

Quality of Service (QoS) Seminar

Presented by:
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Slide 1

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

- **Provide a taxonomy of services applying to QoS**
- **Get some idea of how to think about QoS and how it works**
- **Show how to configure several aspects of QoS using Modular QoS CLI / Class-Based Weighted Fair Queuing**
- **Quick Looks at:**
 - Managing QoS
 - QoS for Voice
 - QoS for the Campus

Topics

- **The QoS Landscape**
- **Configuring QoS**
- **Managing QoS**
- **QoS for Voice**
- **QoS in the Campus**

Why QoS?

- **Because...**
 - Some traffic needs low latency to work well
 - Service Provider customers might pay more for better service
 - Network traffic is not all equally worthwhile
 - WAN bandwidth isn't free (yet)
- **Think of QoS as the network traffic policeperson... insuring smooth flow**



QoS and Network Design

- **Putting QoS on top of a broken network design is like putting fancy tires on a rusty car with a low-horsepower engine**
 - It might improve how things look superficially, but no real performance impact
- **Need hierarchical design using L2 and L3 switching appropriate, fast-converging routing, high availability features where appropriate, etc.**



QoS in the Real World #1

- **Low bandwidth link, protect VoIP**
- **QoS can help smooth out peaks to use existing bandwidth better, if the problem is occasional bursting**
- **QoS can help, but it can't solve a vastly overutilized link → sometimes you just need to get more bandwidth**



QoS in the Real World #2

- **“Prophylactic” or “insurance” use of QoS:**
have lots of bandwidth but who knows what traffic will be hitting the network next...
 - Protect fragile voice or video from being impacted by large file transfers, etc.
 - Even in the campus, traffic bursts can fill output queues temporarily, causing dropped packets



QoS Policy

- Often we put “insurance” in place as a quick fix
- Best: think about what policy is needed, what the organizational objectives are
- Also measure what’s on the network to see what’s out there, what’s consuming the bandwidth
- Form policy, implement, measure, iterate

QoS: Why Do It?

- ***What is the overall objective with QoS?***
- Bandwidth is still costly
- Multiple forms of traffic needs to use links
- Different applications have different traffic requirements
 - Voice, video
 - Mission-critical application
 - FTP and bulk transfer
 - Interactive
- Need to make all forms of traffic work well while sharing the link — **co-existence**

Throwing Bandwidth at Problems

- **Adding bandwidth reduces latency**
 - This may not cure application response times, especially for complex relational databases (SAP, PeopleSoft, ...)
- **The problem: ping-pong behavior at Layers 4-7 can limit throughput**
 - Buying bandwidth is a costly way to reduce latency
 - But it does also usually reduce average queue size (next slide)
- **Prioritization can help here!**

Bandwidth Versus Queue Depth

- **For utilization percent u , the average queue depth (in a queuing probability model) is $q = u / (1-u)$**

u	q
50% = $\frac{1}{2}$	$\frac{1}{2} / (1 - \frac{1}{2}) = 1$
75% = $\frac{3}{4}$	$\frac{3}{4} / (1 - \frac{3}{4}) = 3$
95% = $\frac{19}{20}$	$\frac{19}{20} / (1 - \frac{19}{20}) = 19$

QoS for Voice

- **Reduce latency**
- **Use bandwidth well**
- **Get voice packets out fast**
 - Fragmentation and Interleaving
 - Priority for Voice Packets

Latency...
Latency...
Latency...

More later...



QoS for Servers and Applications

- **Local Director**
- **Distributed Director**
- **Network Director**
- **Load Balancing**
- **Web Caching**
- **Reliability...**
- **High Availability Design**



