



Tuning for Voice Quality

Problem Avoidance

Analyze problem sources and proper design tool/guidelines to ensure voice quality

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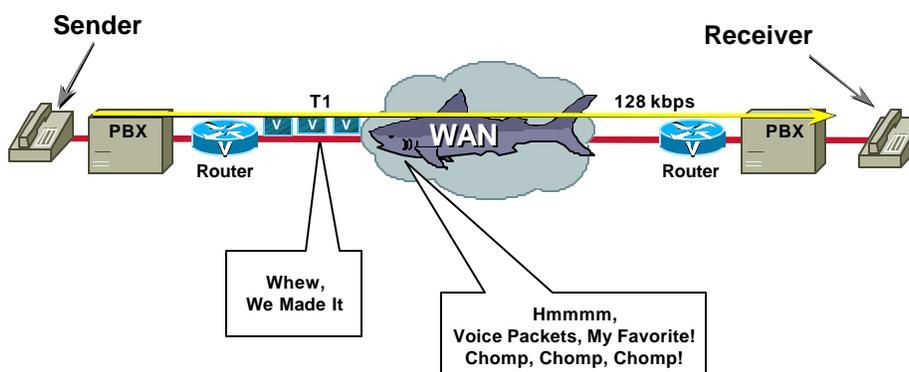
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More Than Just Providing Router QoS

The World Is Not All Point-to-Point Links



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Agenda

- **VoIP Requirements and Challenges**
- Router/Switch Egress QoS Study
- WAN QoS Design Considerations
- Tuning—Audio Level and Echo
- Best Practice Recommendations

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Data and Voice Opposite Needs/Behavior

Data

- Bursty
- Greedy
- Drop sensitive
- Delay insensitive
- TCP retransmits

Voice

- Smooth
- Benign
- Drop insensitive
- Delay sensitive
- UDP best effort

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Voice over IP Protocols

VoIP Is Not Bound to H.323 (H.323 Is a Signaling Protocol)
Many Other Signaling Protocols—MGCP, SGCP, SIP, Etc.

Commonality—Voice Packets Ride on UDP/RTP

Voice Payload G.711, G.729, G.723(.1)

Transport RTP/UDP

Network IP

Link MLPPP/FR/ATM AAL1

Physical ---

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“Payload” Bandwidth Requirements for Various Codecs

Encoding/Compression	Resulting Bit Rate
G.711 PCM A-Law/u-Law	64 kbps (DS0)
G.726 ADPCM	16, 24, 32, 40 kbps
G.727 E-ADPCM	16, 24, 32, 40 kbps
G.729 CS-ACELP	8 kbps
G.728 LD-CELP	16 kbps
G.723.1 CELP	6.3/5.3 kbps

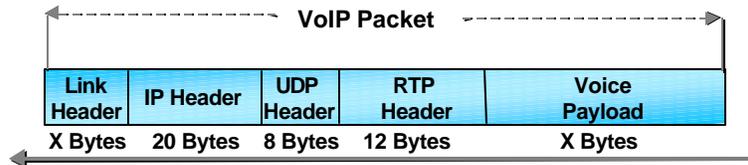
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VoIP Packet Format



- Payload size, PPS and BPS vendor implementation specific
- For example:

Not Including Link Layer Header or CRTP

Cisco Router at G.711	= 160 Byte Voice Payload at 50 pps (80 kbps)
Cisco Router at G.729	= 20 Byte Payload at 50 pps (24 kbps)
Cisco IP Phone at G.711	= 240 Byte Payload at 33 pps (74.6 kbps)
Cisco IP Phone at G.723.1	= 24 Byte Payload at 33 pps (17k bps)

Note—Link Layer Sizes Vary per Media

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Various Link Layer Header Sizes

“Varying Bit Rates per Media”

Example—G.729 with 60 Byte Packet (Voice and IP Header)
at 50 pps (No RTP Header Compression)

Media	Link Layer Header Size	Bit Rate
Ethernet	14 Bytes	29.6 kbps
PPP	6 Bytes	26.4 kbps
Frame Relay	4 Bytes	25.6 kbps
ATM	5 Bytes Per Cell	42.4 kbps

**Note—For ATM a Single 60 Byte Packet Requires
Two 53 Byte ATM Cells**

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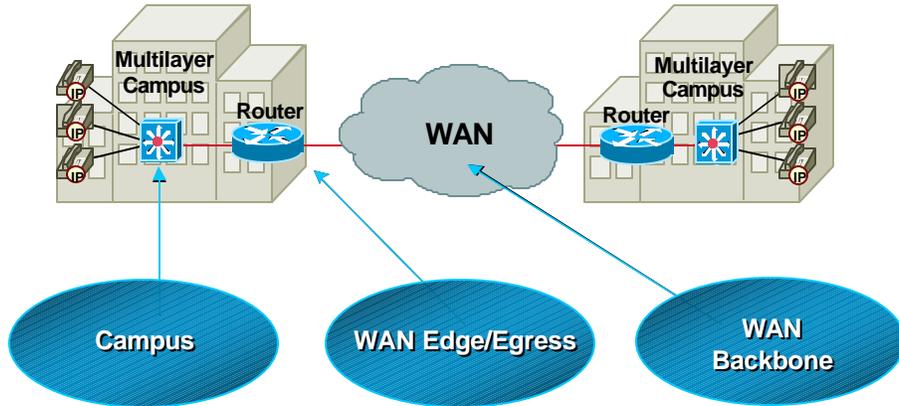
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Domains of QoS Consideration

