CHAPTER 42

Configuring Quality of Service

This chapter describes how to configure quality of service (QoS) with either automatic QoS (auto-QoS) commands or standard QoS commands on a Catalyst 4500 Series Switch. It describes how to specify QoS configuration on different types of interfaces (access, Layer 2 trunk, Layer 3 routed, Etherchannel) as well as VLANs. It also describes how to specify different QoS configurations on different VLANs on a given interface (per-port per-VLAN QoS).

A switch supports a QoS configuration model known as *MQC* (Modular QoS CLI). Please refer to the appropriate configuration section for the supervisor engine on which QoS will be configured. For more information about MQC, see the “Modular Quality of Service Command-Line Interface" section of the *Cisco IOS Quality of Service Solutions Configuration Guide, Release 12.3*.

This chapter addresses both VSS and non-VSS environments. Sections include:

Note For complete syntax and usage information for the switch commands used in this chapter, see the *Cisco Catalyst 4500 Series Switch Command Reference* and related publications at this location:

http://www.cisco.com/en/US/products/hw/switches/ps4324/index.html

If a command is not in the *Catalyst 4500 Series Switch Command Reference*, you can locate it in the Cisco IOS library. See the *Cisco IOS Command Reference* and related publications at this location:

http://www.cisco.com/en/US/products/ps6350/index.html

Overview of QoS

Typically, networks operate on a *best-effort* delivery basis, which means that all traffic has equal priority and an equal chance of being delivered in a timely manner. When congestion occurs, all traffic has an equal chance of being dropped.

QoS selects network traffic (both unicast and multicast), prioritizes it according to its relative importance, and uses congestion avoidance to provide priority-indexed treatment; QoS can also limit the bandwidth used by network traffic. QoS can make network performance more predictable and bandwidth utilization more effective.

This section contains the following subsections:

Prioritization

QoS implementation is based on the DiffServ architecture. This architecture specifies that each packet is classified upon entry into the network. The classification is carried in the IP packet header, using 6 bits from the deprecated IP type of service (TOS) field to carry the classification (*class*) information. Classification can also be carried in the Layer 2 frame. These special bits in the Layer 2 frame or a Layer 3 packet are described here and shown in Figure 42-1:

- Prioritization values in Layer 2 frames:

  Layer 2 Inter-Switch Link (ISL) frame headers have a 1-byte User field that carries an IEEE 802.1p class of service (CoS) value in the three least-significant bits. On interfaces configured as Layer 2 ISL trunks, all traffic is in ISL frames.

  Layer 2 802.1Q frame headers have a 2-byte Tag Control Information field that carries the CoS value in the three most-significant bits, which are called the User Priority bits. On interfaces configured as Layer 2 802.1Q trunks, all traffic is in 802.1Q frames except for traffic in the native VLAN.

  Other frame types cannot carry Layer 2 CoS values.

  Layer 2 CoS values range from 0 for low priority to 7 for high priority.

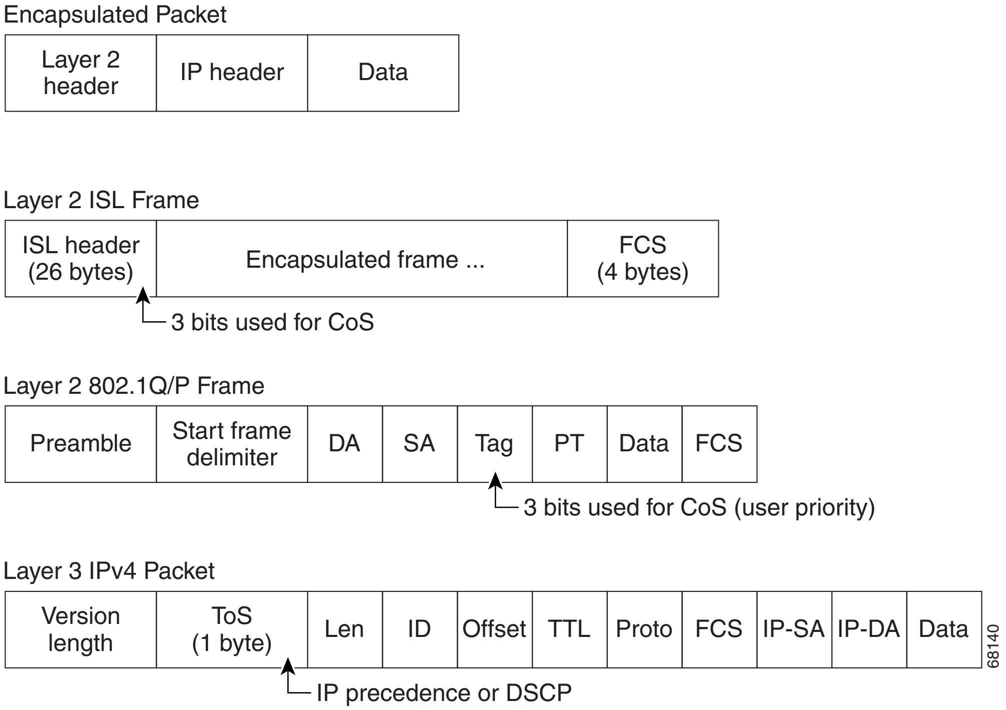
- Prioritization bits in Layer 3 packets:

  Layer 3 IP packets can carry either an IP precedence value or a Differentiated Services Code Point (DSCP) value. QoS supports the use of either value because DSCP values are backward-compatible with IP precedence values.

  IP precedence values range from 0 to 7.

  DSCP values range from 0 to 63.

Figure 42-1 QoS Classification Layers in Frames and Packets



All switches and routers across the Internet rely on the class information to provide the same forwarding treatment to packets with the same class information and different treatment to packets with different class information. The class information in the packet can be assigned by end hosts or by switches or routers along the way, based on a configured policy, detailed examination of the packet, or both. Detailed examination of the packet is expected to happen closer to the edge of the network so that the core switches and routers are not overloaded.

Switches and routers along the path can use the class information to limit the amount of resources allocated per traffic class. The behavior of an individual device when handling traffic in the DiffServ architecture is called per-hop behavior. If all devices along a path provide a consistent per-hop behavior, you can construct an end-to-end QoS solution.

Implementing QoS in your network can be a simple or complex task and depends on the QoS features offered by your internetworking devices, the traffic types and patterns in your network, and the granularity of control you need over incoming and outgoing traffic.

QoS Terminology

The following terms are used when discussing QoS features:

- *Packets* carry traffic at Layer 3.
- *Frames* carry traffic at Layer 2. Layer 2 frames carry Layer 3 packets.
- *Labels* are prioritization values carried in Layer 3 packets and Layer 2 frames:
  - Layer 2 class of service (CoS) values, which range between zero for low priority and seven for high priority:

    Layer 2 Inter-Switch Link (ISL) frame headers have a 1-byte User field that carries an IEEE 802.1p CoS value in the three least significant bits.

Layer 2 802.1Q frame headers have a 2-byte Tag Control Information field that carries the CoS value in the three most significant bits, which are called the User Priority bits.

Other frame types cannot carry Layer 2 CoS values.

Note On interfaces configured as Layer 2 ISL trunks, all traffic is in ISL frames. On interfaces configured as Layer 2 802.1Q trunks, all traffic is in 802.1Q frames except for traffic in the native VLAN.

- Layer 3 IP precedence values—The IP version 4 specification defines the three most significant bits of the 1-byte ToS field as IP precedence. IP precedence values range between zero for low priority and seven for high priority.
- Layer 3 differentiated services code point (DSCP) values—The Internet Engineering Task Force (IETF) has defined the six most significant bits of the 1-byte IP ToS field as the DSCP. The per-hop behavior represented by a particular DSCP value is configurable. DSCP values range between 0 and 63.

Note Layer 3 IP packets can carry either an IP precedence value or a DSCP value. QoS supports the use of either value, since DSCP values are backwards compatible with IP precedence values. See Table 42-1.

Table 42-1 IP Precedence and DSCP Values

3-bit IP Precedence	6 MSb[1] of ToS						6-bit DSCP	3-bit IP Precedence	6 MSb[1] of ToS						6-bit DSCP
	8	7	6	5	4	3			8	7	6	5	4	3	
0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	32
	0	0	0	0	0	1	1		1	0	0	0	0	1	33
	0	0	0	0	1	0	2		1	0	0	0	1	0	34
	0	0	0	0	1	1	3		1	0	0	0	1	1	35
	0	0	0	1	0	0	4		1	0	0	1	0	0	36
	0	0	0	1	0	1	5		1	0	0	1	0	1	37
	0	0	0	1	1	0	6		1	0	0	1	1	0	38
	0	0	0	1	1	1	7		1	0	0	1	1	1	39
1	0	0	1	0	0	0	8	5	1	0	1	0	0	0	40
	0	0	1	0	0	1	9		1	0	1	0	0	1	41
	0	0	1	0	1	0	10		1	0	1	0	1	0	42
	0	0	1	0	1	1	11		1	0	1	0	1	1	43
	0	0	1	1	0	0	12		1	0	1	1	0	0	44
	0	0	1	1	0	1	13		1	0	1	1	0	1	45
	0	0	1	1	1	0	14		1	0	1	1	1	0	46
	0	0	1	1	1	1	15		1	0	1	1	1	1	47

Table 42-1 IP Precedence and DSCP Values (continued)

3-bit IP Precedence	6 MSb[1] of ToS						6-bit DSCP		3-bit IP Precedence	6 MSb[1] of ToS						6-bit DSCP
	8	7	6	5	4	3				8	7	6	5	4	3	
2	0	1	0	0	0	0	16		6	1	1	0	0	0	0	48
	0	1	0	0	0	1	17			1	1	0	0	0	1	49
	0	1	0	0	1	0	18			1	1	0	0	1	0	50
	0	1	0	0	1	1	19			1	1	0	0	1	1	51
	0	1	0	1	0	0	20			1	1	0	1	0	0	52
	0	1	0	1	0	1	21			1	1	0	1	0	1	53
	0	1	0	1	1	0	22			1	1	0	1	1	0	54
	0	1	0	1	1	1	23			1	1	0	1	1	1	55
3	0	1	1	0	0	0	24		7	1	1	1	0	0	0	56
	0	1	1	0	0	1	25			1	1	1	0	0	1	57
	0	1	1	0	1	0	26			1	1	1	0	1	0	58
	0	1	1	0	1	1	27			1	1	1	0	1	1	59
	0	1	1	1	0	0	28			1	1	1	1	0	0	60
	0	1	1	1	0	1	29			1	1	1	1	0	1	61
	0	1	1	1	1	0	30			1	1	1	1	1	0	62
	0	1	1	1	1	1	31			1	1	1	1	1	1	63

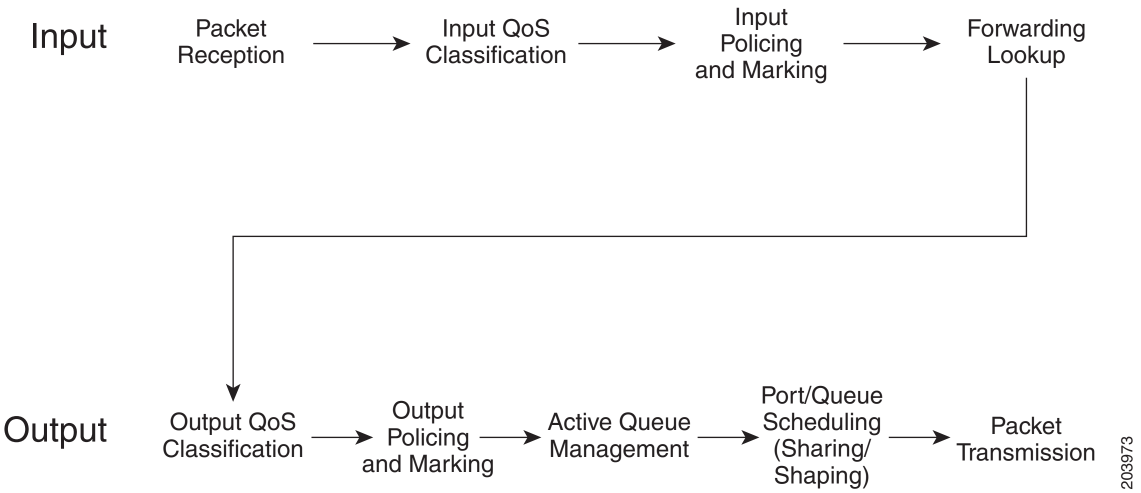
[1] MSb = most significant bit

- *Classification* is the selection of traffic to be marked.
- *Marking*, according to RFC 2475, is the process of setting a Layer 3 DSCP value in a packet; in this publication, the definition of marking is extended to include setting Layer 2 CoS values.
- *Policing* is limiting bandwidth used by a flow of traffic. Policing can mark or drop traffic.

Basic QoS Model

Figure 42-2 illustrates a high-level flow of QoS function.

Figure 42-2 QoS Packet Processing


Input
Packet Reception
Input QoS Classification
Input Policing and Marking
Forwarding Lookup
Output
Output QoS Classification
Output Policing and Marking
Active Queue Management
Port/Queue Scheduling (Sharing/ Shaping)
Packet Transmission
203973

The QoS model proceeds as follows:

Step 1 The incoming packet is classified (based on different packet fields, receive port and/or VLAN) to belong to a traffic class.

Step 2 Depending on the traffic class, the packet is rate-limited/policed and its priority is optionally *marked* (typically at the edge of the network) so that lower priority packets are dropped or marked with lower priority in the packet fields (DSCP and CoS).

Step 3 After the packet has been marked, it is *looked up* for forwarding. This action obtains the transmit port and VLAN to transmit the packet.

Step 4 The packet is classified in the output direction based on the transmit port and/or VLAN. The classification takes into account any marking of the packet by input QoS.

Step 5 Depending on the output classification, the packet is policed, its priority is optionally *(re-)marked*, and the transmit queue for the packet is determined depending on the traffic class.

Step 6 The transmit queue state is dynamically monitored via the AQM (Active Queue Management) algorithm and drop threshold configuration to determine whether the packet should be dropped or enqueued for transmission.

Step 7 If eligible for transmission, the packet is enqueued to a transmit queue. The transmit queue is selected based on output QoS classification criteria. The selected queue provides the desired behavior in terms of latency and bandwidth.

Classification

Classification is the process of distinguishing one kind of traffic from another by examining the fields in the packet. Classification is enabled when a QoS policy-map is attached to an interface.

You specify which fields in the frame or packet that you want to use to classify incoming traffic.

For non-IP traffic, you have the following classification options:

- CoS value in the VLAN tag of the incoming frame is used to classify the packet.
- If the frame does not contain a CoS value, the port's default CoS value ("0") is used for the classification.

  Perform the classification based on a configured MAC ACL, which examines the fields in the Layer 2 header.

For IP traffic, you have the following classification options:

- IP DSCP or IP Precedence in the incoming packet is used for classification. DSCP values range from 0 to 63.
- Perform the classification based on a configured IP standard or extended ACL, which examines various fields in the IP header.

Classification Based on QoS ACLs

A packet can be classified for QoS using multiple match criteria, and the classification can specify whether the packet should match all of the specified match criteria or at least one of the match criteria. To define a QoS classifier, you can provide the match criteria using the *match* statements in a class map.

In the 'match' statements, you can specify the fields in the packet to match on, or you can use IP standard or IP extended ACLs or MAC ACLs. For more information, see the "Classification Based on Class Maps and Policy Maps" section on page 42-7.

If the class map is configured to match all the match criteria, then a packet must satisfy all the match statements in the class map before the QoS action is taken. The QoS action for the packet is not taken if the packet does not match even one match criterion in the class map.

If the class map is configured to match at least one match criterion, then a packet must satisfy at least one of the match statements in the class map before the QoS action is taken. The QoS action for the packet is not taken if the packet does not match any match criteria in the class map.

Note When you use the IP standard and IP extended ACLs, the permit and deny ACEs in the ACL have a slightly different meaning in the QoS context.

- If a packet encounters (and satisfies) an ACE with a "permit," then the packet "matches" the match criterion in the QoS classification.
- If a packet encounters (and satisfies) an ACE with a "deny," then the packet "does not match" the match criterion in the QoS classification.
- If no match with a permit action is encountered and all the ACEs have been examined, then the packet "does not match" the criterion in the QoS classification.

Note When creating an access list, remember that, by default, the end of the access list contains an implicit deny statement for everything if it did not find a match before reaching the end.

After a traffic class has been defined with the class map, you can create a policy that defines the QoS actions for a traffic class. A policy might contain multiple classes with actions specified for each one of them. A policy might include commands to classify the class as a particular aggregate (for example, assign a DSCP) or rate limit the class. This policy is then attached to a particular port on which it becomes effective.

You implement IP ACLs to classify IP traffic by using the **access-list** global configuration command.

When a class-map is created with the **match-all** keyword, you cannot include both IP and MAC ACLs as match criteria.

Classification Based on Class Maps and Policy Maps

A class map is a mechanism that you use to isolate and name a specific traffic flow (or class) from all other traffic. The class map defines the criterion used to match against a specific traffic flow to further classify it; the criteria can include matching the access group defined by the ACL or matching a specific list of DSCP, IP precedence, or L2 CoS values. If you have more than one type of traffic that you want to classify, you can create another class map and use a different name. After a packet is matched against the class-map criteria, you can specify the QoS actions via a policy map.

A policy map specifies the QoS actions for the traffic classes. Actions can include setting a specific CoS, DSCP, or IP precedence value; policing the traffic to a specified rate; specifying the traffic bandwidth limitations; shaping the traffic to a specified rate. Before a policy map can be effective, you must attach it to an interface.

You create a class map by using the **class-map** global configuration command. When you enter the **class-map** command, the switch enters the class-map configuration mode. In this mode, you define the match criteria for the traffic by using the **match** class-map configuration command.

You create and name a policy map by using the **policy-map** global configuration command. When you enter this command, the switch enters the policy-map configuration mode. In this mode, you specify the actions to take on a specific traffic class by using the set, **police**, **bandwidth**, or **shape** policy-map configuration and policy-map class configuration commands. To make the policy map effective, you attach it to an interface by using the **service-policy** interface configuration command.

The policy map can also contain commands that define the policer, (the bandwidth limitations of the traffic) and the action to take if the limits are exceeded. For more information, see the "Policing and Marking" section on page 42-8.

A policy map also has these characteristics:

- A policy map can contain up to 254 class statements.
- You can have different classes within a policy map.

Policing and Marking

Policing involves creating a policer that specifies the bandwidth limits for the traffic. Packets that exceed the limits are *out of profile* or *nonconforming*. Each policer specifies the action to take for packets that are in or out of profile. These actions, carried out by the marker, include passing through the packet without modification, dropping the packet, or marking down the packet with a new DSCP value that is obtained from the configurable policed-DSCP map. You can configure policer within a policy map with the **police** command in policy-map class configuration mode. For information on the policed-DSCP map, see the "Queueing and Scheduling" section on page 42-8.

When configuring policing and policers, keep these items in mind:

- Policers account only for the Layer 2 header length when calculating policer rates. In contrast, shapers account for header length as well as IPG in rate calculations.
- Beginning with Cisco IOS Release 15.0(2)SG (IOS XE 3.2.0), Supervisor Engine 6-E, Supervisor Engine 6L-E, Catalyst 4900M, Catalyst 4948E, Supervisor Engine 7-E, and Supervisor Engine 7L-E support the **qos account layer-all encapsulation** command, which accounts for Layer 1 headers of 20 bytes (12 bytes preamble + 8 bytes IPG) and Layer 2 headers in policing features.
- Only the average rate and committed burst parameters are configurable.
- After you configure the policy map and policing actions, attach the policy to an ingress or egress interface by using the **service-policy** interface configuration command.
- For 2 rate 3 colors (2r3c) policers, if no explicit violation-action is specified, the exceed-action is used as the violate-action.

Queueing and Scheduling

The Catalyst 4500 Series Switch supports 8 transmit queues per port. Once the decision has been made to forward a packet out a port, the output QoS classification determines the transmit queue into which the packet must be enqueued.

Queues are assigned when an output policy attached to a port with one or more queuing related actions for one or more classes of traffic. Because there are only eight queues per port, there are at most eight traffic classes (including *class-default,* the reserved class) with queuing action(s). Classes of traffic that do not have any queuing action are referred to as non-queuing classes. Non-queuing class traffic use the queue corresponding to *class-default*.

Active Queue Management

Active queue management (AQM) is the pro-active approach of informing you about congestion before a buffer overflow occurs. AQM is done using Dynamic buffer limiting (DBL). DBL tracks the queue length for each traffic flow in the switch. When the queue length of a flow exceeds its limit, DBL drop packets.

Sharing Link Bandwidth Among Transmit Queues

The eight transmit queues for a transmit port share the available link bandwidth of that transmit port. You can set the link bandwidth to be shared differently among the transmit queues using the **bandwidth** command in the **policy-map class** configuration command in class mode.

With this command, you assign the minimum guaranteed bandwidth for each transmit queue.

By default, all queues are scheduled in a round robin manner.

Strict Priority / Low Latency Queueing

You can only configure one transmit queue on a port as strict priority (termed Low Latency Queue, or LLQ).

LLQ provides strict-priority queuing for a traffic class. It enables delay-sensitive data, such as voice, to be sent before packets in other queues. The priority queue is serviced first until it is empty or until it falls under r its shape rate. Only one traffic stream can be destined for the priority queue per class-level policy. You enable the priority queue for a traffic class with the **priority policy-map class** configuration command in class mode.

Traffic Shaping

Traffic Shaping provides the ability to control the rate of outgoing traffic in order to make sure that the traffic conforms to the maximum rate of transmission contracted for it. Traffic that meets certain profile can be shaped to meet the downstream traffic rate requirements to handle any data rate mismatches.

Each transmit queue can be configured to transmit a maximum rate using the **shape** command in the **policy-map class** configuration command in class mode

The configuration allows you to specify the maximum rate of traffic. Any traffic that exceeds the configured shape rate is queued and transmitted at the configured rate. If the burst of traffic exceeds the size of the queue, packets are dropped to maintain transmission at the configured shape rate.

Packet Modification

A packet is classified, policed, and queued to provide QoS. Packet modifications can occur during this process:

- For IP packets, classification involves assigning a DSCP to the packet. However, the packet is not modified at this stage; only an indication of the assigned DSCP is carried along. The reason for this is that QoS classification and ACL lookup occur in parallel, and it is possible that the ACL specifies that the packet should be denied and logged. In this situation, the packet is forwarded with its original DSCP to the CPU, where it is again processed through ACL software.

- For non-IP packets, classification involves assigning an internal DSCP to the packet, but because there is no DSCP in the non-IP packet, no overwrite occurs. Instead, the internal DSCP is used both for queueing and scheduling decisions and for writing the CoS priority value in the tag if the packet is being transmitted on either an ISL or 802.1Q trunk port.
- During policing, IP and non-IP packets can have another DSCP assigned to them (if they are out of profile and the policer specifies a markdown DSCP). Once again, the DSCP in the packet is not modified, but an indication of the marked-down value is carried along. For IP packets, the packet modification occurs at a later stage.

Per Port Per VLAN QoS

Per-port per-VLAN QoS (PVQoS) offers differentiated quality-of-services to individual VLANs on a trunk port. It enables service providers to rate limit individual VLAN-based services on each trunk port to a business or a residence. In an enterprise Voice-over-IP environment, it can be used to rate limit voice VLAN even if an attacker impersonates an IP phone. A per-port per-VLAN service policy can be separately applied to either ingress or egress traffic. For configuration details see "Enabling Per-Port Per-VLAN QoS" section on page 42-70.

Flow-based QoS

Note Before reading this section, you should be familiar with implementing Flexible NetFlow (Chapter 65, "Configuring Flexible NetFlow") and QoS implementation in this chapter.