QoS for Dial

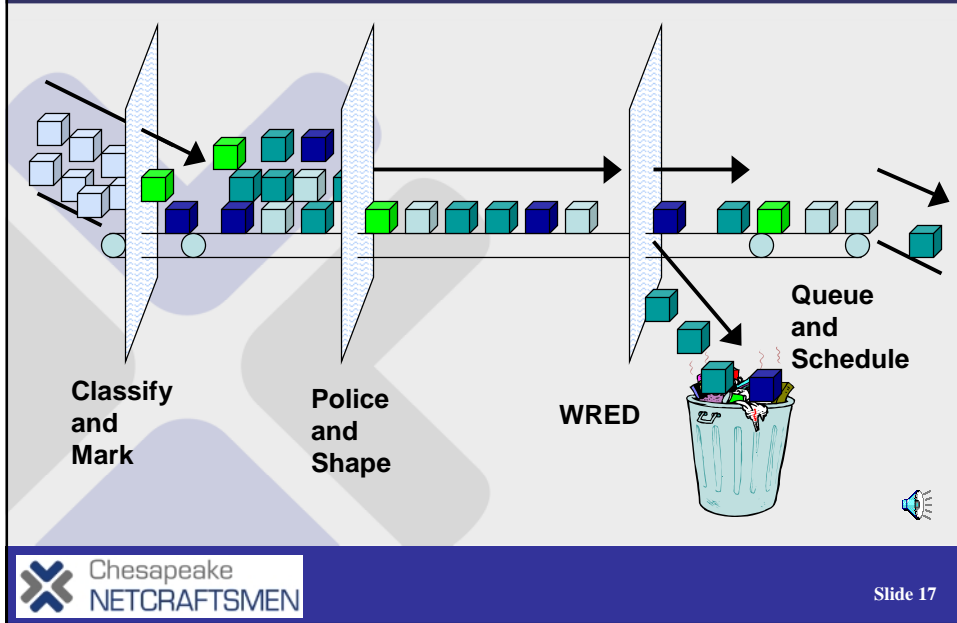
- Modem pools for regular, premium users
- Contention ratios
- IP addressing based on Class of Service (CoS)



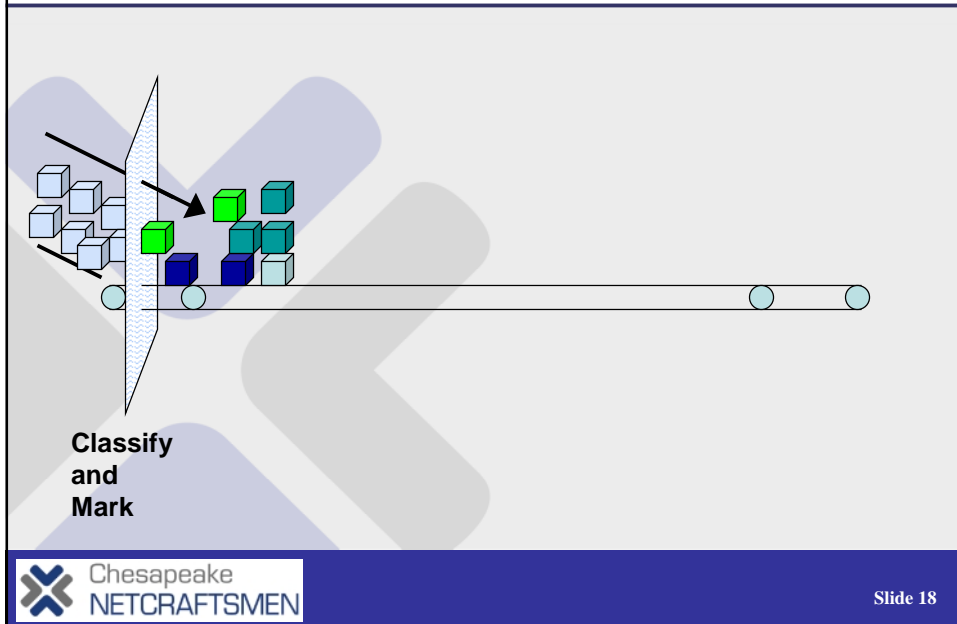
Topics

- The QoS Landscape
- Configuring QoS
- Managing QoS
- QoS for Voice
- QoS in the Campus

The Operations of QoS



Classifying and Marking



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

Ethernet Header: 802.1q type code	802.1q header: VLAN, 3 CoS bits , original type code	IP Header: ToS byte	Payload
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Marking: IP Precedence and Diff-Serv