Requirement - "End to End" Quality of Service (QoS)



Avoiding Loss, Delay and Delay Variation (Jitter)
Strict Prioritization of Voice

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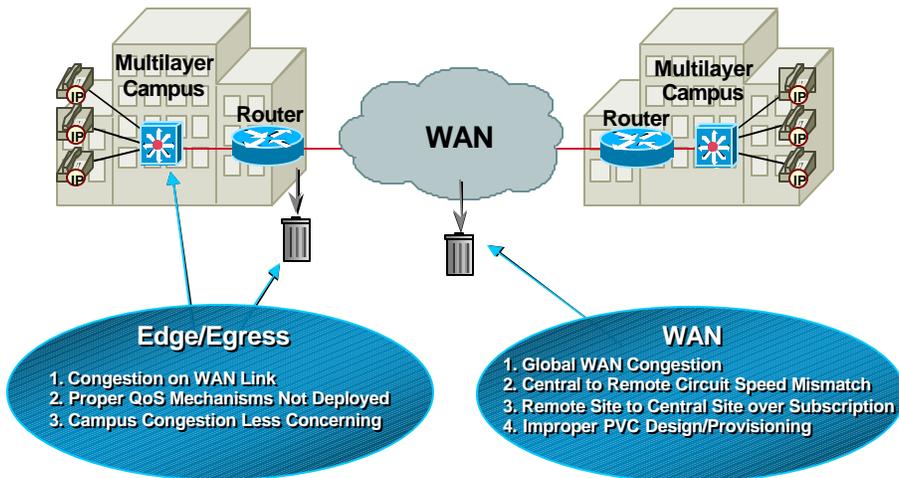
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Loss

Sources of Packet Loss—Congestion



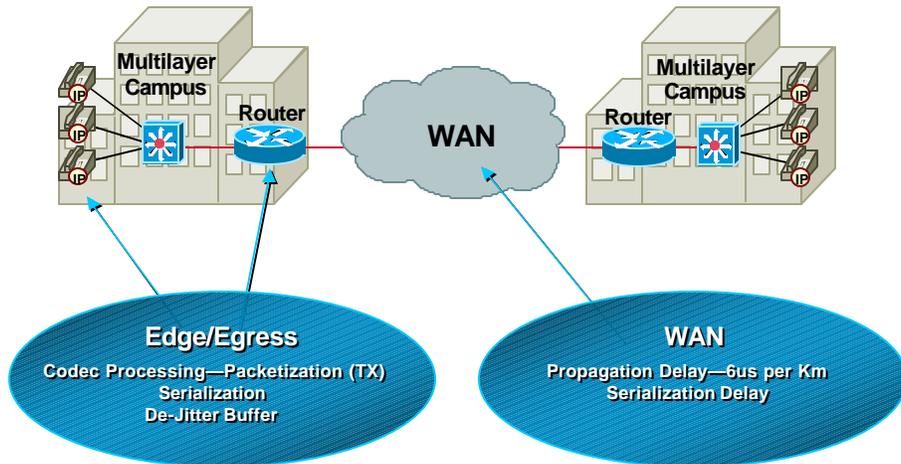
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Delay—Fixed Sources of Fixed Delay



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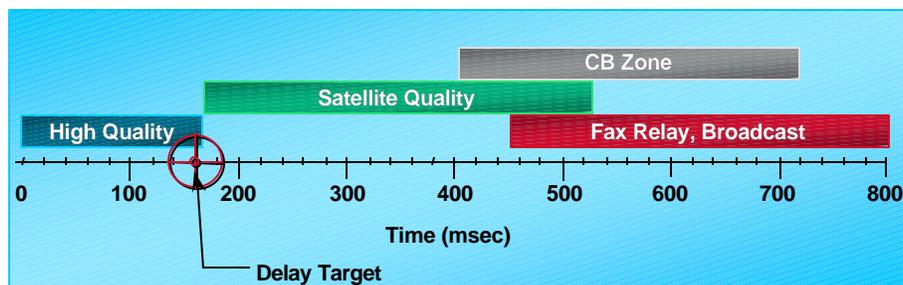
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Delay Budget Goal < 150 ms

Cumulative Transmission Path Delay Avoid the “Human Ethernet”