Flow based QoS enables microflow policing and marking capability to dynamically learn traffic flows. It also rate limits each unique flow to an individual rate. Flow based QoS is available on a Catalyst 4500 Series Switch with the built-in NetFlow hardware support. It can be applied to ingress traffic on both switched and routed interfaces with flow masks defined using Flexible NetFlow (FNF). It supports up to 100,000 individual flows in hardware and up to 512 unique policer configuration. Flow based QoS is typically used in environments where per-user, granular rate-limiting required. For example, per-flow outbound and inbound traffic rate might differ. Flow based QoS is also referred to as User Based Rate Limiting (UBRL).

A *flow* is defined as a stream of packets having the same properties as those defined by the key fields in the FNF flow record. A new flow is created when the value of data in packet's key fields is unique with respect to the flow that already exist.

A flow based QoS policy is possesses one or more classmaps matching on a FNF flow record. Such a classmap must be configured as **match-all** to match all the match criteria specified in the classmap. When a flow based QoS policy is attached to a QoS target, ingress traffic on the target is first classified based on the classification rules specified in the class-map. If the classifier has FNF flow record, the key fields specified in the FNF flow record are applied on the classified traffic to create flows provided the flow does not already exist. The corresponding policy actions (policing and marking) are then applied to these individual flows. Flow-based policers (termed *microflow policers*) rate limit each unique flow. Flows are dynamically created and inactive flows are periodically aged out.

Flow based QoS policy can be attached to QoS targets such as port (P), vlan (V), per-port-per-vlan (PV), and EtherChannel but only in the ingress direction.

For details on now to enable FNF, refer to the "Applying Flow-based QoS Policy" section on page 42-75.

Using Metadata in QoS Policy

Beginning with Cisco IOS Release IOS XE 3.3.0SG and IOS 15.1(1)SG, you can configure class-map with metadata filters. A QoS policy that include such classes is termed a *metadata based QoS policy* or *parameterized QoS policy*. It allows you to classify flows based on intuitive and user friendly metadata attributes rather than individual flow 5-tuple and applicable QoS actions.

Software uses mechanisms like MSI and MSI-Proxy to do the following:

- Identify flows
- Glean metadata information from the traffic received at the network edge
- Generate and transport metadata information using RSVP messages hop-by-hop to every network element along the flow path using on-path RSVP signalling mechanism.

For configuration details on Cisco Medianet Metadata, refer to the following URLs:

http://www.cisco.com/en/US/docs/ios-xml/ios/mdata/configuration/15-mt/metadata-framework.htmll

For details on the metadata commands, refer to the following URL:

http://www.cisco.com/en/US/docs/ios-xml/ios/qos/command/qos-cr-book.html

For configuration details on Cisco Media Services Proxy, refer to the following URL:

http://www.cisco.com/en/US/docs/ios-xml/ios/msp/configuration/15-mt/media-ser-prxy.html

For command details on Cisco Media Services Proxy, refer to the following URL:

http://www.cisco.com/en/US/docs/ios-xml/ios/msp/command/reference/guide/media-ser-prxy.html

Restrictions

The following restrictions apply to using a metadata-based QoS policy on a Catalyst 4500 series switch:

- They can only be attached to target in input direction.
- They can only be attached to physical ports and EtherChannel. They cannot be attached to VLANs, port VLANs, and SVI interfaces.
- A policy can have multiple metadata-based classifiers.
- A class-map can have one or more metadata filters with match-any or match-all semantics.
- Policy actions corresponding to metadata class are applied on aggregate traffic. However, if the metadata filter is configured along with Flexible NetFlow record filter, the policy action (like policer) applies on individual flows.
- If there are no flows associated with metadata filter, the software configures an implicit ACL with a deny ACE.
- If the same metadata QoS policy is applied on multiple interfaces, the policy is installed in hardware in separate TCAM entries for each interface; the TCAM entries are not shared by the interfaces.
- When a new flow is associated with a metadata filter, the software installs a new set of TCAM entries that includes the new flow along with other existing previously-discovered flows.

Observing Metadata Filter Statistics

- Although interfaces with the same metadata policy do not share TCAM resources in hardware, the metadata filter statistics observed with the show policy-map interface *ifname* command are reported as though it were shared.
- Only metadata filter statistics are available. The individual flow statistics are not available.

Example

The following example illustrates a metadata-based QoS policy with two classes using metadata filters:

```
class-map c1
 match application telepresence-media

class-map c2
 match access-group name mysubnet

class-map match-any c3
 match application webex-video
 match application webex-audio

policy-map p1
 class c1
  police cir 10m
 class c2
  set dscp cs1
  police cir 2m
 class c3
  police cir 5m
```

Configuring System Queue Limit

Note This feature is available only from Cisco IOS Release 15.0(2)SG1 and later and Cisco IOS Release XE 3.2.1SG.

With the **hw-module system max-queue-limit** command, the Catalyst 4500 series switch allows you to change the queue limit for all interfaces globally, instead of applying a policy with queue limit to all the interfaces.

To set the queue limit globally, perform this task:

	Command	Purpose
Step 1	Switch# **configure terminal**	Enters global configuration mode.
Step 2	Switch(config)# **hw-module system max-queue-limit** *max-queue-limit*	Sets the queue limit for all interfaces globally. Valid values are from 1024 to 8184. The value must be a multiple of 8.
Step 3	Switch(config)# **exit**	Returns to privileged EXEC mode.
Step 4	Switch# **reload**	Reloads standalone supervisor engine.
	or	
	Switch# **redundancy reload shelf**	Reloads redundancy supervisor engine in SSO mode.
	Switch# **redundancy force-switchover**	Reloads redundancy supervisor engine in RPR mode. This command must be followed by another redundancy force-switchover.

This is a global configuration command. You can override it with the per port, per class, **queue-limit** command.

For a standalone supervisor engine, you must reboot the engine after applying this command.

For redundant supervisors in SSO mode, you must enter the **redundancy reload shelf** command enforce reboot to both the supervisors. For redundancy supervisors in RPR mode, you must execute two consecutive switchovers to enforce the system queue limit on both the supervisors.

This example shows how to set the queue limit globally to 1024 on a standalone supervisor engine:

```
Switch> enable
Switch# configure terminal
Switch(config)# hw-module system max-queue-limit 1024
Switch(config)# exit
Switch# reload  (for standalone supervisors)
Switch# redundancy reload shelf (for redundancy supervisors in SSO mode)
or
Switch# redundancy force-switchover (followed by another redundancy force-switchover, for
redundancy supervisors in RPR mode)
```

Configuring VSS QoS

Note HQoS is not supported on the Catalyst 4500 Series Switch.

Topics include:

- MQC-based QoS Configuration, page 42-48
- Platform-supported Classification Criteria and QoS Features, page 42-48
- Platform Hardware Capabilities, page 42-49
- Prerequisites for Applying a QoS Service Policy, page 42-49
- Restrictions for Applying a QoS Service Policy, page 42-50
- Classification, page 42-50
- Policing, page 42-51
- Marking Network Traffic, page 42-52
- Shaping, Sharing (Bandwidth), Priority Queuing, Queue-limiting and DBL, page 42-59
- Enabling Per-Port Per-VLAN QoS, page 42-70
- Applying Flow-based QoS Policy, page 42-75
- Configuring CoS Mutation, page 42-79
- Configuring System Queue Limit, page 42-80

MQC-based QoS Configuration

Note Starting with Cisco IOS Release 12.2(40)SG, a Catalyst 4900M, a Catalyst 4948E, or a Catalyst 4500 Series Switch with Supervisor Engine 6-E or Supervisor Engine 6L-E use the MQC model of QoS.

To apply QoS, you use the Modular QoS Command-Line Interface (MQC), which is a CLI structure that allows you to complete the following tasks:

- Specify the matching criteria used to define a traffic class.
- Create a traffic policy (policy map). The traffic policy defines the QoS policy actions to be taken for each traffic class.
- Apply the policy actions specified in the policy map to an interface, VLAN, or port and VLAN.

For more information about the MQC, see the "Modular Quality of Service Command-Line Interface" section of the *Cisco IOS Quality of Service Solutions Configuration Guide, Release 12.3*.

Note The incoming traffic is considered trusted by default. Only when the *trusted boundary* feature is enabled on an interface can the port enter untrusted mode. In this mode, the switch marks the DSCP value of an IP packet and the CoS value of the VLAN tag on the Ethernet frame as "0".

Platform-supported Classification Criteria and QoS Features

The following table provides a summary of various classification criteria and actions supported on the Catalyst 4500 Series Switch. For details, refer to the *Catalyst 4500 Series Switch Command Reference*.

Supported classification actions	**Descriptions**
match access-group	Configures the match criteria for a class map on the basis of the specified ACL.
match any	Configures the match criteria for a class map to be successful match criteria for all packets.
match cos	Matches a packet based on a Layer 2 class of service (CoS) marking.
match [ip] dscp	Identifies a specific IP differentiated service code point (DSCP) value as a match criterion. Up to eight DSCP values can be included in one match statement.
match [ip] precedence	Identifies IP precedence values as match criteria.
match protocol	Configures the match criteria for a class map on the basis of the specified protocol.
Supported Qos Features	Descriptions
police	Configures traffic policing.
police (percent)	Configures traffic policing on the basis of a percentage of bandwidth available on an interface.
police (two rates)	Configures traffic policing using two rates, the committed information rate (CIR) and the peak information rate (PIR).
set cos	Sets the Layer 2 class of service (CoS) value of an outgoing packet.
set dscp	Marks a packet by setting the differentiated services code point (DSCP) value in the type of service (ToS) byte of IPv4 or traffic class byte of IPv6 packet.
set precedence	Sets the precedence value in the packet header.
table map support	Unconditional marking of one packet field based on another packet field.
priority	Gives priority to a class of traffic belonging to a policy map.
shape	Shapes traffic to the indicated bit rate according to the algorithm specified.
bandwidth	Provides a guaranteed minimum bandwidth to each of the eight queues.
dbl	Dynamic buffer limit.
queue-limit	Specifies the maximum number of packets a transmit queue can hold.

Note The classification action “match qos-group” is not supported in Cisco Release IOS XE 3.4.0SG and IOS 15.1(2)SG.

Note The QoS feature “set qos-group” is not supported in Cisco Release IOS XE 3.4.0SG and IOS 15.1(2)SG.

Platform Hardware Capabilities

Qos Actions	Numbers of entries supported
Classification	64k input and 64k output classification entries are supported. A given policy can use at most 24k ACLs
Policing	16K policers are supported. Policers are allocated to given direction in blocks of 2k. For example, 2k policers can be used in for input and 14k policers can be used for output. Single rate policers uses one policer entry. Single Rate Three Color Marker (srTCM) (RFC 2697) and Two Rate Three Color Marker (trTCM) (RFC 2698) uses two policer entries
Marking	Marking of Cos and DSCP/Precedence is supported through two marking tables, each capable of supporting 512 entries. There are separate tables for each direction.
Queuing	The queue size is Configurable with the maximum number of entries configurable per port depending on the chassis and line card type.
DBL	You can enable DBL action on all configured class-maps.

Prerequisites for Applying a QoS Service Policy

Unlike the Switch QoS model, there is no prerequisite for enabling QoS on various targets. Just the attachment of a service policy enables QoS and detachment of that policy disables QoS on that target.

Restrictions for Applying a QoS Service Policy

Traffic marking can be configured on an interface, a VLAN, or a port and VLAN. An interface can be a Layer 2 access port, a Layer 2 switch trunk, a Layer 3 routed port, or an EtherChannel. A policy is attached to a VLAN using *vlan configuration* mode.

Attaching QoS service policy to VLANs and EtherChannel is described in the “Policy Associations” section on page 42-73.

Classification

The supervisor engine supports classification of Layer 2, IP, IPv6 packets, and ARP packets marking performed on input can be matched in the output direction. The previous table lists the full set of capabilities. By default, the switch also supports classification resources sharing. Similarly, when the same policy is attached to a port or a VLAN or on per-port per-vlan targets, ACL entries are shared though QoS actions are unique on each target.

For example:

```
    class-map c1
      match ip dscp 50
Policy Map p1
    class c1
      police rate 1 m burst 200000
```

If policy-map p1 is applied to interfaces Gig 1/1 and Gig 1/2, 1 CAM entry is used (one ACE that matches IP packets), but 2 policers are allocated (one per target). So, all IP packets with dscp 50 are policed to 1 mbps on interface Gig 1/1 and packets on interface Gig 1/2 are policed to 1 mbps.

Note With Cisco IOS Release 12.2(46)SG, you can issue the **match protocol arp** command. For details, see the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

Classification Statistics

The supervisor engine supports only packet based classification statistics and TCAM resource sharing. When a policy-map is applied on multiple targets, the command **show policy-map interface** displays the aggregate classification statistics, not those specific to an interface.

Note To obtain per interface policy-map stats, you should configure a unique policy-map name on each interface.

When a policy-map is attached to a port-channel member ports, classification statistics are not displayed.

Configuring a Policy Map

You can attach only one policy map to an interface. Policy maps can contain one or more policy-map classes, each with different match criteria and actions.

Configure a separate policy-map class in the policy map for each type of traffic that an interface receives. Put all commands for each type of traffic in the same policy-map class. QoS does not attempt to apply commands from more than one policy-map class to matched traffic.

Creating a Policy Map

To create a policy map, enter this command:

Command	Purpose
`Switch(config)# [no] policy-map policy_name`	Creates a policy map with a user-specified name. Use the **no** keyword to delete the policy map.

Attaching a Policy Map to an Interface

To create a policy map, enter this command:

Command	Purpose
`Switch(config)# interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface | Port-channel number}`	Selects the interface to configure.
`Switch(config-if)# [no] service-policy input policy_map_name`	Attaches a policy map to the input direction of the interface. Use the no keyword to detach a policy map from an interface.
`Switch(config-if)# end`	Exits configuration mode.
`Switch# show policy-map interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface}`	Verifies the configuration.

Policing

The supervisor engine supports policers in the following operation modes:

- Single Rate Policer Two Color Marker

  This kind of policer is configured with just the committed rate (CIR) and normal burst and it has only conform and exceed actions.
- Single Rate Three Color Marker (srTCM) (RFC 2697)
- Two Rate Three Color Marker (trTCM) (RFC 2698)
- Color Blind Mode

  Policing accuracy of 0.75% of configured policer rate.

  The engine supports 16384 (16 x 1024, 16K) single rate, single burst policers. 16K policers are organized as 8 banks of 2K policers. The policer banks are dynamically assigned (input or output policer bank) by the software depending on the QoS configuration. So, the 16K policers are dynamically partitioned by software as follows:
  - 0 Input Policers and 16K Output Policers
  - 2K Input Policers and 14K Output Policers
  - 4K Input Policers and 12K Output Policers
  - 6K Input Policers and 10K Output Policers
  - 8K Input Policers and 8K Output Policers
  - 10K Input Policers and 6K Output Policers
  - 12K Input Policers and 4K Output Policers
  - 14K Input Policers and 2K Output Policers
  - 16K Input Policers and 0 Output Policers

These numbers represent individual policer entries in the hardware that support a single rate and burst parameter. Based on this, a switch supports the following number of policers:

- 16K Single Rate Policer with Single Burst (Two Color Marker)

- 8K Single Rate Three Color Marker (srTCM)
- 8K Two Rate Three Color Marker (trTCM)

These policers are partitioned between Input and Output in chunks of 2K policer banks. The different types of policers can all co-exist in the system. However, a given type of policer (srTCM, trTCM etc.) is configurable as a block of 128 policers.

Note Two policers are reserved for internal use.

How to Implement Policing

For details on how to implement the policing features on a Catalyst 4500 Series Switch, refer to the Cisco IOS documentation at the following link:

http://www.cisco.com/en/US/docs/ios/12_2/qos/configuration/guide/qcfpolsh.html

Platform Restrictions

Platform restrictions include the following:

- Multi-policer actions can be specified (setting CoS and IP DSCP is supported).
- When unconditional marking and policer based marking exists on the same field(cos or dscp or precedence), policer-based marking is preferred.
- If policer based service-policy is attached to both a port and a VLAN, port-based policed is preferred by default. To over-ride a specific VLAN policy on a given port, then you must configure a per-port per-vlan policy.
- You should not delete a port-channel with a per-port, per-VLAN QoS policy.

  Workaround: Before deleting the port-channel, do the following:

  1. Remove any per-port per-VLAN QoS policies, if any.

  2. Remove the VLAN configuration on the port-channel with the **no vlan-range** command.

Marking Network Traffic

Marking network traffic allows you to set or modify the attributes of traffic (that is, packets) belonging to a specific class or category. When used in conjunction with network traffic classification, marking network traffic is the foundation for enabling many quality of service (QoS) features on your network This module contains conceptual information and the configuration tasks for marking network traffic.

Contents

- "Hardware Capabilities for Marking" section on page 42-57
- "Configuring the Policy Map Marking Action" section on page 42-57
- "Marking Statistics" section on page 42-59

Information About Marking Network Traffic

To mark network traffic, you should understand the following concepts:

- "Purpose of Marking Network Traffic" section on page 42-53
- "Benefits of Marking Network Traffic" section on page 42-53
- "Two Methods for Marking Traffic Attributes" section on page 42-54

Purpose of Marking Network Traffic

Traffic marking is used to identify certain traffic types for unique handling, effectively partitioning network traffic into different categories.

After the network traffic is organized into classes by traffic classification, traffic marking allows you to mark (that is, set or change) a value (attribute) for the traffic belonging to a specific class. For instance, you may want to change the class of service (CoS) value from 2 to 1 in one class, or you may want to change the differentiated services code point (DSCP) value from 3 to 2 in another class. In this module, these values are referred to as attributes or marking fields.

Attributes that can be set and modified include the following:

- CoS value of a tagged Ethernet frame
- DSCP/Precedence value in the Type of Service (ToS) byte of IPv4.
- DSCP /Precedence value in the traffic class byte of IPv6

Benefits of Marking Network Traffic

Traffic marking allows you to fine-tune the attributes for traffic on your network. This increased granularity helps isolate traffic that requires special handling, and thus, helps to achieve optimal application performance.

Traffic marking allows you to determine how traffic will be treated, based on how the attributes for the network traffic are set. It allows you to segment network traffic into multiple priority levels or classes of service based on those attributes, as follows:

- Traffic marking is often used to set the IP precedence or IP DSCP values for traffic entering a network. Networking devices within your network can then use the newly marked IP precedence values to determine how traffic should be treated. For example, voice traffic can be marked with a particular IP precedence or DSCP and strict priority can then be configured to put all packets of that marking into that queue. In this case, the marking was used to identify traffic for strict priority queue.
- Traffic marking can be used to identify traffic for any class-based QoS feature (any feature available in policy map class configuration mode, although some restrictions exist).
- Traffic marking can be used to assign traffic to a QoS group within a switch. The switch can use the QoS groups to determine how to prioritize traffic for transmission. The QoS group value is usually used for one of the two following reasons:
  - To leverage a large range of traffic classes. The QoS group value has 64 different individual markings, similar to DSCP.

– If changing the Precedence or DSCP value is undesirable.

Two Methods for Marking Traffic Attributes

Note This section describes *Unconditional* marking, which differs from *Policer-based* marking. Unconditional marking is based solely on classification.

Method One: Unconditional Explicit Marking (using the set command)

You specify the traffic attribute you want to change with a set command configured in a policy map. The following table lists the available set commands and the corresponding attribute. For details on the set command, refer to the *Catalyst 4500 Series Switch Command Reference*.

Table 42-2 set Commands and Applicable Packet Types

set Commands	Traffic Attribute	Packet Type
set cos	Layer 2 CoS value of the outgoing traffic	Ethernet IPv4, IPv6
set dscp	DSCP value in the ToS byte	IPv4, IPv6
set precedence	precedence value in the packet header	IPv4, IPv6

If you are using individual **set** commands, those set commands are specified in a policy map. The following is a sample of a policy map configured with one of the set commands listed in Table 42-4.

In this sample configuration, the **set cos** command has been configured in the policy map (policy1) to mark the CoS attribute:

```
enable
configure terminal
policy map p1
    class class1
      set cos 3
end
```

For information on configuring a policy map, see the “Creating a Policy Map” section on page 42-51.

The final task is to attach the policy map to the interface. For information on attaching the policy map to the interface, see the “Attaching a Policy Map to an Interface” section on page 42-51.

Method Two: Unconditional Tablemap-based Marking

You can create a table map that can be used to mark traffic attributes. A table map is a kind of two-way conversion chart that lists and maps one traffic attribute to another. A table map supports a many-to-one type of conversion and mapping scheme. The table map establishes a to-from relationship for the traffic attributes and defines the change to be made to the attribute. That is, an attribute is set to one value that is taken from another value. The values are based on the specific attribute being changed. For instance, the Precedence attribute can be a number from 0 to 7, while the DSCP attribute can be a number from 0 to 63.

The following is a sample table map configuration:

```
table-map table-map1
map from 0 to 1
map from 2 to 3
exit
```

The following table lists the traffic attributes for which a to-from relationship can be established using the table map.

Table 42-3 Traffic Attributes for Which a To-From Relationship Can Be Established

The "To" Attribute	The "From" Attribute
Precedence	CoS, DSCP, Precedence
DSCP	COS, DSCP, Precedence
CoS	DSCP, CoS, Precedence

The following is an example of a policy map (policy2) configured to use the table map (table-map1) created earlier:

```
Policy map policy
    class class-default
      set cos dscp table table-map
exit
```

In this example, a mapping relationship was created between the CoS attribute and the DSCP attribute as defined in the table map.

For information on configuring a policy map to use a table map, "Configuring a Policy Map" section on page 42-50.

The final task is to attach the policy map to the interface. For information on attaching the policy map to the interface, see the "Attaching a Policy Map to an Interface" section on page 42-51.

Marking Action Drivers

A marking action can be triggered based on one of the two QoS processing steps.

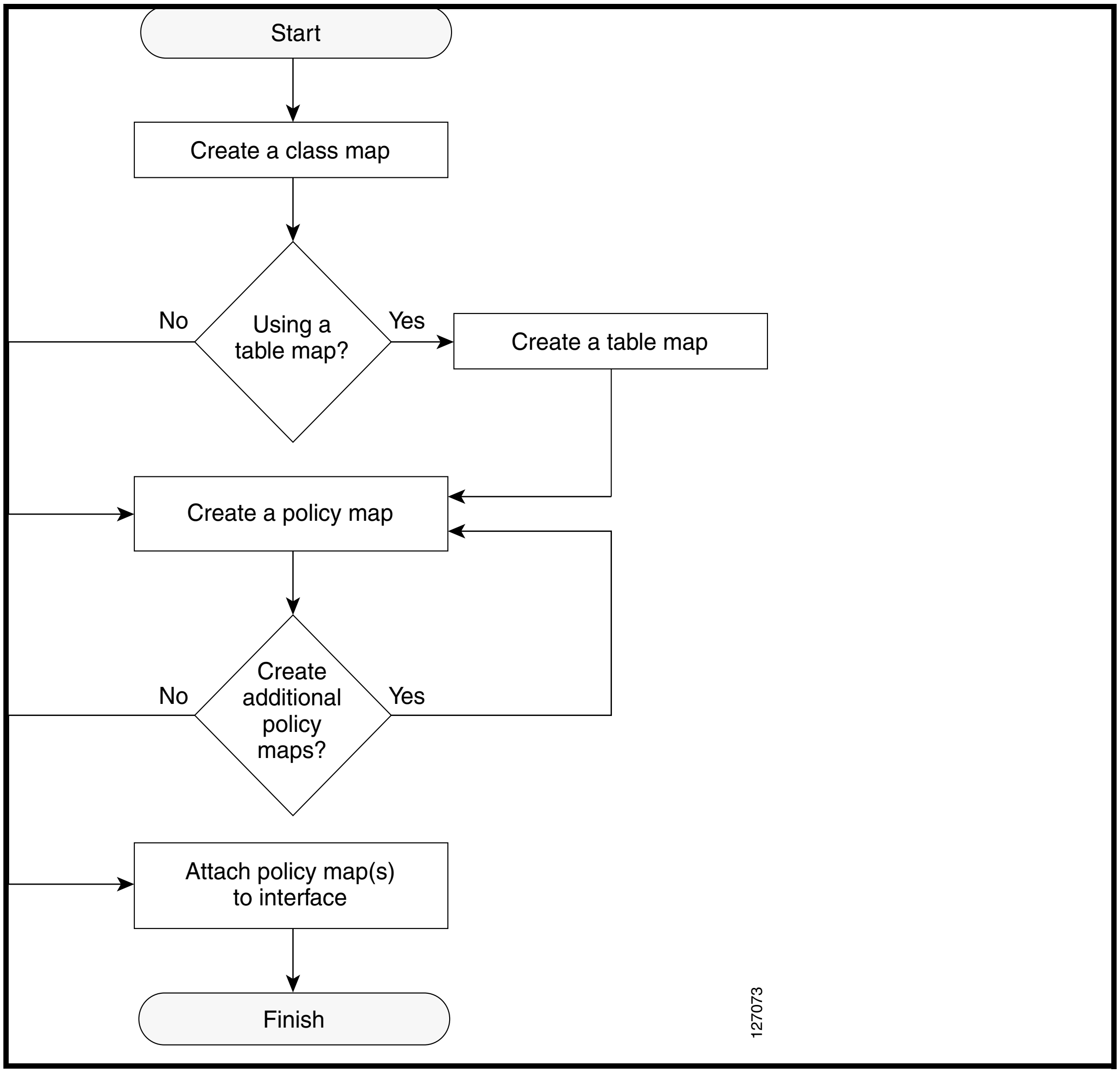
Classification based: In this case, all the traffic matching a class is marked using either explicit or tablemap based method. This method is referred to as *unconditional* marking.