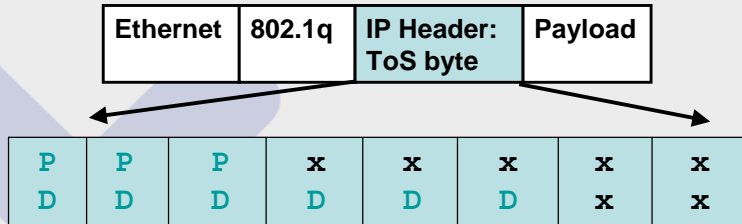
- **IP Precedence marks packets into six classes (2 reserved)**
- **Diff-Serv uses 64 classes (DSCP), retro-compatible**

Number	Name
0	Routine
1	Priority
2	Immediate
3	Flash
4	Flash-override
5	Critical
6	<i>Internet-reserved</i>
7	<i>Network-reserved</i>



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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

Marking — Ways to Set IP Precedence

- Modular CLI Set Commands
- CAR
- Policy Based Routing (PBR)
- QPPB
- RSVP

The Well-Kept Secret of QoS

- **JUST** setting IP Precedence or the DSCP bits *may be enough*
- If WFQ is in place, the weight is based on the marking
- Higher marking gets larger share of bandwidth and gets serviced more often
- *Analogy...*

Configuring QoS — Classes of Service

- **CBWFQ: specify classes of service (and what traffic belongs to each class)**
- **Classification!**

```
Router(config)# class-map missioncritical
Router(config-cmap)# match access-group 101
Router(config-cmap)# exit
Router(config)# class-map voice
Router(config-cmap)# match ip precedence 5
Router(config-cmap)# exit
```

Configuring QoS — Policy

- **CBWFQ: then specify your policy...**

```
Router(config)# policy-map premium_policy
Router(config-pmap)# class voice
Router(config-pmap-c)# priority 56
Router(config-pmap)# class missioncritical
Router(config-pmap-c)# bandwidth 512
Router(config-pmap-c)# queue-limit 64
Router(config-pmap-c)# random-detect
Router(config-pmap)# exit
Router(config-pmap)# class silver
Router(config-pmap-c)# bandwidth percent 30
Router(config-pmap)# exit
Router(config-pmap)# class class-default
Router(config-pmap-c)# fair-queue 10
```

Configuring QoS — Apply the Policy

- **CBWFQ: and apply your policy to interfaces:**

```
Router(config)# interface s1/1
Router(config-if)# service output premium_policy
Router(config-if)# exit
Router(config)# interface s/0/0
Router(config-if)# service output premium_policy
Router(config-if)# exit
```

Classifying with NBAR — Some of the Protocols

Static

- GRE
- ICMP
- IPINIP
- IPSec
- EIGRP
- BGP
- CU-SeeMe
- DHCP/Bootp
- DNS
- Finger
- Gopher
- HTTP
- HTTPS
- IMAP
- IRC
- Kerberos
- L2TP
- LDAP
- MS-PPTP
- MS-SQLServer
- NetBIOS
- NFS
- NNTP
- Lotus Notes
- NTP
- PCAnywhere
- POP3
- PPTP
- RIP
- RSVP
- SFTP
- SHTTP
- SIMAP

- SIRC
- SLDAP
- SNNTP
- SMTP
- SNMP
- SOCKS
- SPOP3
- SSH
- STELNET
- Syslog
- Telnet
- X Windows

Via Stateful Inspection

- FTP
- MS Exchange
- HTTP (URL and MIME)
- Netshow
- Realaudio
- UNIX r-commands
- Oracle SQL*NET
- SunRPC
- TFTP
- StreamWorks
- VDOLive

```
Router(config)# class-map
gold
Router(config-cmap)# match
protocol XWindows
```

Configuring QoS — Using NBAR

- **Classification using Layer 7 protocol names, Web URL's or MIME types, etc.**

```
Router(config)# class-map email
Router(config-cmap)# match protocol pop3
Router(config)# class-map newsfeeds
Router(config-cmap)# match protocol http url "news*"
Router(config)# class-map noisystuff
Router(config-cmap)# match protocol citrix
Router(config-cmap)# exit
```

