



## Policing and Shaping Overview

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Cisco IOS QoS offers two kinds of traffic regulation mechanisms—policing and shaping.

The rate-limiting features of committed access rate (CAR) and the Traffic Policing feature provide the functionality for policing traffic. The features of Generic Traffic Shaping (GTS), Class-Based Traffic Shaping, Distributed Traffic Shaping (DTS), and Frame Relay Traffic Shaping (FRTS) provide the functionality for shaping traffic.

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You can deploy these features throughout your network to ensure that a packet, or data source, adheres to a stipulated contract and to determine the QoS to render the packet. Both policing and shaping mechanisms use the traffic descriptor for a packet—indicated by the classification of the packet—to ensure adherence and service.

Policers and shapers usually identify traffic descriptor violations in an identical manner. They usually differ, however, in the way they respond to violations, for example:

- A policer typically drops traffic. (For example, the CAR rate-limiting policer will either drop the packet or rewrite its IP precedence, resetting the type of service bits in the packet header.)
- A shaper typically delays excess traffic using a buffer, or queueing mechanism, to hold packets and shape the flow when the data rate of the source is higher than expected. (For example, GTS and Class-Based Shaping use a weighted fair queue to delay packets in order to shape the flow, and DTS and FRTS use either a priority queue, a custom queue, or a FIFO queue for the same, depending on how you configure it.)

Traffic shaping and policing can work in tandem. For example, a good traffic shaping scheme should make it easy for nodes inside the network to detect misbehaving flows. This activity is sometimes called policing the traffic of the flow.

This module gives a brief description of the Cisco IOS QoS traffic policing and shaping mechanisms. Because policing and shaping all use the token bucket mechanism, this module first explains how a token bucket works. This module includes the following sections:

- [What Is a Token Bucket?](#)
- [Policing with CAR](#)



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- [Traffic Policing](#)
- [Traffic Shaping \(Regulating Packet Flow\)](#)

## What Is a Token Bucket?

A token bucket is a formal definition of a rate of transfer. It has three components: a burst size, a mean rate, and a time interval ( $T_c$ ). Although the mean rate is generally represented as bits per second, any two values may be derived from the third by the relation shown as follows:

$$\text{mean rate} = \text{burst size} / \text{time interval}$$

Here are some definitions of these terms:

- **Mean rate**—Also called the committed information rate (CIR), it specifies how much data can be sent or forwarded per unit time on average.
- **Burst size**—Also called the Committed Burst (Bc) size, it specifies in bits (or bytes) per burst, how much traffic can be sent within a given unit of time to not create scheduling concerns. (For a shaper, such as GTS, it specifies bits per burst; for a policer, such as CAR, it specifies bytes per burst, per second.)
- **Time interval**—Also called the measurement interval, it specifies the time quantum in seconds per burst.

By definition, over any integral multiple of the interval, the bit rate of the interface will not exceed the mean rate. The bit rate, however, may be arbitrarily fast within the interval.

A token bucket is used to manage a device that regulates the data in a flow. For example, the regulator might be a traffic policer, such as CAR, or a traffic shaper, such as FRTS or GTS. A token bucket itself has no discard or priority policy. Rather, a token bucket discards tokens and leaves to the flow the problem of managing its transmission queue if the flow overdrives the regulator. (Neither CAR nor FRTS and GTS implement either a true token bucket or true leaky bucket.)

In the token bucket metaphor, tokens are put into the bucket at a certain rate. The bucket itself has a specified capacity. If the bucket fills to capacity, newly arriving tokens are discarded. Each token is permission for the source to send a certain number of bits into the network. To send a packet, the regulator must remove from the bucket a number of tokens equal in representation to the packet size.

If not enough tokens are in the bucket to send a packet, the packet either waits until the bucket has enough tokens (in the case of GTS) or the packet is discarded or marked down (in the case of CAR). If the bucket is already full of tokens, incoming tokens overflow and are not available to future packets. Thus, at any time, the largest burst a source can send into the network is roughly proportional to the size of the bucket.

Note that the token bucket mechanism used for traffic shaping has both a token bucket and a data buffer, or queue; if it did not have a data buffer, it would be a policer. For traffic shaping, packets that arrive that cannot be sent immediately are delayed in the data buffer.

For traffic shaping, a token bucket permits burstiness but bounds it. It guarantees that the burstiness is bounded so that the flow will never send faster than the token bucket's capacity, divided by the time interval, plus the established rate at which tokens are placed in the token bucket. See the following formula:

$$(\text{token bucket capacity in bits} / \text{time interval in seconds}) + \text{established rate in bps} = \text{maximum flow speed in bps}$$

This method of bounding burstiness also guarantees that the long-term transmission rate will not exceed the established rate at which tokens are placed in the bucket.