Policer result-based: In this case, a class of traffic is marked differently based on the policer result (conform/exceed/violate) applicable to that packet. This method is referred to as *conditional* marking.

Traffic Marking Procedure Flowchart

Figure 42-5 illustrates the order of the procedures for configuring traffic marking.

Figure 42-3 Traffic marking Procedure Flowchart



Restrictions for Marking Network Traffic

The following restrictions apply to the following packet marking action:

- Only explicit marking is supported for policer-based marking.

Multi-attribute Marking Support

The supervisor engine can mark more than one QoS attribute of a packet matching a class of traffic. For example, DSCP, and CoS can all be set together, using either explicit or tablemap-based marking.

Note When using unconditional explicit marking of multiple fields or policer-based multi-field, multi-region (conform/exceed/violate) marking the number of table maps that can be setup in TOS or COS marking tables will be less than the maximum supported.

Hardware Capabilities for Marking

Catalyst 4900M, Catalyst 4948E, Supervisor Engine 6-E, and Supervisor Engine 6L-E provide a 128 entry marking action (Supervisor Engine 7-E, Supervisor Engine 7L-E, and Supervisor Engine 8-E provide a 256 entry marking action) where each entry specifies the type of marking actions on CoS and DSCP/Precedence fields as well as policer action to transmit/markdown/drop a packet.

One such table is supported for each direction, input and output. This table is used for both unconditional marking as well as policer-based marking. It can be used to support 256 unique marking actions or 64 unique policer-based actions or a combinations of the two.

For each of the marking fields (COS and DSCP), the supervisor engine provides 512 entry marking tables for each direction. These are similar to mapping tables available on supervisor engines that support the switch QoS model. However, these provide an ability to have multiple unique mapping tables that are setup by the user.

For example, the TOS marking table provides marking of DSCP/Precedence fields and can be used as one of the following:

- 64 (32) different tablemaps with each one mapping 8 CoS (16 CoS and CFi) values to DSCP in input (output) direction
- a combination of above two types of tablemaps

Similar mappings are available on the 512 entry COS marking table.

Configuring the Policy Map Marking Action

This section describes how to establish unconditional marking action for network traffic.

As a prerequisites, create a class map (*ipp5)* and a policy map. (Refer to the“Configuring a Policy Map” section on page 42-50).

Note The marking action command options have been extended (refer to Table 42-4 on page 42-54 andTable 42-5 on page 42-55).

Configuring Tablemap-based Unconditional Marking

To configure table-map based unconditional marking, perform this task:

	Command	Purpose
Step 1	`Switch#` **`configure terminal`**	Enters global configuration mode.
Step 2	`Switch(config)#` **`table-map`** ***`name`***	Configures a tablemap.
Step 3	`Switch(config-tablemap)#` **`map from`** *`from_value`* **`to`** *`to_value`*	Creates a map from a *from_value* to a *to_value*
Step 4	`Switch(config-tablemap)#` **`exit`**	Exits table-map configuration mode.
Step 5	`Switch(config)#` **`policy-map`** *`name`*	Enters policy-map configuration mode.
Step 6	`Switch(config-p)#` **`class`** `name`	Selects the class for QoS actions.
Step 7	`Switch(config-p-c)#` **`set cos`** `|` **`dscp`** `|` **`prec cos`** `|` **`dscp`** `|` **`prec`** `[`**`table`** *`name`*`]`	Selects the marking action based on an implicit or explicit table-map.
Step 8	`Switch(config-p-c)#` **`end`**	Exits configuration mode.

	Command	Purpose
Step 9	`Switch# show policy-map name`	Verifies the configuration of the policy-map.
Step 10	`Switch# show table-map name`	Verifies the configuration of the table-map.

The following example shows how to enable marking action using table-map.

```
Switch(config)# table-map dscp2Cos
Switch(config-tablemap)# map from 8 to 1
Switch(config-tablemap)# exit
Switch(config)# policy-map p1
Switch(config-pmap)# class ipp5
Switch(config-pmap-c)# set cos dscp table dscp2Cos
Switch(config-pmap-c)# end
Switch# show policy-map p1

Policy Map p1
    Class ipp5
      set cos dscp table dscp2Qos

Switch# show table-map dscp2Cos

 Table Map dscp2Cos
    from 8 to 1
    default copy
```

Configuring Policer Result-based Conditional Marking

To configure policer result-based conditional marking, setup a single rate or dual rate policer. Refer to the “How to Implement Policing” section on page 42-52.

This example shows how to configure a two rate three-color policer with explicit actions for each policer region:

```
Switch# configure terminal
Switch(config-pmap-c)# policer cir percent 20 pir percent 30
Switch(config-pmap-c-policer)# conform-action set-cos-transmit 3 set-dscp-transmit 10
Switch(config-pmap-c-policer)# exceed-action set-cos-transmit 4 set-dscp-transmit 20
Switch(config-pmap-c-policer)# violate action drop
Switch# show policy-map p1

  Policy Map police
    Class ipp5
     police cir percent 20 pir percent 30
       conform-action set-cos-transmit 3
       conform-action set-dscp-transmit af11
       exceed-action set-cos-transmit 4
       exceed-action set-dscp-transmit af22
       violate-action drop
```

Marking Statistics

The marking statistics indicate the number of packets that are *marked*.

For unconditional marking, the *classification entry* points to an entry in the marking action table that in turn indicates the fields in the packet that are marked. Therefore, the classification statistics by itself indicates the unconditional marking statistics.

For a conditional marking using policer, provided the policer is a packet rate policer, you cannot determine the number packets marked because the policer only provides byte statistics for different policing results.

Shaping, Sharing (Bandwidth), Priority Queuing, Queue-limiting and DBL

The Catalyst 4500 Series Switch supports the Classification-based (class-based) mode for transmit queue selection. In this mode, the transmit queue selection is based on the Output QoS classification lookup.

Note Only output (egress) queuing is supported.

The supervisor engine supports 8 transmit queues per port. Once the forwarding decision has been made to forward a packet out a port, the output QoS classification determines the transmit queue into which the packet needs to be enqueued.

By default, without any service policies associated with a port, there are two queues (a control packet queue and a default queue) with no guarantee as to the bandwidth or kind of prioritization. The only exception is that system generated control packets are enqueued into control packet queue so that control traffic receives some minimum link bandwidth.

Queues are assigned when an output policy attached to a port with one or more queuing related actions for one or more classes of traffic. Because there are only eight queues per port, there can be at most eight classes of traffic (including the reserved class, class-default) with queuing action(s). Classes of traffic that do not have any queuing action are referred to as *non-queuing* classes. Non-queuing class traffic ends up using the queue corresponding to class class-default.

When a queuing policy (a policy with queuing action) is attached, the control packet queue is deleted and the control packets are enqueued into respective queue per their classification. An egress QoS class must be configured to match IP Precedence 6 and 7 traffic, and a bandwidth guarantee must be configured.

Dynamic resizing of queues (queue limit class-map action) is supported through the use of the **queue-limit** command. Based on the chassis and line card type, all eight queues on a port are configured with equal queue size.

Shaping

Shaping enables you to delay out-of-profile packets in queues so that they conform to a specified profile. Shaping is distinct from policing. Policing drops packets that exceed a configured threshold, whereas shaping *buffers* packets so that traffic remains within a given threshold. Shaping offers greater *smoothness* in handling traffic than policing. You enable average-rate traffic shaping on a traffic class with the **policy-map** class configuration command.

The supervisor engine supports a range of 32kbps to 10 gbps for shaping, with a precision of approximately +/- 0.75 per cent.

When a queuing class is configured without any explicit shape configuration, the queue shape is set to the link rate.

To configure class-level shaping in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map policy-map-name`	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class class-name`	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)# shape average {cir-bps [optional_postfix] | percent percent}`	Enables average-rate traffic shaping. You can specify the shaping rate in absolute value or as a percentage: • For *cir-bps* [*optional_postfix*]*,* specify the shaping rate in bps. Range is 32000 to 10000000000 bps. Supply an optional postfix (K, M, G). • For *percent*, specify the percentage of link rate to shape the class of traffic. The range is 1 to 100. By default, average-rate traffic shaping is disabled.
Step 5	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 6	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 7	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.
Step 8	`Switch(config-interface)# service-policy output policy-map-name`	Specifies the policy-map name, and apply it a physical interface.
Step 9	`Switch(config-interface)# end`	Returns to privileged EXEC mode.

Step 10	`Switch# show policy-map [policy-map-name [class class-map-name]]`
	or
	`Switch# show policy-map interface interface-id`
		Verifies your entries.

Step 11	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** *class-name* policy-map configuration command. To disable the average-rate traffic shaping, use the **no shape average** policy-map class configuration command.

This example shows how to configure class-level, average-rate shaping. It limits traffic class class1 to a data transmission rate of 256 kbps:

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# shape average 256000
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch#

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
       shape average 256000
```

This example shows how to configure class-level, average shape percentage to 32% of link bandwidth for queuing-class traffic:

```
Switch# configure terminal
Switch(config)# policy-map queuing-policy
Switch(config-pmap)# class queuing-class
Switch(config-pmap-c)# shape average percent 32
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output queuing-policy1
Switch(config-if)# end
Switch #

Switch# show policy-map queuing-policy
  Policy Map queuing-policy
    Class queuing-class
       Average Rate Traffic Shaping
       cir 32%
```

Sharing(bandwidth)

The bandwidth assigned to a class of traffic is the minimum bandwidth that is guaranteed to the class during congestion. Transmit Queue Sharing is the process by which output link bandwidth is shared among multiple queues of a given port.

The supervisor engine supports a range of 32 kbps to 10 gbps for sharing, with a precision of approximately +/- 0.75 per cent. The sum of configured bandwidth across all queuing classes should not exceed the link bandwidth.

To configure class-level bandwidth action in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map` *`policy-map-name`*	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class` *`class-name`*	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.

	Command	Purpose
Step 4	`Switch(config-pmap-class)# bandwidth {bandwidth-kbps | percent percent}`	Specifies the minimum bandwidth provided to a class belonging to the policy map when there is traffic congestion in the switch. If the switch is not congested, the class receives more bandwidth than you specify with the **bandwidth** command. By default, no bandwidth is specified. You can specify the bandwidth in kbps or as a percentage: o For *bandwidth-kbps*, specify the bandwidth amount in kbps assigned to the class. The range is 32 to 10000000. o For *percent*, specify the percentage of available bandwidth assigned to the class. The range is 1 to 100. Specify all the class bandwidths in either kbps or in percentages, but not a mix of both.
Step 5	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 6	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 7	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.
Step 8	`Switch(config-interface)# service-policy output policy-map-name`	Specifies the policy-map name, and apply it a physical interface.
Step 9	`Switch(config-interface)# end`	Returns to privileged EXEC mode.

Step 10	`Switch# show policy-map [policy-map-name [class class-map-name]]`
	or
	`Switch# show policy-map interface interface-id`
		Verifies your entries.

Step 11	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** ***class-name*** policy-map configuration command. To return to the default bandwidth, use the **no bandwidth** policy-map class configuration command.

This example shows how to create a class-level policy map called policy11 for three classes called prec1, prec2, and prec3. In the policy for these classes, 30 percent of the available bandwidth is assigned to the queue for the first class, 20 percent is assigned to the queue for the second class, and 10 percent is assigned to the queue for the third class.

```
Switch # configure terminal
Switch(config)# policy-map policy11
Switch(config-pmap)# class prec1
Switch(config-pmap-c)# bandwidth percent 30
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec2
Switch(config-pmap-c)# bandwidth percent 20
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec3
Switch(config-pmap-c)# bandwidth percent 10
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy11
Switch(config-if)# end
Switch #

Switch# show policy-map policy11
  Policy Map policy11
    Class prec1
      bandwidth percent 30
    Class prec2
      bandwidth percent 20
    Class prec3
      bandwidth percent 10
```

This example shows how to create a class-level policy map called policy11 for three classes called prec1, prec2, and prec3. In the policy for these classes, 300 mbps of the available bandwidth is assigned to the queue for the first class, 200 mbps is assigned to the queue for the second class, and 100 mbps is assigned to the queue for the third class.

```
Switch # configure terminal
Switch(config)# policy-map policy11
Switch(config-pmap)# class prec1
Switch(config-pmap-c)# bandwidth 300000
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec2
Switch(config-pmap-c)# bandwidth 200000
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec3
Switch(config-pmap-c)# bandwidth 100000
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy11
Switch(config-if)# end
Switch #

Switch# show policy-map policy11
  Policy Map policy11
    Class prec1
      bandwidth 300000 (kbps)
    Class prec2
      bandwidth 200000 (kbps)
    Class prec3
      bandwidth 100000 (kbps)
```

When a queuing class is configured without any explicit share/bandwidth configuration, because the queue is not guaranteed any minimum bandwidth, the hardware queue is programmed to get a share of any unallocated bandwidth on the port as shown in the following example.

If there is no bandwidth remaining for the new queue or if the unallocated bandwidth is not sufficient to meet the minimum configurable rate (32kbps) for all queues which do not have any explicit share/bandwidth configuration, then the policy association is rejected.

For example, if there are two queues as given below

```
policy-map queue-policy
   class q1
     bandwidth percent 10

   class q2
     bandwidth percent 20
```

then the bandwidth allocation for the queues is as follows

```
q1 = 10%
           q2 = 20%
```

```
class-default = 70%
```

Similarly, when another queuing class (say q3) is added without any explicit bandwidth (say, just a shape command), then the bandwidth allocation is

```
q1 = 10%
          q2 = 20%
          q3 = min(35%, q3-shape-rate)
class-default = max(35%, (100 - (q1 + q2 + q3 )))
```

Priority queuing

Only one transmit queue on a port can be configured as *strict priority* (termed Low Latency Queue, or LLQ).

LLQ provides strict-priority queuing for a traffic class. It enables delay-sensitive data, such as voice, to be sent *before* packets in other queues. The priority queue is serviced first until it is empty or until it is under its shape rate. Only one traffic stream can be destined for the priority queue per class-level policy. You enable the priority queue for a traffic class with the **priority policy-map class** configuration command at the class mode.

A LLQ can starve other queues unless it is rate limited. The supervisor engine does not support *conditional policing* where a 2-parameter policer (rate, burst) becomes effective when the queue is *congested* (based on queue length). However, it supports application of an unconditional policer to rate limit packets enqueued to the strict priority queue.

When a priority queue is configured on one class of a policy map, only *bandwidth remaining* is accepted on other classes, guaranteeing a minimum bandwidth for other classes from the remaining bandwidth of what is left after using the priority queue. When a priority queue is configured with a policer, then either *bandwidth* or *bandwidth remaining* is accepted on other classes.

Note Use *bandwidth* or *bandwidth remaining* on all classes. You cannot apply *bandwidth* on one class and *bandwidth remaining* on another class within a policy map.

To enable class-level priority queuing in a service policy, follow these steps:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map policy-map-name`	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class class-name`	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)# priority`	Enables the strict-priority queue, and give priority to a class of traffic. By default, strict-priority queueing is disabled.
Step 5	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 6	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 7	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.

	Command	Purpose
Step 8	`Switch(config-interface)# service-policy output policy-map-name`	Specifies the policy-map name, and apply it a physical interface.
Step 9	`Switch(config-interface)# end`	Returns to privileged EXEC mode.

Step 10	`Switch# show policy-map [policy-map-name [class class-map-name]]`
	or
	`Switch# show policy-map interface interface-id`
		Verifies your entries.

Step 11	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** *class-name* policy-map configuration command. To disable the priority queue, use the **no priority** *policy-map-class* configuration command.

This example shows how to configure a class-level policy called policy1. Class 1 is configured as the priority queue, which is serviced first until it is empty.

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# priority
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch #

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
      priority
```

Queue-limiting

When a class-based queue is instantiated on a physical port, it is set up with a default size. This size represents the number of queue entries in which packets belonging to that class of traffic can be queued. The scheduler moves packets from the queue that are ready for transmission, based on the queue shape, bandwidth, and priority configuration.

The queue-limit provides the maximum number of packets that can be in the queue at any given time. When the queue is full, an attempt to enqueue any further packets results in tail drop. However, if dynamic buffer limiting (DBL) is enabled on the queue, packets get a probabilistic drop based on the DBL algorithm, even when the queue is not full.

The **queue-limit** command can be configured under a class only when queue scheduling, such as bandwidth, shape, or priority is already configured. The only exception to this requirement is the support of the stand-alone **queue-limit** command on the class-default class.

Queue Memory

The number of queue entries that can be allocated has to be a multiple of 8 and can range from 16 to 8184. When a class-based queue is instantiated on a physical port, it is given a default number of entries. This default queue size is based on the number of slots in the chassis and the number of front-panel ports in each slot.

Catalyst 4900M, Catalyst 4948E, Supervisor Engine 6-E, and Supervisor Engine 6L-E have 512 K (524,288) queue entries of which the system sets aside 100 K (102,400) queue entries in a free reserve pool. Of the remaining 412 K (421,88), the drop port is provided 8184 entries and the CPU ports are assigned 11704 entries. Supervisor Engine 7-E and Supervisor Engine 8-E have 1M (1,048,576) queue entries of which the system sets aside 100K (102,400) queue entries in a free reserve pool. Of the remaining queue entries, the drop port is provided 8184 entries, 24576 entries for recirculation ports and the CPU ports are assigned 8656 entries. Supervisor Engine 7L-E has a 512 K queue entries.

The remaining entries are divided equally among the slots in the chassis. In a redundant chassis the two supervisor slots are treated as one for the purpose of this entries distribution. Within each slot the number of queue entries are equally divided among the front-panel ports present on the line card in that slot.

When the user configuration for queue entries on an interface exceeds its dedicated quota, the system attempts to satisfy the configuration from the free reserve pool. The entries from the free reserve pool are allocated to interfaces on a first-come first-served basis.

Service Policy Association

When a QoS service-policy with queuing actions is configured, but no explicit queue-limit command is attached in the egress direction on a physical interface, each of the class-based queues gets the same number of queue entries from within the dedicated quota for that physical port. When a queue is explicitly given a size using the queue-limit command, the switch tries to allocate all the entries from within the dedicated quota for the interface. If the required number of entries is greater than the dedicated quota for the interface, the switch tries to allocate the entries from the free reserve.

The queue entries associated with a queue always have to be consecutive. This requirement can result in fragmentation of the 512K of the queue entries that are shared across the switch. For example, an interface may not have enough entries for a queue in its dedicated quota and thus have to use the free reserve to set up that queue. In this case, the queue entries from the dedicated quota remain unused because they cannot be shared with any other port or slot.

When the QoS service-policy associated with an interface is removed, any queue entries taken from the free reserve are returned to the free reserve pool. The interface queuing configuration reverts to two queues — class-default and the control-packet queue with default shape, bandwidth, and size. The control-packet queue is set up with size 16 whereas the default queue is set up with the maximum size possible based on the dedicated quota for that interface.

Queue Allocation Failure

The switch might not be able to satisfy the explicit queue size required on one or more queues on an interface because of fragmentation of queue memory or lack of enough free reserve entries. In this scenario, the switch logs an error message to notify you of the failure. The QoS service-policy is left configured on the interface. You can fix the error by removing the QoS service-policy and examining the current usage of the queue entries from the free reserve by other ports on the switch.

Note Do not attach a QoS policy with the maximum queue-limit (8184) to a large number of targets in a VSS system. This will cause continuous reloads on the standby supervisor engine.

To configure class-level queue-limit in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch#` **`configure terminal`**	Enters global configuration mode.
Step 2	`Switch(config)#` **`policy-map`** *`policy-map-name`*	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)#` **`class`** *`class-name`*	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)#` **`shape average`** `{`*`cir-bps`* `[`*`optional_postfix`*`]` **`|`** **`percent`** *`percent`*`}`	Enables average-rate traffic shaping. You can specify the shaping rate in absolute value or as a percentage: • For *cir-bps* [*optional_postfix*], specify the shaping rate in bps. Range is 32000 to 10000000000 bps. Supply an optional postfix (K, M, G). • For *percent*, specify the percentage of link rate to shape the class of traffic. The range is 1 to 100. By default, average-rate traffic shaping is disabled.
Step 5	`Switch(config-pmap-class)#` **`queue-limit`** *`number-of-packets`*	Provides an explicit queue size in packets. The size must be a multiple of 8 and ranging from 16 to 8184.
Step 6	`Switch(config-pmap-class)#` **`exit`**	Returns to policy-map configuration mode.
Step 7	`Switch(config-pmap)#` **`exit`**	Returns to global configuration mode.
Step 8	`Switch(config)#` **`interface`** *`interface-id`*	Specifies a physical port and enter interface configuration mode.
Step 9	`Switch(config-interface)#` **`service-policy output`** *`policy-map-name`*	Specifies the policy-map name, and apply it a physical interface.
Step 10	`Switch(config-interface)#` **`end`**	Returns to privileged EXEC mode.

Step 11	`Switch#` **`show policy-map`** `[`*`policy-map-name`* **`[class`** *`class-map-name`*`]]`
	or
	`Switch#` **`show policy-map interface`** *`interface-id`*
		Verifies your entries.

Step 12	`Switch#` **`copy running-config startup-config`**	(Optional) Saves your entries in the configuration file.

To remove the explicit queue size use the **no queue-limit** command under the class in a policy-map.

