Quality of Service for Voice Over IP (QoS for VoIP)

Presented by:

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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

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Objectives

- **Upon completion of this seminar, you should be able to:**
  - Explain the need for QoS for VoIP
  - Describe factors affecting network voice quality
  - Explain some ways QoS can improve the quality of VoIP in a network

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Topics

- **Why QoS for Voice?**
- **QoS Review**
- **Techniques for QoS for VoIP**
- **A Little Call Admission Control**

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Network Convergence

- **Run data, voice, video, new applications over the same networks**
  - High availability network
  - New strategic applications for mixed media
- **Reduced costs**
  - One infrastructure to maintain
  - Aggregated bandwidth is (much) cheaper
  - PBX and trunking costs
  - Old + new skills to manage VoIP

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Where Does QoS Fit In?

- **QoS protects VoIP on shared media**
  - The culprit: bursty data applications
  - Lose 2 VoIP packets and get lower quality VoIP
- **QoS can prioritize VoIP**
  - VoIP is sensitive to delay and jitter (fluctuations in delay)
  - Prioritization minimizes those effects

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Topics

- **Why QoS for Voice?**
- **QoS Review**
- **Techniques for QoS for VoIP**
- **A Little Call Admission Control**

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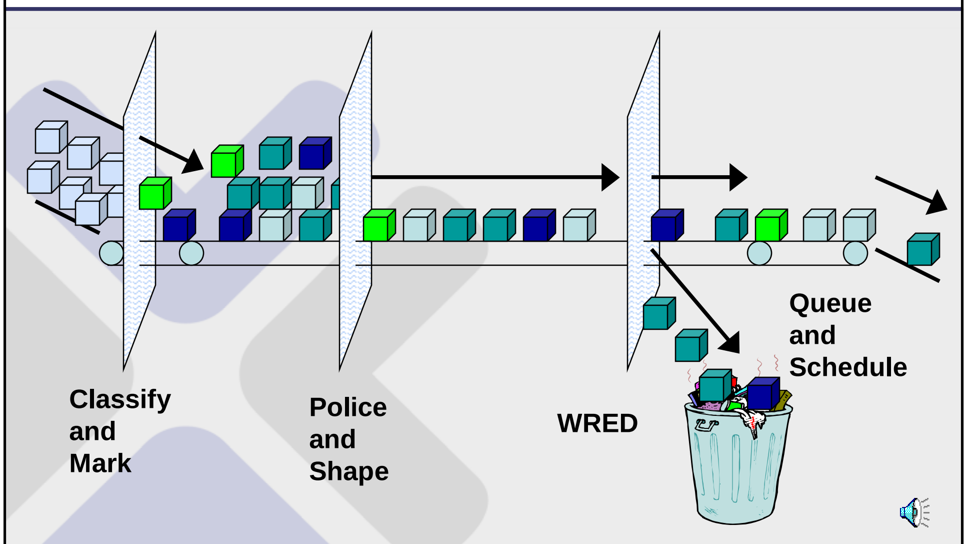
The Operations of QoS



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What Can QoS do for VoIP?

- **Classify and mark**
  - Identify and set Layer 2 or 3 header bits to mark classes of traffic and indicate desired treatment to downstream devices
- **Just setting the IP Precedence or DSCP bits (coming slide) can provide preferential treatment for a class of traffic**
  - When used with WFQ or CBWFQ
  - WFQ is on by default on E1 or slower serial links

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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	*Internet-reserved*
7	*Network-reserved*

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Layer 3 Marking

Ethernet	802.1q	IP Header: ToS byte	Payload

P	P	P	x	x	x	x	x
D	D	D	D	D	D	x	x

- **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

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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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What Can QoS do for VoIP?

- **Police and shape**
  - Control bursts of excess traffic and bandwidth used by high bandwidth applications
  - Business high-bandwidth applications:
    - Network server backups
    - Business Video on Demand (VoD)
  - Non-business high-bandwidth applications:
    - Napster, Kazaa, Gnutella
    - Non-business Video on Demand (news, ads, web sites, etc.)