# Policing with CAR

Committed access rate (CAR) embodies a rate-limiting feature for policing traffic, in addition to its packet classification feature discussed in the “[Classification Overview](#)” module. The rate-limiting feature of CAR manages the access bandwidth policy for a network by ensuring that traffic falling within specified rate parameters is sent, while dropping packets that exceed the acceptable amount of traffic or sending them with a different priority. The exceed action for CAR is to drop or mark down packets.

The rate-limiting function of CAR does the following:

- Allows you to control the maximum rate of traffic sent or received on an interface.
- Gives you the ability to define Layer 3 aggregate or granular incoming or outgoing (ingress or egress) bandwidth rate limits and to specify traffic handling policies when the traffic either conforms to or exceeds the specified rate limits.

Aggregate bandwidth rate limits match all of the packets on an interface or subinterface. Granular bandwidth rate limits match a particular type of traffic based on precedence, MAC address, or other parameters.

CAR is often configured on interfaces at the edge of a network to limit traffic into or out of the network.

## How CAR Works

CAR examines traffic received on an interface or a subset of that traffic selected by access list criteria. It then compares the rate of the traffic to a configured token bucket and takes action based on the result. For example, CAR will drop the packet or rewrite the IP precedence by resetting the type of service (ToS) bits. You can configure CAR to send, drop, or set precedence.

Aspects of CAR rate limiting are explained in the following sections:

- [Matching Criteria](#)
- [Rate Limits](#)
- [Conform and Exceed Actions](#)
- [Multiple Rate Policies](#)

CAR utilizes a token bucket measurement. Tokens are inserted into the bucket at the committed rate. The depth of the bucket is the burst size. Traffic arriving at the bucket when sufficient tokens are available is said to conform, and the corresponding number of tokens are removed from the bucket. If a sufficient number of tokens are not available, then the traffic is said to exceed.

## Matching Criteria

Traffic matching entails identification of traffic of interest for rate limiting, precedence setting, or both. Rate policies can be associated with one of the following qualities:

- Incoming interface
- All IP traffic
- IP precedence (defined by a rate-limit access list)
- MAC address (defined by a rate-limit access list)

- Multiprotocol Label Switching (MPLS) experimental (EXP) value (defined by a rate-limit access list)
- IP access list (standard and extended)

CAR provides configurable actions, such as send, drop, or set precedence when traffic conforms to or exceeds the rate limit.

**Note**

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Matching to IP access lists is more processor intensive than matching based on other criteria.

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## Rate Limits

CAR propagates bursts. It does no smoothing or shaping of traffic, and therefore does no buffering and adds no delay. CAR is highly optimized to run on high-speed links—DS3, for example—in distributed mode on Versatile Interface Processors (VIPs) on the Cisco 7500 series.

CAR rate limits may be implemented either on input or output interfaces or subinterfaces including Frame Relay and ATM subinterfaces.

### What Rate Limits Define

Rate limits define which packets conform to or exceed the defined rate based on the following three parameters:

- Average rate. The average rate determines the long-term average transmission rate. Traffic that falls under this rate will always conform.
- Normal burst size. The normal burst size determines how large traffic bursts can be before some traffic exceeds the rate limit.
- Excess Burst size. The Excess Burst (Be) size determines how large traffic bursts can be before all traffic exceeds the rate limit. Traffic that falls between the normal burst size and the Excess Burst size exceeds the rate limit with a probability that increases as the burst size increases.

The maximum number of tokens that a bucket can contain is determined by the normal burst size configured for the token bucket.

When the CAR rate limit is applied to a packet, CAR removes from the bucket tokens that are equivalent in number to the byte size of the packet. If a packet arrives and the byte size of the packet is greater than the number of tokens available in the standard token bucket, extended burst capability is engaged if it is configured.

### Extended Burst Value

Extended burst is configured by setting the extended burst value greater than the normal burst value. Setting the extended burst value equal to the normal burst value excludes the extended burst capability. If extended burst is not configured, given the example scenario, the exceed action of CAR takes effect because a sufficient number of tokens are not available.

When extended burst is configured and this scenario occurs, the flow is allowed to borrow the needed tokens to allow the packet to be sent. This capability exists so as to avoid tail-drop behavior, and, instead, engage behavior like that of Random Early Detection (RED).

## How Extended Burst Capability Works

Here is how the extended burst capability works. If a packet arrives and needs to borrow  $n$  number of tokens because the token bucket contains fewer tokens than its packet size requires, then CAR compares the following two values:

- Extended burst parameter value.
- Compounded debt. Compounded debt is computed as the sum over all  $ai$ :
  - $a$  indicates the actual debt value of the flow after packet  $i$  is sent. Actual debt is simply a count of how many tokens the flow has currently borrowed.
  - $i$  indicates the  $i$ th packet that attempts to borrow tokens since the last time a packet was dropped.