This example shows how to configure a class-based queue with an explicit **queue-limit** command. It limits traffic class class1 to a queue of size 4048:

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# shape average 256000
Switch(config-pmap-c)# queue-limit 4048
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch#

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
       shape average 256000
       queue-limit 4048
Switch#
```

Active Queue Management (AQM) via Dynamic Buffer Limiting (DBL)

AQM provides buffering control of traffic flows prior to queuing a packet into a transmit queue of a port. This is of significant interest in a shared memory switch, ensuring that certain flows do not hog the switch packet memory.

Note The supervisor engine supports active switch buffer management via DBL.

Except for the default class of traffic (class class-default), you can configure DBL action only when at least one of the other queuing action is configured.

To configure class-level dbl action along with shaping in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map policy-map-name`	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class class-name`	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)# shape average cir-bps`	Enables average-rate traffic shaping. Specify the committed information rate, the bit rate that traffic is shaped to, in bps. The range is 32000 to 10000000000 bps. By default, average-rate traffic shaping is disabled.
Step 5	`Switch(config-pmap-class)# dbl`	Enables DBL on the queue associated with this class of traffic
Step 6	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 7	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 8	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.
Step 9	`Switch(config-interface)# service-policy output policy-map-name`	Specifies the policy-map name, and apply it a physical interface.
Step 10	`Switch(config-interface)# end`	Returns to privileged EXEC mode.

	Command	Purpose

Step 11	`Switch# `**`show policy-map`**` [`*`policy-map-name`*` `**`[class`**` `*`class-map-name`*`]]`
	or
	`Switch# `**`show policy-map interface`**` `*`interface-id`*
		Verifies your entries.

Step 12	`Switch# `**`copy running-config startup-config`**	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** *class-name* policy-map configuration command. To disable DBL on the associated queue, use the **no dbl** policy-map class configuration command.

The following example shows how to configure class-level, DBL action along with average-rate shaping. It enables DBL on the queue associated with traffic-class *class1*.

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# shape average 256000
Switch(config-pmap-c)# dbl
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch#

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
       shape average 256000
     dbl
```

Transmit Queue Statistics

Transmit queue statistics are visible by entering the **show policy-map interface** command:

```
Switch# show policy-map interface gigabitEthernet 1/1
 GigabitEthernet1/1

  Service-policy output: queuing-policy

    Class-map: queuing-class (match-all)
      1833956 packets
      Match: cos  1
      Queueing
      (total drops)  1006239
      (bytes output) 56284756
      shape (average) cir 320000000, bc 1280000, be 1280000
      target shape rate 320000000

    Class-map: class-default (match-any)
      1 packets
      Match: any

      (total drops)  0
      (bytes output) 2104
```

Enabling Per-Port Per-VLAN QoS

The per-port per-VLAN QoS feature enables you to specify different QoS configurations on different VLANs on a given interface. Typically, you use this feature on trunk or voice VLANs (Cisco IP Phone) ports, as they belong to multiple VLANs.

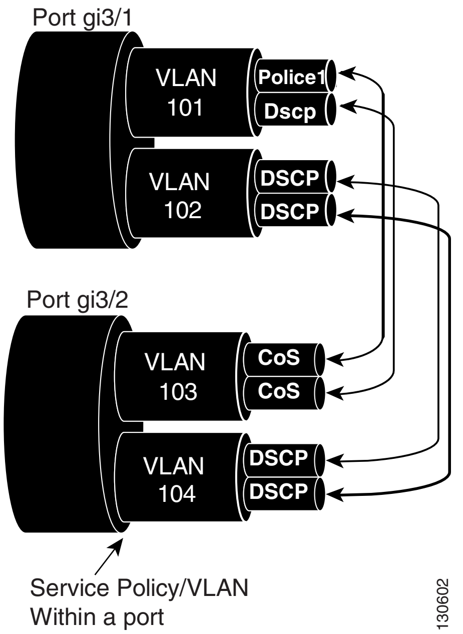
To configure per-port per-VLAN QoS, perform this task:

	Command	Purpose
Step 1	`Switch(config)#` **`interface`** `{`**`fastethernet`** `|` **`gigabitethernet`** `|` **`tengigabitethernet`**`}` *`slot/interface`* `|` **`Port-channel`** *`number`*	Selects the interface to configure.
Step 2	`Switch(config-if)#` **`vlan-range`** *`vlan_range`*	Specifies the VLANs involved.
Step 3	`Switch(config-if-vlan-range)#` **`service-policy`** **`{input`** `|` **`output}`** *`policy-map`*	Specifies the policy-map and direction.
Step 4	`Switch(config-if-vlan-range)#` **`exit`**	Exits class-map configuration mode.
Step 5	`Switch(config-if)#` **`end`**	Exits configuration interface mode.
Step 6	`Switch#` **`show policy-map interface`** *`interface_name`*	Verifies the configuration.

Example 1

Figure 42-6 displays a sample topology for configuring PVQoS. The trunk port gi3/1 is comprised of multiple VLANs (101 and 102). Within a port, you can create your own service policy per VLAN. This policy, performed in hardware, might consist of ingress and egress Policing or giving precedence to voice packet over data.

Figure 42-4 Per-Port Per-VLAN Topology



The following configuration file shows how to perform ingress and egress policing per VLAN using the policy-map P31_QOS applied to port Gigabit Ethernet 3/1:

```
ip access-list 101 permit ip host 1.2.2.2 any
ip access-list 103 permit ip any any
Class-map match-all RT

match ip access-group 101
Class-map Match all PD

match ip access-group 103
Policy-map P31_QoS

Class RT


Police 200m 16k conform transmit exceed drop

Class PD


Police 100m 16k conform transmit exceed drop

Interface Gigabit 3/1
Switchport
Switchport trunk encapsulation dot1q
Switchport trunk allowed vlan 101-102
    Vlan range 101
        Service-policy input P31_QoS
        Service-policy output P31_QoS
    Vlan range 102
        Service-policy input P32_QoS
        Service-policy output P32_QoS
```

Example 2

Let us assume that interface Gigabit Ethernet 6/1 is a trunk port and belongs to VLANs 20, 300-301, and 400. The following example shows how to apply policy-map p1 for traffic in VLANs 20 and 400 and policy map p2 to traffic in VLANs 300 through 301:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet 6/1
Switch(config-if)# vlan-range 20,400
Switch(config-if-vlan-range)# service-policy input p1
Switch(config-if-vlan-range)# exit
Switch(config-if)# vlan-range 300-301
Switch(config-if-vlan-range)# service-policy output p2
Switch(config-if-vlan-range)# end
Switch#
```

Example 3

The following command shows how to display policy-map statistics on VLAN 20 configured on Gigabit Ethernet interface 6/1:

```
Switch# show policy-map interface gigabitEthernet 6/1 vlan 20

 GigabitEthernet6/1 vlan 20

  Service-policy input: p1

    Class-map: c1 (match-all)
      0 packets
      Match: cos  1
      Match: access-group 100
      police:
          cir 100000000 bps, bc 3125000 bytes
```

```
        conformed 0 bytes; actions:
          transmit
        exceeded 0 bytes; actions:
          drop
        conformed 0000 bps, exceed 0000 bps

    Class-map: class-default (match-any)
      0 packets
      Match: any
```

Example 4

The following command shows how to display policy-map statistics on all VLANs configured on Gigabit Ethernet interface 6/1:

```
Switch# show policy-map interface gigabitEthernet 6/1

 GigabitEthernet6/1 vlan 20

  Service-policy input: p1

    Class-map: c1 (match-all)
      0 packets
      Match: cos  1
      Match: access-group 100
      police:
          cir 100000000 bps, bc 3125000 bytes
        conformed 0 bytes; actions:
          transmit
        exceeded 0 bytes; actions:
          drop
        conformed 0000 bps, exceed 0000 bps

    Class-map: class-default (match-any)
      0 packets
      Match: any

 GigabitEthernet6/1 vlan 300

  Service-policy output: p2

    Class-map: c1 (match-all)
      0 packets
      Match: cos  1
      Match: access-group 100
      QoS Set
        dscp 50
      police:
          cir 200000000 bps, bc 6250000 bytes
        conformed 0 bytes; actions:
          transmit
        exceeded 0 bytes; actions:
          drop
        conformed 0000 bps, exceed 0000 bps

    Class-map: class-default (match-any)
      0 packets
      Match: any

 GigabitEthernet6/1 vlan 301

  Service-policy output: p2
```

```
Class-map: c1 (match-all)
  0 packets
  Match: cos  1
  Match: access-group 100
  QoS Set
    dscp 50
  police:
      cir 200000000 bps, bc 6250000 bytes
    conformed 0 bytes; actions:
      transmit
    exceeded 0 bytes; actions:
      drop
    conformed 0000 bps, exceed 0000 bps
```

Policy Associations

The supervisor engine supports per-port, per-VLAN policies. The associated policies are attached to the interface, VLAN, and a specific VLAN on a given port, respectively.

A policy can be associated with a variety of objects. The following table lists the objects and the actions allowed.

Table 42-1 Table QoS Policy Associations

Object	Action
Physical port	Policing, marking, and queuing
VLAN	Policing and marking
Port and VLAN (PV)	Policing and marking
EtherChannel	Policing and marking
EtherChannel member port	Queuing

Qos Action Restrictions

- The same actions cannot be performed multiple times in a given direction on different targets. In other words, it is not possible to police the packets both on port and VLAN in the input direction. However, the user can police on the input port and on the output VLAN.
- Queuing actions are only allowed in the egress direction and only on the physical port.
- Percentage-based actions like policer cannot be configured on a VLAN, Port and VLAN (PV) and EtherChannel.
- Port channel or VLAN configuration can only have a policing or a marking action, not a queueing action.

Qos Policy priorities

- If a policy on a port and a VLAN are configured with conflicting actions (such as policing or marking actions on both a port and VLAN), the port policy is picked.
- If policy on a VLAN on a given port must be over-written, the user can configure PV policy.

Qos Policy merging

Applicable policies are applied to a given packet in given direction. For example, if you configure egress VLAN-based police and marking, followed by selective queuing on the port, then actions from both policies will be applied for this packet.

The following policy-map configuration restrictions are imposed on an EtherChannel:

- only policing and marking actions are supported at the EtherChannel level
- only queuing actions are supported at the physical member port level

A packet can be marked (dscp or cos fields) by the EtherChannel policy. If the physical member port policy uses a classification based on dscp or cos fields, it must be based on the marked (modified) value. To ensure proper operation, the following restriction is placed on the EtherChannel.

The classification criteria for the policy-map on the physical member ports has to based only on one type of field:

- dscp
- precedence
- cos
- any non marking field (no dscp or cos based classification)

Classification criteria for the policy-map on the physical member ports cannot be based on a combination of fields. This restriction ensures that if the EtherChannel policy is marking down dscp or cos, the marked (modified) value-based classification can be implemented in hardware.

Note Auto-QoS macros with SRND4 generate class-maps with more than one type of match. These class-maps need to be modified to use only with one matching type when applied on EtherChannel member ports.

Note Classification criteria for the policy-map on the physical member ports cannot be modified to add a new type of field.

Auto-QoS is not supported on EtherChannel or its member ports. A physical port configured with Auto-QoS is not allowed to become a member of a physical port.

Software QoS

At the highest level, there are two types of locally sourced traffic (such as control protocol packets, pings, and telnets) from the switch: high priority traffic (typically the control protocol packets like OSPF Hellos and STP) and low priority packets (all other packet types).

The QoS treatment for locally-sourced packets differs for the two types.

The supervisor engine provides a way to apply QoS to packets processed in the software path. The packets that get this QoS treatment in software can be classified into two types: software switched packets and software generated packets.

On reception, software switched packets are sent to the CPU that in turn sends them out of another interface. For such packets, input software QoS provides input marking and output software QoS provides output marking and queue selection.

The software generated packets are the ones locally sourced by the switch. The type of output software QoS processing applied to these packets is the same as the one applied to software switched packets. The only difference in the two is that the software switched packets take input marking of the packet into account for output classification purpose.

High Priority Packets

High priority packets are marked as one of the following:

- internally with PAK_PRIORITY
- with IP Precedence of 6 (for IP packets)
- with CoS of 6 (for VLAN Tagged packets)

These packets behave as follows:

- They are not dropped because of any policing, AQM, drop thresholds (or any feature that can drop a packet) configured as per the egress service policy. However, they might be dropped because of hardware resource constraints (packet buffers, queue full, etc.).
- They are classified and marked as per the marking configuration of the egress service policy that could be a port or VLAN (refer to the "Policy Associations" section on page 42-73.
- These high priority packets are enqueued to queue on the egress port based on the following criteria:
  - If there is no egress queuing policy on the port, the packet is queued to a control packet queue that is setup separately from the default queue and has 5 percent of the link bandwidth reserved for it.
  - If there is an egress queuing policy on the port, the queue is selected based on the classification criteria applicable to the packet.

Low Priority Packets

Packets that are not considered high priority (as described previously) are considered *unimportant*. These include locally sourced pings, telnet, and other protocol packets. They undergo the same treatment as any other packet that is transiting the given transmit port including egress classification, marking and queuing.

Applying Flow-based QoS Policy

Flow based QoS enables microflow policing and marking capability to dynamically learn traffic flows. It also rate limits each unique flow to an individual rate. Flow based QoS is available with the built-in NetFlow hardware support.

For more overview information, refer to the "Flow-based QoS" section on page 42-10.

The following steps show how to apply Flow based QoS policy to QoS targets:

Step 1 Create a FNF flow record by specifying the key fields that identify unique flows. You can use any FNF flow records that are associated with the FNF monitor.

Step 2 Create a class-map to specify the set of match criteria. Include the FNF flow record from Step 1 in the class-map match criteria using the **match flow record** command. Then, configure the class-map to match all the match criteria with **class-map match-all** *class_name*.

Step 3 Create a policy-map and define actions associated with class-map from Step 2.

Step 4 Attach the policy to one or more QoS targets.

Examples

The following examples illustrate how to configure Flow based QoS policy and apply microflow policers on individual flows.

Example 1

This example assumes there are multiple users (identified by source IP address) on the subnet 192.168.10.*. The configuration below shows how to configure a flow based QoS policy that uses micro policing to limit the per-user traffic with the source address in the range of 192.168.10.*. The microflow policer is configured with a CIR of 1Mbps, "conform action" as transmit, and "exceed action" as drop.

Step 1: Define an ACL to match traffic with specified source address.

```
Switch(config)# ip access-list extended UserGroup1
Switch(config-ext-nacl)# permit ip 192.168.10.0 0.0.0.255 any
Switch(config-ext-nacl)# exit
Switch(config)#
```

Step 2: Define a flow record to create flows with source address as key.

```
Switch(config)# flow record r1
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# exit
Switch(config)#
```

Step 3: Configure classmap to match on the UserGroup1 and specify flow record definition for flow creation.

```
Switch(config)# class-map match-all c1
Switch(config-cmap)# match access-group name UserGroup1
Switch(config-cmap)# match flow record r1
Switch(config-cmap)# exit
Switch(config)#
```

Step 4: Configure flow based QoS policy-map with microflow policing action for the matching traffic.

```
Switch(config)# policy-map p1
Switch(config-pmap)# class c1
Switch(config-pmap-c)# police cir 1m
Switch(config-pmap-c-police)# conform-action transmit
Switch(config-pmap-c-police)# exceed-action drop
Switch(config-pmap-c-police)# exit
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
```

Step 5: Attach flow QoS policy to the interface.

```
Switch(config)# interface gigabitEthernet3/1
Switch(config-if)# service-policy input p1
Switch(config-if)#
```

Use the **show** commands (described in the policy and marking sections of this chapter) to display the policy-map configuration and interface specific policy-map statistics.

Example 2.

This example assumes there are multiple users (identified by source IP address) on subnets 192.168.10.* and 172.20.55.*. The first requirement is to police with a CIR of 500Kbps and a PIR of 650Kbps on any TCP traffic originating from 192 network to any destination at any given time. The **exceed action** keyword marks down the dscp value to 32. The second requirement is to police per-user traffic originating from 172 network to CIR of 2Mbps and unconditionally mark the traffic with dscp 10.

Step 1: Define an ACL to match traffic with specified source address.

```
Switch(config)# ip access-list extended UserGroup1
Switch(config-ext-nacl)# permit ip 19 2.168.10.0 0.0.0.255 any
Switch(config-ext-nacl)# exit
Switch(config)# ip access-list extended UserGroup2
Switch(config-ext-nacl)# permit ip 172.20.55.0 0.0.0.255 any
Switch(config-ext-nacl)# exit
Switch(config)#
```

Step 2: Define a flow record to create flows with source address as key.

```
Switch(config)# flow record r1
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# match ipv4 destination address
Switch(config-flow-record)# match transport tcp source-port
Switch(config-flow-record)# match transport tcp destination-port
Switch(config-flow-record)# exit
Switch(config)# flow record r2
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# exit
Switch(config)#
```

Step 3: Configure classmap to match on the UserGroup1 and specify flow record definition for flow creation.

```
Switch(config)# class-map match-all c1
Switch(config-cmap)# match access-group name UserGroup1
Switch(config-cmap)# match flow record r1
Switch(config-cmap)# exit
Switch(config)# class-map match-all c2
Switch(config-cmap)# match access-group name UserGroup2
Switch(config-cmap)# match flow record r2
Switch(config-cmap)# exit
Switch(config)#
```

Step 4: Configure flow based QoS policy-map with microflow policing action for the matching traffic.

```
Switch(config)# policy-map p1
Switch(config-pmap)# class c1
Switch(config-pmap-c)# police cir 500k pir 650k
Switch(config-pmap-c-police)# conform-action transmit
Switch(config-pmap-c-police)# exceed-action set-dscp-transmit 32
Switch(config-pmap-c-police)# violate-action drop
Switch(config-pmap-c-police)# exit
Switch(config-pmap-c)# exit
Switch(config-pmap)# class c2
Switch(config-pmap-c)# set dscp 10
Switch(config-pmap-c)# police cir 2m
Switch(config-pmap-c-police)# conform-action transmit
Switch(config-pmap-c-police)# exceed-action drop
Switch(config-pmap-c-police)# exit
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
```

Step 5: Attach flow QoS policy to the interface.

```
Switch(config)# interface gigabitEthernet3/1
Switch(config-if)# service-policy input p1
Switch(config-if)# exit
```

Use the show commands described in the QoS section to display the policy-map configuration and interface specific policy-map statistics.

Example 3

Assume that there are two active flows on FastEthernet interface 6/1:

Table 42-2

SrcIp	DStIp	IPProt	SrcL4Port	DstL4Port
192.168.10.10	192.168.20.20	20	6789	81
192.168.10.10	192.168.20.20	20	6789	21

With the following configuration, each flow is policed to 1000000 bps with an allowed 9000 burst value.

```
Switch(config)# flow record r1
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# match ipv4 destination address
Switch(config-flow-record)# match transport tcp source-port
Switch(config-flow-record)# match transport tcp destination-port
Switch(config-flow-record)# match transport udp source-port
Switch(config-flow-record)# match transport udp destination-port
Switch(config-flow-record)# exit
Switch(config)# class-map match-all c1
Switch(config-cmap)# match flow record r1
Switch(config-cmap)# exit
Switch(config)# policy-map p1
Switch(config-pmap)# class c1
Switch(config-pmap-c)# police 1000000 9000
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface fastEthernet 6/1
Switch(config-if)# service-policy input p1
Switch(config-if)# end
```

Configuration Guidelines

The general guidelines for creating, configuring, modifying, deleting a flow based QoS policy and attaching (and detaching) a flow based QoS policy to a supported target is the same as described in the QoS section. The following description and restriction applies to Flow based QoS policy:

- A classmap can have multiple match statements but only one FNF flow record can be specified in a class-map.
- A flow record must have at least one key field before it can be used in a classmap. Non-key fields can be present in the flow record. However, all the non-key fields are ignored by microflow QoS. Only key-fields are used for flow creation.
- If a FNF flow record is referenced in any class-map, the flow record cannot be modified. Remove the flow record from all classmaps before modifying it.
- A classmap with a FNF flow record must be configured as **match-all**; traffic hitting the class-map must satisfy all match criteria in the class-map.

- A policy can contain multiple classes and each class-map may contain the same or different FNF flow record.
- Flow based QoS policy and FNF monitor both cannot be applied on the same target at the same time.
- When the interface mode changes from switchport to routed port and vice versa, any Flow QoS policy attached to the port remains applied after the mode change.
- There are 3 types of FNF flow records: ipv4, ipv6, and datalink. The datalink flow record is mutually exclusive with the ipv4 and ipv6 flow records; a classmap with the datalink flow record cannot co-exist with classmap having a ipv4 or ipv6 flow record in the same policy and vice-versa.
- Classmap class-default is not editable; it cannot be configured with the match flow record. Instead, you can configure the policy with a class-map that uses a match any filter and the flow record.
- Traffic is classified in the same order in which class-map is defined in a policy. Hence, if a FNF flow record is the only match statement in a class-map, the classifier matches all packets of the type identified by the flow record. This means that any subsequent class-map in the same policy matching on the same traffic type will be redundant and will never be hit.
- Policers associated with classmap having flow record are called *microflow policers*. The CIR and PIR rates for microflow policers cannot be configured using the percent keyword.
- Flow records within the same policy must include appropriate key fields to ensure flows created from different classmaps are unique and distinct. Otherwise, the resulting flows from different classmap cannot be distinguished. In such cases, policy actions corresponding to the classmap which created the first flow in hardware will apply and results will not be always be as expected.
- Flows from traffic received on different QoS targets are distinct even if the same policy is applied to those targets.
- A flow is aged out if the it is inactive for more than 5 seconds; there is no traffic matching the flow for a period longer than 5 sec.
- When a flow is aged out, policer state information associated with the flow is also deleted. When a new flow is created, the policer instance for the flow is re-initialized.
- Flows created by flow based QoS policy exist in hardware only and cannot be exported (as with FNF monitor).
- Per-flow statistics are not available for flows created by flow based QoS policy.
- Class-map statistics indicate the number of packets matching the classifier. It does not represent individual flow stats.
- Policer statistics show the aggregate policer statistics of individual flow.
- Information about the flows created by hardware are not available and not displayed in the show commands associated with QoS policy-map. Only class-map and policer statistics are displayed in the output of the **show policy-map** commands.

Configuring CoS Mutation

CoS reflection and CoS mutation are supported on Supervisor Engine 6-E and Catalyst 4900M. Below is an example of how to apply CoS reflection.

Let us say that traffic arrives on interface gigabit 2/5 with VLAN 10 and COS 1, 2, ... We want traffic to egress interface gigabit 2/6 with outer tag VLAN 11 and CoS copied from C-tag, where C-tag is VLAN 10 and COS 1, 2, ...

