

# Quality of Service (QoS) in the Campus

**Presented by:  
Dr. Peter J. Welcher**



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## About the Speaker

- **Dr. Pete Welcher**
  - Cisco CCIE #1773, CCSI #94014, CCIP
  - Network design & management consulting
    - Stock quotation firm, 3000 routers, TCP/IP
    - Second stock quotation firm, 2000 routers, UDP broadcasts
    - Hotel chain, 1000 routers, SNA
    - Government agency, 1500 routers
  - Teach many of the Cisco courses
- **Enterprise Networking Magazine articles**
  - <http://www.netcraftsmen.net/welcher/papers>



## Objectives

Upon completion of this seminar, you will be able to:

- Explain why we need QoS in a Campus switched network
- Describe the various Cisco switch QoS capabilities
- Configure QoS features in a Cisco 6500 model switch
- Configure QoS features in a Cisco 4000 model switch (Sup II or Sup III)
- Explain key aspects of switch-based QoS techniques for VoIP and Video



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## Topics

- **Why QoS for the Campus?**
- QoS, CoS, and Trust Boundary
- Cisco Switch QoS Capabilities
- Configuring QoS: Cisco 6500 switch, CatOS
- Configuring QoS: Cisco 6500 switch, Native IOS
- Configuring QoS: Cisco 4000 switch
- Switch-Based QoS for VoIP and Video



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## Why QoS in the Campus?

- **Bursts can fill up queues**
- **Going from high-speed to low-speed media**
- **Or aggregation of traffic upstream**
  - Result: VoIP and other “delicate” traffic can get dropped
  - QoS and prioritization can protect the VoIP or Video traffic
  - Also, do what you can to minimize latency



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## Campus QoS is Different

- **Campus QoS is about managing transmit buffers in switches**
  - Not as much about bandwidth
  - Use multiple queues to prevent transmit queue congestion and resulting [drops](#)
  - Keep low latency and low jitter



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## Design Assumptions

- **Assumption: solid modern redundant switched network design**
- **QoS for the Campus requires:**
  - L2/L3 hierarchy with redundancy
  - Small, predictable Spanning Tree
  - Rapid convergence features
    - Port host mode
    - EtherChannel
    - Uplink fast
    - Backbone fast

## Topics

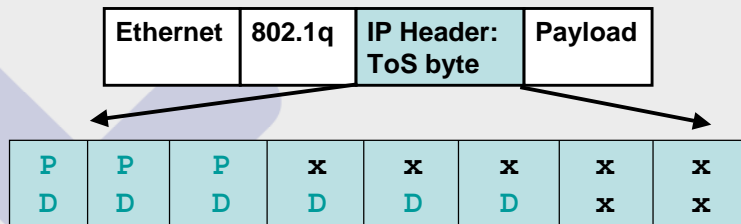
- **Why QoS for the Campus?**
- **QoS, CoS, and Trust Boundary**
- **Cisco Switch QoS Capabilities**
- **Configuring QoS: Cisco 6500 switch**
- **Configuring QoS: Cisco 6500 switch, Native IOS**
- **Configuring QoS: Cisco 4000 switch**
- **Switch-Based QoS for VoIP and Video**

## Layer 2 Marking

- **CoS refers to 3 bits of marking available in ISL and 802.1q/p frames**
  - Requires trunking headers at L2
  - No way to mark ordinary L2 Ethernet frames
- **Terminology:**
  - Packet = L3 PDU
  - Frame = L2 PDU

<b>Ethernet Header:</b> 802.1q type code	<b>802.1q header:</b> VLAN, <u>3 CoS bits</u> , original type code	<b>IP Header:</b> ToS byte	<b>Payload</b>
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## Layer 3 Marking



- **IP header ToS byte used for IP marking**
- **IP Precedence: 3 bits, 0-7**
  - 6 & 7 reserved for system use
- **Diff Serv: 6 bits, 0-63**
  - Backwards compatible