ITU's G.114 “Recommendation” = 0–150 msec 1-Way Delay

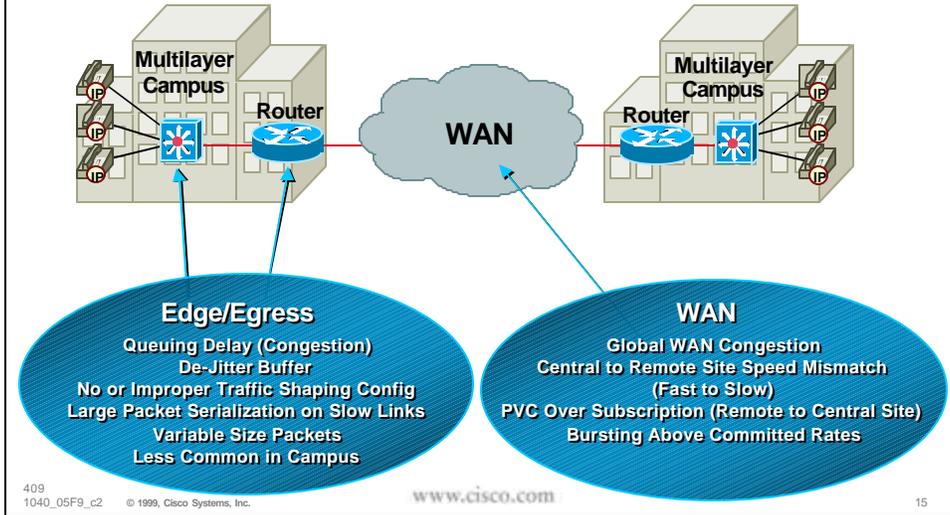
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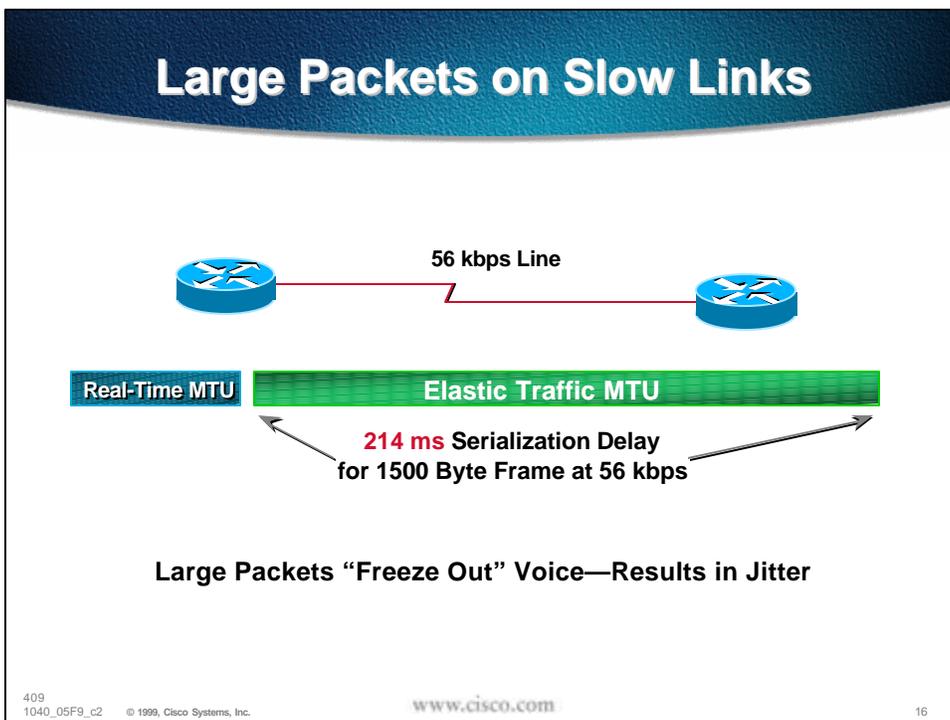
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Delay—Variable Sources of Variable Delay



Large Packets on Slow Links



QoS Needs

- **Campus**
Bandwidth minimizes QoS issues
- **WAN edge**
QoS “starts” in the WAN—a **must**
- **WAN considerations**
Often forgotten or misunderstood—
a must

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Agenda

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- **WAN QoS Design Considerations**
- **Tuning—Audio Level and Echo**
- **Best Practice Recommendations**

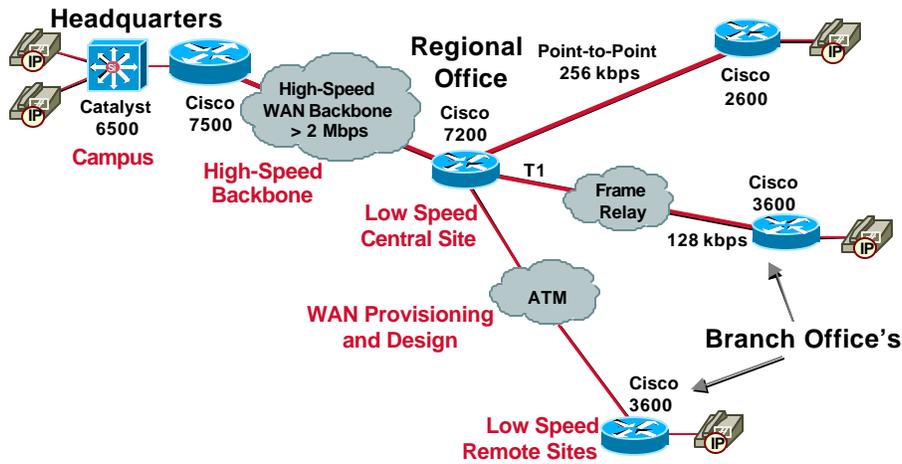
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Case Study: End-to-End Quality of Service



