Router(config-if)#commit
```

To **modify an overhead accounting value,** you must:

1. Remove the existing QoS policy and re-add it.
2. Configure the new overhead accounting value.

```
Router#conf
Router(config)#int hundredGigE 0/0/0/2
Router(config-if)#no service-policy input policer
Router(config-if)#service-policy input policer account user-defined -20
Router(config-if)#commit
Router#sh run int hundredGigE 0/0/0/2
interface HundredGigE0/0/0/2
service-policy input policer account user-defined -20
!
```

Positive Accounting Use Case

If QoS commitment includes Preamble, Frame Delimiter & Interframe Gap and has the following configuration:

```
service-policy input <foo> account user-defined +20
```

For QoS purposes, your router treats this packet as a packet of size = Actual Packet size + 20. Hence, the effective policing and shaping is *reduced* to match the downstream interface.

Negative Accounting Use Case

If QoS commitment to your router does not include VLAN header information, and has the following configuration:

```
service-policy input <foo> account user-defined -4
```

For QoS purposes, your router treats this packet as a packet of size = Actual Packet size – 4. Hence, the effective policing and shaping is *increased* to match the downstream interface.

Associated Commands

service-policy (overhead accounting)

Traffic Shaping

Traffic shaping allows you to control the traffic flow exiting an interface to match its transmission to the speed of the remote target interface and ensure that the traffic conforms to policies contracted for it. Traffic adhering to a particular profile can be shaped to meet downstream requirements, hence eliminating bottlenecks in topologies with data-rate mismatches.

Note If you apply a policy map that has configured traffic policing and traffic shaping on the basis of a percentage of bandwidth available on the interface and you change the speed of the interface, you must delete that policy map and reattach it to the interface. Else, QoS programming for the earlier speed remains in effect and does not change with change in the port speed.

Note Traffic shaping is supported only in egress direction.

Configure Traffic Shaping

The traffic shaping performed on outgoing interfaces is done at the Layer 1 level and includes the Layer 1 header in the rate calculation.

Guidelines

- Only egress traffic shaping is supported.
- It is mandatory to configure all the eight traffic-class classes (including class-default) for the egress policies.
- You can configure **shape average** command along with **priority** command.

Configuration Example

You have to accomplish the following to complete the traffic shaping configuration:

1. Creating or modifying a policy-map that can be attached to one or more interfaces
2. Specifying the traffic class whose policy has to be created or changed
3. Shaping the traffic to a specific bit rate and set peak burst size
4. Attaching the policy-map to an output interface

```
Router# configure
Router(config)#class-map c5
Router(config-cmap)#match traffic-class 5
Router(config-cmap)#commit

Router(config)# policy-map egress_policy1
Router(config-pmap)# class c5
Router(config-pmap-c)# shape average percent 50 1000
Router(config-pmap-c# exit
Router(config-pmap)# exit
Router(config)# interface HundredGigE 0/1/0/0
Router(config-if)# service-policy output egress_policy1
Router(config-if)# commit
```

Running Configuration

```
class-map c5
 match traffic-class 5
commit

policy-map egress_policy1
 class c5
  shape average percent 50 1000
 !
 class class-default
 !
 end-policy-map
!

interface HundredGigE0/6/0/18
 service-policy output egress_policy1
!
```

Verification