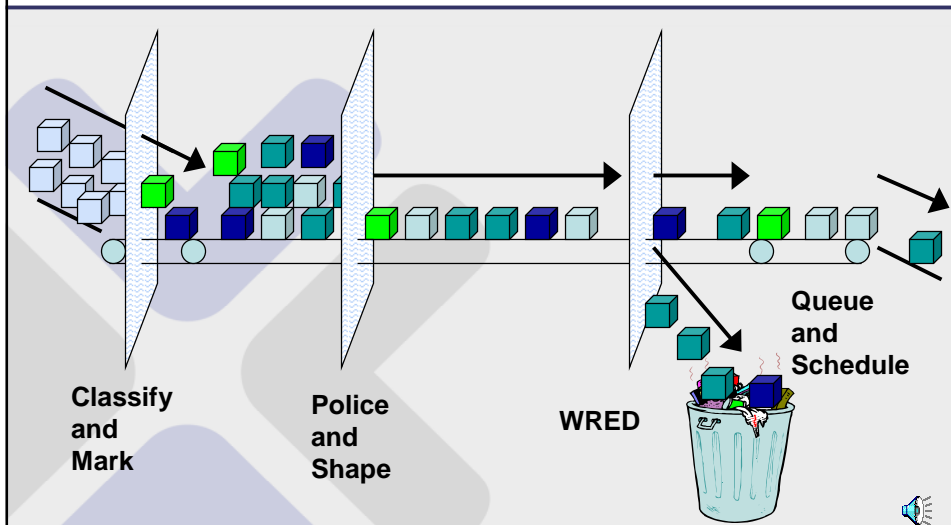
# IP Precedence and DiffServ

Precedence	DiffServ	DSCP	
7	111xxxxx	Class Selector 7	CS7 111000xx 56
6	110xxxxx	Class Selector 6	CS6 110000xx 48
		Expedited Forwarding	EF 101110xx 46
5	101xxxxx	Class Selector 5	CS5 101000xx 40
		Assured Forwarding 4	AF4 100dd0xx 34,36,38
4	100xxxxx	Class Selector 4	CS4 100000xx 32
		Assured Forwarding 3	AF3 011dd0xx 26,28,30
3	011xxxxx	Class Selector 3	CS3 011000xx 24
		Assured Forwarding 2	AF2 010dd0xx 18,20,22
2	010xxxxx	Class Selector 2	CS2 010000xx 16
		Assured Forwarding 1	AF1 001dd0xx 10,12,14
1	001xxxxx	Class Selector 1	CS1 001000xx 8
0	000xxxxx	Best Effort	BE 000000xx 0



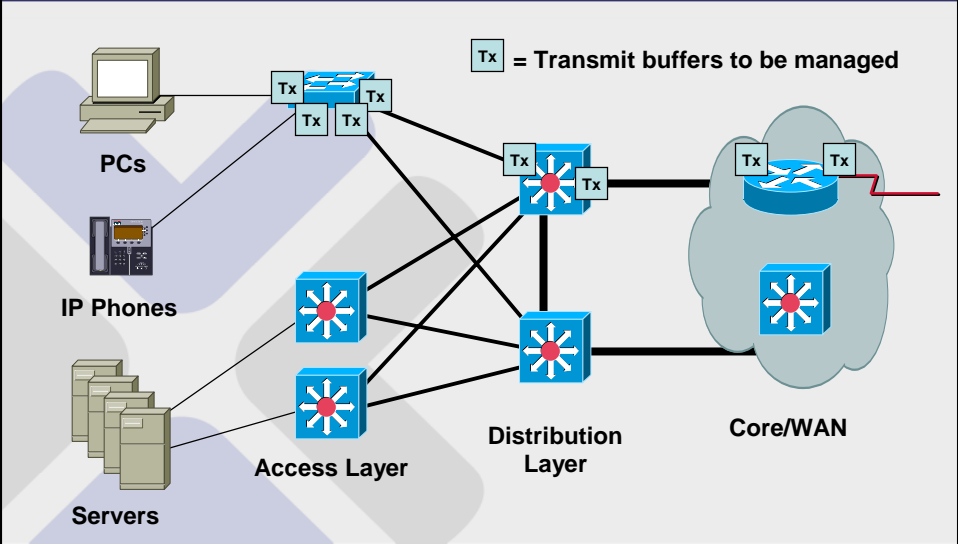
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# The Operations of QoS



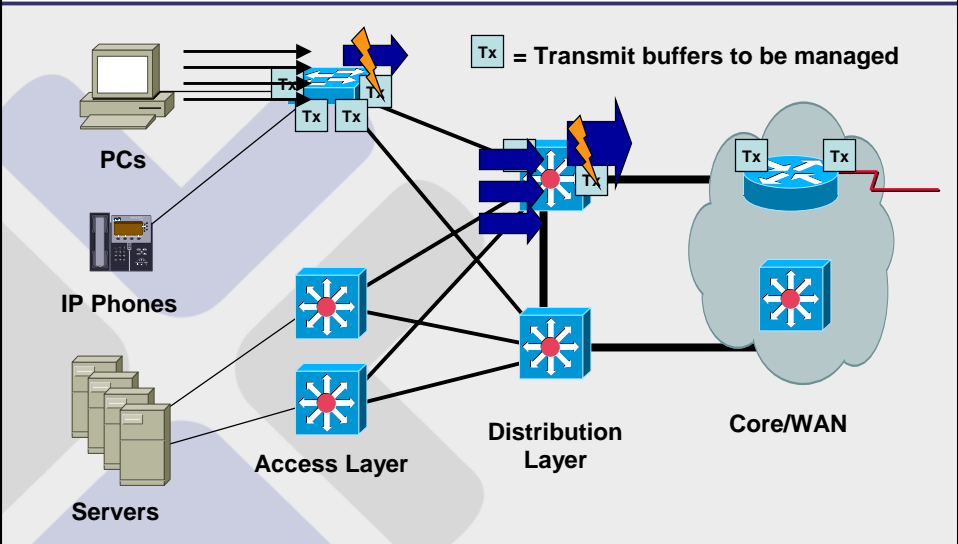
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# QoS in a Campus