```
class-map match-all c2
```

```
  match cos  2
class-map match-all c1
  match cos  1
!
policy-map my
class c1
   set cos 1
class c2
  set cos 2

interface GigabitEthernet2/5
switchport mode trunk
switchport vlan mapping 10 dot1q-tunnel 11
spanning-tree bpdufilter enable
service-policy input my
!
interface GigabitEthernet2/6
switchport mode trunk
```

Configuring System Queue Limit

Note This feature is available only from Cisco IOS Release 15.0(2)SG1 and later and Cisco IOS Release XE 3.2.1SG.

With the **hw-module system max-queue-limit** command, the Catalyst 4500 series switch allows you to change the queue limit for all interfaces globally, instead of applying a policy with queue limit to all the interfaces.

To set the queue limit globally, perform this task:

	Command	Purpose
Step 1	`Switch#` **`configure terminal`**	Enters global configuration mode.
Step 2	`Switch(config)#` **`hw-module system max-queue-limit`** *`max-queue-limit`*	Sets the queue limit for all interfaces globally. Valid values are from 1024 to 8184. The value must be a multiple of 8.

	Command	Purpose
Step 3	`Switch(config)# exit`	Returns to privileged EXEC mode.

Step 4	`Switch# reload`
	or
	`Switch# redundancy reload shelf`
	`Switch# redundancy force-switchover`
		Reloads standalone supervisor engine.
		Reloads redundancy supervisor engine in SSO mode.
		Reloads redundancy supervisor engine in RPR mode.
		This command must be followed by another redundancy force-switchover.

This is a global configuration command. You can override it with the per port, per class, **queue-limit** command.

For a standalone supervisor engine, you must reboot the engine after applying this command.

For redundant supervisors in SSO mode, you must enter the **redundancy reload shelf** command enforce reboot to both the supervisors. For redundancy supervisors in RPR mode, you must execute two consecutive switchovers to enforce the system queue limit on both the supervisors.

This example shows how to set the queue limit globally to 1024 on a standalone supervisor engine:

```
Switch> enable
Switch# configure terminal
Switch(config)# hw-module system max-queue-limit 1024
Switch(config)# exit
Switch# reload  (for standalone supervisors)
Switch# redundancy reload shelf (for redundancy supervisors in SSO mode)
or
Switch# redundancy force-switchover (followed by another redundancy force-switchover, for
redundancy supervisors in RPR mode)
```

Configuring QoS on a Standalone Supervisor Engine 6-E/6L-E or Supervisor Engine 7-E/7L-E/8-E

Note HQoS is not supported on the Catalyst 4500 Series Switch.

Topics include:

- MQC-based QoS Configuration, page 42-48
- Platform-supported Classification Criteria and QoS Features, page 42-48
- Platform Hardware Capabilities, page 42-49
- Prerequisites for Applying a QoS Service Policy, page 42-49
- Restrictions for Applying a QoS Service Policy, page 42-50
- Classification, page 42-50
- Policing, page 42-51
- Marking Network Traffic, page 42-52
- Shaping, Sharing (Bandwidth), Priority Queuing, Queue-limiting and DBL, page 42-59

- Enabling Per-Port Per-VLAN QoS, page 42-70
- Applying Flow-based QoS Policy, page 42-75
- Configuring CoS Mutation, page 42-79
- Configuring System Queue Limit, page 42-80

MQC-based QoS Configuration

Note Starting with Cisco IOS Release 12.2(40)SG, a Catalyst 4900M, a Catalyst 4948E, or a Catalyst 4500 Series Switch with Supervisor Engine 6-E or Supervisor Engine 6L-E use the MQC model of QoS.

To apply QoS, you use the Modular QoS Command-Line Interface (MQC), which is a CLI structure that allows you to complete the following tasks:

- Specify the matching criteria used to define a traffic class.
- Create a traffic policy (policy map). The traffic policy defines the QoS policy actions to be taken for each traffic class.
- Apply the policy actions specified in the policy map to an interface, VLAN, or port and VLAN.

For more information about the MQC, see the “Modular Quality of Service Command-Line Interface” section of the *Cisco IOS Quality of Service Solutions Configuration Guide, Release 12.3*.

Note The incoming traffic is considered trusted by default. Only when the *trusted boundary* feature is enabled on an interface can the port enter untrusted mode. In this mode, the switch marks the DSCP value of an IP packet and the CoS value of the VLAN tag on the Ethernet frame as “0”.

Platform-supported Classification Criteria and QoS Features

The following table provides a summary of various classification criteria and actions supported on the Catalyst 4500 Series Switch. For details, refer to the *Catalyst 4500 Series Switch Command Reference*.

Supported classification actions	**Descriptions**
match access-group	Configures the match criteria for a class map on the basis of the specified ACL.
match any	Configures the match criteria for a class map to be successful match criteria for all packets.
match cos	Matches a packet based on a Layer 2 class of service (CoS) marking.
match [ip] dscp	Identifies a specific IP differentiated service code point (DSCP) value as a match criterion. Up to eight DSCP values can be included in one match statement.
match [ip] precedence	Identifies IP precedence values as match criteria.
match protocol	Configures the match criteria for a class map on the basis of the specified protocol.
match qos-group	Identifies a specific QoS group value as a match criterion. Applies only on the egress direction.
Supported Qos Features	Descriptions

Supported classification actions	Descriptions
police	Configures traffic policing.
police (percent)	Configures traffic policing on the basis of a percentage of bandwidth available on an interface.
police (two rates)	Configures traffic policing using two rates, the committed information rate (CIR) and the peak information rate (PIR).
set cos	Sets the Layer 2 class of service (CoS) value of an outgoing packet.
set dscp	Marks a packet by setting the differentiated services code point (DSCP) value in the type of service (ToS) byte of IPv4 or traffic class byte of IPv6 packet.
set precedence	Sets the precedence value in the packet header.
set qos-group	Sets a QoS group identifier (ID) that can be used later to classify packets.
table map support	Unconditional marking of one packet field based on another packet field.
priority	Gives priority to a class of traffic belonging to a policy map.
shape	Shapes traffic to the indicated bit rate according to the algorithm specified.
bandwidth	Provides a guaranteed minimum bandwidth to each of the eight queues.
dbl	Dynamic buffer limit.
queue-limit	Specifies the maximum number of packets a transmit queue can hold.

Platform Hardware Capabilities

Qos Actions	Numbers of entries supported
Classification	64k input and 64k output classification entries are supported. A given policy can use at most 24k ACLs
Policing	16K policers are supported. Policers are allocated to given direction in blocks of 2k. For example, 2k policers can be used in for input and 14k policers can be used for output. Single rate policers uses one policer entry. Single Rate Three Color Marker (srTCM) (RFC 2697) and Two Rate Three Color Marker (trTCM) (RFC 2698) uses two policer entries
Marking	Marking of Cos and DSCP/Precedence is supported through two marking tables, each capable of supporting 512 entries. There are separate tables for each direction.
Queuing	The queue size is Configurable with the maximum number of entries configurable per port depending on the chassis and line card type.
DBL	You can enable DBL action on all configured class-maps.

Prerequisites for Applying a QoS Service Policy

Unlike the Switch QoS model, there is no prerequisite for enabling QoS on various targets. Just the attachment of a service policy enables QoS and detachment of that policy disables QoS on that target.

Restrictions for Applying a QoS Service Policy

Traffic marking can be configured on an interface, a VLAN, or a port and VLAN. An interface can be a Layer 2 access port, a Layer 2 switch trunk, a Layer 3 routed port, or an EtherChannel. A policy is attached to a VLAN using *vlan configuration* mode.

Attaching QoS service policy to VLANs and EtherChannel is described in the "Policy Associations" section on page 42-73.

Classification

The supervisor engine supports classification of Layer 2, IP, IPv6 packets, and ARP packets marking performed on input can be matched in the output direction. The previous table lists the full set of capabilities. By default, the switch also supports classification resources sharing. Similarly, when the same policy is attached to a port or a VLAN or on per-port per-vlan targets, ACL entries are shared though QoS actions are unique on each target.

For example:

```
    class-map c1
      match ip dscp 50
```

```
Policy Map p1
    class c1
      police rate 1 m burst 200000
```

If policy-map p1 is applied to interfaces Gig 1/1 and Gig 1/2, 1 CAM entry is used (one ACE that matches IP packets), but 2 policers are allocated (one per target). So, all IP packets with dscp 50 are policed to 1 mbps on interface Gig 1/1 and packets on interface Gig 1/2 are policed to 1 mbps.

Note With Cisco IOS Release 12.2(46)SG, you can issue the **match protocol arp** command. For details, see the *Catalyst 4500 Series Switch Cisco IOS Command Reference*.

Classification Statistics

The supervisor engine supports only packet based classification statistics and TCAM resource sharing. When a policy-map is applied on multiple targets, the command **show policy-map interface** displays the aggregate classification statistics, not those specific to an interface.

Note To obtain per interface policy-map stats, you should configure a unique policy-map name on each interface.

When a policy-map is attached to a port-channel member ports, classification statistics are not displayed.

Configuring a Policy Map

You can attach only one policy map to an interface. Policy maps can contain one or more policy-map classes, each with different match criteria and actions.

Configure a separate policy-map class in the policy map for each type of traffic that an interface receives. Put all commands for each type of traffic in the same policy-map class. QoS does not attempt to apply commands from more than one policy-map class to matched traffic.

Creating a Policy Map

To create a policy map, enter this command:

Command	Purpose
`Switch(config)# [no] policy-map policy_name`	Creates a policy map with a user-specified name. Use the **no** keyword to delete the policy map.

Attaching a Policy Map to an Interface

To create a policy map, enter this command:

Command	Purpose
`Switch(config)# interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface | Port-channel number}`	Selects the interface to configure.
`Switch(config-if)# [no] service-policy input policy_map_name`	Attaches a policy map to the input direction of the interface. Use the no keyword to detach a policy map from an interface.
`Switch(config-if)# end`	Exits configuration mode.
`Switch# show policy-map interface {vlan vlan_ID | {fastethernet | gigabitethernet} slot/interface}`	Verifies the configuration.

Policing

The supervisor engine supports policers in the following operation modes:

- Single Rate Policer Two Color Marker

  This kind of policer is configured with just the committed rate (CIR) and normal burst and it has only conform and exceed actions.
- Single Rate Three Color Marker (srTCM) (RFC 2697)
- Two Rate Three Color Marker (trTCM) (RFC 2698)
- Color Blind Mode

  Policing accuracy of 0.75% of configured policer rate.

  The engine supports 16384 (16 x 1024, 16K) single rate, single burst policers. 16K policers are organized as 8 banks of 2K policers. The policer banks are dynamically assigned (input or output policer bank) by the software depending on the QoS configuration. So, the 16K policers are dynamically partitioned by software as follows:
  - 0 Input Policers and 16K Output Policers
  - 2K Input Policers and 14K Output Policers
  - 4K Input Policers and 12K Output Policers
  - 6K Input Policers and 10K Output Policers
  - 8K Input Policers and 8K Output Policers

  - 10K Input Policers and 6K Output Policers
  - 12K Input Policers and 4K Output Policers
  - 14K Input Policers and 2K Output Policers
  - 16K Input Policers and 0 Output Policers

These numbers represent individual policer entries in the hardware that support a single rate and burst parameter. Based on this, a switch supports the following number of policers:

- 16K Single Rate Policer with Single Burst (Two Color Marker)
- 8K Single Rate Three Color Marker (srTCM)
- 8K Two Rate Three Color Marker (trTCM)

These policers are partitioned between Input and Output in chunks of 2K policer banks. The different types of policers can all co-exist in the system. However, a given type of policer (srTCM, trTCM etc.) is configurable as a block of 128 policers.

Note Two policers are reserved for internal use.

How to Implement Policing

For details on how to implement the policing features on a Catalyst 4500 Series Switch, refer to the Cisco IOS documentation at the following link:

http://www.cisco.com/en/US/docs/ios/12_2/qos/configuration/guide/qcfpolsh.html

Platform Restrictions

Platform restrictions include the following:

- Multi-policer actions can be specified (setting CoS and IP DSCP is supported).
- When unconditional marking and policer based marking exists on the same field(cos or dscp or precedence), policer-based marking is preferred.
- If policer based service-policy is attached to both a port and a VLAN, port-based policed is preferred by default. To over-ride a specific VLAN policy on a given port, then you must configure a per-port per-vlan policy.
- You should not delete a port-channel with a per-port, per-VLAN QoS policy.

  Workaround: Before deleting the port-channel, do the following:

  1. Remove any per-port per-VLAN QoS policies, if any.

  2. Remove the VLAN configuration on the port-channel with the **no vlan-range** command.

Marking Network Traffic

Marking network traffic allows you to set or modify the attributes of traffic (that is, packets) belonging to a specific class or category. When used in conjunction with network traffic classification, marking network traffic is the foundation for enabling many quality of service (QoS) features on your network This module contains conceptual information and the configuration tasks for marking network traffic.

Contents

Information About Marking Network Traffic

To mark network traffic, you should understand the following concepts:

- "Purpose of Marking Network Traffic" section on page 42-53
- "Benefits of Marking Network Traffic" section on page 42-53
- "Two Methods for Marking Traffic Attributes" section on page 42-54

Purpose of Marking Network Traffic

Traffic marking is used to identify certain traffic types for unique handling, effectively partitioning network traffic into different categories.

After the network traffic is organized into classes by traffic classification, traffic marking allows you to mark (that is, set or change) a value (attribute) for the traffic belonging to a specific class. For instance, you may want to change the class of service (CoS) value from 2 to 1 in one class, or you may want to change the differentiated services code point (DSCP) value from 3 to 2 in another class. In this module, these values are referred to as attributes or marking fields.

Attributes that can be set and modified include the following:

- CoS value of a tagged Ethernet frame
- DSCP/Precedence value in the Type of Service (ToS) byte of IPv4.
- QoS group identifier (ID)
- DSCP /Precedence value in the traffic class byte of IPv6

Benefits of Marking Network Traffic

Traffic marking allows you to fine-tune the attributes for traffic on your network. This increased granularity helps isolate traffic that requires special handling, and thus, helps to achieve optimal application performance.

Traffic marking allows you to determine how traffic will be treated, based on how the attributes for the network traffic are set. It allows you to segment network traffic into multiple priority levels or classes of service based on those attributes, as follows:

- Traffic marking is often used to set the IP precedence or IP DSCP values for traffic entering a network. Networking devices within your network can then use the newly marked IP precedence values to determine how traffic should be treated. For example, voice traffic can be marked with a particular IP precedence or DSCP and strict priority can then be configured to put all packets of that marking into that queue. In this case, the marking was used to identify traffic for strict priority queue.

- Traffic marking can be used to identify traffic for any class-based QoS feature (any feature available in policy map class configuration mode, although some restrictions exist).

Two Methods for Marking Traffic Attributes

Note This section describes *Unconditional* marking, which differs from *Policer-based* marking. Unconditional marking is based solely on classification.

Method One: Unconditional Explicit Marking (using the set command)

You specify the traffic attribute you want to change with a set command configured in a policy map. The following table lists the available set commands and the corresponding attribute. For details on the set command, refer to the *Catalyst 4500 Series Switch Command Reference*.

Table 42-4 set Commands and Applicable Packet Types

set Commands	Traffic Attribute	Packet Type
set cos	Layer 2 CoS value of the outgoing traffic	Ethernet IPv4, IPv6
set dscp	DSCP value in the ToS byte	IPv4, IPv6
set precedence	precedence value in the packet header	IPv4, IPv6
set qos-group	QoS group ID	Ethernet, IPv4, IPv6

If you are using individual **set** commands, those set commands are specified in a policy map. The following is a sample of a policy map configured with one of the set commands listed in Table 42-4.

In this sample configuration, the **set cos** command has been configured in the policy map (policy1) to mark the CoS attribute:

```
enable
configure terminal
policy map p1
    class class1
      set cos 3
end
```

For information on configuring a policy map, see the “Creating a Policy Map” section on page 42-51.

The final task is to attach the policy map to the interface. For information on attaching the policy map to the interface, see the “Attaching a Policy Map to an Interface” section on page 42-51.

Method Two: Unconditional Tablemap-based Marking

You can create a table map that can be used to mark traffic attributes. A table map is a kind of two-way conversion chart that lists and maps one traffic attribute to another. A table map supports a many-to-one type of conversion and mapping scheme. The table map establishes a to-from relationship for the traffic attributes and defines the change to be made to the attribute. That is, an attribute is set to one value that is taken from another value. The values are based on the specific attribute being changed. For instance, the Precedence attribute can be a number from 0 to 7, while the DSCP attribute can be a number from 0 to 63.

The following is a sample table map configuration:

```
table-map table-map1
map from 0 to 1
map from 2 to 3
exit
```

The following table lists the traffic attributes for which a to-from relationship can be established using the table map.

Table 42-5 Traffic Attributes for Which a To-From Relationship Can Be Established

The "To" Attribute	The "From" Attribute
Precedence	CoS, QoS group, DSCP, Precedence
DSCP	COS, QoS group, DSCP, Precedence
CoS	DSCP, QoS group, CoS, Precedence

The following is an example of a policy map (policy2) configured to use the table map (table-map1) created earlier:

```
Policy map policy
    class class-default
      set cos dscp table table-map
exit
```

In this example, a mapping relationship was created between the CoS attribute and the DSCP attribute as defined in the table map.

For information on configuring a policy map to use a table map, "Configuring a Policy Map" section on page 42-50.

The final task is to attach the policy map to the interface. For information on attaching the policy map to the interface, see the "Attaching a Policy Map to an Interface" section on page 42-51.

Marking Action Drivers

A marking action can be triggered based on one of the two QoS processing steps.

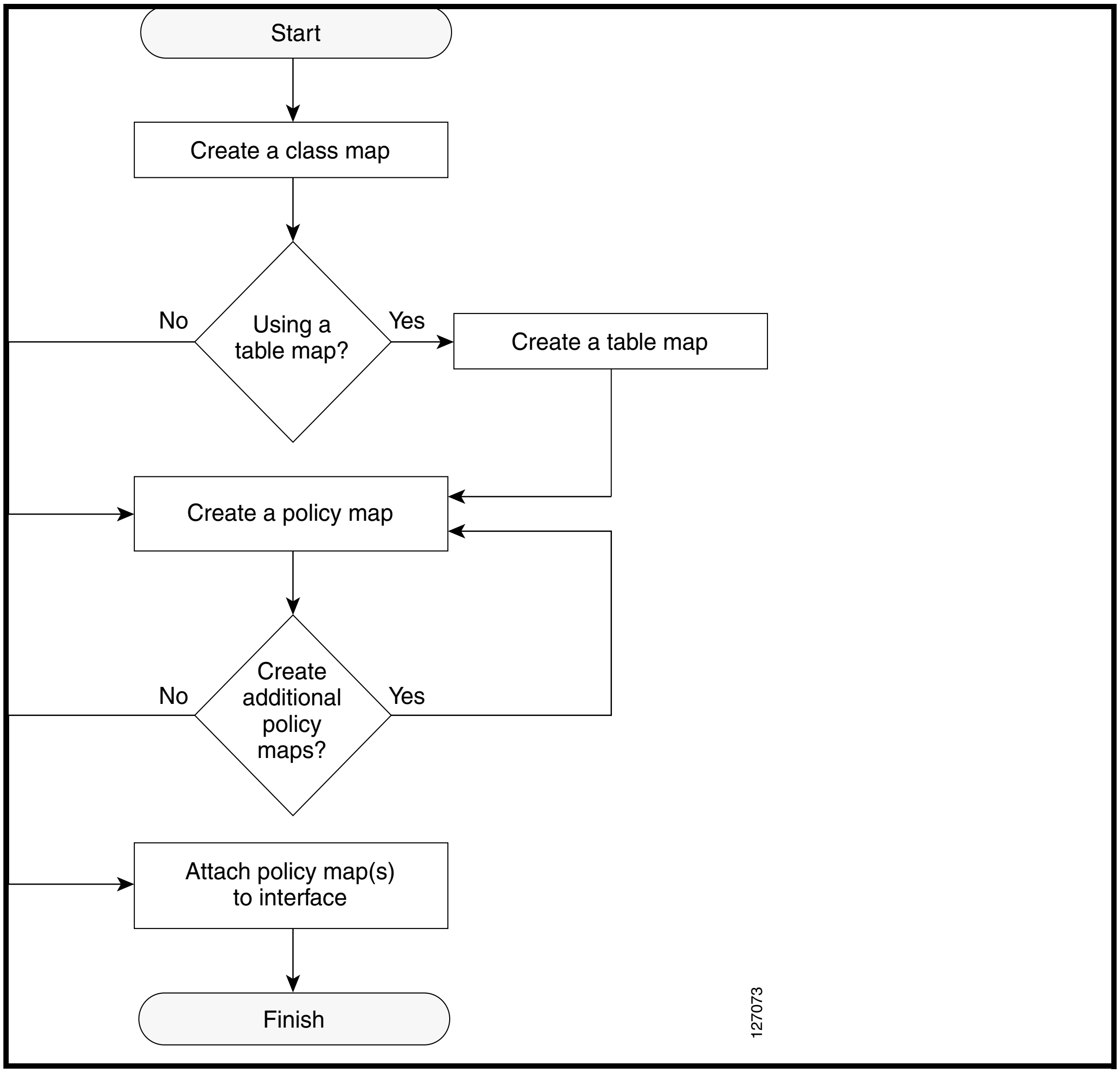
Classification based: In this case, all the traffic matching a class is marked using either explicit or tablemap based method. This method is referred to as *unconditional* marking.

Policer result-based: In this case, a class of traffic is marked differently based on the policer result (conform/exceed/violate) applicable to that packet. This method is referred to as *conditional* marking.

Traffic Marking Procedure Flowchart

Figure 42-5 illustrates the order of the procedures for configuring traffic marking.

Figure 42-5 Traffic marking Procedure Flowchart



Restrictions for Marking Network Traffic

The following restrictions apply to packet marking actions:

- QoS-group can be marked only in the input direction and can only support unconditional explicit marking.
- Only explicit marking is supported for policer-based marking.

Multi-attribute Marking Support

The supervisor engine can mark more than one QoS attribute of a packet matching a class of traffic. For example, DSCP, CoS, and QoS-group can all be set together, using either explicit or tablemap-based marking.

Note When using unconditional explicit marking of multiple fields or policer-based multi-field, multi-region (conform/exceed/violate) marking the number of tablemaps that can be setup in TOS or COS marking tables will be less than the maximum supported.

Hardware Capabilities for Marking

Catalyst 4900M, Catalyst 4948E, Supervisor Engine 6-E, and Supervisor Engine 6L-E provide a 128 entry marking action (Supervisor Engine 7-E, Supervisor Engine 7L-E, and Supervisor Engine 8-E provide a 256 entry marking action) where each entry specifies the type of marking actions on CoS and DSCP/Precedence fields as well as policer action to transmit/markdown/drop a packet.

One such table is supported for each direction, input and output. This table is used for both unconditional marking as well as policer-based marking. It can be used to support 256 unique marking actions or 64 unique policer-based actions or a combinations of the two.

For each of the marking fields (COS and DSCP), the supervisor engine provides 512 entry marking tables for each direction. These are similar to mapping tables available on supervisor engines that support the switch QoS model. However, these provide an ability to have multiple unique mapping tables that are setup by the user.

For example, the TOS marking table provides marking of DSCP/Precedence fields and can be used as one of the following:

- 8 different tablemaps with each mapping the 64 DSCP or qos-group values to another DSCP
- 64 (32) different tablemaps with each one mapping 8 CoS (16 CoS and CFi) values to DSCP in input (output) direction
- a combination of above two types of tablemaps

Similar mappings are available on the 512 entry COS marking table.

Configuring the Policy Map Marking Action

This section describes how to establish unconditional marking action for network traffic.

As a prerequisites, create a class map (*ipp5)* and a policy map. (Refer to the"Configuring a Policy Map" section on page 42-50).

Note The marking action command options have been extended (refer to Table 42-4 on page 42-54 andTable 42-5 on page 42-55).

Configuring Tablemap-based Unconditional Marking

To configure table-map based unconditional marking, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# table-map name`	Configures a tablemap.
Step 3	`Switch(config-tablemap)# map from from_value to to_value`	Creates a map from a *from_value* to a *to_value*

	Command	Purpose
Step 4	Switch(config-tablemap)# **exit**	Exits table-map configuration mode.
Step 5	Switch(config)# **policy-map** *name*	Enters policy-map configuration mode.
Step 6	Switch(config-p)# **class** name	Selects the class for QoS actions.
Step 7	Switch(config-p-c)# **set cos** | **dscp** | **prec cos** | **dscp** | **prec** | **qos-group** [**table** *name*]	Selects the marking action based on an implicit or explicit table-map.
Step 8	Switch(config-p-c)# **end**	Exits configuration mode.
Step 9	Switch# **show policy-map** ***name***	Verifies the configuration of the policy-map.
Step 10	Switch# **show table-map name**	Verifies the configuration of the table-map.

The following example shows how to enable marking action using table-map.