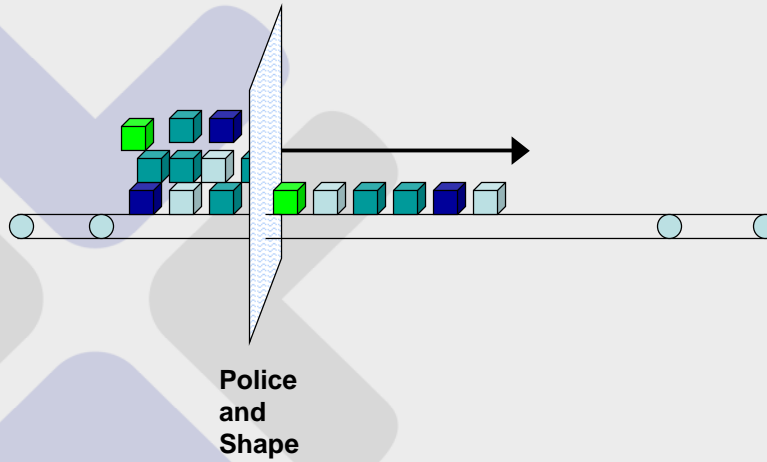
NBAR Protocol Discovery

- **Let the router do the work...**

```
Router(config)# interface ethernet 0/0
Router(config-if)# ip nbar protocol-discovery
Router(config-if)# end

Router# show ip nbar protocol-discovery [interface
interface-spec] [stats {byte-count | bit-rate | packet-
count}] [{protocol protocol-name | top-n number}]
```

Policing and Shaping



Policing Methods

- **CAR (inbound, outbound)**
- **CBWFQ Policing (outbound)**



Configuring QoS — Policing

- Specify where to police (and direction)
- Specify policing bps, burst-normal, burst-max, etc.

```
Router(config)# class-map police
Router(config-cmap)# match input interface e0/0

Router(config)# policy-map inputlan
Router(config-pmap)# class police
Router(config-pmap-c)# police 81000 2000 2504 conform-
action transmit exceed-action set-qos-transmit 4
```

Configuring QoS — CAR

- Mark and police, all in one...

```
interface S0
description 128Kbps to R2
rate-limit input access-group 101 128000 8000 16000
conform-action set-prec-transmit 5
exceed-action set-prec-transmit 3
rate-limit input access-group 102 64000 8000 16000
conform-action set-prec-transmit 3
exceed-action set-prec-transmit 1
ip address 200.200.14.250 255.255.255.252
!
access-list 101 permit tcp any any eq www
access-list 102 permit tcp any any eq ftp
```

CAR and Policer Actions

- **Transmit**
- **Drop**
- **Set precedence and transmit**
- **CBWFQ policing only:**
 - Set DSCP or QoS-group and transmit
- **CAR only:**
 - Set precedence and continue
 - Continue
 - To next CAR statement in list

Traffic Shaping Methods

- **Generic Traffic Shaping (GTS)**
- **FR Traffic Shaping**
- **CBWFQ Shaping**

Configuring CBWFQ Traffic Shaping

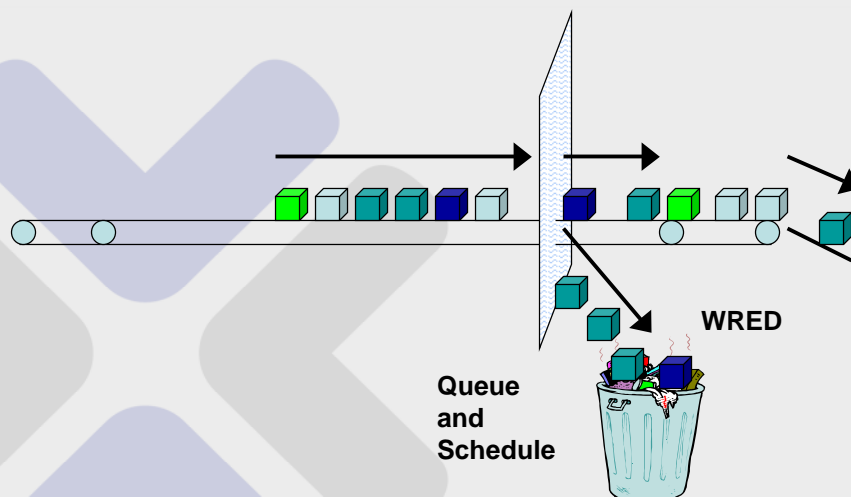
- **Shape to average or peak, rate, burst size, excess burst size**

```
router(config)# class-map onsizefitsall
router(config-cmap)# match any
router(config-cmap)# exit

router(config)# policy-map dts-doit
router(config-pmap)# class onsizefitsall
router(config-pmap-c)# shape average 10000000
router(config-pmap-c)# exit

router(config)# interface pos1/0/0
router(config-if)# service-policy output dts-doit
```