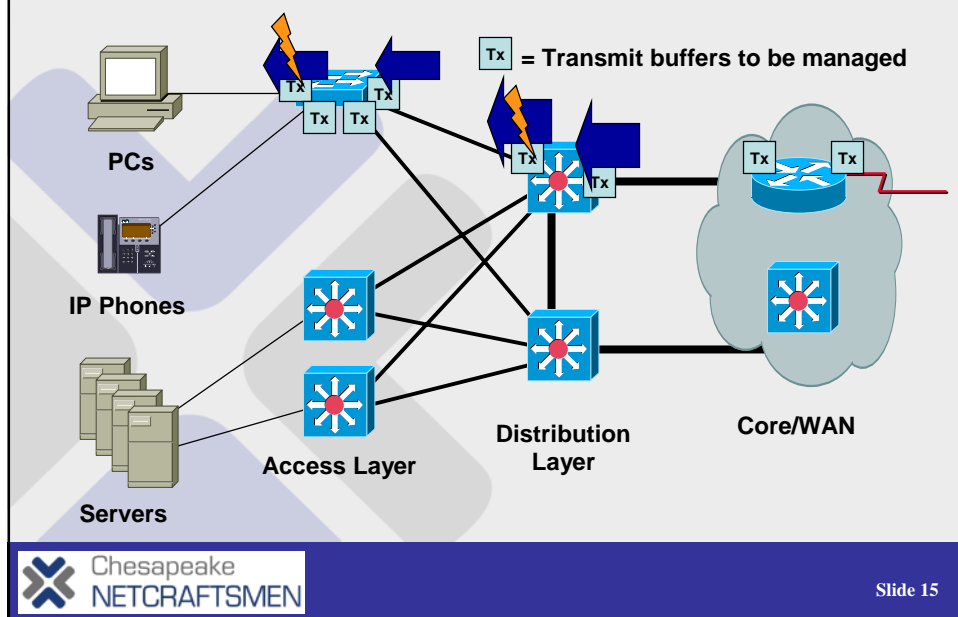
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# QoS in a Campus -- Aggregation