If the compounded debt is greater than the extended burst value, the exceed action of CAR takes effect. After a packet is dropped, the compounded debt is effectively set to 0. CAR will compute a new compounded debt value equal to the actual debt for the next packet that needs to borrow tokens.

If the actual debt is greater than the extended limit, all packets will be dropped until the actual debt is reduced through accumulation of tokens in the token bucket.

Dropped packets do not count against any rate or burst limit. That is, when a packet is dropped, no tokens are removed from the token bucket.



### Note

Though it is true the entire compounded debt is forgiven when a packet is dropped, the actual debt is not forgiven, and the next packet to arrive to insufficient tokens is immediately assigned a new compounded debt value equal to the current actual debt. In this way, actual debt can continue to grow until it is so large that no compounding is needed to cause a packet to be dropped. In effect, at this time, the compounded debt is not really forgiven. This scenario would lead to excessive drops on streams that continually exceed normal burst. (See the example in the following section, “[Actual and Compounded Debt Example](#).”)

Testing of TCP traffic suggests that the chosen normal and extended burst values should be on the order of several seconds worth of traffic at the configured average rate. That is, if the average rate is 10 Mbps, then a normal burst size of 10 to 20 Mb and an Excess Burst size of 20 to 40 Mb would be appropriate.

## Recommended Burst Values

Cisco recommends the following values for the normal and extended burst parameters:

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normal burst = configured rate * (1 byte)/(8 bits) * 1.5 seconds
extended burst = 2 * normal burst
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With the listed choices for parameters, extensive test results have shown CAR to achieve the configured rate. If the burst values are too low, then the achieved rate is often much lower than the configured rate.

## Actual and Compounded Debt Example

This example shows how the compounded debt is forgiven, but the actual debt accumulates.

For this example, assume the following parameters:

- Token rate is 1 data unit per time unit
- Normal burst size is 2 data units
- Extended burst size is 4 data units
- 2 data units arrive per time unit

After 2 time units, the stream has used up its normal burst and must begin borrowing one data unit per time unit, beginning at time unit 3:

Time	DU arrivals	Actual Debt	Compounded Debt
1	2	0	0
2	2	0	0
3	2	1	1
4	2	2	3
5	2	3 (temporary)	6 (temporary)

At this time a packet is dropped because the new compounded debt (6) would exceed the extended burst limit (4). When the packet is dropped, the compounded debt effectively becomes 0, and the actual debt is 2. (The values 3 and 6 were only temporary and do not remain valid in the case where a packet is dropped.) The final values for time unit 5 follow. The stream begins borrowing again at time unit 6.

Time	DU arrivals	Actual Debt	Compounded Debt
5	2	2	0
6	2	3	3
7	2	4 (temporary)	7 (temporary)

At time unit 6, another packet is dropped and the debt values are adjusted accordingly.

Time	DU arrivals	Actual Debt	Compounded Debt
7	2	3	0

## Conform and Exceed Actions

CAR utilizes a token bucket, thus CAR can pass temporary bursts that exceed the rate limit as long as tokens are available.

Once a packet has been classified as conforming to or exceeding a particular rate limit, the router performs one of the following actions on the packet:

- Transmit—The packet is sent.
- Drop—The packet is discarded.
- Set precedence and transmit—The IP Precedence (ToS) bits in the packet header are rewritten. The packet is then sent. You can use this action to either color (set precedence) or recolor (modify existing packet precedence) the packet.
- Continue—The packet is evaluated using the next rate policy in a chain of rate limits. If there is not another rate policy, the packet is sent.
- Set precedence and continue—Set the IP Precedence bits to a specified value and then evaluate the next rate policy in the chain of rate limits.

For VIP-based platforms, two more actions are possible:

- Set QoS group and transmit—The packet is assigned to a QoS group and sent.
- Set QoS group and continue—The packet is assigned to a QoS group and then evaluated using the next rate policy. If there is not another rate policy, the packet is sent.

## Multiple Rate Policies

A single CAR rate policy includes information about the rate limit, conform actions, and exceed actions. Each interface can have multiple CAR rate policies corresponding to different types of traffic. For example, low priority traffic may be limited to a lower rate than high priority traffic. When there are multiple rate policies, the router examines each policy in the order entered until the packet matches. If no match is found, the default action is to send.

Rate policies can be independent: each rate policy deals with a different type of traffic. Alternatively, rate policies can be cascading: a packet may be compared to multiple different rate policies in succession.

Cascading of rate policies allows a series of rate limits to be applied to packets to specify more granular policies (for example, you could rate limit total traffic on an access link to a specified subrate bandwidth and then rate limit World Wide Web traffic on the same link to a given proportion of the subrate limit) or to match packets against an ordered sequence of policies until an applicable rate limit is encountered (for example, rate limiting several MAC addresses with different bandwidth allocations at an exchange point). You can configure up to a 100 rate policies on a subinterface.