```
Switch(config)# table-map dscp2Cos
Switch(config-tablemap)# map from 8 to 1
Switch(config-tablemap)# exit
Switch(config)# policy-map p1
Switch(config-pmap)# class ipp5
Switch(config-pmap-c)# set cos dscp table dscp2Cos
Switch(config-pmap-c)# end
Switch# show policy-map p1

Policy Map p1
    Class ipp5
      set cos dscp table dscp2Qos

Switch# show table-map dscp2Cos

 Table Map dscp2Cos
    from 8 to 1
    default copy
```

Configuring Policer Result-based Conditional Marking

To configure policer result-based conditional marking, setup a single rate or dual rate policer. Refer to the "How to Implement Policing" section on page 42-52.

This example shows how to configure a two rate three-color policer with explicit actions for each policer region:

```
Switch# configure terminal
Switch(config-pmap-c)# policer cir percent 20 pir percent 30
Switch(config-pmap-c-policer)# conform-action set-cos-transmit 3 set-dscp-transmit 10
Switch(config-pmap-c-policer)# exceed-action set-cos-transmit 4 set-dscp-transmit 20
Switch(config-pmap-c-policer)# violate action drop
Switch# show policy-map p1

  Policy Map police
    Class ipp5
     police cir percent 20 pir percent 30
       conform-action set-cos-transmit 3
       conform-action set-dscp-transmit af11
       exceed-action set-cos-transmit 4
       exceed-action set-dscp-transmit af22
       violate-action drop
```

Marking Statistics

The marking statistics indicate the number of packets that are *marked*.

For unconditional marking, the *classification entry* points to an entry in the marking action table that in turn indicates the fields in the packet that are marked. Therefore, the classification statistics by itself indicates the unconditional marking statistics.

For a conditional marking using policer, provided the policer is a packet rate policer, you cannot determine the number packets marked because the policer only provides byte statistics for different policing results.

Shaping, Sharing (Bandwidth), Priority Queuing, Queue-limiting and DBL

The Catalyst 4500 Series Switch supports the Classification-based (class-based) mode for transmit queue selection. In this mode, the transmit queue selection is based on the Output QoS classification lookup.

Note Only output (egress) queuing is supported.

The supervisor engine supports 8 transmit queues per port. Once the forwarding decision has been made to forward a packet out a port, the output QoS classification determines the transmit queue into which the packet needs to be enqueued.

By default, without any service policies associated with a port, there are two queues (a control packet queue and a default queue) with no guarantee as to the bandwidth or kind of prioritization. The only exception is that system generated control packets are enqueued into control packet queue so that control traffic receives some minimum link bandwidth.

Queues are assigned when an output policy attached to a port with one or more queuing related actions for one or more classes of traffic. Because there are only eight queues per port, there can be at most eight classes of traffic (including the reserved class, class-default) with queuing action(s). Classes of traffic that do not have any queuing action are referred to as *non-queuing* classes. Non-queuing class traffic ends up using the queue corresponding to class class-default.

When a queuing policy (a policy with queuing action) is attached, the control packet queue is deleted and the control packets are enqueued into respective queue per their classification. An egress QoS class must be configured to match IP Precedence 6 and 7 traffic, and a bandwidth guarantee must be configured.

Dynamic resizing of queues (queue limit class-map action) is supported through the use of the **queue-limit** command. Based on the chassis and line card type, all eight queues on a port are configured with equal queue size.

Shaping

Shaping enables you to delay out-of-profile packets in queues so that they conform to a specified profile. Shaping is distinct from policing. Policing drops packets that exceed a configured threshold, whereas shaping *buffers* packets so that traffic remains within a given threshold. Shaping offers greater *smoothness* in handling traffic than policing. You enable average-rate traffic shaping on a traffic class with the **policy-map** class configuration command.

The supervisor engine supports a range of 32kbps to 10 gbps for shaping, with a precision of approximately +/- 0.75 per cent.

When a queuing class is configured without any explicit shape configuration, the queue shape is set to the link rate.

To configure class-level shaping in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map policy-map-name`	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class class-name`	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)# shape average {cir-bps [optional_postfix] | percent percent}`	Enables average-rate traffic shaping. You can specify the shaping rate in absolute value or as a percentage: • For *cir-bps* [*optional_postfix*], specify the shaping rate in bps. Range is 32000 to 10000000000 bps. Supply an optional postfix (K, M, G). • For *percent*, specify the percentage of link rate to shape the class of traffic. The range is 1 to 100. By default, average-rate traffic shaping is disabled.
Step 5	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 6	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 7	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.
Step 8	`Switch(config-interface)# service-policy output policy-map-name`	Specifies the policy-map name, and apply it a physical interface.
Step 9	`Switch(config-interface)# end`	Returns to privileged EXEC mode.

Step 10	`Switch# show policy-map [policy-map-name [class class-map-name]]`
	or
	`Switch# show policy-map interface interface-id`
		Verifies your entries.

Step 11	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** *class-name* policy-map configuration command. To disable the average-rate traffic shaping, use the **no shape average** policy-map class configuration command.

This example shows how to configure class-level, average-rate shaping. It limits traffic class class1 to a data transmission rate of 256 kbps:

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# shape average 256000
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch#

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
       shape average 256000
```

This example shows how to configure class-level, average shape percentage to 32% of link bandwidth for queuing-class traffic:

```
Switch# configure terminal
Switch(config)# policy-map queuing-policy
Switch(config-pmap)# class queuing-class
Switch(config-pmap-c)# shape average percent 32
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output queuing-policy1
Switch(config-if)# end
Switch #

Switch# show policy-map queuing-policy
  Policy Map queuing-policy
    Class queuing-class
       Average Rate Traffic Shaping
       cir 32%
```

Sharing(bandwidth)

The bandwidth assigned to a class of traffic is the minimum bandwidth that is guaranteed to the class during congestion. Transmit Queue Sharing is the process by which output link bandwidth is shared among multiple queues of a given port.

The supervisor engine supports a range of 32 kbps to 10 gbps for sharing, with a precision of approximately +/- 0.75 per cent. The sum of configured bandwidth across all queuing classes should not exceed the link bandwidth.

To configure class-level bandwidth action in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch#` **`configure terminal`**	Enters global configuration mode.
Step 2	`Switch(config)#` **`policy-map`** *`policy-map-name`*	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)#` **`class`** *`class-name`*	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.

	Command	Purpose
Step 4	Switch(config-pmap-class)# **bandwidth** {*bandwidth-kbps* | **percent** *percent*}	Specifies the minimum bandwidth provided to a class belonging to the policy map when there is traffic congestion in the switch. If the switch is not congested, the class receives more bandwidth than you specify with the **bandwidth** command. By default, no bandwidth is specified. You can specify the bandwidth in kbps or as a percentage: o For *bandwidth-kbps*, specify the bandwidth amount in kbps assigned to the class. The range is 32 to 10000000. o For *percent*, specify the percentage of available bandwidth assigned to the class. The range is 1 to 100. Specify all the class bandwidths in either kbps or in percentages, but not a mix of both.
Step 5	Switch(config-pmap-class)# **exit**	Returns to policy-map configuration mode.
Step 6	Switch(config-pmap)# **exit**	Returns to global configuration mode.
Step 7	Switch(config)# **interface** *interface-id*	Specifies a physical port and enter interface configuration mode.
Step 8	Switch(config-interface)# **service-policy output** *policy-map-name*	Specifies the policy-map name, and apply it a physical interface.
Step 9	Switch(config-interface)# **end**	Returns to privileged EXEC mode.
Step 10	Switch# **show policy-map** **[***policy-map-name* **[class** *class-map-name***]]** **or** Switch# **show policy-map interface** *interface-id*	Verifies your entries.
Step 11	Switch# **copy running-config startup-config**	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** ***class-name*** policy-map configuration command. To return to the default bandwidth, use the **no bandwidth** policy-map class configuration command.

This example shows how to create a class-level policy map called policy11 for three classes called prec1, prec2, and prec3. In the policy for these classes, 30 percent of the available bandwidth is assigned to the queue for the first class, 20 percent is assigned to the queue for the second class, and 10 percent is assigned to the queue for the third class.

```
Switch # configure terminal
Switch(config)# policy-map policy11
Switch(config-pmap)# class prec1
Switch(config-pmap-c)# bandwidth percent 30
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec2
Switch(config-pmap-c)# bandwidth percent 20
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec3
Switch(config-pmap-c)# bandwidth percent 10
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy11
Switch(config-if)# end
Switch #

Switch# show policy-map policy11
  Policy Map policy11
    Class prec1
      bandwidth percent 30
    Class prec2
      bandwidth percent 20
    Class prec3
      bandwidth percent 10
```

This example shows how to create a class-level policy map called policy11 for three classes called prec1, prec2, and prec3. In the policy for these classes, 300 mbps of the available bandwidth is assigned to the queue for the first class, 200 mbps is assigned to the queue for the second class, and 100 mbps is assigned to the queue for the third class.

```
Switch # configure terminal
Switch(config)# policy-map policy11
Switch(config-pmap)# class prec1
Switch(config-pmap-c)# bandwidth 300000
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec2
Switch(config-pmap-c)# bandwidth 200000
Switch(config-pmap-c)# exit
Switch(config-pmap)# class prec3
Switch(config-pmap-c)# bandwidth 100000
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy11
Switch(config-if)# end
Switch #

Switch# show policy-map policy11
  Policy Map policy11
    Class prec1
      bandwidth 300000 (kbps)
    Class prec2
      bandwidth 200000 (kbps)
    Class prec3
      bandwidth 100000 (kbps)
```

When a queuing class is configured without any explicit share/bandwidth configuration, because the queue is not guaranteed any minimum bandwidth, the hardware queue is programmed to get a share of any unallocated bandwidth on the port as shown in the following example.

If there is no bandwidth remaining for the new queue or if the unallocated bandwidth is not sufficient to meet the minimum configurable rate (32kbps) for all queues which do not have any explicit share/bandwidth configuration, then the policy association is rejected.

For example, if there are two queues as given below

```
policy-map queue-policy
   class q1
     bandwidth percent 10

   class q2
     bandwidth percent 20
```

then the bandwidth allocation for the queues is as follows

```
q1 = 10%
           q2 = 20%
```

```
class-default = 70%
```

Similarly, when another queuing class (say q3) is added without any explicit bandwidth (say, just a shape command), then the bandwidth allocation is

```
q1 = 10%
          q2 = 20%
          q3 = min(35%, q3-shape-rate)
class-default = max(35%, (100 - (q1 + q2 + q3 )))
```

Priority queuing

Only one transmit queue on a port can be configured as *strict priority* (termed Low Latency Queue, or LLQ).

LLQ provides strict-priority queuing for a traffic class. It enables delay-sensitive data, such as voice, to be sent *before* packets in other queues. The priority queue is serviced first until it is empty or until it is under its shape rate. Only one traffic stream can be destined for the priority queue per class-level policy. You enable the priority queue for a traffic class with the **priority policy-map class** configuration command at the class mode.

A LLQ can starve other queues unless it is rate limited. The supervisor engine does not support *conditional policing* where a 2-parameter policer (rate, burst) becomes effective when the queue is *congested* (based on queue length). However, it supports application of an unconditional policer to rate limit packets enqueued to the strict priority queue.

When a priority queue is configured on one class of a policy map, only *bandwidth remaining* is accepted on other classes, guaranteeing a minimum bandwidth for other classes from the remaining bandwidth of what is left after using the priority queue. When a priority queue is configured with a policer, then either *bandwidth* or *bandwidth remaining* is accepted on other classes.

Note Use *bandwidth* or *bandwidth remaining* on all classes. You cannot apply *bandwidth* on one class and *bandwidth remaining* on another class within a policy map.

To enable class-level priority queuing in a service policy, follow these steps:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map policy-map-name`	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class class-name`	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)# priority`	Enables the strict-priority queue, and give priority to a class of traffic. By default, strict-priority queueing is disabled.
Step 5	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 6	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 7	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.

	Command	Purpose
Step 8	`Switch(config-interface)#` **`service-policy output`** *`policy-map-name`*	Specifies the policy-map name, and apply it a physical interface.
Step 9	`Switch(config-interface)#` **`end`**	Returns to privileged EXEC mode.

Step 10	`Switch#` **`show policy-map`** `[`*`policy-map-name`* **`[class`** *`class-map-name`*`]]`
	or
	`Switch#` **`show policy-map interface`** *`interface-id`*
		Verifies your entries.

Step 11	`Switch#` **`copy running-config startup-config`**	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** *class-name* policy-map configuration command. To disable the priority queue, use the **no priority** *policy-map-class* configuration command.

This example shows how to configure a class-level policy called policy1. Class 1 is configured as the priority queue, which is serviced first until it is empty.

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# priority
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch #

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
      priority
```

Queue-limiting

When a class-based queue is instantiated on a physical port, it is set up with a default size. This size represents the number of queue entries in which packets belonging to that class of traffic can be queued. The scheduler moves packets from the queue that are ready for transmission, based on the queue shape, bandwidth, and priority configuration.

The queue-limit provides the maximum number of packets that can be in the queue at any given time. When the queue is full, an attempt to enqueue any further packets results in tail drop. However, if dynamic buffer limiting (DBL) is enabled on the queue, packets get a probabilistic drop based on the DBL algorithm, even when the queue is not full.

The **queue-limit** command can be configured under a class only when queue scheduling, such as bandwidth, shape, or priority is already configured. The only exception to this requirement is the support of the stand-alone **queue-limit** command on the class-default class.

Queue Memory

The number of queue entries that can be allocated has to be a multiple of 8 and can range from 16 to 8184. When a class-based queue is instantiated on a physical port, it is given a default number of entries. This default queue size is based on the number of slots in the chassis and the number of front-panel ports in each slot.

Catalyst 4900M, Catalyst 4948E, Supervisor Engine 6-E, and Supervisor Engine 6L-E have 512 K (524,288) queue entries of which the system sets aside 100 K (102,400) queue entries in a free reserve pool. Of the remaining 412 K (421,88), the drop port is provided 8184 entries and the CPU ports are assigned 11704 entries. Supervisor Engine 7-E and Supervisor Engine 8-E have 1M (1,048,576) queue entries of which the system sets aside 100K (102,400) queue entries in a free reserve pool. Of the remaining queue entries, the drop port is provided 8184 entries, 24576 entries for recirculation ports and the CPU ports are assigned 8656 entries. Supervisor Engine 7L-E has a 512 K queue entries.

The remaining entries are divided equally among the slots in the chassis. In a redundant chassis the two supervisor slots are treated as one for the purpose of this entries distribution. Within each slot the number of queue entries are equally divided among the front-panel ports present on the line card in that slot.

When the user configuration for queue entries on an interface exceeds its dedicated quota, the system attempts to satisfy the configuration from the free reserve pool. The entries from the free reserve pool are allocated to interfaces on a first-come first-served basis.

Service Policy Association

When a QoS service-policy with queuing actions is configured, but no explicit queue-limit command is attached in the egress direction on a physical interface, each of the class-based queues gets the same number of queue entries from within the dedicated quota for that physical port. When a queue is explicitly given a size using the queue-limit command, the switch tries to allocate all the entries from within the dedicated quota for the interface. If the required number of entries is greater than the dedicated quota for the interface, the switch tries to allocate the entries from the free reserve.

The queue entries associated with a queue always have to be consecutive. This requirement can result in fragmentation of the 512K of the queue entries that are shared across the switch. For example, an interface may not have enough entries for a queue in its dedicated quota and thus have to use the free reserve to set up that queue. In this case, the queue entries from the dedicated quota remain unused because they cannot be shared with any other port or slot.

When the QoS service-policy associated with an interface is removed, any queue entries taken from the free reserve are returned to the free reserve pool. The interface queuing configuration reverts to two queues — class-default and the control-packet queue with default shape, bandwidth, and size. The control-packet queue is set up with size 16 whereas the default queue is set up with the maximum size possible based on the dedicated quota for that interface.

Queue Allocation Failure

The switch might not be able to satisfy the explicit queue size required on one or more queues on an interface because of fragmentation of queue memory or lack of enough free reserve entries. In this scenario, the switch logs an error message to notify you of the failure. The QoS service-policy is left configured on the interface. You can fix the error by removing the QoS service-policy and examining the current usage of the queue entries from the free reserve by other ports on the switch.

To configure class-level queue-limit in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map policy-map-name`	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class class-name`	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)# shape average {cir-bps [optional_postfix] | percent percent}`	Enables average-rate traffic shaping. You can specify the shaping rate in absolute value or as a percentage: • For *cir-bps* [*optional_postfix*], specify the shaping rate in bps. Range is 32000 to 10000000000 bps. Supply an optional postfix (K, M, G). • For *percent*, specify the percentage of link rate to shape the class of traffic. The range is 1 to 100. By default, average-rate traffic shaping is disabled.
Step 5	`Switch(config-pmap-class)# queue-limit number-of-packets`	Provides an explicit queue size in packets. The size must be a multiple of 8 and ranging from 16 to 8184.
Step 6	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 7	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 8	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.
Step 9	`Switch(config-interface)# service-policy output policy-map-name`	Specifies the policy-map name, and apply it a physical interface.
Step 10	`Switch(config-interface)# end`	Returns to privileged EXEC mode.

Step 11	`Switch# show policy-map [policy-map-name [class class-map-name]]`
	or
	`Switch# show policy-map interface interface-id`
		Verifies your entries.

Step 12	`Switch# copy running-config startup-config`	(Optional) Saves your entries in the configuration file.

To remove the explicit queue size use the **no queue-limit** command under the class in a policy-map.

This example shows how to configure a class-based queue with an explicit **queue-limit** command. It limits traffic class class1 to a queue of size 4048:

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# shape average 256000
Switch(config-pmap-c)# queue-limit 4048
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch#

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
       shape average 256000
       queue-limit 4048
Switch#
```

Active Queue Management (AQM) via Dynamic Buffer Limiting (DBL)

AQM provides buffering control of traffic flows prior to queuing a packet into a transmit queue of a port. This is of significant interest in a shared memory switch, ensuring that certain flows do not hog the switch packet memory.

Note The supervisor engine supports active switch buffer management via DBL.

Except for the default class of traffic (class class-default), you can configure DBL action only when at least one of the other queuing action is configured.

To configure class-level dbl action along with shaping in a service policy, perform this task:

	Command	Purpose
Step 1	`Switch# configure terminal`	Enters global configuration mode.
Step 2	`Switch(config)# policy-map policy-map-name`	Creates a policy map by entering the policy-map name, and enter policy-map configuration mode. By default, no policy maps are defined.
Step 3	`Switch(config-pmap)# class class-name`	Specifies the name of the class whose traffic policy you want to create or change, and enter policy-map class configuration mode. By default, no traffic classes are defined.
Step 4	`Switch(config-pmap-class)# shape average cir-bps`	Enables average-rate traffic shaping. Specify the committed information rate, the bit rate that traffic is shaped to, in bps. The range is 32000 to 10000000000 bps. By default, average-rate traffic shaping is disabled.
Step 5	`Switch(config-pmap-class)# dbl`	Enables DBL on the queue associated with this class of traffic
Step 6	`Switch(config-pmap-class)# exit`	Returns to policy-map configuration mode.
Step 7	`Switch(config-pmap)# exit`	Returns to global configuration mode.
Step 8	`Switch(config)# interface interface-id`	Specifies a physical port and enter interface configuration mode.
Step 9	`Switch(config-interface)# service-policy output policy-map-name`	Specifies the policy-map name, and apply it a physical interface.
Step 10	`Switch(config-interface)# end`	Returns to privileged EXEC mode.

	Command	Purpose

Step 11	`Switch#` **`show policy-map`** `[`*`policy-map-name`* **`[class`** *`class-map-name`*`]]`
	or
	`Switch#` **`show policy-map interface`** *`interface-id`*
		Verifies your entries.

Step 12	`Switch#` **`copy running-config startup-config`**	(Optional) Saves your entries in the configuration file.

To delete an existing policy map, use the **no policy-map** *policy-map-name* global configuration command. To delete an existing class, use the **no class** *class-name* policy-map configuration command. To disable DBL on the associated queue, use the **no dbl** policy-map class configuration command.

The following example shows how to configure class-level, DBL action along with average-rate shaping. It enables DBL on the queue associated with traffic-class *class1*.

```
Switch# configure terminal
Switch(config)# policy-map policy1
Switch(config-pmap)# class class1
Switch(config-pmap-c)# shape average 256000
Switch(config-pmap-c)# dbl
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface gigabitethernet1/1
Switch(config-if)# service-policy output policy1
Switch(config-if)# end
Switch#

Switch# show policy-map policy1
  Policy Map policy1
    Class class1
       shape average 256000
     dbl
```

Transmit Queue Statistics

Transmit queue statistics are visible by entering the **show policy-map interface** command:

```
Switch# show policy-map interface gigabitEthernet 1/1
 GigabitEthernet1/1

  Service-policy output: queuing-policy

    Class-map: queuing-class (match-all)
      1833956 packets
      Match: cos  1
      Queueing
      (total drops)  1006239
      (bytes output) 56284756
      shape (average) cir 320000000, bc 1280000, be 1280000
      target shape rate 320000000

    Class-map: class-default (match-any)
      1 packets
      Match: any

      (total drops)  0
      (bytes output) 2104
```

Enabling Per-Port Per-VLAN QoS

The per-port per-VLAN QoS feature enables you to specify different QoS configurations on different VLANs on a given interface. Typically, you use this feature on trunk or voice VLANs (Cisco IP Phone) ports, as they belong to multiple VLANs.

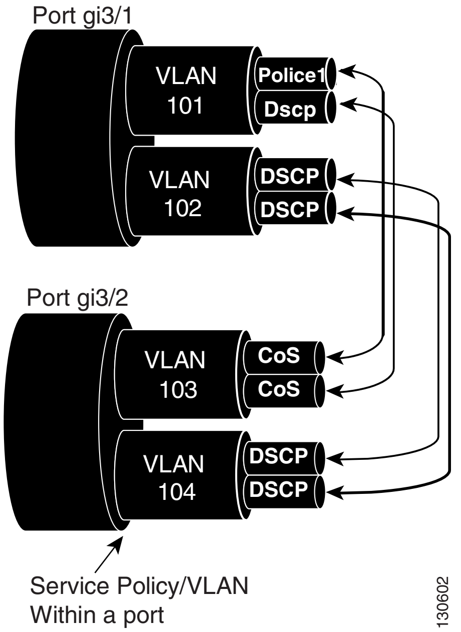
To configure per-port per-VLAN QoS, perform this task:

	Command	Purpose
Step 1	`Switch(config)#` **`interface`** {**`fastethernet`** | **`gigabitethernet`** | **`tengigabitethernet`**} *`slot/interface`* | **`Port-channel`** *`number`*	Selects the interface to configure.
Step 2	`Switch(config-if)#` **`vlan-range`** *`vlan_range`*	Specifies the VLANs involved.
Step 3	`Switch(config-if-vlan-range)#` **`service-policy`** **`{input`** | **`output}`** *`policy-map`*	Specifies the policy-map and direction.
Step 4	`Switch(config-if-vlan-range)#` **`exit`**	Exits class-map configuration mode.
Step 5	`Switch(config-if)#` **`end`**	Exits configuration interface mode.
Step 6	`Switch#` **`show policy-map interface`** *`interface_name`*	Verifies the configuration.

Example 1

Figure 42-6 displays a sample topology for configuring PVQoS. The trunk port gi3/1 is comprised of multiple VLANs (101 and 102). Within a port, you can create your own service policy per VLAN. This policy, performed in hardware, might consist of ingress and egress Policing or giving precedence to voice packet over data.