```
Router#  ios#show qos interface tenGigE 0/0/0/0 output

Wed Jul 10 14:18:37.783 UTC
NOTE:- Configured values are displayed within parentheses
Interface TenGigE0/0/0/0 ifh 0x120  -- output policy
NPU Id:                        0
Total number of classes:       1
Interface Bandwidth:           10000000 kbps
Policy Name:                   test
VOQ Base:                      1024
Accounting Type:               Layer1 (Include Layer 1 encapsulation and above)
------------------------------------------------------------------------------
Level1 Class                             =   class-default
Egressq Queue ID                         =   1024 (Default LP queue)
Queue Max. BW.                           =   5031499 kbps (50 %)
Queue Min. BW.                           =   0 kbps (default)
Inverse Weight / Weight                  =   1 / (BWR not configured)
Guaranteed service rate                  =   5000000 kbps
Peak burst                               =   2240 bytes (1000 bytes)
TailDrop Threshold                       =   6258688 bytes / 10 ms (default)
```

Important Notes

From Cisco IOS XR Release 6.6.25 onwards, a shaper on a bundle interface also allows absolute rates apart from the already supported units of percentage, per-thousand and per-million.

Related Topics

- Congestion Management Overview, on page 1

Associated Commands

- shape average

Port Shaping

Port shaping, or port-based traffic shaping, is a technique used in QoS to control and manage network traffic on specific ports. You can assign a network's traffic to different ports based on the destination or source IP address, application, or protocol. Port shaping allows you to prioritize or limit the bandwidth on specific ports to ensure that critical applications receive sufficient network resources while non-critical traffic is restricted.

By implementing port shaping, you can define rules and policies to control the bandwidth allocated to specific ports. This enables you to prioritize critical traffic, such as voice or video conferencing, and restrict or limit the bandwidth for less critical traffic, such as file downloads or web browsing.

Port shaping can help prevent network congestion, optimize network performance, and ensure that bandwidth is allocated efficiently to meet the requirements of different applications or services.

Key Differences Between VOQ-Level and Port-Level Shapers

Table 1: Differences Between VOQ-level and Port-level Shapers

VOQ-Level Shaper	Port-Level Shaper
Operates at the individual output queue level within a network device. It shapes the traffic on a per-queue basis.	Operates at a network device's interface or port level. It shapes the overall traffic on the port, affecting all the traffic passing through that interface.
Helps prevent congestion and manage bandwidth allocation for different traffic flows or classes within the device.	Helps manage the aggregate bandwidth usage for the entire port, ensuring fair sharing of resources and preventing excessive congestion.
Allows for granular control and shaping of traffic at the queue level, enabling prioritization and allocation of bandwidth for different types of traffic.	Provides high-level control over the shaping of traffic, as it shapes all the traffic passing through the port without differentiating between individual flows or classes.
Useful when you need to manage and shape traffic per-flow or per-class basis, providing more precise control.	Helpful when you want to manage the overall bandwidth utilization of a port and ensure fairness among different traffic flows without the need for fine-grained control or differentiation between specific traffic types.

Burst Size for VOQ-Level Shaper

Virtual Output Queue (VOQ)-level shaper burst refers to the burst size or capacity set in a VOQ-level shaper.

A VOQ level shaper within a switch or router regulates the rate at which packets are transmitted from the VOQs to the output ports in a given time interval.

The burst size or capacity in a VOQ-level shaper determines the maximum number of packets or bytes transmitted from a VOQ during a burst. It defines the burst size allowed before the shaper starts limiting the traffic to conform to the specified rate.

For example, if you want to rate limit traffic to 20 Mbps and you set the burst size to 1000000 bytes, then the traffic rate is measured in a time window of:

1000000*8/20000000 sec= 400 ms

This means that 1000000 Bytes are allowed within the time window of 400 ms, no matter how fast they are sent, and that if there are more bytes in this time window, the shaper that you configured takes action.

The burst setting is thus essential in VOQ-level shaping as it affects the burstiness or the ability to handle traffic bursts. A larger burst size allows larger traffic bursts to be transmitted before the shaping mechanism restricts the flow to conform to the desired rate. Similarly, a smaller burst size limits the burstiness of the traffic and ensures a smoother and more controlled transmission.

Configure Burst Size for VOQ-Level Shaper

Can we get one configuration and verification example for VOQ-level shaper and burst which captures what was happening pre-R7111?

Traffic Policing

Traffic policing allows you to control the maximum rate of traffic sent or received on an interface and to partition a network into multiple priority levels or class of service (CoS).Traffic policing manages the maximum rate of traffic through a token bucket algorithm. The token bucket algorithm uses user-configured values to determine the maximum rate of traffic allowed on an interface at a given moment in time. The token bucket algorithm is affected by all traffic entering or leaving the interface (depending on where the traffic policy with traffic policing is configured) and is useful in managing network bandwidth in cases where several large packets are sent in the same traffic stream. By default, the configured bandwidth value takes into account the Layer 2 encapsulation that is applied to traffic leaving the interface.