Queuing, Scheduling, and Packet Dropping



Queuing Techniques – Historical

- **FIFO**
- **Priority Queueing (PQ)**
- **Custom Queueing (CQ)**
- **Weighted Fair Queueing (WFQ)**



Queuing Techniques – Modern

- **Class-Based Weighted Fair Queueing (CBWFQ)**
 - dWFQ, FdWFQ (Flow dWFQ), ToS-WFQ
- **Weighted Round Robin (WRR)**
 - 8500, perhaps other high-speed hardware
- **Modified Deficit Round Robin (MDRR)**
 - 12000 GSR
- ***Weights determine frequency of queue servicing (WFQ, CBWFQ) or ratio of queue servicing (WRR, MDRR)***

Packet Scheduling: Prioritization

- **PQ-WFQ (Priority Queuing for WFQ)**
 - First attempt
- **LLQ (Priority Queuing for CBWFQ)**
 - Final cut
- **Use these to prioritize voice or video**
 - VoIP
 - IPVC
 - IPTV

Packet Dropping Techniques

- **Tail Drop**
- **Weighted Random Early Detection (WRED)**
 - Distributed:
dWRED
 - FBWRED (Flow-
Based WRED)



Topics

- The QoS Landscape
- Configuring QoS
- **Managing QoS**
- QoS for Voice
- QoS in the Campus

Managing QoS: Products

- Cisco **QoS Policy Manager (QPM)**
- Cisco **QoS Device Manager (QDM)**
- Cisco **Internetwork Performance Manager (IPM)**
- Cisco **Service Management Solution (SMS)**
 - Service Level Manager (SLM) and Collection Managers
- **Cisco Partner Products**
 - Concord
 - InfoVista
 - Others
 - See also http://www.cisco.com/pcgi-bin/ecoa/Search?choose_category=EMBU&the_examples=Select%20All&the_examples_1=Select%20All

QPM

- **Cisco QoS Policy Manager (QPM)**
 - Graphical interface (GUI) for configuring QoS across many of the Cisco routers and switches
 - Manages QoS across the network
 - Sends configurations out to devices
- **QPM 2.0 includes and can use a multi-vendor standard — COPS (Common Open Policy Server) Protocol**
- *Will be used in our demos today*

QDM

- **Cisco QoS Device Manager (QDM)**
 - FREE!
 - Download from CCO, put into flash on 7200, 2600, 3600
 - Point your browser, configure or monitor (graph) QoS on that one device
 - *“Training wheels for QoS”*
- [See also PDM, which manages PIX configuration similarly]

SAA

- **Cisco Service Assurance Agent (SAA)**
 - Former Response Time Reporter (RTR) with extensions
 - SAA sends simulated traffic and measures round-trip times, and frame loss rates
 - Single packets or now scripted transaction sequences (as of 12.2(2)T)
 - Bounce traffic off real host or another router
 - *You already have it: included in every post-12.0 IOS image!*
 - No need to buy and maintain separate Windows/Linux boxes and software to do this
 - SAA can send SNMP traps if the round-trip time exceeds a threshold (single time, repeatedly, or other variants)

SAA: What It Can Measure

- **SAA can send and measure round-trip times or server response times using:**
 - SNA PU/LU echo, or SSCP-RU echo, DLSw+
 - ICMP path echo
 - TCP or UDP to a port
 - Simulated VoIP, repeated measurements w/ jitter
 - DNS or DHCP
 - HTTP Get of a URL
 - FTP

SAA in 12.2(2)T Adds...