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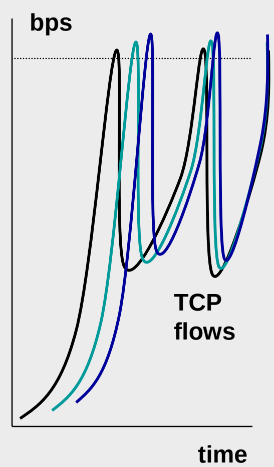
What Can QoS do for VoIP?

- **Congestion Avoidance**
  - Weighted Random Early Detection (“WRED”)
  - When queue average depth over time rises, start dropping less important packets to preserve queue space (bandwidth) for more important packets
  - Slow down TCP flows to prevent “group slowdown”



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What Can QoS do for VoIP?

- **Queue and schedule**
  - Prioritization gets VoIP or IP Video Conferencing (IPVC) out of the router first
  - Intelligent queuing and scheduling with Class-Based Weighted Fair Queuing deliver a mix of policy techniques
  - Co-existence for all the applications running on shared media

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What Can QoS do for VoIP?

- **RSVP**
  - Bandwidth reservation for Call Admission Control
    - See later slides
  - Each RSVP flow of traffic is automatically assigned a weight to guarantee bandwidth with WFQ or CBWFQ
  - Currently there is no bandwidth enforcement (limitation) mechanism tied to RSVP

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CBWFQ / MQC

- **The preferred technique for configuring QoS has become Modular QoS CLI (MQC), also called Class-Based Weighted Fair Queuing (CBWFQ)**
- **There are 3 steps to configure this**
  – Define your classes of traffic (classify)
  – Define your policies using those classes
  – Apply to one or more interfaces (in, out)

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CBWFQ / MQC Example

```
class-map match-any voice
  match ip dscp EF
policy-map SlowLink
  class voice
    priority 120
  class tunes
    police 8000 conform-action drop
        exceed-action drop
interface serial 0
  service-policy output SlowLink
```

1: Define classes

2: Define policies

3: Apply

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Topics

- **Why QoS for Voice?**
- **QoS Review**
- **Techniques for QoS for VoIP**
- **A Little Call Admission Control**

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Step 1 Towards QoS

- **Good stable hierarchical WAN and hierarchical campus network**
  - Too many WAN hops can lead to high latency
- **Redundant, high-availability design**
- **Protocols configured for quick failover**
- **Some network management in place**
  - Some bandwidth reporting and capacity planning
  - Reporting and resolution of outages
- ***If the network is down, that's REALLY bad QoS!***

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Expectations and QoS

- **QoS can do good things, but it can't do the impossible**
  – QoS can help protect critical traffic on occasionally congested links
  – QoS is not a cure for really inadequate bandwidth
  – VoIP needs its fair share of bandwidth too

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QoS, VoIP, and Speeds

- **64-256 Kbps**
  – Rather low bandwidth, need to do as much as we can to optimize QoS
- **T1 speed and above**
  – Don't need to protect against some of the low-speed issues
  – Can't use some of the tools: CPU impact
- **Higher speeds**
  – Use QoS as insurance, protect VoIP

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Overview of How QoS Helps Voice

- **Reduce latency**
- **Get voice packets out first!**
  - Prioritize voice traffic
  - Prioritize voice on the campus network too
- **Use low bandwidth efficiently**
- **Avoid VoIP packet loss**
- **Don't forget your signaling traffic…**
  - Slow signaling = slow call completion
- ***Call Admission Control***

Latency…

Latency…

Latency…

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QoS for VoIP Techniques

- **Slow links**
  - Use bandwidth wisely: cRTP
  - Reduce latency: LFI
- **All links**
  - Prioritize voice: PQ-WFQ or LLQ