Traffic policing also provides a certain amount of bandwidth management by allowing you to set the burst size (Bc) for the committed information rate (CIR). See, Committed Bursts and Excess Bursts, on page 14.

The router supports the following traffic policing mode(s):

- Single-Rate Two-Color (SR2C) in color-blind mode. See Single-Rate Policer, on page 15.
- Single-Rate Three-Color (SR3C) in color-blind mode.
- Two-Rate Three-Color (2R3C) in color-blind mode. See Two-Rate Policer, on page 19 .

Note In NC57-18DD-SE,QoS enhanced stats is enabled by default.

Restrictions

- If you apply a policy map that has configured traffic policing and traffic shaping on the basis of a percentage of bandwidth available on the interface and you change the speed of the interface, you must delete that policy map and reattach it to the interface. Else, QoS programming for the earlier speed remains in effect and does not change with change in the port speed.
- Traffic policing is supported only in ingress direction, and only color-blind mode is supported.
- The policing rate accuracy may vary up to +/-2% from the configured policer value.
- Ensure that you don't configure a policer and match criteria for **discard-class** in the same class. Even though the configuration is allowed, the policer doesn't work and allows all traffic without dropping packets.
- Policer marking is not supported.
- Policers are configured in the interface at the core level and "show qos int <>" value is displayed at the NPU level.

  For policers configured in a bundle interface where bundle members are from the same NPU but different cores (NPU cores), each member sends the traffic up to the core level policer configuration, but "show qos int <>" displays the NPU level policer output.
- Example:

  For bundle interface with two 10GE members (same NPU, but one interface from core0, one interface from core1) 2R3C policer applied on bundle interface (1G confirm rate , 1G exceed rate – total 2G policer rate) will be shown on the "show qos int <>" output):

  Interface in core0 – 500 Mbps confirm rate, 500 Mbps exceed rate

  Interface in core1 – 500 Mbps confirm rate, 500 Mbps exceed rate

  For traffic in one out of two interfaces, the policed rate will be 1Gbps. For traffic on two interfaces, policed rate will be 2Gbps.

Committed Bursts and Excess Bursts

Unlike a traffic shaper, a traffic policer does not buffer excess packets and transmit them later. Instead, the policer executes a "send or do not send" policy without buffering. Policing uses normal or committed burst (bc) values and excess burst values (be) to ensure that the router reaches the configured committed information rate (CIR). Policing decides if a packet conforms or exceeds the CIR based on the burst values you configure. Burst parameters are based on a generic buffering rule for routers, which recommends that you configure buffering to be equal to the round-trip time bit-rate to accommodate the outstanding TCP windows of all connections in times of congestion. During periods of congestion, proper configuration of the excess burst parameter enables the policer to drop packets less aggressively.

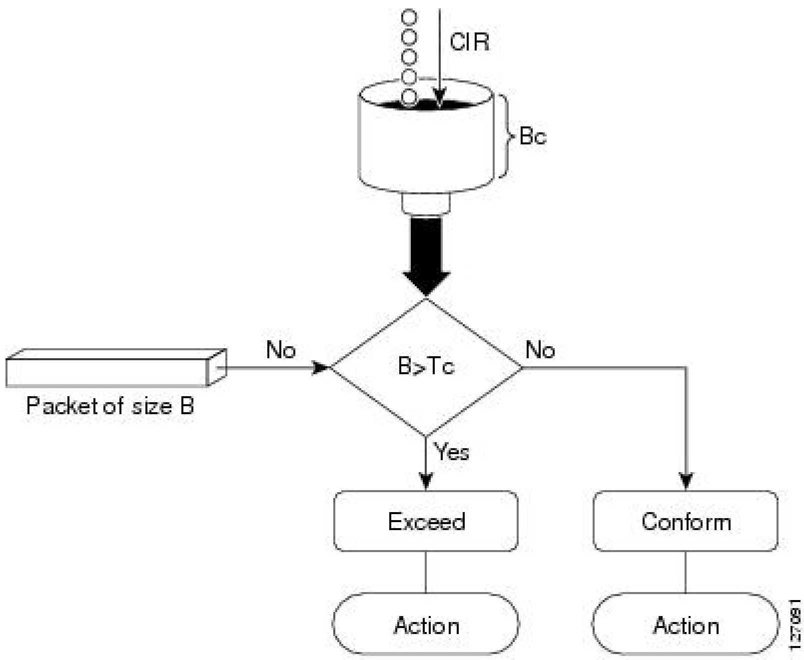
For more details, see Committed Bursts, on page 25 and Excess Bursts, on page 26.

Single-Rate Policer

Single-Rate Two-Color Policer

A single-rate two-color (SR2C) policer provides one token bucket with two actions for each packet: a conform action and an exceed action.

Figure 2: Workflow of Single-Rate Two-Color Policer



Based on the committed information rate (CIR) value, the token bucket is updated at every refresh time interval. The Tc token bucket can contain up to the Bc value, which can be a certain number of bytes or a period of time. If a packet of size B is greater than the Tc token bucket, then the packet exceeds the CIR value and a default action is performed. If a packet of size B is less than the Tc token bucket, then the packet conforms and a different default action is performed.

Single-Rate Three-Color Policer

A single-rate three-color (SR3C) policer provides one token bucket with three actions for each packet: a conform action, an exceed action and a violate action. The packet is marked based on the CIR value and the two associated burst size - committed burst size (CBS) and excess burst size (EBS). If a packet does not exceed the CBS, it is marked as conformed packet. The packet is marked as exceeded if it exceeds CBS, but not the EBS. If it exceeds the EBS as well, it is marked as violate packet.

Configure Traffic Policing (Single-Rate Two-Color)

Traffic policing is often configured on interfaces at the edge of a network to limit the rate of traffic entering or leaving the network. The default conform action for single-rate two color policer is to transmit the packet and the default exceed action is to drop the packet. Users cannot modify these default actions.

Configuration Example

You have to accomplish the following to complete the traffic policing configuration:

1. Creating or modifying a policy-map that can be attached to one or more interfaces
2. Specifying the traffic class whose policy has to be created or changed
3. (Optional) Specifying the marking action
4. Specifying the policy rate for the traffic
5. Attaching the policy-map to an input interface