- **Scripted transaction round-trip times for:**
 - Frame Relay
 - IP/TV
 - LDAP
 - Lotus Notes “send email”
 - NNTP
 - Arbitrary Ascii/Binary/Hex pattern
 - POP3 email retrieval
 - SAP (several activities)
 - SMTP send email emulation



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IPM

- **Cisco [Internetwork Performance Manager \(IPM\)](#)**
 - Comes bundled with CW2000 RWAN bundle
 - You may already have it and just haven't looked at it
 - Configures the SAA feature in multiple routers (using SNMP sets)
 - Doesn't set up the scripted SAA monitoring, yet
 - Collects historical or real-time SAA round-trip time data and graphs it
 - Multiple samples from multiple routers collected
 - View one at a time
 - Good ad hoc reporting and troubleshooting tool, fine for small to intermediate networks



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SMS/SLM

- **Cisco Service Management Solution (SMS)**
 - Service Level Manager (SLM) and Collection Managers
 - “Industrial strength” configuration, data collection, reporting of SAA data
 - Can supplement the SMS/SLM reporting with Concord or InfoVista if their reports add enough value to be worth the money to you

Other Tools

- **Routers/Layer 3 Switches**
 - NetFlow
 - Reports and aggregates on ToS byte
 - RMON Thresholds
- **Catalyst 5xxx, 6xxx Switches**
 - Mini-RMON for utilization reporting
 - TopN
- **Catalyst 6xxx Switches**
 - QoS export feature
 - Track traffic volumes for various IP Precedence or DSCP values: bytes, packets

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- Configuring QoS
- Managing QoS
- QoS for Voice
- QoS in the Campus

QoS for Voice

- Reduce latency
- Low bandwidth: use it efficiently
- Get voice packets out first!
- *Call Admission Control*

Latency...
Latency...
Latency...



Latency

- **The voice courses or Networkers presentation go into latency budget**
- **Need good network design**
 - Too many hops can be a show-stopper!
- **Sources of delay**
 - Codec
 - [Queuing](#)
 - [Wait for packet being transmitted](#)
 - [Serialization](#)
 - Jitter buffer
 - Other
- **Can also consider [signaling](#) delay**

Using Low Bandwidth Efficiently

- **Compressed RTP**
 - IP + UDP + RTP header = 40 bytes
 - Payload is typically 20 bytes
 - Much overhead!
 - cRTP reduces that to 2-4 bytes by assigning each connection an ID
 - cRTP sends the connection ID + changing bits
 - Use 1/3 to 1/2 the bandwidth! (E.g. 8K vs 24K)
- **Consider CPU impact, use with <T1 speed links**

Using Low Bandwidth Efficiently

- **Fragmentation and Interleaving**
 - FRF.12 for Frame-Relay links
 - ATM -- not applicable
 - MLPPP/LFI for PPP links
 - MTU size reduction (avoid if possible)
- **Fragment large data frames, slip voice frames ahead of remaining fragments for large frame under transmission**

Get VoIP Out First

- **Priority for VoIP Packets**
 - PQ-WFQ
 - `ip rtp priority` command
 - LLQ (PQ-CBWFQ)
 - `CBWFQ / MQC priority` command

Priority for VoIP — LLQ

```
Router(config)# policy-map premium_policy
Router(config-pmap)# class voice
Router(config-pmap-c)# priority 128
Router(config-pmap)# exit
```

```
Router(config)# policy-map premium_policy
Router(config-pmap)# class voice
Router(config-pmap-c)# priority percent 25
Router(config-pmap)# exit
```



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Local Call Admission Control Techniques

- **Local CAC techniques**
 - Physical DS0 count
 - Max-connections
 - Configure per dial peer, works well in some topologies
 - Voice-bandwidth for FR
 - Trunk conditioning (busy or OOS)
 - Keepalives detect connection trunk failures
 - Triggers busy or out-of-service to PBX
 - LVBO, Local Busy-Out Monitor
 - Busyout when specified interfaces down
 - Force ports or trunks into busyout state



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Measurement or Resource-Based CAC Techniques

- **Measurement-based CAC techniques**
 - AVBO (based on SAA, busy out whole trunk)
 - PSTN fallback (based on SAA, per call)
- **Resource-based CAC techniques**
 - Resource Availability Indicator (RAI)
 - At call-terminating gateway
 - DS0 and DSP availability
 - Gatekeeper Zone Bandwidth
 - Also useful with H.323 video
 - RSVP (with H.323)
 - Guarantees QoS for call duration (vs. at time of call)