Applying Proper Tools in Proper Location

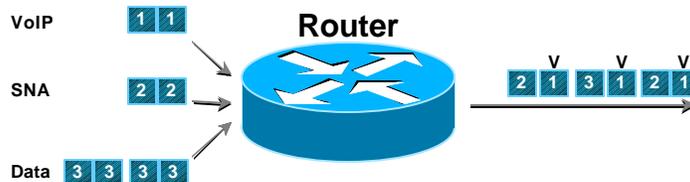
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Router/Switch Egress QoS Tools “Three Classes of QoS Tools”



- **Prioritization**
Low Speed WAN, High Speed WAN, Campus
- **Link Efficiency**
Fragment and Interleave, Compression, VAD
- **Traffic Shaping**
Speed Mismatches + To Avoid Bursting

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Prioritization

Low Speed WAN Egress QoS

Two MB or Less

- IP precedence
- RSVP
- Class-based weighted fair queuing - CBWFQ

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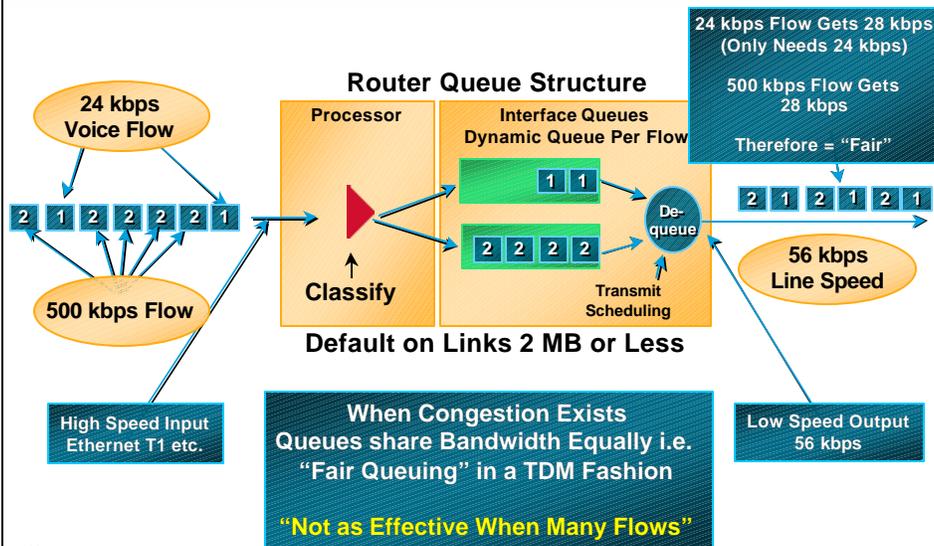
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Weighted Fair Queuing (WFQ)

Treats Flows with same IP Precedence Equally



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Displaying WFQ

Emphasizing the “Fair” in Weighted Fair Queuing
 Note: The Lower the Weight of a Flow, the More Bandwidth it Gets

```
HUB3640#show queue se 0/0
Input queue: 0/75/0 (size/max/drops); Total output drops: 0
Queuing strategy: weighted fair
Output queue: 31/64/0 (size/threshold/drops)
Conversations 2/4 (active/max active)
Reserved Conversations 0/0 (allocated/max allocated)
```

Weight =
4096/(1+ IP Prec)

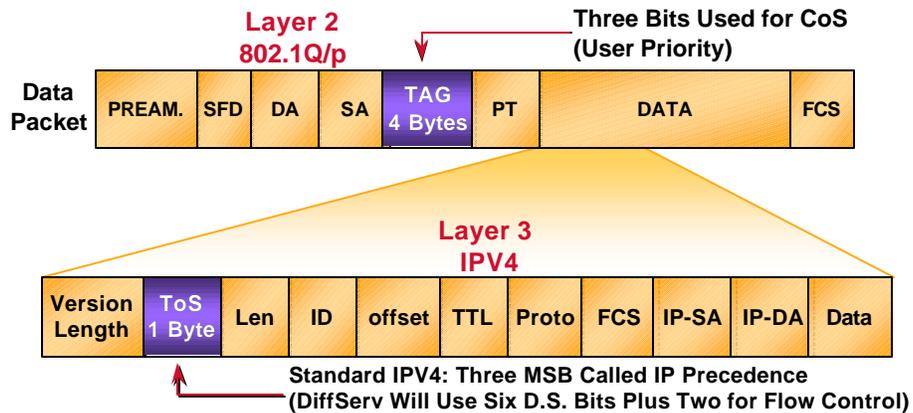
```
(depth/weight/discards/interleaves) 24/4096/0/0
Conversation 184, linktype: ip, length: 1504
source: 10.1.5.2, destination: 10.1.6.1, id: 0x04CF, ttl: 31,
TOS: 0 prot: 6, source port 1503, destination port 21
```