```
Router# configure
Router(config)# policy-map test-police-1
Router(config-pmap)# class  ipv6-6
Router(config-pmap-c)# set dscp cs2 (optional)
Router(config-pmap-c)# set qos-group 7 (optional)
Router(config-pmap-c)# police rate percent 20 burst 10000 bytes
Router(config-pmap-c-police)# exit
Router(config-pmap-c)# exit
Router(config-pmap)# exit
Router(config)# interface HundredGigE 0/6/0/18
Router(config-if)# service-policy input test-police-1
Router(config-if)# commit
```

Running Configuration

```
class-map match-any ipv6-6
 match precedence 3
 end-class-map
!

policy-map test-police-1
 class ipv6-6
  set dscp cs2
  set qos-group 7
  police rate percent 20 burst 10000 bytes
   !
  !
 class class-default
  !
 end-policy-map
!

interface HundredGigE0/6/0/18
 service-policy input test-police-1
 service-policy output test-priority-1
!
```

Verification

```
Router# show qos interface hundredGigE 0/6/0/18 input

NOTE:- Configured values are displayed within parentheses
Interface HundredGigE0/6/0/18 ifh 0x3000220  -- input policy
NPU Id:                        3
```

```
Total number of classes:       2
Interface Bandwidth:           100000000 kbps
Accounting Type:               Layer1 (Include Layer 1 encapsulation and above)
------------------------------------------------------------------------------
Level1 Class                              =   ipv6-6
New dscp                                  =   16
New qos group                             =   7

Policer Bucket ID                         =   0x102a0
Policer Stats Handle                      =   0x8a8090c0
Policer committed rate                    =   19980000 kbps (20 %)
Policer conform burst                     =   9856 bytes (10000 bytes)

Level1 Class                              =   class-default

Default Policer Bucket ID                 =   0x102a1
Default Policer Stats Handle              =   0x8a808e78
Policer not configured for this class
```

Related Topics

- Traffic Policing, on page 13

Associated Commands

- police rate

Configure Traffic Policing (Single-Rate Three-Color)

The default conform action and exceed actions for single-rate three-color policer are to transmit the packet and the default violate action is to drop the packet. User cannot modify these default actions.

Configuration Example

You have to accomplish the following to complete the traffic policing configuration:

1. Creating or modifying a policy-map that can be attached to one or more interfaces
2. Specifying the traffic class whose policy has to be created or changed
3. (Optional) Specifying the marking action
4. Configuring the policy rate for the traffic along with the peak-burst values
5. Attaching the policy-map to an input interface

```
Router# configure
Router(config)# policy-map test-police-1R3C
Router(config-pmap)# class ipv4-5
Router(config-pmap-c)# set qos-group 2 (optional)
Router(config-pmap-c)# police rate percent 20 burst 100000 bytes peak-burst 190000 bytes
Router(config-pmap-c-police)# exit
Router(config-pmap-c)# exit
Router(config-pmap)# exit
Router(config)# interface HundredGigE 0/6/0/18
Router(config-if)# service-policy input test-police-1R3C
```

```
Router(config-if)# commit
```

Running Configuration

```
class-map match-any ipv4-5
 match precedence 3
 end-class-map
!

policy-map test-police-1R3C
 class ipv4-5
  set qos-group 7
  police rate percent 20 burst 100000 bytes peak-burst 190000 bytes
  !
 !
 class class-default
 !
 end-policy-map
!

interface HundredGigE0/6/0/18
 service-policy input test-police-1R3C
 service-policy output test-priority-1
!
```

Verification

```
Router# show qos interface hundredGigE 0/6/0/18 input

NOTE:- Configured values are displayed within parentheses
Interface HundredGigE0/6/0/18 ifh 0x3000220  -- input policy
NPU Id:                        3
Total number of classes:       2
Interface Bandwidth:           100000000 kbps
Accounting Type:               Layer1 (Include Layer 1 encapsulation and above)
------------------------------------------------------------------------------
Level1 Class                             =   ipv4-5
New qos group                            =   2

Policer Bucket ID                        =   0x102a1
Policer Stats Handle                     =   0x8a8090c0
Policer committed rate                   =   19980000 kbps (20 %)
Policer conform burst                    =   99584 bytes (100000 bytes)
Policer exceed burst                     =   188672 bytes (190000 bytes)