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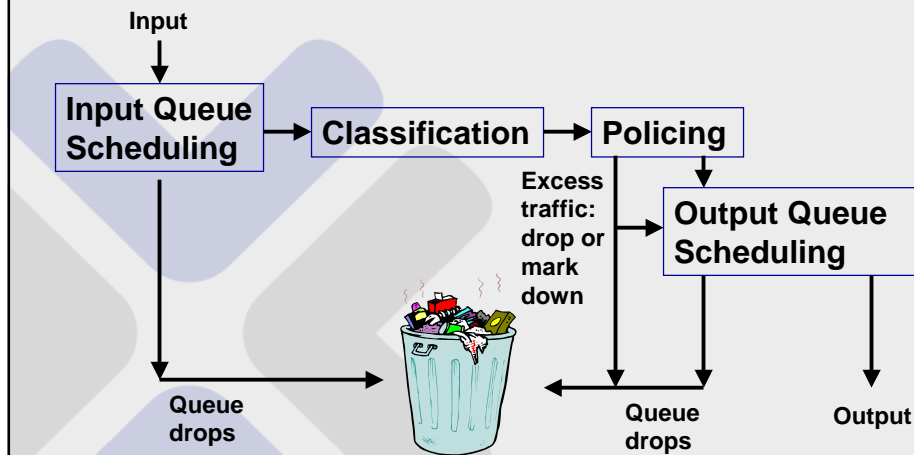
Why QoS in the Campus?

- **Bursts can fill up queues as you go from high-speed to low-speed media**
 - Result: VoIP and other “delicate” traffic can get dropped
 - QoS and prioritization can protect the VoIP or video traffic
 - Also, lets you do what you can to minimize latency

Terminology

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

QoS in Cat 6xxx



Cat6: Input Marking and Queuing

- **Port untrusted?**
 - If so, apply port CoS, hand off to PFC (skip congestion avoidance)
- **ISL or 802.1q?**
 - If NOT, apply port CoS and continue
- **Port trusts IP Prec? Or DSCP?**
 - Hand off to PFC (bypassing congestion avoidance)
- **Port set to trust CoS!**
 - Use CoS to queue/threshold 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 field, handed off to Policer**
 - ACL can be used for untrusted traffic
- **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

Cat6: Egress Marking and Queuing

- **PFC hands off to output queues**
- **For traffic via MSFC, CoS will be zero**
 - L3 switched traffic bypasses the MSFC
 - WAN traffic received by PFC with CoS=0
- **Output queues**
 - These depend on hardware card
 - IP traffic from PFC has ToS written into IP header
 - Any ISL or 802.1q output has CoS set
 - Frame is transmitted

Port Capabilities

- show port capabilities

- **Receive:**

- 1q4t
- 1p1q4t
- Etc.

- **Transmit**

- 2q2t
- 1p2q2t
- Etc.

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

* Priority queue, if present, pulls 5 into a separate queue

Sample Configuration

- **Basic QoS**

```
set qos enable
set port qos 1/1 trust trust-cos
```

- ACL to classify frames

```
set port qos 3/1-48 port-based
set port qos 3/1-48 trust untrusted
```

```
!
```

```
set qos acl ip voipacl dscp 40 ip any any
set qos acl map voipacl 3/1-48
```

Other Info

- **Policers can be**
 - Aggregate
 - Named or per-interface
 - Microflow
 - Source MAC, destination MAC aggregated into microflow
- **Interfaces can be either**
 - VLAN-based QoS
 - Port-based QoS

Summary

- **We examined many of the QoS tools**
- **We saw how to configure some aspects of QoS**
- **We discussed how to manage QoS**
- **We looked at some of the issues involved in QoS for Voice**
- **Happy QoS'ing!**

Where to Get More Info

- **Cisco CCIP certification track DQOS course**
- **Cisco Service Provider IQOS course**
- **For more info (and links), see my CiscoWorld articles**
 - <http://www.netcraftsmen.net/welcher>

Questions

Any Questions?

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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