High
Bandwidth
Flow

```
(depth/weight/discards/interleaves) 2/4096/0/0
Conversation 227, linktype: ip, length: 68
source: 10.1.1.2, destination: 10.1.1.1, id: 0xFCF, ttl: 31,
TOS: 0 prot: 17, source port 49608, destination port 49608
```

VoIP
Flow

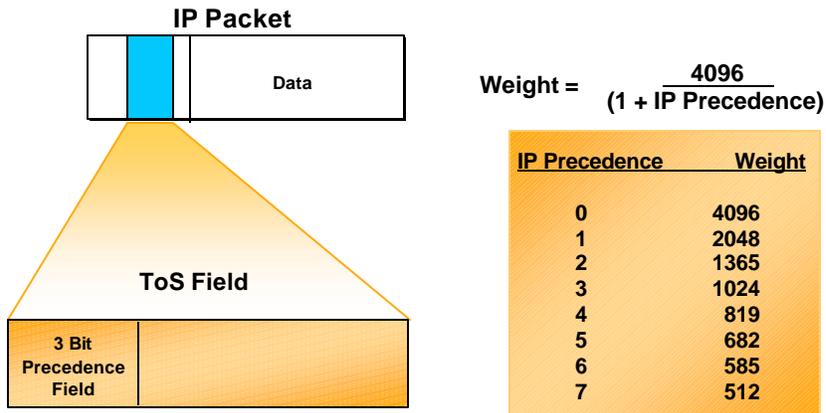
Traffic Differentiation Mechanisms IP Precedence and 802.1p



- Layer 2 mechanisms are not assured end-to-end
- Layer 3 mechanisms provide end-to-end classification

IP Precedence

“Controlling WFQ’s De-queuing Behavior”



- IP Precedence

Not a QoS Mechanism turned on in the router
 “In Band” QoS Signaling—Set in the End Point

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Displaying Effects of IP Precedence

This Is Using the “Weight” in Weighted Fair Queuing

```
HUB3640#show queue se 0/0
Input queue: 0/75/0 (size/max/drops); Total output drops: 0
Queuing strategy: weighted fair
Output queue: 9/64/0 (size/threshold/drops)
Conversations 2/7 (active/max active)
Reserved Conversations 0/0 (allocated/max allocated)
```

```
(depth/weight/discards/interleaves) 1/585/0/0
Conversation 90, linktype: ip, length: 68
source: 10.1.5.2, destination: 10.1.6.1, id: 0x0064, ttl: 255,
TOS: 192 prot: 17, source port 16384, destination port 16384
```

VoIP Flow

```
(depth/weight/discards/interleaves) 8/4096/0/0
Conversation 219, linktype: ip, length: 1504
source: 10.1.1.2, destination: 10.1.1.1, id: 0x1C7E, ttl: 31,
TOS: 0 prot: 6, source port 49604, destination port 21
```

FTP Flow

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IP Precedence with WFQ

Calculating Given Flow Bandwidth Based on IP Precedence Under Congestion

$$\text{Flow A BW} = \left(\frac{\text{Flow A "Parts"}}{\text{Sum of all Flow "Parts"}} \right) \times \text{Circuit Bandwidth}$$

Individual Flow "Parts" = 1 + IP Precedence

IP Precedence	Flow "Parts"
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8

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IP Precedence Flow Bandwidth Calculation Example

$$\text{Flow A BW} = \left(\frac{\text{Flow A "Parts"}}{\text{Sum of all Flow "Parts"}} \right) \times \text{Circuit Bandwidth}$$

Example A

56 kbps Link

2—VoIP Flows A+B at 24 kbps (IP Prec 0)
2—FTP Flows at 56 kbps (IP Prec 0)

$$14 \text{ kbps} = \left(\frac{1}{4} \right) \times 56 \text{ kbps}$$

14 kbps **Not** Suitable for a 24 kbps Flow
Example of Many Flows with WFQ and Equal Precedence Flows

Weighted "Fair" Queuing

Example B

56 kbps Link

2—VoIP Flows A+B at 24 kbps (IP Prec 5)
2—FTP Flows at 56 kbps (IP Prec 0)

$$24 \text{ kbps} = \left(\frac{6}{14} \right) \times 56 \text{ kbps}$$

24 kbps **Suitable** for a 24 kbps Flow

WFQ Preferring IP Precedence

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IP Precedence No Admission Control

**Moral of the Story: Know Your Environment,
Voice Traffic Patterns etc. Recommendations for
Certain Bandwidth's to Follow**

Example C

56 kbps Link

2—VoIP Flow's at 24 kbps (IP Prec 5)

4—FTP Flows at 56 kbps (IP Prec 0)

$$21 \text{ kbps} = \left(\frac{6}{16}\right) \times 56 \text{ kbps}$$

21 kbps **Not** Suitable for a 24 kbps Flow

RTP Header Compression Would Help Since
it Would reduce VoIP Flow to 11.2 kbps
Also RSVP or CBWFQ