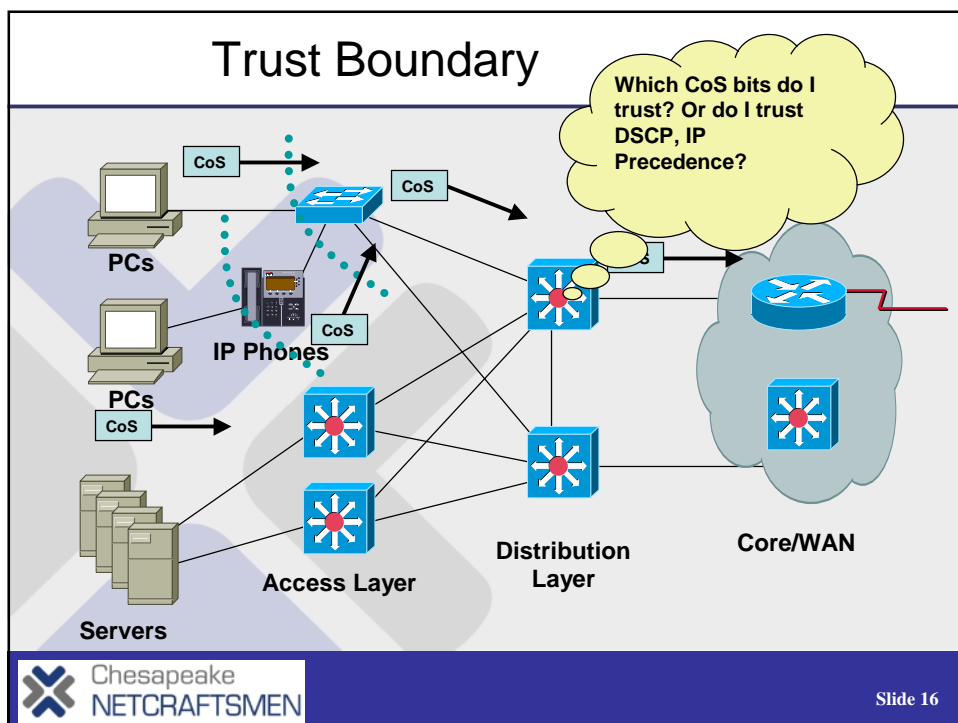


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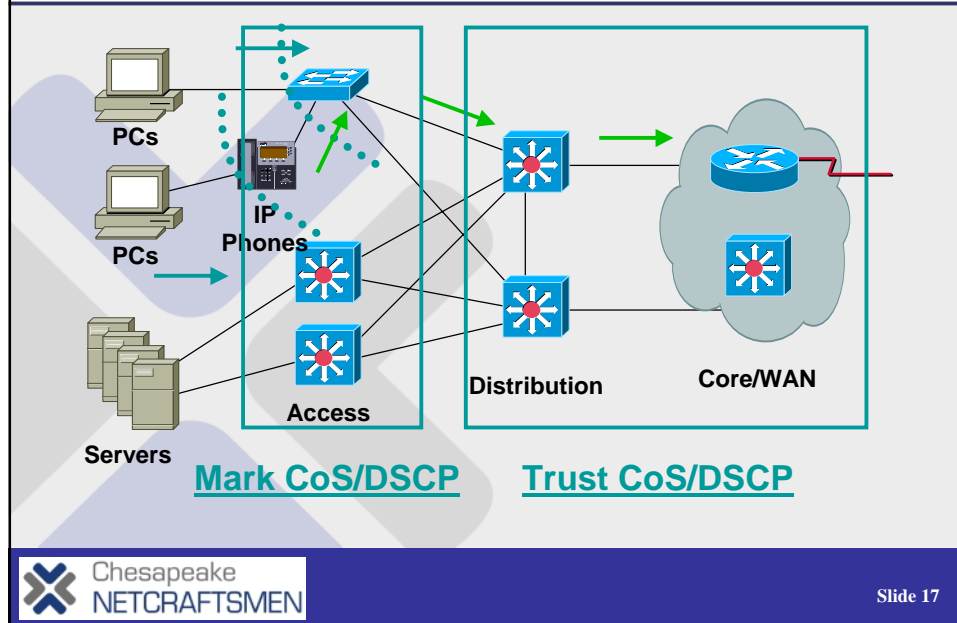
## QoS in a Campus – High to Low Speed



## Trust Boundary



## Mark at the Edge, Trust Elsewhere

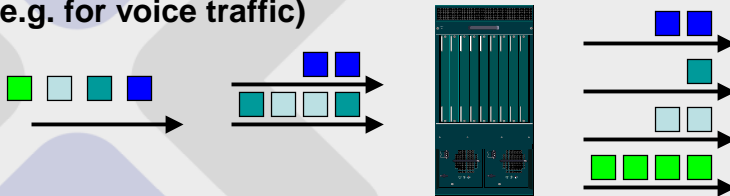


## Topics

- Why QoS for the Campus?
- QoS, CoS, and Trust Boundary
- Cisco Switch QoS Capabilities
- Configuring QoS: Cisco 6500 switch
- Configuring QoS: Cisco 6500 switch, Native IOS
- Configuring QoS: Cisco 4000 switch
- Switch-Based QoS for VoIP and Video

## Queues in the Catalyst Series

- The various switch models and line cards have different numbers of input and output queues
- Input queues are useful for intelligent drop strategies when there is switching delay (rare in Cisco gear)
  - Cisco intelligence in dropping requires trusting received CoS
- Output queues are useful for scheduling: giving more service to higher priority traffic, or for priority queues (e.g. for voice traffic)



## Queues Available Depend on Line Card / Hardware

- `show port capabilities`

Access Switch Model	Queues Available
2900, 3500	2Q1T
3550	1P3Q2T, 4Q2T
4000 (Sup II)	2Q1T
4000 (Sup III)	1P3Q2T
6500	2Q2T Tx, 1Q4T Rx (10/100 classic) 1P2Q2T Tx, 1P1Q4T Rx (gig classic)

\* This is not intended as a complete list of all queue types/line cards that may be available

## Queues Available Depend on Line Card / Hardware

Distribution/Core Switch Model	Queues Available
4000 (Sup III)	1P3Q2T
6500	2Q2T Tx, 1Q4T Rx (10/100 classic) 1P2Q2T Tx, 1P1Q4T Rx (gig classic) 1P3Q1T Tx, 1P1Q Rx (10/100 fabric) 1P2Q1T Tx, 1P1Q8T Rx (gig fabric)

\* This is not intended as a complete list of all queue types/line cards that may be available



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## QoS in Cat 3500, 2900 XL

Feature	What's Available
Queues	2 transmit queues (2Q1T)
Queue mapping	CoS mapped: 0-3 to low queue, 4-7 to high queue, not configurable
Scheduling	Priority scheduling on queues
Trust	CoS trusted
Classification	None
Marking	Port can mark CoS on unmarked traffic
Mapping	None
Notes	Stacked switches may present QoS issues



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## QoS in Catalyst 2950

Feature	What's Available
Queues	4
Queue mapping	CoS maps to 4 queues: 0-1, 2-3, 4-5, 6-7
Scheduling	Strict priority or Weighted Round Robin (WRR). Priority scheduling on by default.
Trust	Trust DSCP or CoS
Classification	802.1p, DSCP (limited: 13), or ACL (limited)
Marking	Can mark or over-ride DSCP or CoS by port
Mapping	Can map CoS to/from DSCP

## QoS for Catalyst 3550

Feature	What's Available
Queues	1P3Q2T or 4Q2T: 4 transmit queues
Queue mapping	CoS maps to 4 queues: 0-1, 2-3, 4-5, 6-7 Need to assign CoS 5 to priority queue.
Scheduling	Strict priority or Weighted Round Robin (WRR). Need to configure 4 <sup>th</sup> queue for priority.
Trust	Trust DSCP or CoS
Classification	802.1p, DSCP, or ACL
Marking	Can mark or over-ride DSCP or CoS by port
Mapping	Can map CoS to/from DSCP

## QoS for Catalyst 4000, Sup II

Feature	What's Available
Queues	2Q1T: 2 queues
Queue mapping	Must map CoS to queues or else all queue 1, values mapped in pairs. Need to assign CoS 5 to priority queue.
Scheduling	Round robin
Trust	CoS-based, all ports trusted
Classification	
Marking	Can mark unmarked traffic with CoS
Mapping	