Level1 Class                             =   class-default

Default Policer Bucket ID                =   0x102a1
Default Policer Stats Handle             =   0x8a808e78
Policer not configured for this class
```

Related Topics

- Traffic Policing, on page 13

Associated Commands

- police rate

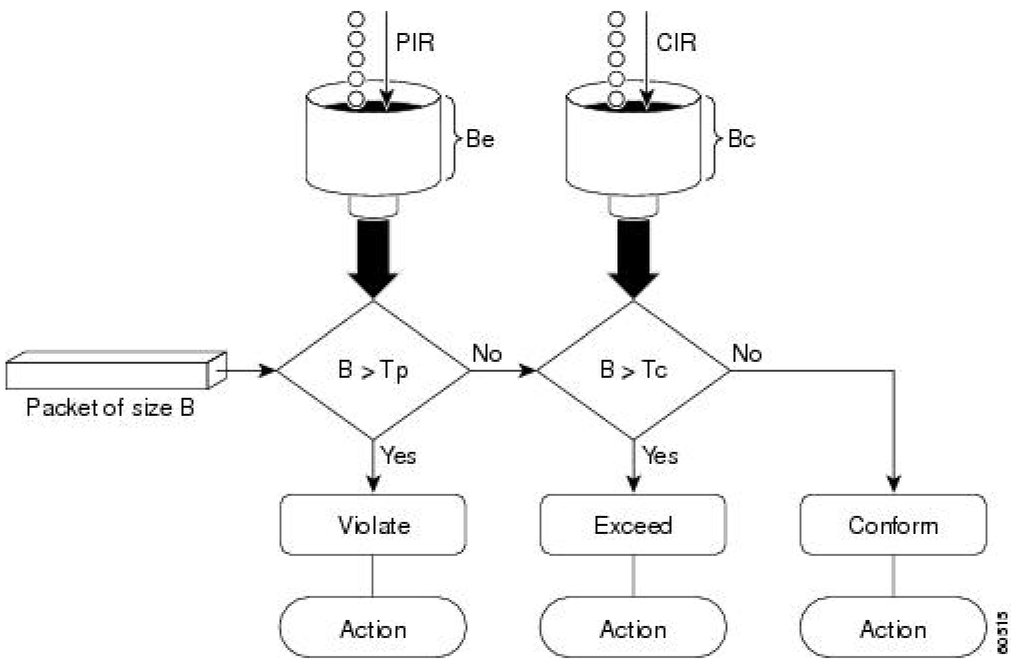
Two-Rate Policer

The two-rate policer manages the maximum rate of traffic by using two token buckets: the committed token bucket and the peak token bucket. The dual-token bucket algorithm uses user-configured values to determine the maximum rate of traffic allowed on a queue at a given moment. In this way, the two-rate policer can meter traffic at two independent rates: the committed information rate (CIR) and the peak information rate (PIR).

The dual-token bucket algorithm provides users with three actions for each packet—a conform action, an exceed action, and an optional violate action. Traffic entering a queue with the two-rate policer configured is placed into one of these categories. The actions are pre-determined for each category. The default conform and exceed actions are to transmit the packet, and the default violate action is to drop the packet.

This figure shows how the two-rate policer marks a packet and assigns a corresponding action to the packet.

Figure 3: Marking Packets and Assigning Actions—Two-Rate Policer



Also, see Two-Rate Policer Details, on page 26.

The router supports Two-Rate Three-Color (2R3C) policer.

Configure Traffic Policing (Two-Rate Three-Color)

The default conform and exceed actions for two-rate three-color (2R3C) policer are to transmit the packet and the default violate action is to drop the packet. Users cannot modify these default actions.

Configuration Example

You have to accomplish the following to complete the two-rate three-color traffic policing configuration:

1. Creating or modifying a policy-map that can be attached to one or more interfaces
2. Specifying the traffic class whose policy has to be created or changed
3. Specifying the packet marking
4. Configuring two rate traffic policing
5. Attaching the policy-map to an input interface

```
Router# configure
Router(config)# policy-map policy1
Router(config-pmap)# class ipv4-7
Router(config-pmap-c)# set qos-group 4
Router(config-pmap-c)# police rate percent 20 burst 100000 bytes peak-rate percent 50
peak-burst 200000 bytes
Router(config-pmap-c-police)# exit
Router(config-pmap-c)# exit
Router(config-pmap)# exit
Router(config)# interface HundredGigE 0/6/0/18
Router(config-if)# service-policy input policy1
Router(config-if)# commit
```

Running Configuration

```
policy-map policy1
 class ipv4-7
  set qos-group 4
  police rate percent 20 burst 100000 bytes peak-rate percent 50 peak-burst 200000 bytes
  !
 !

interface HundredGigE 0/6/0/18
 service-policy input policy1
!
```

Verification

```
Router# show policy-map interface HundredGigE 0/6/0/18

NOTE:- Configured values are displayed within parentheses
Interface HundredGigE0/6/0/18 ifh 0x3000220  -- input policy
NPU Id:                        3
Total number of classes:       8
Interface Bandwidth:           100000000 kbps
Accounting Type:               Layer1 (Include Layer 1 encapsulation and above)
------------------------------------------------------------------------------
Level1 Class                             =   ipv4-4
- - -
- - -
Level1 Class                             =   ipv4-7
New qos group                            =   4