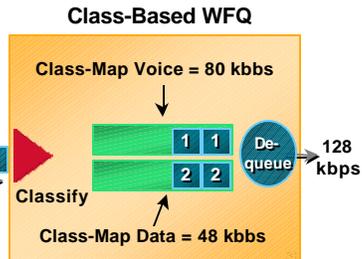
Class-Based Weighted Fair Queuing CBWFQ

- Queues represent “classes” that have an associated minimum bandwidth in kbps
- Traffic assigned to classes via a “policy-map”
- Max 64 classes which support:
 - WFQ between classes
 - RED per class

Class-Based Weighted Fair Queuing CBWFQ

```

class-map data
match input-interface Ethernet0/0
class-map class-default
match any
class-map voice
match access-group 101
!
!
policy-map WAN
class voice
bandwidth 80
class data
bandwidth 48
!
interface Serial0/1
ip address 10.1.6.2 255.255.255.0
bandwidth 128
no ip directed-broadcast
service-policy output WAN
!
access-list 101 permit ip any any precedence critical
    
```



Any Packet with IP Precedence = 5 Gets Assigned to a Class That will Get a Minimum of 80 kbps on a 128 kbps Circuit

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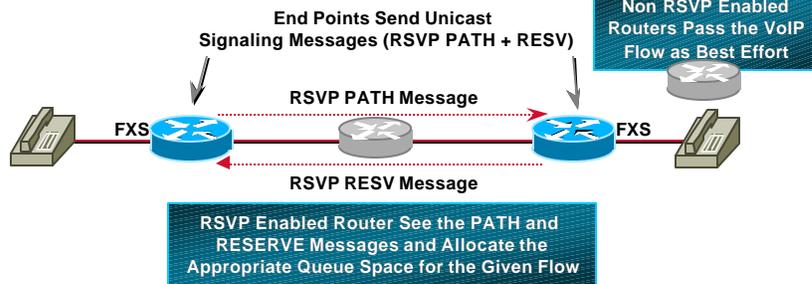
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RSVP: Resource Reservation Protocol

- IETF signaling protocol
 - Reservation of bandwidth and delay
- Flow can be signaled by end station or by router (static reservation)
- Basically reserves queue space



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Configuring RSVP

Interface Command

ip rsvp bandwidth [interface-kbps] [single-flow-kbps]

```
interface Serial0/0
ip address 10.1.1.2 255.255.0.0
ip rsvp bandwidth 96 96
bandwidth 128
fair-queue 64 256 1000
```

$$\text{RSVP Flow Weight} = \frac{\text{Greatest BW Reservation on the link}}{\text{Conversation BW}}$$

Make Sure the Bandwidth Statement Accurately Reflects the Circuit Bandwidth

By Default 75% of the "Bandwidth" Statement Is Reservable

bottom#sho ip rsvp installed

BPS	To	From	Protoc	DPort	Sport	Weight	Conversation
24K	10.1.1.1	10.1.1.2	UDP	16384	16384	4	264

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Monitoring RSVP Queue Operation

bottom#sho que se 0

Input queue: 0/75/0 (size/max/drops); Total output drops: 0

Queueing strategy: weighted fair

Output queue: 23/64/0 (size/threshold/drops)

Conversations 3/5 (active/max active)

Reserved Conversations 1/1 (allocated/max allocated)

(depth/weight/discards/interleaves) 21/4096/0/0

Conversation 195, linktype: ip, length: 1504

source: 10.1.5.1, destination: 10.1.6.1, id: 0xD5E8, ttl: 31,

TOS: 0 prot: 6, source port 1503, destination port 21

FTP Flow

(depth/~~weight~~/discards/interleaves) 2/~~4~~0/0

Conversation 264, linktype: ip, length: 68

source: 10.1.1.2, destination: 10.1.1.1, id: 0xAFE9, ttl: 31,

TOS: 0 prot: 17, source port 16348, destination port 16384

Reserved VoIP Flow

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Prioritization

High-Speed WAN Egress QoS

Greater than 2 MB

- Distributed weighted fair queuing
- WRED
- IP to ATM CoS

At High-Speeds Processor Oriented QoS Mechanisms Not Efficient

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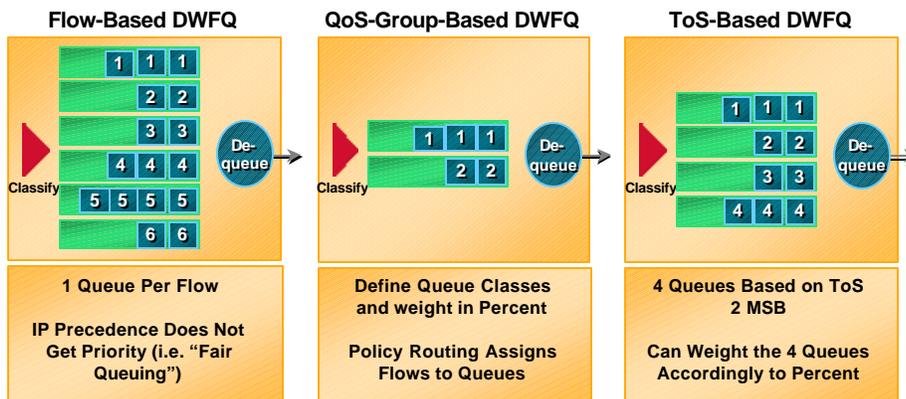
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High-Speed Prioritization