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Adding Bandwidth

- **Adding bandwidth reduces serialization delay**
- **Adding bandwidth usually reduces queue size, hence reduces queuing delay**
  – Unless link is badly oversubscribed
- **Adding bandwidth costs money**
  – Especially when you do it across a lot of leased line, FR, or ATM sites

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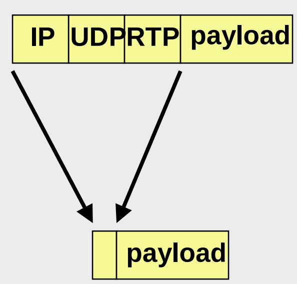
Use Low Bandwidth Efficiently: CRTP

- **Compressed RTP**
  – IP + UDP + RTP header = 40 bytes
  – Payload is typically 20 bytes
  – 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**
  – Should be OK up to 1/2 Mbps or so



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cRTP -- 2

```
ip rtp header-compression
```

- **Interface command**
- **cRTP is faster in newer Cisco IOS code:**
  - Version 12.1 and later: fast-switched or CEF-switched
    - **Beware CPU impact in prior releases**
    - **Depends on what else the CPU is doing**

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CRTP on Frame Relay

- **Usually configured with on the physical interface**
- **Can be configured for selected PVC's only as part of a frame-relay map command**

```
frame-relay ip rtp header-compress [passive]
```

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Latency

- **The voice courses or Networkers presentations go into latency budget at length**
- **The main causes of delay are:**
  - Codec
  - **Queuing ***
  - **Wait for packet being transmitted ***
  - **Serialization ***
  - Jitter buffer
  - Other
  - * = the causes of delay that we can do something about
- **Can also consider signaling delay**
  - Time to initiate ring, time after phone answered to complete call

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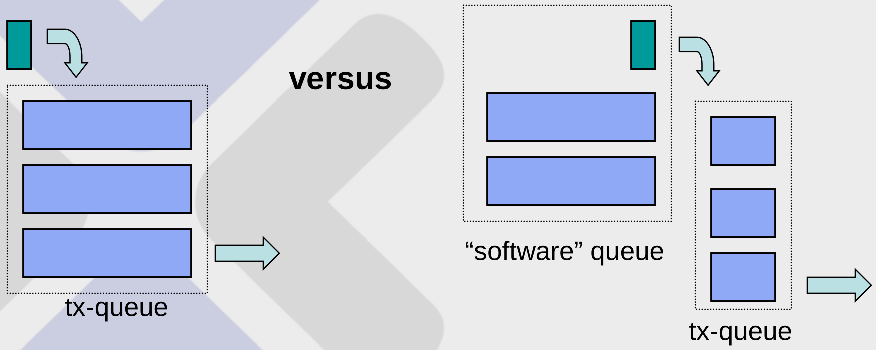
Link Fragmentation and Interleaving

- **Fragment large data frames, slip voice frames ahead of queued packets for large frame under transmission**



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Link Fragmentation and Interleaving

- **Ways to do Fragmentation and Interleaving:**
  - FRF.12 for Frame-Relay links, VoIPoFR & VoFR
  - VoFR: use FRF.11, esp. if speed very low
  - MLPPP/LFI for PPP links
  - ATM -- not applicable (generally higher speed)
    - Can use PPP over ATM if desired
    - E.g. FR to ATM service interworking
  - MTU size reduction
    - Avoid if at all possible, may make congestion worse due to retransmissions

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Link Fragmentation and Interleaving -- 2

- **Useful up to ½ T1 to T1 speed**
  - CPU impact
  - Not really needed above that speed
- **Do use the same fragment size on both ends of the link**

Link Speed	# Bytes in 10 msec
56 K	**70**
64 K	**80**
128 K	**160**
256	**320**
512	**640**
768	**960**