## QoS for Catalyst 4000, Sup III

Feature	What's Available
Queues	1P3Q2T or 4Q2T: 4 transmit queues
Queue mapping	CoS maps to 4 queues: 0-1, 2-3, 4-5, 6-7
Scheduling	Need to configure priority queuing for queue 3 to make sure CoS 5 is serviced. Strict priority or Weighted Round Robin (WRR).
Trust	Trust DSCP or CoS
Classification	802.1p, DSCP, or ACL
Marking	Can mark or over-ride DSCP or CoS by port
Mapping	Can map CoS to/from DSCP
Notes	Be careful not to over-subscribe cards, also 32 Gbps max

## QoS for Catalyst 4000 or 4500, Sup IV

Feature	What's Available
Queues	1P3Q2T or 4Q2T: 4 transmit queues
Queue mapping	Assign to queues based on CoS
Scheduling	Configurable queue thresholds, WRR weights
Trust	Trust CoS, IP Precedence, or DSCP 10/100 cards need ACL configured to trust traffic
Classification	802.1p, DSCP, or ACL
Marking	Can mark or over-ride DSCP or CoS by port
Mapping	Can map CoS to/from DSCP
Notes	Cisco IOS-based QoS. Adds DBL, Dynamic Buffer Limiting, to Sup III.

## QoS for Catalyst 6500, PFC

Feature	What's Available
Queues	1P3Q2T or 4Q2T: 4 transmit queues
Queue mapping	Assign to queues based on CoS
Scheduling	Configurable queue thresholds, WRR weights
Trust	Trust CoS, IP Precedence, or DSCP 10/100 cards need ACL configured to trust traffic
Classification	802.1p, DSCP, or ACL
Marking	Can mark or over-ride DSCP or CoS by port
Mapping	Can map CoS to/from DSCP
Notes	1p2q2t, 1p3q1t, and 1p2q1t ports have (WRED)-drop thresholds in transmit queues. 1p1q8t has WRED-drop thresholds in receive queue.

## QoS for Catalyst 6500, PFC2

Feature	What's Available
Queues	1P3Q2T or 4Q2T: 4 transmit queues
Queue mapping	Assign to queues based on CoS
Scheduling	Configurable queue thresholds, WRR weights
Trust	Trust CoS, IP Precedence, or DSCP 10/100 cards need ACL configured to trust traffic
Classification	802.1p, DSCP, or ACL
Marking	Can mark or over-ride DSCP or CoS by port
Mapping	Can map CoS to/from DSCP
Notes	Cisco IOS-based QoS. Can push QoS to a DFC (Distributed Forwarding Card). Policing allows excess rate (two threshold policing).

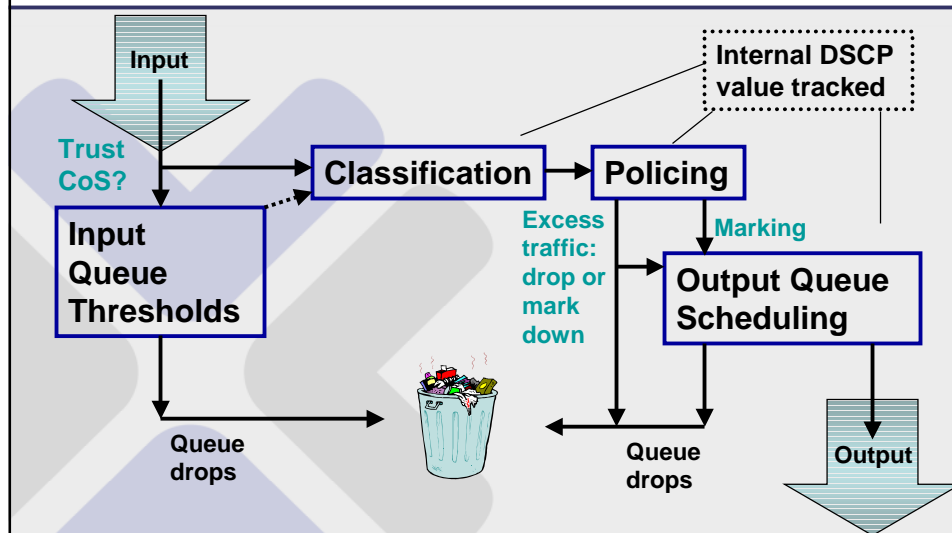
## Topics

- Why QoS for the Campus?
- QoS, CoS, and Trust Boundary
- Cisco Switch QoS Capabilities
- **Configuring QoS: Cisco 6500 switch**
- Configuring QoS: Cisco 6500 switch, Native IOS
- Configuring QoS: Cisco 4000 switch
- Switch-Based QoS for VoIP and Video

## Thinking About 6500-Based QoS

- “Hardware” or PFC-based QoS is being done by switching hardware, using PFC or PFC2 for Layer 3 classification and rewrites
- “Software QoS” is done in MSFC or MSFC2 – router IOS-based QoS
- Layer 3 switched traffic uses hardware QoS
- Hardware QoS is therefore very relevant for most traffic passing through the switch