Distributed Weighted Fair Queuing (DWFQ)

VIP2-40 or Better (Versatile Interface Processor)



- Cannot be configured on sub-interfaces—yet

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ToS-Based DWFQ Configuration Example

```
interface Serial1/1/0
ip address 10.1.5.1 255.255.255.0
no ip directed-broadcast
ip route-cache distributed
fair-queue tos
fair-queue tos 1 weight 20
fair-queue tos 1 limit 197
fair-queue tos 2 weight 30
fair-queue tos 2 limit 197
fair-queue tos 3 weight 40
fair-queue tos 3 limit 197
```

Queue Bandwidth in Percent

```
7500#sho queu se 1/1/0
Serial1/1/0 queue size 54
  packets output 1859402, wfq drops 0, nobuffer drops 0
WFQ: aggregate queue limit 395, individual queue limit 197
max available buffers 395
```

Data Flow
Voice Flow

```
Class 0: weight 10 limit 197 qsize 61 packets output 600387 drops 0
Class 1: weight 20 limit 197 qsize 1 packets output 529548 drops 0
Class 2: weight 30 limit 197 qsize 0 packets output 1610 drops 0
Class 3: weight 40 limit 197 qsize 0 packets output 0 drops 0
```

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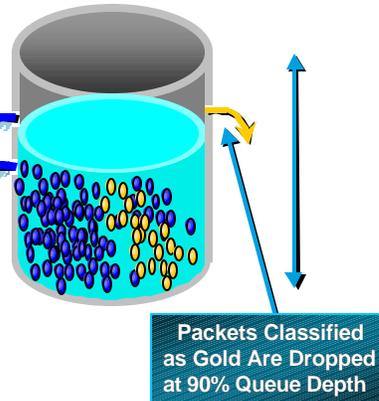
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Weighted RED

- WRED:

In the event packets need to be dropped, what class of packets should be dropped

Packets Classified as Blue Start Dropping at a 50% Queue Depth. Drop Rate Is Increased as Queue Depth Is Increased



Packets Classified as Gold Are Dropped at 90% Queue Depth

WRED Benefit for VoIP:
Maintain Room in Queue, and if Packets **Must** be Dropped "Avoid" Dropping Voice

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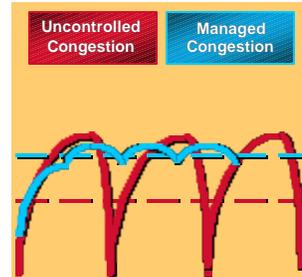
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WRED Congestion Avoidance Maximize Data Goodput

Adjustable Drop Probabilities (from "show interface")

Queuing strategy: random early detection (RED)
mean queue depth: 56

drops:	class	random	tail	min-th	max-th	mark-prob
	0	4356	0	20	40	1/10
Data Flow Prec = 0	1	0	0	22	40	1/10
	2	0	0	24	40	1/10
	3	0	0	26	40	1/10
	4	0	0	28	40	1/10
	5	0	0	30	40	1/10
Voice Flow Prec = 5	6	0	0	33	40	1/10
	7	0	0	35	40	1/10
	rsvp	0	0	37	40	1/10



- Accommodate burstiness
- "Less" drop probability for higher priority flows (VoIP)
- Does **not** protect against flows that do not react to drop
For example, extremely heavy UDP flow can overflow WRED queue

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Make Sure That IP QoS Policies Are Preserved in an ATM Network

- IP-ATM CoS: Differentiated services over standard ATM
- Requires PA-A3/deluxe PA
 - IP precedence to ATM CoS mapping
 - IP RSVP to ATM services

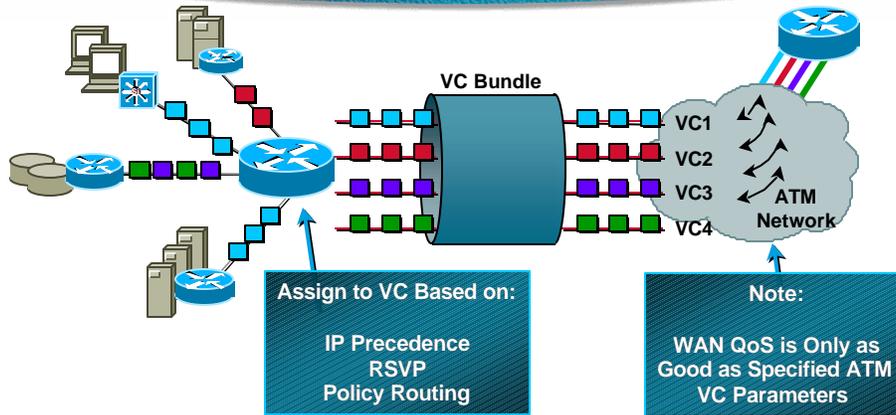
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Precedence to VC Mapping