Policer Bucket ID                        =   0x102a3
Policer Stats Handle                     =   0x8a8089e8
Policer committed rate                   =   19980000 kbps (20 %)
Policer peak rate                        =   49860000 kbps (50 %)
```

```
Policer conform burst                    =   99584 bytes (100000 bytes)
Policer exceed burst                     =   199168 bytes (200000 bytes)

Level1 Class                             =   class-default

Policer Bucket ID                        =   0x102a7
Policer Stats Handle                     =   0x8a7c8510
Policer committed rate                   =   29880000 kbps (30 %)
Policer conform burst                    =   4194304 bytes (default)
```

Important Notes

- From Cisco IOS XR Release 6.6.25 onwards:
  - a committed information rate of 0 kbps is supported, which is the only exception to the minimum rate of 22 kbps for both commit and excess rates.
  - a policer on a bundle interface also allows absolute rates apart from the already supported units of percent, per-thousand and per-million.
- A policer is programmed per NPU core on a bundle interface. So, all members on a bundle interface from the same core share the policer.

Related Topics

- Two-Rate Policer, on page 19

Associated Commands

- police rate

Per-thousand and Per-million Units

Shaper and policer rates can be configured in units of per-thousand and per-million on bundle interfaces. This provides the ability to provision shape and police rates down to 100 kbps on bundle or link aggregation (LAG) interfaces even with 100 GE bundle members.

For example, consider a 100GE interface and simple policy.

```
Interface HundredGig0/0/0/0
Service-policy output TEST
Policy-map TEST
Class C
 Shape average per-thousand 5
End-policy
```

Per thousand represents 0.1% of the link bandwidth and per million represents 0.0001% of the link bandwidth.

Which means that for a 100G link, 5 parts per thousand is 0.5% of the link bandwidth. Hence, the shape average per thousand of 5 in the above example enforces a shaper of 500 Mbps.

Shared Policer

The classification of the incoming packet occurs only once. However, based on the different classification criteria, the shared policer feature allows sharing of the policer bucket amongst two or more classes in a QoS policy map . That is, the same token bucket is used for a traffic flow matching against any of the classes sharing the policer.

For example, let us say a policer of 10 Mbps is shared among two classes C1 and C2. This feature ensures that both C1 and C2 get traffic flow assigned on First Come First Serve (FCFS) basis. Also that, if C2 does not have any traffic, C1 uses all of the 10 Mbps for transmission.

This feature includes two components:

- Policer Bucket Shared
- Policer Bucket Referred

Policer Bucket Shared

The policer bucket shared feature defines and shares a policer bucket instance among multiple classes.

Here is a sample configuration that defines and shares policer bucket instance sp1 :

```
policy-map parent
        class long-distance
          police bucket shared sp1 rate 1 mbps
```

In this configuration, a policy-map for class long-distance traffic type is created to police at 1Mbps rate and the policer bucket is shared.

Policer Bucket Referred

The policer bucket referred feature refers a defined policer bucket instance. Shared policer is not supported across policy levels. This means for example, that parent and child policy cannot share a common bucket.

Here is a sample configuration that refers shared policer bucket instance sp1 :

```
policy-map voip-child
        class long-distance-voip
         police bucket referred sp1
```

In this configuration, a policy-map for class long-distance-voip traffic type is created and the shared policer bucket sp1 is referred.

Shared Policer Statistics

Currently, individual class statistics are not available as a default option for shared policer. You can access statistics in the following modes.

Aggregate Mode

In this mode the policer bucket is shared among two or more classes. However, statistics are not available for every individual class. You can view the aggregate statistics that combine the numbers for all the classes sharing the policer bucket.

Per-Class Mode

In this mode the policer bucket is shared among two or more classes, and you can also view individual class statistics. However, when this mode is active, the Policy-Based Tunnel Selection (PBTS) mechanism is disabled. To enable the per-class mode, you must configure the **hw-module profile qos shared-policer-per-class-stats** command.

Restrictions and Guidelines

The following restrictions and guidelines apply while configuring the shared policer feature.

- When shared policer is enabled in per-class mode, Policy-Based Tunnel Selection (PBTS) mechanism is disabled. In other words, shared policer-per-class-mode and PBTS are mutually exclusive features.
- Shared policer is not supported across policy levels. This means, for example, that parent and child policies cannot share a common policer bucket.
- Shared policer is not supported in ingress peering mode.
- Shared policer is supported within classes of the same policy. However, cross-policy bucket sharing is not supported.
- There are no limitations on the number of classes that can share policer.
- There are no changes in policer scale numbers in the aggregate and per-class modes.
- All the existing policer types (1R2C, 1R3C and 2R3C) are supported.
- You must reload the affected line card to enable the per-class-stats mode.

Configuring Shared Policer

To configure shared policer, you must:

1. Create a class map to be used for matching packets to the specified class.
2. Create a policy map to be used for matching packets to the specified class.
3. Specify a class name.
4. Define and share a policer bucket.
5. Specify a class name.
6. Refer a shared policer bucket.