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LFI: ML-PPP

- **Create multilink virtual interface**
- **Configure ML-PPP LFI:**

```
interface multilink 1
  ip address …
  ppp multilink
  ppp multilink fragment-delay 20
  ppp multilink interleave
```

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LFI with FRF.12

- **Newer versions of this also prioritize VoIPoFR as well as VoFR traffic**
  - You must however set the fragment size bigger than the VoIP packet size

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Configuring FRTS FRF.12

```
interface serial 0
encapsulation frame-relay
ip address …
frame-relay traffic-shaping
class FrameRules

map-class frame-relay FrameRules
frame-relay cir 128000
frame-relay mincir 128000
frame-relay bc 2000
frame-relay fragment 160
frame-relay fair-queue
```

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FR or ATM Tip

- **If you can buy prioritized service for Voice from your Service Provider, consider dual PVC's**
  - One for voice, one for data
  - This can be especially effective when data bandwidth is low, e.g. 56-256 Kbps or so
- **Get a good SLA (if you can)**
- **Be careful, with some providers this doesn't buy you much**

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QoS on FR

- **Some of the features like cRTP and LFI may require configuring FRTS on subinterfaces**
- **Modular QoS CLI / CBWFQ is configured:**
  - On the FRTS pseudo-interface (class map) in earlier Cisco IOS versions
  - On the FR subinterface in newer versions

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Using Bandwidth Efficiently

- **Other considerations:**
  - Consider using a high-compression codec
  - Consider VAD
    - Off by default (for a reason)
  - Control echo
  - Observe resulting voice quality
- **Personally observed in lab: an 8 Kbps codec gave mediocre voice quality, but it took a sincere effort to congest the 56K link before it got worse!**
- **Trade-offs!**

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Get VoIP Out of the Router Fast

- **Priority for VoIP Packets**
- **PQ-WFQ**
  – Prioritizes specified range of UDP ports, RTP packets
  – `ip rtp priority` command
- **Low Latency Queuing: LLQ**
  – Also called PQ-CBWFQ
  – CBWFQ / MQC `priority` command
  – More flexible prioritization

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RTP Priority vs. LLQ

- **LLQ is the recommended technique going forward**
  – Works well, flexible, powerful
- **LLQ does police (drop) excess traffic to prevent starvation of lower priority queues**
  – You do need to track how much VoIP you have in your network and manage traffic levels