## QoS in Cat 6500 with PFC



## QoS in 6500, No PFC

- **With only a Layer 2 Switching Engine, QoS can classify traffic using:**
  - Layer 2 destination MAC addresses
  - VLANs
  - Marking using Layer 2 CoS values
- **Cannot use or set Layer 3 IP precedence or DSCP values**

## Cat6: Ingress Marking and Queuing

- **Port untrusted?**
  - If so, **apply port CoS**, hand off to PFC (skip congestion avoidance)
- **Port trusts IP Prec? Or DSCP?**
  - Hand off to PFC (bypassing congestion avoidance)
  - Trusting DSCP gives access to inbound DSCP value
- **Port set to trust CoS!**
  - If frame is ISL or 802.1q, use CoS to apply drop threshold to frame, hand off survivors to PFC
  - If no CoS (ordinary frame), CoS = port value

## Cat6: PFC / Layer 3 Processing

- Internal DSCP value used, carried along with the frame
- If trusted, DSCP, IP Prec, or CoS mapped to internal DSCP field, handed off to Policer
- ACL can be used to classify untrusted traffic
- Trust and ACL's can be per-port or per-VLAN
  - Per-VLAN for trunk ports



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## Cat6: Policer

- **Policer output is frame + internal DSCP value, mapped back to CoS before handoff to egress interface**
  - Policer may drop excess traffic, or may mark down the internal DSCP value
  - 63 microflow policers, 1023 aggregate policers, can combine them
- **Aggregate: named or per-interface**
  - Example: all web traffic
- **Micro: source/destination MAC**
  - Example: one web flow



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## Cat6: Egress Marking and Queuing

- **PFC hands off to output queues**
- **For traffic via MSFC, CoS will be zero**
  - MSFC2: CoS = IP Precedence
  - L3 switched traffic bypasses the MSFC
    - Multi-layer switched, with exceptions
  - But WAN traffic is received by PFC with CoS=0
  - Sup III uses CEF: should have MLS entry without going via MSFC
  - MSFC2 routed traffic has CoS set on outgoing trunk ports
- **Output queues depend on hardware card capabilities**
  - IP traffic from PFC has ToS written into IP header
  - If outgoing port is trunking, CoS set in header
  - Frame is transmitted

## Map Tables

- **CoS and IP Precedence have 8 possible values**
- **DSCP has 64 possible values**
- **On ingress, CoS or IP Precedence maps to DSCP using a map table**
- **On egress, DSCP maps to CoS using a map table**

```
set qos cos-dscp-map 0 8 16 26 32 46 48 56
set qos ipprec-dscp-map 0 8 16 26 32 46 48 56
set qos dscp-cos-map 0-7: 0 8-15: 1
```

## Port Capabilities

- **show port capabilities**

- **Receive:**

- 1q4t
- 1p1q4t
- Etc.

- **Transmit**

- 2q2t
- 1p2q2t
- Etc.

CoS	Rx, 1Q, In Threshold	Tx, 2Q, Out Threshold
0-1	50%	80%
2-3	60%	100%
4-5 *	80%	80%
6-7	100%	100%

\* Priority queue, if present, moves CoS 5 into a separate queue

## Sample Access 6500 Configuration

- **Note: VLAN 110 is the aux VLAN for the IP phones.**

```
c6k> (enable) set qos enable
c6k> (enable) set port qos 5/1-48 vlan-based
c6k> (enable) set port qos 5/1-48 trust-ext untrusted
c6k> (enable) set port qos 5/1-48 trust trust-cos
c6k> (enable) set qos acl ip ACL-IP-PHONES trust-cos any
c6k> (enable) commit qos acl ACL-IP-PHONES
c6k> (enable) set qos acl map ACL-IP-PHONES 110
```

## Sample Distribution 6500

```
c6k> (enable) set qos enable
c6k> (enable) set qos map 1p2q2t tx queue 2 1 cos 3
c6k> (enable) set qos map 2q2t tx queue 2 1 cos 3
c6k> (enable) set port qos 1/1 port-based
c6k> (enable) set port qos 1/1 trust trust-dscp
```

Note: CoS 3 is the VoIP control traffic. VoIP (CoS = 5) is automatically put into the priority queue (1P2Q2T) or queue 2 (2Q2T).

Note2: Port 1/1 is a Layer 3 switch, so we trust DSCP. If the access switch is Layer 2, then trust CoS, VLAN-based.