```
RP/0/RSP0/CPU0:ios(config)#class-map match-any c1
RP/0/RSP0/CPU0:ios(config-cmap)#match precedence 1
RP/0/RSP0/CPU0:ios(config-cmap)#end-class-map
RP/0/RSP0/CPU0:ios(config)#class-map match-any c2
RP/0/RSP0/CPU0:ios(config-cmap)#match precedence 2
RP/0/RSP0/CPU0:ios(config-cmap)#end-class-map
RP/0/RSP0/CPU0:ios(config)#policy-map s-pol
RP/0/RSP0/CPU0:ios(config-pmap)#class c1
RP/0/RSP0/CPU0:ios(config-pmap-c)#police bucket shared 1 rate 10 mbps
RP/0/RSP0/CPU0:ios(config-pmap-c-police)#exit
RP/0/RSP0/CPU0:ios(config-pmap-c)#exit
RP/0/RSP0/CPU0:ios(config-pmap)#class c2
RP/0/RSP0/CPU0:ios(config-pmap-c)#police bucket referred 1
RP/0/RSP0/CPU0:ios(config-pmap-c-police)#class class-default
```

```
RP/0/RSP0/CPU0:ios(config-pmap-c)#exit
RP/0/RSP0/CPU0:ios(config-pmap)#exit
RP/0/RSP0/CPU0:ios(config)#interface HundredGigE 0/6/0/18
RP/0/RSP0/CPU0:ios(config-if)#service-policy input s-pol
RP/0/RSP0/CPU0:ios(config-if)#commit
```

Running Configuration

```
class-map match-any c1
 match precedence 1
 end-class-map

class-map match-any c2
 match precedence 2
 end-class-map

policy-map s-pol
 class c1
  police bucket shared 1 rate 10 mbps
  !
 !
 class c2
  police bucket referred 1
  !
 !
 class class-default
 !
 end-policy-map
!

interface HundredGigE0/6/0/18
 service-policy input s-pol
!
```

Verification

In Aggregate Mode

```
RP/0/RP0/CPU0:ios#sh policy-map interface tenGigE 0/0/0/0 input
Fri Nov 15 12:55:56.817 UTC

TenGigE0/0/0/0 input: s-pol

Class c1
  Classification statistics          (packets/bytes)     (rate - kbps)
    Matched             :         1784530245/228419871360         8640780
    Transmitted         :            2067504/264640512             10011
    Total Dropped       :         1782462741/228155230848         8630769
  Policing statistics                (packets/bytes)     (rate - kbps)
    Policed(conform)    :            2067504/264640512             10011
    Policed(exceed)     :         1782462741/228155230848         8630769
    Policed(violate)    :                  0/0                     0
    Policed and dropped :         1782462741/228155230848
Class c2
  Classification statistics          (packets/bytes)     (rate - kbps)
    Matched             :                  0/0                     0
    Transmitted         :                  0/0                     0
    Total Dropped       :                  0/0                     0
  Policing statistics                (packets/bytes)     (rate - kbps)

Policed(conform)    :                  0/0                     0
    Policed(exceed)     :                  0/0                     0
    Policed(violate)    :                  0/0                     0
```

```
    Policed and dropped :                   0/0
Class class-default
  Classification statistics          (packets/bytes)     (rate - kbps)
    Matched             :                   0/0                    0
    Transmitted         :                   0/0                    0
    Total Dropped       :                   0/0                    0
Policy Bag Stats time: 1573822531986  [Local Time: 11/15/19 12:55:31.986]
```

In Per-Class Mode

```
RP/0/RP0/CPU0:ios#sh policy-map interface tenGigE 0/0/0/0 input
Fri Nov 15 15:18:18.319 UTC