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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
```


Signaling Traffic

- **H.323, SIP, MGCP**
- **Used for call setup (busy, ring, handset pickup and call completion)**
- **User perception of quality may be affected if call setup is slow**
- **Consider setting signaling traffic to IP Precedence level 3 or DSCP AF31**

Classifying Signaling Traffic

Protocol	Transport &Ports
Skinny (Cisco phone to Call Manager)	**TCP 2000-2002**
H.323	**TCP 1720, 11xxx**
MGCP	**UDP 2427, 2428**
SIP	**UDP 5060**

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Jitter

- **LFI should reduce jitter on slow links**
- **Can use Traffic Shaping on bursty classes of traffic**
- **LLQ or prioritization may reduce the impact of data traffic bursts**
  - VoIP traffic gets sent ahead of the data
  - But: queuing in the FR or other WAN network?

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ATM VC-Bundles

- Requires PA-A3 on 7200/7500 with right processor, OC-3 or IMA not AIP on 2600/3600
- Can create bundle of VC's with one address
- Can map precedence levels to VC's in bundle
- If one VC in bundle fails, can automatically shift its traffic to another ("bumping")
- Per-VC WFQ, CBWFQ, LLQ support
- See also http://www.cisco.com/en/US/partner/products/sw/iosswrel/ps1835/products_configuration_guide_chapter09186a00800bd9ea.html

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Topics

- Why QoS for Voice?
- QoS Review
- Techniques for QoS for VoIP
- A Little Call Admission Control

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What is Call Admission Control?

- **Call Admission Control denies additional calls when a resource (bandwidth) runs out**
- **“Protect voice from voice”**
  - If there is too much voice, LLQ will drop packets from all conversations
  - Better to force excess calls through PSTN
- **This applies, only more so, with IPVC**

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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 tunks 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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RSVP

- **In general, application traffic receivers can reserve bandwidth along the path back to the server, using RSVP**
- **Routers allocate bandwidth from pool upon request, or signal an error**
- **RSVP gives a scalable topology-and application-independent way to administer and reserve bandwidth**

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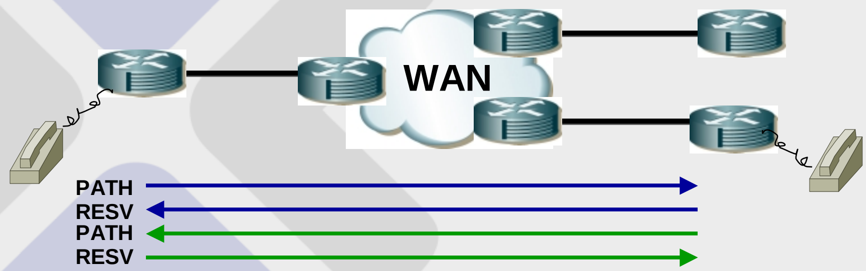
RSVP

- **Cisco H.323 v1 and v2 gateway call setup is now synchronized with RSVP (Call Manager is not)**
  - Call will fail unless RSVP reservation succeeds
  - The RSVP reservation guarantees the requested bandwidth, using weights to work with the WFQ and CBWFQ schedulers



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IP Video-Conferencing

- **IP Video-Conferencing (VC):**
  - Current Best Practice is to set Video Conferencing traffic to IP Precedence 4 (DSCP AF41)
  - Set signaling and control traffic to precedence 3 (DSCP AF31)
  - You don’t want a burst of video disrupting voice at Precedence level 5 (DSCP EF).
    - Can do LLQ for IPVC
    - Can do CBWFQ “bandwidth” command instead
    - I personally don’t want to mix voice and video in priority queues
  - Strongly consider H.323 gatekeeper, RSVP, and CAC

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Streaming Video

- **Streaming video is more tolerant of delay and jitter**
  – Delay is evened out by the jitter buffer
  – Non-interactive so 1-5 seconds delay not a real problem
- **Send streaming video as AF13 traffic**
  – Medium priority application grade traffic
  – High drop priority when there's congestion

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Campus Switches and VoIP

- **Prioritize VoIP in switches**
  – The 6500 line cards have been adding more hardware queues as they evolve
  – The newer ones tend to have a hardware priority queue
- **Why QoS? Have lots of bandwidth…**
  – Still need to protect VoIP from tail drops when traffic burst occurs

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VoIP and Special Access Media

- **Cable, DSL, Wireless LAN QoS …**
  – Need media-specific access link support for QoS
  – DOCSIS for cable
  – New Cisco WAP's
- **See Networkers 2002 presentations for details**
  – There's lots of details
- **The main point: apply the above techniques where available**

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Summary

In this talk we have

- **Reviewed QoS basics and CBWFQ**
- **Talked about cRTP, LFI**
- **Seen how to configure LLQ**
- **Discussed markings for VoIP, Signaling, IPVC, and streaming video**

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Where to Get More Info

- **Cisco DQOS or IQOS courses**
- **Cisco Telephony QoS Design Guide**
  - http://www.cisco.com/univercd/cc/td/doc/product/voice/ip_tele/avvidqos/index.htm
- **Networkers 2002 slides**
  - http://www.cisco.com/networkers/nw02/presos/docs/NSC-215.pdf
  - http://www.cisco.com/networkers/nw02/presos
  - http://www.cisco.com/networkers/nw02/presos/pws/docs
- **For more info (and links), see my CiscoWorld articles**
  - http://www.netcraftsmen.net/welcher/papers

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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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