## Restrictions of CAR and VIP-Distributed CAR

CAR and VIP-distributed CAR can only be used with IP traffic. Non-IP traffic is not rate limited.

CAR or VIP-distributed CAR can be configured on an interface or subinterface. However, CAR and VIP-distributed CAR are not supported on the following interfaces:

- Fast EtherChannel
- Tunnel
- PRI
- Any interface that does not support Cisco Express Forwarding (CEF)

CAR is only supported on ATM subinterfaces with the following encapsulations: aal5snap, aal5mux, and aal5nlpid.



**Note**

CAR provides rate limiting and does not guarantee bandwidth. CAR should be used with other QoS features, such as distributed weighted fair queueing (DWFQ), if premium bandwidth assurances are required.

## 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).

The Traffic Policing feature manages the maximum rate of traffic through a token bucket algorithm. The token bucket algorithm can use the 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 (depending on where the traffic policy with Traffic Policing configured) and is useful in managing network bandwidth in cases where several large packets are sent in the same traffic stream.

The token bucket algorithm provides users with three actions for each packet: a conform action, an exceed action, and an optional violate action. Traffic entering the interface with Traffic Policing configured is placed into one of these categories. Within these three categories, users can decide packet

treatments. For instance, packets that conform can be configured to be transmitted, packets that exceed can be configured to be sent with a decreased priority, and packets that violate can be configured to be dropped.

Traffic Policing is often configured on interfaces at the edge of a network to limit the rate of traffic entering or leaving the network. In the most common Traffic Policing configurations, traffic that conforms is transmitted and traffic that exceeds is sent with a decreased priority or is dropped. Users can change these configuration options to suit their network needs.

The Traffic Policing feature supports the following MIBs:

- CISCO-CLASS-BASED-QOS-MIB
- CISCO-CLASS-BASED-QOS-CAPABILITY-MIB

This feature also supports RFC 2697, *A Single Rate Three Color Marker*.

For information on how to configure the Traffic Policing feature, see the [“Configuring Traffic Policing”](#) module.

## Benefits of Traffic Policing

### Bandwidth Management Through Rate Limiting

Traffic policing allows you to control the maximum rate of traffic sent or received on an interface. Traffic policing is often configured on interfaces at the edge of a network to limit traffic into or out of the network. Traffic that falls within the rate parameters is sent, whereas traffic that exceeds the parameters is dropped or sent with a different priority.

### Packet Marking Through IP Precedence, QoS Group, and DSCP Value Setting

Packet marking allows you to partition your network into multiple priority levels or classes of service (CoS), as follows:

- Use traffic policing to set the IP precedence or differentiated services code point (DSCP) values for packets entering the network. Networking devices within your network can then use the adjusted IP Precedence values to determine how the traffic should be treated. For example, the DWRED feature uses the IP Precedence values to determine the probability that a packet will be dropped.
- Use traffic policing to assign packets to a QoS group. The router uses the QoS group to determine how to prioritize packets.

## Restrictions for Traffic Policing

The following restrictions apply to the Traffic Policing feature:

- On a Cisco 7500 series router, traffic policing can monitor CEF switching paths only. In order to use the Traffic Policing feature, CEF must be configured on both the interface receiving the packet and the interface sending the packet.
- On a Cisco 7500 series router, traffic policing cannot be applied to packets that originated from or are destined to a router.
- Traffic policing can be configured on an interface or a subinterface.
- Traffic policing is not supported on the following interfaces:
  - Fast EtherChannel
  - Tunnel

- PRI
- Any interface on a Cisco 7500 series router that does not support CEF

## Prerequisites for Traffic Policing

On a Cisco 7500 series router, CEF must be configured on the interface before traffic policing can be used.

For additional information on CEF, see the [“Cisco Express Forwarding Features Roadmap”](#) module.

## Traffic Shaping (Regulating Packet Flow)

Regulating the packet flow (that is, the flow of traffic) on the network is also known as traffic shaping. Traffic shaping allows you to control the speed of traffic leaving an interface. This way, you can match the flow of the traffic to the speed of the interface receiving the packet.

Cisco provides three mechanisms for regulating or shaping traffic: Class-Based Traffic Shaping, Generic Traffic Shaping (GTS), and Frame Relay Traffic Shaping (FRTS).

For more information about traffic shaping, see the [“Regulating Packet Flow Using Traffic Shaping”](#) module.

For information on configuring Frame Relay and FRTS, see the [“Configuring Frame Relay”](#) module and the [“MQC-Based Frame Relay Traffic Shaping”](#) module, respectively.

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