TenGigE0/0/0/0 input: s-pol

Class c1
  Classification statistics          (packets/bytes)     (rate - kbps)
    Matched             :         1005369276/128687267328         4320337
    Transmitted         :            1163300/148902400            5013
    Total Dropped       :         1004205976/128538364928         4315324
  Policing statistics                (packets/bytes)     (rate - kbps)
    Policed(conform)    :            1163300/148902400            5013
    Policed(exceed)     :         1004205976/128538364928         4315324
    Policed(violate)    :                   0/0                    0
    Policed and dropped :         1004205976/128538364928
Class c2
  Classification statistics          (packets/bytes)     (rate - kbps)
    Matched             :         1005341342/128683691776         4320335
    Transmitted         :            1166269/149282432            4997
    Total Dropped       :         1004175073/128534409344         4315338
  Policing statistics                (packets/bytes)     (rate - kbps)
    Policed(conform)    :            1166269/149282432            4997
    Policed(exceed)     :         1004175073/128534409344         4315338
    Policed(violate)    :                   0/0                    0
    Policed and dropped :         1004175073/128534409344
Class class-default
  Classification statistics          (packets/bytes)     (rate - kbps)
    Matched             :              49159/6292352               0
    Transmitted         :              49159/6292352               0
    Total Dropped       :                   0/0                    0
Policy Bag Stats time: 1573831087338  [Local Time: 11/15/19 15:18:07.338]
```

Related Commands hw-module profile qos shared-policer-per-class-stats

References for Modular QoS Congestion Management

Committed Bursts

The committed burst (bc) parameter of the police command implements the first, conforming (green) token bucket that the router uses to meter traffic. The bc parameter sets the size of this token bucket. Initially, the token bucket is full and the token count is equal to the committed burst size (CBS). Thereafter, the meter updates the token counts the number of times per second indicated by the committed information rate (CIR).

The following describes how the meter uses the conforming token bucket to send packets:

- If sufficient tokens are in the conforming token bucket when a packet arrives, the meter marks the packet green and decrements the conforming token count by the number of bytes of the packet.
- If there are insufficient tokens available in the conforming token bucket, the meter allows the traffic flow to borrow the tokens needed to send the packet. The meter checks the exceeding token bucket for the number of bytes of the packet. If the exceeding token bucket has a sufficient number of tokens available, the meter marks the packet.

  Green and decrements the conforming token count down to the minimum value of 0.

  Yellow, borrows the remaining tokens needed from the exceeding token bucket, and decrements the exceeding token count by the number of tokens borrowed down to the minimum value of 0.
- If an insufficient number of tokens is available, the meter marks the packet red and does not decrement either of the conforming or exceeding token counts.

Note When the meter marks a packet with a specific color, there must be a sufficient number of tokens of that color to accommodate the entire packet. Therefore, the volume of green packets is never smaller than the committed information rate (CIR) and committed burst size (CBS). Tokens of a given color are always used on packets of that color.

Excess Bursts

The excess burst (be) parameter of the police command implements the second, exceeding (yellow) token bucket that the router uses to meter traffic. The exceeding token bucket is initially full and the token count is equal to the excess burst size (EBS). Thereafter, the meter updates the token counts the number of times per second indicated by the committed information rate (CIR).

The following describes how the meter uses the exceeding token bucket to send packets:

- When the first token bucket (the conforming bucket) meets the committed burst size (CBS), the meter allows the traffic flow to borrow the tokens needed from the exceeding token bucket. The meter marks the packet yellow and then decrements the exceeding token bucket by the number of bytes of the packet.
- If the exceeding token bucket does not have the required tokens to borrow, the meter marks the packet red and does not decrement the conforming or the exceeding token bucket. Instead, the meter performs the exceed-action configured in the police command (for example, the policer drops the packets).

Two-Rate Policer Details

The committed token bucket can hold bytes up to the size of the committed burst (bc) before overflowing. This token bucket holds the tokens that determine whether a packet conforms to or exceeds the CIR as the following describes:

- A traffic stream is conforming when the average number of bytes over time does not cause the committed token bucket to overflow. When this occurs, the token bucket algorithm marks the traffic stream green.
- A traffic stream is exceeding when it causes the committed token bucket to overflow into the peak token bucket. When this occurs, the token bucket algorithm marks the traffic stream yellow. The peak token bucket is filled as long as the traffic exceeds the police rate.

The peak token bucket can hold bytes up to the size of the peak burst (be) before overflowing. This token bucket holds the tokens that determine whether a packet violates the PIR. A traffic stream is violating when it causes the peak token bucket to overflow. When this occurs, the token bucket algorithm marks the traffic stream red.

For example, if a data stream with a rate of 250 kbps arrives at the two-rate policer, and the CIR is 100 kbps and the PIR is 200 kbps, the policer marks the packet in the following way:

- 100 kbps conforms to the rate
- 100 kbps exceeds the rate
- 50 kbps violates the rate

The router updates the tokens for both the committed and peak token buckets in the following way:

- The router updates the committed token bucket at the CIR value each time a packet arrives at the interface. The committed token bucket can contain up to the committed burst (bc) value.
- The router updates the peak token bucket at the PIR value each time a packet arrives at the interface. The peak token bucket can contain up to the peak burst (be) value.
- When an arriving packet conforms to the CIR, the router takes the conform action on the packet and decrements both the committed and peak token buckets by the number of bytes of the packet.
- When an arriving packet exceeds the CIR, the router takes the exceed action on the packet, decrements the committed token bucket by the number of bytes of the packet, and decrements the peak token bucket by the number of overflow bytes of the packet.
- When an arriving packet exceeds the PIR, the router takes the violate action on the packet, but does not decrement the peak token bucket.

See Two-Rate Policer, on page 19.