Figure 42-6 Per-Port Per-VLAN Topology



The following configuration file shows how to perform ingress and egress policing per VLAN using the policy-map P31_QOS applied to port Gigabit Ethernet 3/1:

```
ip access-list 101 permit ip host 1.2.2.2 any
ip access-list 103 permit ip any any
Class-map match-all RT

match ip access-group 101
Class-map Match all PD

match ip access-group 103
Policy-map P31_QoS

Class RT


Police 200m 16k conform transmit exceed drop

Class PD


Police 100m 16k conform transmit exceed drop

Interface Gigabit 3/1
Switchport
Switchport trunk encapsulation dot1q
Switchport trunk allowed vlan 101-102
    Vlan range 101
        Service-policy input P31_QoS
        Service-policy output P31_QoS
    Vlan range 102
        Service-policy input P32_QoS
        Service-policy output P32_QoS
```

Example 2

Let us assume that interface Gigabit Ethernet 6/1 is a trunk port and belongs to VLANs 20, 300-301, and 400. The following example shows how to apply policy-map p1 for traffic in VLANs 20 and 400 and policy map p2 to traffic in VLANs 300 through 301:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet 6/1
Switch(config-if)# vlan-range 20,400
Switch(config-if-vlan-range)# service-policy input p1
Switch(config-if-vlan-range)# exit
Switch(config-if)# vlan-range 300-301
Switch(config-if-vlan-range)# service-policy output p2
Switch(config-if-vlan-range)# end
Switch#
```

Example 3

The following command shows how to display policy-map statistics on VLAN 20 configured on Gigabit Ethernet interface 6/1:

```
Switch# show policy-map interface gigabitEthernet 6/1 vlan 20

 GigabitEthernet6/1 vlan 20

  Service-policy input: p1

    Class-map: c1 (match-all)
      0 packets
      Match: cos  1
      Match: access-group 100
      police:
          cir 100000000 bps, bc 3125000 bytes
```

```
        conformed 0 bytes; actions:
          transmit
        exceeded 0 bytes; actions:
          drop
        conformed 0000 bps, exceed 0000 bps

    Class-map: class-default (match-any)
      0 packets
      Match: any
```

Example 4

The following command shows how to display policy-map statistics on all VLANs configured on Gigabit Ethernet interface 6/1:

```
Switch# show policy-map interface gigabitEthernet 6/1

 GigabitEthernet6/1 vlan 20

  Service-policy input: p1

    Class-map: c1 (match-all)
      0 packets
      Match: cos  1
      Match: access-group 100
      police:
          cir 100000000 bps, bc 3125000 bytes
        conformed 0 bytes; actions:
          transmit
        exceeded 0 bytes; actions:
          drop
        conformed 0000 bps, exceed 0000 bps

    Class-map: class-default (match-any)
      0 packets
      Match: any

 GigabitEthernet6/1 vlan 300

  Service-policy output: p2

    Class-map: c1 (match-all)
      0 packets
      Match: cos  1
      Match: access-group 100
      QoS Set
        dscp 50
      police:
          cir 200000000 bps, bc 6250000 bytes
        conformed 0 bytes; actions:
          transmit
        exceeded 0 bytes; actions:
          drop
        conformed 0000 bps, exceed 0000 bps

    Class-map: class-default (match-any)
      0 packets
      Match: any

 GigabitEthernet6/1 vlan 301

  Service-policy output: p2
```

```
Class-map: c1 (match-all)
  0 packets
  Match: cos  1
  Match: access-group 100
  QoS Set
    dscp 50
  police:
      cir 200000000 bps, bc 6250000 bytes
    conformed 0 bytes; actions:
      transmit
    exceeded 0 bytes; actions:
      drop
    conformed 0000 bps, exceed 0000 bps
```

Policy Associations

The supervisor engine supports per-port, per-VLAN policies. The associated policies are attached to the interface, VLAN, and a specific VLAN on a given port, respectively.

A policy can be associated with a variety of objects. The following table lists the objects and the actions allowed.

Table 42-3 Table QoS Policy Associations

Object	Action
Physical port	Policing, marking, and queuing
VLAN	Policing and marking
Port and VLAN (PV)	Policing and marking
EtherChannel	Policing and marking
EtherChannel member port	Queuing

Qos Action Restrictions

- The same actions cannot be performed multiple times in a given direction on different targets. In other words, it is not possible to police the packets both on port and VLAN in the input direction. However, the user can police on the input port and on the output VLAN.
- Queuing actions are only allowed in the egress direction and only on the physical port.
- Percentage-based actions like policer cannot be configured on a VLAN, Port and VLAN (PV) and EtherChannel.
- Port channel or VLAN configuration can only have a policing or a marking action, not a queueing action.

Qos Policy priorities

- If a policy on a port and a VLAN are configured with conflicting actions (such as policing or marking actions on both a port and VLAN), the port policy is picked.
- If policy on a VLAN on a given port must be over-written, the user can configure PV policy.

Qos Policy merging

Applicable policies are applied to a given packet in given direction. For example, if you configure egress VLAN-based police and marking, followed by selective queuing on the port, then actions from both policies will be applied for this packet.

The following policy-map configuration restrictions are imposed on an EtherChannel:

- only policing and marking actions are supported at the EtherChannel level
- only queuing actions are supported at the physical member port level

A packet can be marked (dscp or cos fields) by the EtherChannel policy. If the physical member port policy uses a classification based on dscp or cos fields, it must be based on the marked (modified) value. To ensure proper operation, the following restriction is placed on the EtherChannel.

The classification criteria for the policy-map on the physical member ports has to based only on one type of field:

- dscp
- precedence
- cos
- any non marking field (no dscp or cos based classification)

Classification criteria for the policy-map on the physical member ports cannot be based on a combination of fields. This restriction ensures that if the EtherChannel policy is marking down dscp or cos, the marked (modified) value-based classification can be implemented in hardware.

Note Classification criteria for the policy-map on the physical member ports cannot be modified to add a new type of field.

Auto-QoS is not supported on EtherChannel or its member ports. A physical port configured with Auto-QoS is not allowed to become a member of a physical port.

Software QoS

At the highest level, there are two types of locally sourced traffic (such as control protocol packets, pings, and telnets) from the switch: high priority traffic (typically the control protocol packets like OSPF Hellos and STP) and low priority packets (all other packet types).

The QoS treatment for locally-sourced packets differs for the two types.

The supervisor engine provides a way to apply QoS to packets processed in the software path. The packets that get this QoS treatment in software can be classified into two types: software switched packets and software generated packets.

On reception, software switched packets are sent to the CPU that in turn sends them out of another interface. For such packets, input software QoS provides input marking and output software QoS provides output marking and queue selection.

The software generated packets are the ones locally sourced by the switch. The type of output software QoS processing applied to these packets is the same as the one applied to software switched packets. The only difference in the two is that the software switched packets take input marking of the packet into account for output classification purpose.

High Priority Packets

High priority packets are marked as one of the following:

- internally with PAK_PRIORITY
- with IP Precedence of 6 (for IP packets)
- with CoS of 6 (for VLAN Tagged packets)

These packets behave as follows:

- They are not dropped because of any policing, AQM, drop thresholds (or any feature that can drop a packet) configured as per the egress service policy. However, they might be dropped because of hardware resource constraints (packet buffers, queue full, etc.).
- They are classified and marked as per the marking configuration of the egress service policy that could be a port or VLAN (refer to the “Policy Associations” section on page 42-73.
- These high priority packets are enqueued to queue on the egress port based on the following criteria:
  - If there is no egress queuing policy on the port, the packet is queued to a control packet queue that is setup separately from the default queue and has 5 percent of the link bandwidth reserved for it.
  - If there is an egress queuing policy on the port, the queue is selected based on the classification criteria applicable to the packet.

Low Priority Packets

Packets that are not considered high priority (as described previously) are considered *unimportant*. These include locally sourced pings, telnet, and other protocol packets. They undergo the same treatment as any other packet that is transiting the given transmit port including egress classification, marking and queuing.

Applying Flow-based QoS Policy

Flow based QoS enables microflow policing and marking capability to dynamically learn traffic flows. It also rate limits each unique flow to an individual rate. Flow based QoS is available with the built-in NetFlow hardware support.

For more overview information, refer to the “Flow-based QoS” section on page 42-10.

The following steps show how to apply Flow based QoS policy to QoS targets:

Step 1 Create a FNF flow record by specifying the key fields that identify unique flows. You can use any FNF flow records that are associated with the FNF monitor.

Step 2 Create a class-map to specify the set of match criteria. Include the FNF flow record from Step 1 in the class-map match criteria using the **match flow record** command. Then, configure the class-map to match all the match criteria with **class-map match-all** *class_name*.

Step 3 Create a policy-map and define actions associated with class-map from Step 2.

Step 4 Attach the policy to one or more QoS targets.

Examples

The following examples illustrate how to configure Flow based QoS policy and apply microflow policers on individual flows.

Example 1

This example assumes there are multiple users (identified by source IP address) on the subnet 192.168.10.*. The configuration below shows how to configure a flow based QoS policy that uses micro policing to limit the per-user traffic with the source address in the range of 192.168.10.*. The microflow policer is configured with a CIR of 1Mbps, "conform action" as transmit, and "exceed action" as drop.

Step 1: Define an ACL to match traffic with specified source address.

```
Switch(config)# ip access-list extended UserGroup1
Switch(config-ext-nacl)# permit ip 192.168.10.0 0.0.0.255 any
Switch(config-ext-nacl)# exit
Switch(config)#
```

Step 2: Define a flow record to create flows with source address as key.

```
Switch(config)# flow record r1
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# exit
Switch(config)#
```

Step 3: Configure classmap to match on the UserGroup1 and specify flow record definition for flow creation.

```
Switch(config)# class-map match-all c1
Switch(config-cmap)# match access-group name UserGroup1
Switch(config-cmap)# match flow record r1
Switch(config-cmap)# exit
Switch(config)#
```

Step 4: Configure flow based QoS policy-map with microflow policing action for the matching traffic.

```
Switch(config)# policy-map p1
Switch(config-pmap)# class c1
Switch(config-pmap-c)# police cir 1m
Switch(config-pmap-c-police)# conform-action transmit
Switch(config-pmap-c-police)# exceed-action drop
Switch(config-pmap-c-police)# exit
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
```

Step 5: Attach flow QoS policy to the interface.

```
Switch(config)# interface gigabitEthernet3/1
Switch(config-if)# service-policy input p1
Switch(config-if)#
```

Use the **show** commands (described in the policy and marking sections of this chapter) to display the policy-map configuration and interface specific policy-map statistics.

Example 2.

This example assumes there are multiple users (identified by source IP address) on subnets 192.168.10.* and 172.20.55.*. The first requirement is to police with a CIR of 500Kbps and a PIR of 650Kbps on any TCP traffic originating from 192 network to any destination at any given time. The **exceed action** keyword marks down the dscp value to 32. The second requirement is to police per-user traffic originating from 172 network to CIR of 2Mbps and unconditionally mark the traffic with dscp 10.

Step 1: Define an ACL to match traffic with specified source address.

```
Switch(config)# ip access-list extended UserGroup1
Switch(config-ext-nacl)# permit ip 19 2.168.10.0 0.0.0.255 any
Switch(config-ext-nacl)# exit
Switch(config)# ip access-list extended UserGroup2
Switch(config-ext-nacl)# permit ip 172.20.55.0 0.0.0.255 any
Switch(config-ext-nacl)# exit
Switch(config)#
```

Step 2: Define a flow record to create flows with source address as key.

```
Switch(config)# flow record r1
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# match ipv4 destination address
Switch(config-flow-record)# match transport tcp source-port
Switch(config-flow-record)# match transport tcp destination-port
Switch(config-flow-record)# exit
Switch(config)# flow record r2
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# exit
Switch(config)#
```

Step 3: Configure classmap to match on the UserGroup1 and specify flow record definition for flow creation.

```
Switch(config)# class-map match-all c1
Switch(config-cmap)# match access-group name UserGroup1
Switch(config-cmap)# match flow record r1
Switch(config-cmap)# exit
Switch(config)# class-map match-all c2
Switch(config-cmap)# match access-group name UserGroup2
Switch(config-cmap)# match flow record r2
Switch(config-cmap)# exit
Switch(config)#
```

Step 4: Configure flow based QoS policy-map with microflow policing action for the matching traffic.

```
Switch(config)# policy-map p1
Switch(config-pmap)# class c1
Switch(config-pmap-c)# police cir 500k pir 650k
Switch(config-pmap-c-police)# conform-action transmit
Switch(config-pmap-c-police)# exceed-action set-dscp-transmit 32
Switch(config-pmap-c-police)# violate-action drop
Switch(config-pmap-c-police)# exit
Switch(config-pmap-c)# exit
Switch(config-pmap)# class c2
Switch(config-pmap-c)# set dscp 10
Switch(config-pmap-c)# police cir 2m
Switch(config-pmap-c-police)# conform-action transmit
Switch(config-pmap-c-police)# exceed-action drop
Switch(config-pmap-c-police)# exit
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
```

Step 5: Attach flow QoS policy to the interface.

```
Switch(config)# interface gigabitEthernet3/1
Switch(config-if)# service-policy input p1
Switch(config-if)# exit
```

Use the show commands described in the QoS section to display the policy-map configuration and interface specific policy-map statistics.

Example 3

Assume that there are two active flows on FastEthernet interface 6/1:

Table 42-4

SrcIp	DStIp	IPProt	SrcL4Port	DstL4Port
192.168.10.10	192.168.20.20	20	6789	81
192.168.10.10	192.168.20.20	20	6789	21

With the following configuration, each flow is policed to 1000000 bps with an allowed 9000 burst value.

```
Switch(config)# flow record r1
Switch(config-flow-record)# match ipv4 source address
Switch(config-flow-record)# match ipv4 destination address
Switch(config-flow-record)# match transport tcp source-port
Switch(config-flow-record)# match transport tcp destination-port
Switch(config-flow-record)# match transport udp source-port
Switch(config-flow-record)# match transport udp destination-port
Switch(config-flow-record)# exit
Switch(config)# class-map match-all c1
Switch(config-cmap)# match flow record r1
Switch(config-cmap)# exit
Switch(config)# policy-map p1
Switch(config-pmap)# class c1
Switch(config-pmap-c)# police 1000000 9000
Switch(config-pmap-c)# exit
Switch(config-pmap)# exit
Switch(config)# interface fastEthernet 6/1
Switch(config-if)# service-policy input p1
Switch(config-if)# end
```

Configuration Guidelines

The general guidelines for creating, configuring, modifying, deleting a flow based QoS policy and attaching (and detaching) a flow based QoS policy to a supported target is the same as described in the QoS section. The following description and restriction applies to Flow based QoS policy:

- A classmap can have multiple match statements but only one FNF flow record can be specified in a class-map.
- A flow record must have at least one key field before it can be used in a classmap. Non-key fields can be present in the flow record. However, all the non-key fields are ignored by microflow QoS. Only key-fields are used for flow creation.
- If a FNF flow record is referenced in any class-map, the flow record cannot be modified. Remove the flow record from all classmaps before modifying it.
- A classmap with a FNF flow record must be configured as **match-all**; traffic hitting the class-map must satisfy all match criteria in the class-map.

- A policy can contain multiple classes and each class-map may contain the same or different FNF flow record.
- Flow based QoS policy and FNF monitor both cannot be applied on the same target at the same time.
- When the interface mode changes from switchport to routed port and vice versa, any Flow QoS policy attached to the port remains applied after the mode change.
- There are 3 types of FNF flow records: ipv4, ipv6, and datalink. The datalink flow record is mutually exclusive with the ipv4 and ipv6 flow records; a classmap with the datalink flow record cannot co-exist with classmap having a ipv4 or ipv6 flow record in the same policy and vice-versa.
- Classmap class-default is not editable; it cannot be configured with the match flow record. Instead, you can configure the policy with a class-map that uses a match any filter and the flow record.
- Traffic is classified in the same order in which class-map is defined in a policy. Hence, if a FNF flow record is the only match statement in a class-map, the classifier matches all packets of the type identified by the flow record. This means that any subsequent class-map in the same policy matching on the same traffic type will be redundant and will never be hit.
- Policers associated with classmap having flow record are called *microflow policers*. The CIR and PIR rates for microflow policers cannot be configured using the percent keyword.
- Flow records within the same policy must include appropriate key fields to ensure flows created from different classmaps are unique and distinct. Otherwise, the resulting flows from different classmap cannot be distinguished. In such cases, policy actions corresponding to the classmap which created the first flow in hardware will apply and results will not be always be as expected.
- Flows from traffic received on different QoS targets are distinct even if the same policy is applied to those targets.
- A flow is aged out if the it is inactive for more than 5 seconds; there is no traffic matching the flow for a period longer than 5 sec.
- When a flow is aged out, policer state information associated with the flow is also deleted. When a new flow is created, the policer instance for the flow is re-initialized.
- Flows created by flow based QoS policy exist in hardware only and cannot be exported (as with FNF monitor).
- Per-flow statistics are not available for flows created by flow based QoS policy.
- Class-map statistics indicate the number of packets matching the classifier. It does not represent individual flow stats.
- Policer statistics show the aggregate policer statistics of individual flow.
- Information about the flows created by hardware are not available and not displayed in the show commands associated with QoS policy-map. Only class-map and policer statistics are displayed in the output of the **show policy-map** commands.

Configuring CoS Mutation

CoS reflection and CoS mutation are supported on Supervisor Engine 6-E and Catalyst 4900M. Below is an example of how to apply CoS reflection.

Let us say that traffic arrives on interface gigabit 2/5 with VLAN 10 and COS 1, 2, ... We want traffic to egress interface gigabit 2/6 with outer tag VLAN 11 and CoS copied from C-tag, where C-tag is VLAN 10 and COS 1, 2, ...

```
class-map match-all c2
```

```
  match cos  2

class-map match-all c1

  match cos  1

!

policy-map my

class c1

   set cos 1

class c2

  set cos 2


interface GigabitEthernet2/5

switchport mode trunk

switchport vlan mapping 10 dot1q-tunnel 11

spanning-tree bpdufilter enable

service-policy input my

!

interface GigabitEthernet2/6

switchport mode trunk
```

Configuring System Queue Limit

Note This feature is available only from Cisco IOS Release 15.0(2)SG1 and later and Cisco IOS Release XE 3.2.1SG.

With the **hw-module system max-queue-limit** command, the Catalyst 4500 series switch allows you to change the queue limit for all interfaces globally, instead of applying a policy with queue limit to all the interfaces.

To set the queue limit globally, perform this task:

	Command	Purpose
Step 1	`Switch#` **`configure terminal`**	Enters global configuration mode.
Step 2	`Switch(config)#` **`hw-module system max-queue-limit`** *`max-queue-limit`*	Sets the queue limit for all interfaces globally. Valid values are from 1024 to 8184. The value must be a multiple of 8.

	Command	Purpose
Step 3	`Switch(config)#` **`exit`**	Returns to privileged EXEC mode.
Step 4	`Switch#` **`reload`**	Reloads standalone supervisor engine.
	or	
	`Switch#` **`redundancy reload shelf`**	Reloads redundancy supervisor engine in SSO mode.
	`Switch#` **`redundancy force-switchover`**	Reloads redundancy supervisor engine in RPR mode. This command must be followed by another redundancy force-switchover.

This is a global configuration command. You can override it with the per port, per class, **queue-limit** command.

For a standalone supervisor engine, you must reboot the engine after applying this command.

For redundant supervisors in SSO mode, you must enter the **redundancy reload shelf** command enforce reboot to both the supervisors. For redundancy supervisors in RPR mode, you must execute two consecutive switchovers to enforce the system queue limit on both the supervisors.

This example shows how to set the queue limit globally to 1024 on a standalone supervisor engine:

```
Switch> enable
Switch# configure terminal
Switch(config)# hw-module system max-queue-limit 1024
Switch(config)# exit
Switch# reload  (for standalone supervisors)
Switch# redundancy reload shelf (for redundancy supervisors in SSO mode)
or
Switch# redundancy force-switchover (followed by another redundancy force-switchover, for
redundancy supervisors in RPR mode)
```

Configuring VSS Auto-QoS

Note Auto-QoS cannot be applied to VLANs or EtherChannel interfaces.

Note If you have an auto-QoS policy on a port connected to a device that supports CDP, the port is automatically trusted. However, if the device does not support CDP (like legacy Digital Media Player), QoS trust must be applied manually.

The Catalyst 4500 Series Switch employs the MQC model. This means that instead of using certain global configurations (like qos and qos dbl), auto-QoS applied to any interface on a switch configures several global class-maps and policy-maps.

We need QoS in both directions, both on inbound and outbound. Inbound, the switch port needs to trust the DSCP in the packet (done by default). Outbound, the switch port needs to give voice packets "front of line" priority. If voice is delayed too long by waiting behind other packets in the outbound queue, the end host drops the packet because it arrives outside of the receive window for that packet.

Note QoS is a two way street. So, it might work in one direction and not in the other.

- There are 7 policy maps that must be defined (5 Input, 2 output)
- AutoQos-4.0-Input-Policy
- AutoQos-VoIP-Input-Cos-Policy
- AutoQos-VoIP-Input-Dscp-Policy
- AutoQos-4.0-Cisco-Phone-Input-Policy
- AutoQos-4.0-Output-Policy
- AutoQos-4.0-Cisco-Softphone-Input-Policy
- AutoQos-VoIP-Output-Policy

On all ports. The problem with COS is that packets on the native VLAN is marked as zero.

The class maps used for input matching are as follows:

```
! for control traffic between the phone and the callmanager
! and phone to phone [Bearer] DSCP matching

class-map match-all AutoQos-VoIP-Control-Dscp26
  match  dscp af31
class-map match-all AutoQos-VoIP-Control-Dscp24
  match  dscp cs3
class-map match-all AutoQos-VoIP-Bearer-Dscp
  match  dscp ef

! for control traffic and phone to phone [Bearer] COS matching
! Note: Both CS3 and AF31 control traffic maps to COS 3

class-map match-all AutoQos-VoIP-Control-Cos
  match cos  3
class-map match-all AutoQos-VoIP-Bearer-Cos
  match cos  5

! for control traffic between the softphonephone and the callmanager
! and softphone  to softphonephone [Bearer] DSCP matching
Class Map match-all AutoQos-4.0-Multimedia-Conf-Classify (id 36)
   Match access-group name AutoQos-4.0-ACL-Multimedia-Conf
Class Map match-all AutoQos-4.0-Signaling-Classify (id 2)
   Match access-group name AutoQos-4.0-ACL-Signaling
Class Map match-all AutoQos-4.0-Transaction-Classify (id 18)
   Match access-group name AutoQos-4.0-ACL-Transactional-Data
Class Map match-all AutoQos-4.0-Bulk-Data-Classify (id 29)
   Match access-group name AutoQos-4.0-ACL-Bulk-Data
Class Map match-all AutoQos-4.0-Scavenger-Classify (id 1)
   Match access-group name AutoQos-4.0-ACL-Scavenger

! for untrueted interfaces
class-map match-all AutoQos-4.0-Multimedia-Conf-Classify
           match access-group name AutoQos-4.0-ACL-Multimedia-Conf
   class-map match-all AutoQos-4.0-Signaling-Classify
     match access-group name AutoQos-4.0-ACL-Signaling
   class-map match-all AutoQos-4.0-Transaction-Classify
     match access-group name AutoQos-4.0-ACL-Transactional-Data
   class-map match-all AutoQos-4.0-Bulk-Data-Classify
     match access-group name AutoQos-4.0-ACL-Bulk-Data
   class-map match-all AutoQos-4.0-Scavenger-Classify
     match access-group name AutoQos-4.0-ACL-Scavenger
```

```
         class-map match-all AutoQos-4.0-Default-Classify
     match access-group name AutoQos-4.0-ACL-Default

! for interfaces with video devices
class-map match-any AutoQos-4.0-VoIP
      match dscp ef
      match cos 5
    class-map match-all AutoQos-4.0-Broadcast-Vid
      match dscp cs5
    class-map match-all AutoQos-4.0-Realtime-Interact
      match dscp cs4
    class-map match-all AutoQos-4.0-Network-Ctrl
      match dscp cs7
    class-map match-all AutoQos-4.0-Internetwork-Ctrl
      match dscp cs6
    class-map match-any AutoQos-4.0-Signaling
      match dscp cs3
      match cos 3
    class-map match-all AutoQos-4.0-Network-Mgmt
      match dscp cs2
    class-map match-any AutoQos-4.0-Multimedia-Conf
      match dscp af41
      match dscp af42
      match dscp af43
   class-map match-any AutoQos-4.0-Multimedia-Stream
      match dscp af31
      match dscp af32
      match dscp af33
    class-map match-any AutoQos-4.0-Transaction-Data
      match dscp af21
      match dscp af22
      match dscp af23
    class-map match-any AutoQos-4.0-Bulk-Data
      match dscp af11
      match dscp af12
      match dscp af13
    class-map match-all AutoQos-4.0-Scavenger
      match dscp cs1
```

The class maps are intended to identify control and data (bearer) voice traffic for either an Layer 2 or Layer 3 interface.

The 2 Input policy maps, one for matching DSCP and one for matching COS, where DSCP and COS are set to an assigned qos-group used in outbound policy-maps are as follows:

```
policy-map AutoQos-VoIP-Input-Dscp-Policy
  class AutoQos-VoIP-Bearer-Dscp
  class AutoQos-VoIP-Control-Dscp26
  class AutoQos-VoIP-Control-Dscp24

! Note: For COS, Control traffic only has a single COS value of 3 (versus DSCP which has 2
values to match). So, only 2 class-maps instead of 3 like above.

policy-map AutoQos-VoIP-Input-Cos-Policy
  class AutoQos-VoIP-Bearer-Cos
  class AutoQos-VoIP-Control-Cos

The input policy maps are as follows:

policy-map AutoQos-4.0-Input-Policy
class AutoQos-4.0-VoIP
class AutoQos-4.0-Broadcast-Vid
class AutoQos-4.0-Realtime-Interact
class AutoQos-4.0-Network-Ctrl
class AutoQos-4.0-Internetwork-Ctrl
class AutoQos-4.0-Signaling
class AutoQos-4.0-Network-Mgmt
class AutoQos-4.0-Multimedia-Conf
class AutoQos-4.0-Multimedia-Stream
class AutoQos-4.0-Transaction-Data
class AutoQos-4.0-Bulk-Data
class AutoQos-4.0-Scavenger
policy-map AutoQos-4.0-Classify-Police-Input-Policy
class AutoQos-4.0-Multimedia-Conf-Classify
   set dscp af41
   set cos 4
    police cir 5000000 bc 8000
      exceed-action drop
 class AutoQos-4.0-Signaling-Classify
   set dscp cs3
   set cos 3
    police cir 32000 bc 8000
      exceed-action drop
 class AutoQos-4.0-Transaction-Classify
  set dscp af21
   set cos 2
    police cir 10000000 bc 8000
      exceed-action set-dscp-transmit cs1
      exceed-action set-cos-transmit 1
class AutoQos-4.0-Bulk-Data-Classify
   set dscp af11
   set cos 1
    police cir 10000000 bc 8000
      exceed-action set-dscp-transmit cs1
      exceed-action set-cos-transmit 1
class AutoQos-4.0-Scavenger-Classify
   set dscp cs1
   set cos 1
    police cir 10000000 bc 8000
      exceed-action drop
 class AutoQos-4.0-Default-Classify
   set dscp default
   set cos 0
    police cir 10000000 bc 8000
      exceed-action set-dscp-transmit cs1
      exceed-action set-cos-transmit 1
policy-map AutoQos-4.0-Cisco-Phone-Input-Policy
class AutoQos-4.0-VoIP-Data-Cos
   set dscp ef
    police cir 128000 bc 8000
      exceed-action set-dscp-transmit cs1
      exceed-action set-cos-transmit 1
class AutoQos-4.0-VoIP-Signal-Cos
   set dscp cs3
    police cir 32000 bc 8000
      exceed-action set-dscp-transmit cs1
      exceed-action set-cos-transmit 1
class class-default
   set dscp default
   set cos 0
policy-map AutoQos-4.0-Classify-Input-Policy
class AutoQos-4.0-Multimedia-Conf-Classify
   set dscp af41
   set cos 4
class AutoQos-4.0-Signaling-Classify
   set dscp cs3
   set cos 3
class AutoQos-4.0-Transaction-Classify
```

```
   set dscp af21
   set cos 2
class AutoQos-4.0-Bulk-Data-Classify
   set dscp af11
   set cos 1
class AutoQos-4.0-Scavenger-Classify
   set dscp cs1
   set cos 1
class AutoQos-4.0-Default-Classify
   set dscp default
   set cos 0
!