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## Sample 6500 ACL for VoIP Control Traffic

- Skinny uses TCP 2000-2002
- H.323 uses TCP 1720, 11000-11999
- MGCP uses UDP 2427

```
c6k> (enable) set qos acl IP VOIPCTL dscp 26 tcp any any
range 2000 2002
c6k> (enable) set qos acl IP VOIPCTL dscp 26 tcp any any
eq 1720
c6k> (enable) set qos acl IP VOIPCTL dscp 26 tcp any any
range 11000 11999
c6k> (enable) set qos acl IP VOIPCTL dscp 26 udp any any
eq 2427
c6k> (enable) set qos acl IP VOIPCTL trust-cos any
c6k> (enable) commit qos acl IP VOIPCTL
```



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## Topics

- Why QoS for the Campus?
- QoS, CoS, and Trust Boundary
- Cisco Switch QoS Capabilities
- Configuring QoS: Cisco 6500 switch
- **Configuring QoS: Cisco 6500 switch, Native IOS**
- Configuring QoS: Cisco 4000 switch
- Switch-Based QoS for VoIP and Video

## 6500, Port Capabilities

- Native IOS uses slightly different syntax to check port capabilities:

```
show queuing interface <interface-name>  
| include type
```

## Viewing DSCP Mapping Information

```
Router# show mls qos map | begin Dscp-cos map
Dscp-cos map: (dscp= d1d2)
d1 : d2 0 1 2 3 4 5 6 7 8 9
-----
0 : 00 00 00 00 00 00 00 00 00 01
1 : 01 01 01 01 01 01 00 02 02 02
2 : 02 02 02 02 00 03 03 03 03 03
3 : 03 03 00 04 04 04 04 04 04 04
4 : 00 05 05 05 05 05 05 05 00 06
5 : 06 06 06 06 00 06 07 07 07 07
6 : 07 07 07 07
...
```



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## Configuring QoS on PFC2 (IOS)

- **Use MQC / CBWFQ with some restrictions and changes**
- **Class maps:**
  - Can match L3 Precedence and DSCP values
  - Can match IOS ACL's (IP, IPX, MAC)
  - Single match command only!
- **Policy maps**
  - Can use **trust** commands for classes: `trust [ cos | dscp | ip-precedence ]`
  - Classes can use aggregate or microflow policers
  - Bandwidth, priority, queue-limit, random-detect, set not supported for **hardware** switched traffic
- **You will not be informed of erroneous use of unsupported keywords until policy map is attached to an interface**



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## Hardware Marking

- **For now, use a policy-map class-specific police command to do marking**
  - Distribution and Core switches probably trust cos or dscp anyway
  - It is preferable be trusting where possible since inbound congestion avoidance can then occur
  - But edge switches that can classify and mark required for this approach

## 6500, Native IOS QoS Policing

- **How to create a named aggregate policer and apply it within a policy map:**

```
mls qos aggregate-policer my-aggr-1 1000000 5000000
conform-action transmit
exceed-action policed-dscp-transmit

policy-map SwitchPolicy1
class xyz
  police aggregate my-aggr-1
```

## 6500, Native IOS QoS Policing – 2

- **Policed dscp marks down DSCP values for excess traffic**
  - Map table used to configure this, default is no markdown
- **Example of using an anonymous aggregate policer within a policy map:**

```
policy-map SwitchPolicy1
  class xyz
    police flow 1000000 100000 conform-action transmit
    exceed-action policed-dscp
!
mls qos map policed-dscp normal-burst 1 2 3 4 to 0
```

## 6500, Native IOS QoS Policing – 3

- **How to create a per-flow (microflow) policer and apply it within a policy map:**

```
policy-map SwitchPolicy1
  class xyz
    police flow 1000000 100000 conform-action transmit
    exceed-action policed-dscp
```

Use "flow" to do  
microflow policing

## Policer Rules – 1

- **Aggregate policing works independently on DFC modules and the PFC2**
  - Separate aggregates on each
  - PFC2 aggregates traffic for all non-DFC modules
- **Microflow policers by default only affects MSFC2 routed traffic**
  - Configure `mls qos bridged` to change this
- **To avoid inconsistency, make sure all traffic policed by the same aggregate policer has the same trust state**



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## Policer Rules – 2

- **If traffic is both aggregate and microflow policed, both must be in the same policy-map class, and both must use the same conform-action keyword**
- **Conform-action keywords:**
  - Drop
  - Set-dscp-transmit \* (IP traffic only)
  - Set-prec-transmit \* (IP traffic only)
  - Transmit



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## Policer Rules – 3

- **Exceed-action and violate-action keywords:**
  - Drop
  - Policed-dscp \* (IP traffic only)
  - Transmit

## Policer Rules – 4

- **Granularity of CIR/PIR for policing depends on the rate (32 K and up increments)**
- **There are default token bucket (burst) sizes**
  - Minimum size is 1000 (bytes)
  - To sustain the policed rate, burst size should be at least rate / 4000
  - ( $T_c = 1/4000$  second = 0.25 msec)
  - Set burst size larger than a typical frame, preferably multiple of TCP window size
- **Default conform action is transmit**
- **Default exceed (and violate) action is drop**

## 6500, Sample Native IOS Other Commands

```
mls qos
mls qos map ip-prec-dscp 0 8 16 26 32 46 48 56
mls qos map cos-dscp 0 8 16 26 32 46 48 56
!
int range gig 1/1 - 2 ! Note spaces around '-'
  wrr-queue cos-map 2 1 3
  wrr-queue cos-map 2 2 4
!
int gig 2/1
  mls qos vlan-based
  mls qos trust cos
  mls qos bridged
  switchport trunk encaps dot1q
  switchport mode trunk
```

Receive queue #,  
threshold, cos-values

Use when applying service  
policy to the vlan interface



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## Sample 6500, Native IOS QoS