The output policy maps are as follows:

policy-map AutoQos-4.0-Output-Policy
class AutoQos-4.0-Scavenger-Queue
    bandwidth remaining percent 1
class AutoQos-4.0-Priority-Queue
    priority
    police cir percent 30 bc 33 ms
class AutoQos-4.0-Control-Mgmt-Queue
    bandwidth remaining percent 10
class AutoQos-4.0-Multimedia-Conf-Queue
    bandwidth remaining percent 10
class AutoQos-4.0-Multimedia-Stream-Queue
    bandwidth remaining percent 10
class AutoQos-4.0-Trans-Data-Queue
    bandwidth remaining percent 10
    dbl
class AutoQos-4.0-Bulk-Data-Queue
    bandwidth remaining percent 4
    dbl
class class-default
    bandwidth remaining percent 25
    dbl
```

The three policy maps are defined as follows:

- policy-map AutoQos-VoIP-Input-Dscp-Policy

  This policy map is applied as an input service policy on an Layer 3 interface (such as an uplink connection to a neighboring switch) when auto-QoS is configured on the port.

- policy-map AutoQos-VoIP-Input-Cos-Policy

  This policy map is applied as an input service policy on an Layer 2 interface that could be either an uplink connection or a port hooked to a Cisco IP Phone.

- policy-map AutoQos-VoIP-Output-Policy

  This policy map is applied as an output policy for any port on which auto-QoS is configured, establishing policy governing egress traffic on the port based on whether it is voice data or control traffic.

The purpose of the input policy maps is to identify voice data or control traffic and mark it as such as it traverses the switch. The output policy map matches the packets on the marking occurring on ingress and then applies egress parameters such as bandwidth, policing and/or priority queuing.

For switch-to-switch connections, the **[no] auto qos voip trust** command is used to apply an input and output service policy on the interface:

```
service-policy input AutoQos-VoIP-Input-Cos-Policy
```

OR

```
service-policy input AutoQos-VoIP-Input-Dscp-Policy
```

AND

```
service-policy output AutoQos-VoIP-Output-Policy
```

The selection of the input policy depends on whether the port is Layer 2 or Layer 3. For Layer 2, the policy trusts the Cos setting in the received packets. For Layer 3 ports, it relies on the DSCP value contained in the packets.

For phone connected ports, the **[no] auto qos voice cisco-phone** command is used to apply the following service policy to the port:

```
qos trust device cisco-phone

service-policy input AutoQos-VoIP-Input-Cos-Policy
```

AND

```
service-policy output AutoQos-VoIP-Output-Policy
```

It establishes a trusted boundary that recognizes Cisco IP Phones and trusts the Cos setting of the packets from the phone. If a Cisco IP Phone is not detected, the Cos field is ignored and the packets are not classified as voice traffic. Upon detecting a Cisco phone, the ingress packets are marked based on the Cos value in the packets. This marking is used on egress for proper traffic classification and handling.

Auto qos srnd4—Is generated when any new auto qos command is configured on an interface and migrates from legacy CLIs to generate new configurations. This CLI only generates a global configuration if during migration, one or more interfaces has legacy auto-QoS enabled

Auto qos video—Generates QoS configuration for untrusted interfaces. It incorporates a service-policy to classify the traffic coming from untrusted desktops/devices and marks them accordingly.

Auto qos void cisco-softphone—Generate QoS configuration for interfaces connected to PCs running the Cisco IP SoftPhone application and marks as police traffic stemming from such interfaces. Ports configured with this CLI are considered untrusted.

Auto qos classify—Generates QoS configuration for untrusted interfaces. It applies a service-policy to classify the traffic stemming from untrusted desktops or devices and marks them accordingly. The service-policies generated do not police.

Configuring Auto-QoS on a Standalone Supervisor Engine 6-E/6L-E or Supervisor Engine 7-E/7L-E/8-E

Note Auto-QoS cannot be applied to VLANs or EtherChannel interfaces.

Note If you have an auto-QoS policy on a port connected to a device that supports CDP, the port is automatically trusted. However, if the device does not support CDP (like legacy Digital Media Player), QoS trust must be applied manually.

The Catalyst 4500 Series Switch employs the MQC model. This means that instead of using certain global configurations (like qos and qos dbl), auto-QoS applied to any interface on a switch configures several global class-maps and policy-maps.

Auto-QoS matches traffic and assigns each matched packet to qos-groups. This allows the output policy map to put specific qos-groups into specific queues, including into the priority queue.

We need QoS in both directions, both on inbound and outbound. Inbound, the switch port needs to trust the DSCP in the packet (done by default). Outbound, the switch port needs to give voice packets "front of line" priority. If voice is delayed too long by waiting behind other packets in the outbound queue, the end host drops the packet because it arrives outside of the receive window for that packet.

Note QoS is a two way street. So, it might work in one direction and not in the other.

- There are 7 policy maps that must be defined (5 Input, 2 output)
- AutoQos-4.0-Input-Policy
- AutoQos-VoIP-Input-Cos-Policy
- AutoQos-VoIP-Input-Dscp-Policy
- AutoQos-4.0-Cisco-Phone-Input-Policy
- AutoQos-4.0-Output-Policy
- AutoQos-4.0-Cisco-Softphone-Input-Policy
- AutoQos-VoIP-Output-Policy

On all ports. The problem with COS is that packets on the native VLAN is marked as zero.

The class maps used for input matching are as follows:

```
! for control traffic between the phone and the callmanager
! and phone to phone [Bearer] DSCP matching
! Note: Control traffic can be either AF31 or CS3. So, we match to both values and assign
them to different qos-groups when matching DSCP and only a single group when matching COS.

class-map match-all AutoQos-VoIP-Control-Dscp26
  match  dscp af31
class-map match-all AutoQos-VoIP-Control-Dscp24
  match  dscp cs3
class-map match-all AutoQos-VoIP-Bearer-Dscp
  match  dscp ef

! for control traffic and phone to phone [Bearer] COS matching
! Note: Both CS3 and AF31 control traffic maps to COS 3

class-map match-all AutoQos-VoIP-Control-Cos
  match cos  3
class-map match-all AutoQos-VoIP-Bearer-Cos
  match cos  5

! for control traffic between the softphonephone and the callmanager
! and softphone  to softphonephone [Bearer] DSCP matching
Class Map match-all AutoQos-4.0-Multimedia-Conf-Classify (id 36)
   Match access-group name AutoQos-4.0-ACL-Multimedia-Conf
Class Map match-all AutoQos-4.0-Signaling-Classify (id 2)
   Match access-group name AutoQos-4.0-ACL-Signaling
Class Map match-all AutoQos-4.0-Transaction-Classify (id 18)
   Match access-group name AutoQos-4.0-ACL-Transactional-Data
Class Map match-all AutoQos-4.0-Bulk-Data-Classify (id 29)
   Match access-group name AutoQos-4.0-ACL-Bulk-Data
Class Map match-all AutoQos-4.0-Scavenger-Classify (id 1)
   Match access-group name AutoQos-4.0-ACL-Scavenger

! for untrueted interfaces
```

```
class-map match-all AutoQos-4.0-Multimedia-Conf-Classify
           match access-group name AutoQos-4.0-ACL-Multimedia-Conf
   class-map match-all AutoQos-4.0-Signaling-Classify
     match access-group name AutoQos-4.0-ACL-Signaling
   class-map match-all AutoQos-4.0-Transaction-Classify
     match access-group name AutoQos-4.0-ACL-Transactional-Data
   class-map match-all AutoQos-4.0-Bulk-Data-Classify
     match access-group name AutoQos-4.0-ACL-Bulk-Data
   class-map match-all AutoQos-4.0-Scavenger-Classify
     match access-group name AutoQos-4.0-ACL-Scavenger
         class-map match-all AutoQos-4.0-Default-Classify
     match access-group name AutoQos-4.0-ACL-Default

! for interfaces with video devices
class-map match-any AutoQos-4.0-VoIP
      match dscp ef
      match cos 5
    class-map match-all AutoQos-4.0-Broadcast-Vid
      match dscp cs5
    class-map match-all AutoQos-4.0-Realtime-Interact
      match dscp cs4
    class-map match-all AutoQos-4.0-Network-Ctrl
      match dscp cs7
    class-map match-all AutoQos-4.0-Internetwork-Ctrl
      match dscp cs6
    class-map match-any AutoQos-4.0-Signaling
      match dscp cs3
      match cos 3
    class-map match-all AutoQos-4.0-Network-Mgmt
      match dscp cs2
    class-map match-any AutoQos-4.0-Multimedia-Conf
      match dscp af41
      match dscp af42
      match dscp af43
   class-map match-any AutoQos-4.0-Multimedia-Stream
      match dscp af31
      match dscp af32
      match dscp af33
    class-map match-any AutoQos-4.0-Transaction-Data
      match dscp af21
      match dscp af22
      match dscp af23
    class-map match-any AutoQos-4.0-Bulk-Data
      match dscp af11
      match dscp af12
      match dscp af13
    class-map match-all AutoQos-4.0-Scavenger
      match dscp cs1
```

The class maps are intended to identify control and data (bearer) voice traffic for either an Layer 2 or Layer 3 interface.

The 2 Input policy maps, one for matching DSCP and one for matching COS, where DSCP and COS are set to an assigned qos-group used in outbound policy-maps are as follows:

```
policy-map AutoQos-VoIP-Input-Dscp-Policy
  class AutoQos-VoIP-Bearer-Dscp
   set qos-group 46
  class AutoQos-VoIP-Control-Dscp26
   set qos-group 26
  class AutoQos-VoIP-Control-Dscp24
   set qos-group 24
```

```
! Note: For COS, Control traffic only has a single COS value of 3 (versus DSCP which has 2
values to match). So, only 2 class-maps instead of 3 like above.

policy-map AutoQos-VoIP-Input-Cos-Policy
  class AutoQos-VoIP-Bearer-Cos
   set qos-group 46
  class AutoQos-VoIP-Control-Cos
   set qos-group 24

Policy Map AutoQos-4.0-Input-Policy
    Class AutoQos-4.0-VoIP
      set qos-group 32
    Class AutoQos-4.0-Broadcast-Vid
      set qos-group 32
    Class AutoQos-4.0-Realtime-Interact
      set qos-group 32
    Class AutoQos-4.0-Network-Ctrl
      set qos-group 16
    Class AutoQos-4.0-Internetwork-Ctrl
      set qos-group 16
    Class AutoQos-4.0-Signaling
      set qos-group 16
    Class AutoQos-4.0-Network-Mgmt
      set qos-group 16
    Class AutoQos-4.0-Multimedia-Conf
      set qos-group 34
    Class AutoQos-4.0-Multimedia-Stream
      set qos-group 26
    Class AutoQos-4.0-Transaction-Data
      set qos-group 18
    Class AutoQos-4.0-Bulk-Data
      set qos-group 10
    Class AutoQos-4.0-Scavenger
      set qos-group 8


  Policy Map AutoQos-4.0-Cisco-Phone-Input-Policy
    Class AutoQos-4.0-VoIP-Data-Cos
      set dscp ef
      set qos-group 32
     police cir 128000 bc 8000
       conform-action transmit
       exceed-action set-dscp-transmit cs1
       exceed-action set-cos-transmit 1
    Class AutoQos-4.0-VoIP-Signal-Cos
      set dscp cs3
      set qos-group 16
     police cir 32000 bc 8000
       conform-action transmit
       exceed-action set-dscp-transmit cs1
       exceed-action set-cos-transmit 1
    Class AutoQos-4.0-Default-Classify
      set dscp default
      set cos 0
     police cir 10000000 bc 8000
       conform-action transmit
       exceed-action set-dscp-transmit cs1
       exceed-action set-cos-transmit 1

Policy Map AutoQos-4.0-Cisco-Softphone-Input-Policy
    Class AutoQos-4.0-VoIP-Data
      set dscp ef
      set cos 5
      set qos-group 32
     police cir 128000 bc 8000
       conform-action transmit
       exceed-action set-dscp-transmit cs1
       exceed-action set-cos-transmit 1
    Class AutoQos-4.0-VoIP-Signal
      set dscp cs3
      set cos 3
      set qos-group 16
     police cir 32000 bc 8000
       conform-action transmit
       exceed-action set-dscp-transmit cs1
       exceed-action set-cos-transmit 1
    Class AutoQos-4.0-Multimedia-Conf-Classify
      set dscp af41
      set cos 4
      set qos-group 34
     police cir 5000000 bc 8000
       conform-action transmit
       exceed-action drop
    Class AutoQos-4.0-Signaling-Classify
      set dscp cs3
      set cos 3
      set qos-group 16
     police cir 32000 bc 8000
       conform-action transmit
       exceed-action drop
    Class AutoQos-4.0-Transaction-Classify
      set dscp af21
      set cos 2
      set qos-group 18
     police cir 10000000 bc 8000
       conform-action transmit
       exceed-action set-dscp-transmit cs1
       exceed-action set-cos-transmit 1
    Class AutoQos-4.0-Bulk-Data-Classify
      set dscp af11
      set cos 1
      set qos-group 10
     police cir 10000000 bc 8000
       conform-action transmit
       exceed-action set-dscp-transmit cs1
       exceed-action set-cos-transmit 1
    Class AutoQos-4.0-Scavenger-Classify
      set dscp cs1
      set cos 1
      set qos-group 8
     police cir 10000000 bc 8000
       conform-action transmit
       exceed-action drop
    Class AutoQos-4.0-Default-Classify
      set dscp default
      set cos 0

  Policy Map AutoQos-4.0-Classify-Input-Policy
    Class AutoQos-4.0-Multimedia-Conf-Classify
      set dscp af41
      set cos 4
      set qos-group 34
    Class AutoQos-4.0-Signaling-Classify
      set dscp cs3
      set cos 3
      set qos-group 16
    Class AutoQos-4.0-Transaction-Classify
      set dscp af21
```

```
      set cos 2
      set qos-group 18
    Class AutoQos-4.0-Bulk-Data-Classify
      set dscp af11
      set cos 1
      set qos-group 10
    Class AutoQos-4.0-Scavenger-Classify
      set dscp cs1
      set cos 1
      set qos-group 8
    Class AutoQos-4.0-Default-Classify
      set dscp default
      set cos 0
```

The class maps used for Output matching are as follows:

```
! Since we assigned matched traffic to a qos-group on input,
! we only need to match the qos-group on output

! Note: Any other traffic not matched on input and assigned to a qos-group goes into the
class-default queue

! for control traffic (CS3 and AF31)
class-map match-all AutoQos-VoIP-Control-QosGroup24
  match qos-group 24
class-map match-all AutoQos-VoIP-Control-QosGroup26
  match qos-group 26

! For phone to phone (Bearer EF) traffic
class-map match-all AutoQos-VoIP-Bearer-QosGroup
  match qos-group 46
```

```
! For softphone
Class Map match-any AutoQos-4.0-Scavenger-Queue (id 24)
  Match qos-group 8
  Match   dscp cs1 (8)
Class Map match-all AutoQos-4.0-Priority-Queue (id 3)
  Match qos-group 32
Class Map match-all AutoQos-4.0-Control-Mgmt-Queue (id 28)
  Match qos-group 16
Class Map match-all AutoQos-4.0-Multimedia-Conf-Queue (id 10)
  Match qos-group 34
Class Map match-all AutoQos-4.0-Multimedia-Stream-Queue (id 5)
  Match qos-group 26
Class Map match-all AutoQos-4.0-Trans-Data-Queue (id 30)
  Match qos-group 18
Class Map match-all AutoQos-4.0-Bulk-Data-Queue (id 17)
  Match qos-group 10
```

Note The previous section listing defines the AutoQoS macros for defining QoS guidelines prior to *Solution Reference Network Design 4.0 (SRND4)*. Starting with Cisco Release XE 3.3.0(SG) and 15.1(1)SG, the Catalyst 4500 Series Switch supports the **auto qos srnd4** command.

The following classes are required and generated by all SRND4 CLIs.

```
class-map match-all AutoQos-4.0-Priority-Queue
      match qos-group 32
    class-map match-all AutoQos-4.0-Control-Mgmt-Queue
      match qos-group 16
    class-map match-all AutoQos-4.0-Multimedia-Conf-Queue
      match qos-group 34
    class-map match-all AutoQos-4.0-Multimedia-Stream-Queue
      match qos-group 26
    class-map match-all AutoQos-4.0-Trans-Data-Queue
      match qos-group 18
    class-map match-all AutoQos-4.0-Bulk-Data-Queue
            match qos-group 10
    class-map match-any AutoQos-4.0-Scavenger-Queue
      match qos-group 8
      match dscp cs1
```

The output policy maps are as follows:

```
! Each class maps to a different qos-group with
! class-default taking any traffic not assigned to a qos-group

! Note: in this example, the outbound policy map drops voice packets when the priority
queue exceeds 33% utilization of the link. Each deployment must establish their own upper
bound for voice packets.

policy-map AutoQos-VoIP-Output-Policy
  class AutoQos-VoIP-Bearer-QosGroup
   set dscp ef
   set cos 5
   priority
   police cir percent 33
  class AutoQos-VoIP-Control-QosGroup26
   set dscp af31
   set cos 3
   bandwidth remaining percent 5
  class AutoQos-VoIP-Control-QosGroup24
   set dscp cs3
   set cos 3
   bandwidth remaining percent 5
  class class-default
   dbl
```

Note There are no default cos-to-dscp or dscp-to-cos mappings on the. Values must be explicitly set for trunks.

```
Policy Map AutoQos-4.0-Output-Policy
    Class AutoQos-4.0-Scavenger-Queue
      bandwidth remaining percent 1
    Class AutoQos-4.0-Priority-Queue
      priority
     police cir percent 30 bc 33 ms
       conform-action transmit
       exceed-action drop
    Class AutoQos-4.0-Control-Mgmt-Queue
      bandwidth remaining percent 10
    Class AutoQos-4.0-Multimedia-Conf-Queue
      bandwidth remaining percent 10
    Class AutoQos-4.0-Multimedia-Stream-Queue
      bandwidth remaining percent 10
    Class AutoQos-4.0-Trans-Data-Queue
      bandwidth remaining percent 10
      dbl
    Class AutoQos-4.0-Bulk-Data-Queue
      bandwidth remaining percent 4
      dbl
    Class class-default
      bandwidth remaining percent 25
      dbl
```

The three policy maps are defined as follows:

- policy-map AutoQos-VoIP-Input-Dscp-Policy

  This policy map is applied as an input service policy on an Layer 3 interface (such as an uplink connection to a neighboring switch) when auto-QoS is configured on the port.

- policy-map AutoQos-VoIP-Input-Cos-Policy

  This policy map is applied as an input service policy on an Layer 2 interface that could be either an uplink connection or a port hooked to a Cisco IP Phone.

- policy-map AutoQos-VoIP-Output-Policy

  This policy map is applied as an output policy for any port on which auto-QoS is configured, establishing policy governing egress traffic on the port based on whether it is voice data or control traffic.

The purpose of the input policy maps is to identify voice data or control traffic and mark it as such as it traverses the switch. The output policy map matches the packets on the marking occurring on ingress and then applies egress parameters such as bandwidth, policing and/or priority queuing.

For switch-to-switch connections, the **[no] auto qos voip trust** command is used to apply an input and output service policy on the interface:

```
service-policy input AutoQos-VoIP-Input-Cos-Policy
```

OR

```
service-policy input AutoQos-VoIP-Input-Dscp-Policy
```

AND

```
service-policy output AutoQos-VoIP-Output-Policy
```

The selection of the input policy depends on whether the port is Layer 2 or Layer 3. For Layer 2, the policy trusts the Cos setting in the received packets. For Layer 3 ports, it relies on the DSCP value contained in the packets.

For phone connected ports, the **[no] auto qos voice cisco-phone** command is used to apply the following service policy to the port:

```
qos trust device cisco-phone

service-policy input AutoQos-VoIP-Input-Cos-Policy
```

AND

```
service-policy output AutoQos-VoIP-Output-Policy
```

It establishes a trusted boundary that recognizes Cisco IP Phones and trusts the Cos setting of the packets from the phone. If a Cisco IP Phone is not detected, the Cos field is ignored and the packets are not classified as voice traffic. Upon detecting a Cisco phone, the ingress packets are marked based on the Cos value in the packets. This marking is used on egress for proper traffic classification and handling.

Auto qos srnd4—Is generated when any new auto qos command is configured on an interface and migrates from legacy CLIs to generate new configurations. This CLI only generates a global configuration if during migration, one or more interfaces has legacy auto-QoS enabled

Auto qos video—Generates QoS configuration for untrusted interfaces. It incorporates a service-policy to classify the traffic coming from untrusted desktops/devices and marks them accordingly.

Auto qos void cisco-softphone—Generate QoS configuration for interfaces connected to PCs running the Cisco IP SoftPhone application and marks as police traffic stemming from such interfaces. Ports configured with this CLI are considered untrusted.

Auto qos classify—Generates QoS configuration for untrusted interfaces. It applies a service-policy to classify the traffic stemming from untrusted desktops or devices and marks them accordingly. The service-policies generated do not police.