- Some other options:

```
int gig 2/3
  mls qos
  mls qos flow-policing
  mls qos cos 0
  wrr-queue bandwidth 3 1
```

Enable qos and  
microflow policing  
(both on by default)

Set the port default  
value

Bandwidth ratios for  
queues



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## Topics

- Why QoS for the Campus?
- QoS, CoS, and Trust Boundary
- Cisco Switch QoS Capabilities
- Configuring QoS: Cisco 6500 switch
- Configuring QoS: Cisco 6500 switch, Native IOS
- **Configuring QoS: Cisco 4000 switch**
- Switch-Based QoS for VoIP and Video

## Sample Catalyst 4000 Sup II Configuration

```
c4k> (enable) set qos enable
c4k> (enable) set qos map 2q1t 1 1 cos 0-1
c4k> (enable) set qos map 2q1t 2 1 cos 2-3
c4k> (enable) set qos map 2q1t 2 1 cos 4-5
c4k> (enable) set qos map 2q1t 2 1 cos 6-7
```

## Cat 4000, Sup III QoS

- **Use MQC / CBWFQ similarly to 6500**
  - Same Class-map and Policy-map restrictions
- **Omit “mls” from some commands**
  - qos
  - qos vlan-based
  - qos cos *value*, qos dscp *value*
  - qos map dscp *policed list* to *value*
- **Can configure transmit bandwidth rate and shaping per queue on some interfaces**
- **QoS mapping syntax is a little different (see below)**



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## Sample Catalyst 4000 Sup III Configuration

```
qos map cos 1 to dscp 8
qos map cos 2 to dscp 16
qos map dscp 26 to tx-queue 2
qos
!
! MQC / CBWFQ configuration ...
interface gig 1/1
  qos trust cos
  service-policy in MyPolicy1
  tx-queue 3
  priority high ! Make queue 3 a Priority Queue
```



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## Sample Catalyst 4000 Sup III Configuration – 2

```
interface gig 1/1
  tx-queue 3
  bandwidth rate 1000000
  shape 1000000
```

## Topics

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- Configuring QoS: Cisco 6500 switch
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## VoIP Traffic and Packet Drops

- **Lost packets = voice clipping and skips**
- **Current DSP algorithms can correct 30 ms of lost voice**
- **VoIP uses 20 ms of voice payload per VoIP packet**
- **Can only afford to lose a single VoIP RTP packet before voice degrades**

## Queues and VoIP

- **Use a separate queue for VoIP to prevent drops**
- **Delay should not be a factor**
- **Separate voice and video**
- **Disable Flow Control**
  - Off by default
  - Not smart about which queue is full
- **Do not use WRED on the VoIP and video queues**
  - Don't want packets getting randomly dropped

## Queues

- **Don't try to put every class of traffic into separate queues**
  - Resulting default queue may be very small
- **Do mark control, signaling, management traffic as important**
  - And put it into a separate queue, if available

## VoIP AUX VLAN

- **Can use an auxiliary VLAN for VoIP traffic**
- **Mark PC traffic as CoS 0, VoIP as CoS 5**
  - Or trust Layer 3 ToS (IP Precedence or DSCP)
  - [Do you trust L2, L3 from your PC's?](#)
- **If you want to do Layer 3 re-marking at the edge switch, having AUX VLAN and unique VoIP addresses really helps!**

## Summary

You should now be able to:

- Explain why we need QoS in a Campus switched network
- Describe the various Cisco switch QoS capabilities
- Configure QoS features in a Cisco 6500 model switch
- Configure QoS features in a Cisco 4000 model switch (Sup II or Sup III)
- Explain key aspects of switch-based QoS for VoIP

## Where to Get More Info

- **CCO links:**
  - <http://www.cisco.com/networkers/nw02/presos/docs/RST-222.pdf>
  - <http://www.cisco.com/networkers/nw02/presos/pws/docs/PS-544.pdf>
  - [http://www.cisco.com/univercd/cc/td/doc/product/voice/ip\\_tele/avvidqos/index.htm](http://www.cisco.com/univercd/cc/td/doc/product/voice/ip_tele/avvidqos/index.htm)
- **For more info (and links), see my CiscoWorld articles**
  - <http://www.netcraftsmen.net/welcher>

## Questions

# Any Questions?



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## A Word From Us ...



- **We can provide**
  - Network design review: how to make what you have work better
  - Periodic strategic advice: what's the next step for your network or staff
  - Network management tools & procedures advice: what's right for you
  - Implementation guidance (your staff does the details) or full implementation
- **We do**
  - Small- and Large-Scale Routing and Switching (design, health check, etc.)
  - IPsec VPN and V3PN (design and implementation)
  - QoS (strategy, design and implementation)
  - IP Telephony (preparedness survey, design, and implementation)
  - Call Manager deployment
  - Security
  - Network Management (design, installation, tuning, tech transfer, etc.)



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## Cisco Certifications

**Chesapeake Netcraftsmen**  
**is certified by Cisco in:**



- IP Telephony
- Network Management
- Wireless
- Security
- (Routing and Switching)



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