- VC bundle—multiple VCs for each IP adjacency
- Separate VC for each IP CoS
- WRED, WFQ, or CBWFQ runs on each VC queue

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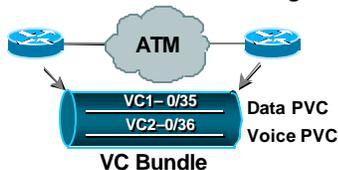
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IP to ATM Egress QoS Tools

IP to ATM CoS Interworking



```
interface ATM0/0/0.7 point-to-point
ip address 10.1.40.1 255.255.255.0
no ip directed-broadcast
bundle gene
protocol ip 10.1.40.2 broadcast
encapsulation aal5snap
pvc-bundle 0/35 ← Data PVC
other
pvc-bundle 0/36 ← Voice PVC
precedence 5-7
```

Only One Routing Adjacency per "Bundle"
Bundle Appears as One Logical Interface

If High Precedence VC Fails, it Can "Bump"
Traffic to a Lower Precedence VC,
or Entire Bundle Can be Declared Down

Data PVC
All Low Priority Traffic Assigned
to this PVC

Voice PVC
High Priority Traffic Assigned to VC Based on
IP Precedence (5-7 in This Case)

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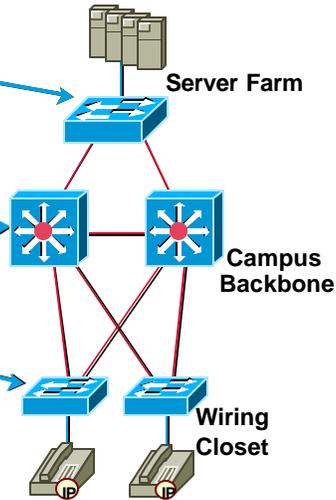
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Prioritization Campus QoS Needs

- **Catalyst 6XXX**
Two queues + two drop thresholds per port
Classification + policing
- **Catalyst 8500**
Four queues
- **Catalyst 5XXX**
1 queue WRED four drop thresholds
Reclassification



Campus QoS Need Based on
Customer Environment

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Link Efficiency Low-Speed WAN QoS Tools

- **Fragmentation and interleave (LFI)**
- **RTP header compression (CRTP)**
- **Voice Activity Detection (VAD)**

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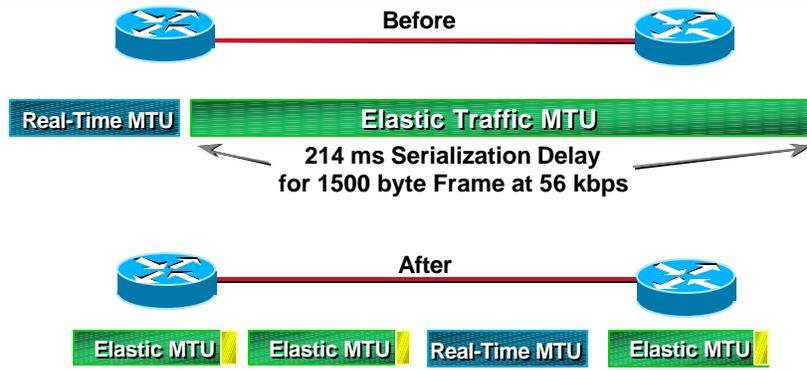
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Fragmentation and Interleave Only Needed on Slow Links



Mechanisms

Point-to-Point Links—MLPPP with Fragmentation and Interleave
 Frame Relay—FRF.12 (Voice and Data Can Use Single PVC)
 ATM—(Voice and Data Need Separate VC's on Slow Links)

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Configuring Multilink PPP Fragmentation and Interleave



```

interface Virtual-Template1
ip unnumbered Loopback0
bandwidth 128
fair-queue 64 256 1000
ppp multilink
ppp multilink fragment-delay 10
ppp multilink interleave
!
interface Serial0
no ip address
encapsulation ppp
bandwidth 128
no fair-queue
ppp multilink
    
```

Desired Max Blocking Delay in ms

Fragmentation Size a Result of this and "Bandwidth" Statement

```

interface Virtual-Template1
ip unnumbered Loopback0
bandwidth 128
fair-queue 64 256 1000
ppp multilink
ppp multilink fragment-delay 10
ppp multilink interleave
!
interface Serial0
no ip address
encapsulation ppp
bandwidth 128
no fair-queue
ppp multilink
    
```

Note: Issues with multiple links in a bundle and CRTP at the same time

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Low Speed Frame Relay FRF.12 Configuration

Hub3640#

```
interface Serial0/0
no ip address
encapsulation frame-relay
bandwidth 1300000
frame-relay traffic-shaping
!
interface Serial0/0.1 point-to-point
ip address 10.1.1.1 255.255.255.0
no ip directed-broadcast
bandwidth 1300000
frame-relay class gene

map-class frame-relay gene
frame-relay fragment 70
no frame-relay adaptive-shaping
frame-relay bc 2000
frame-relay mincir 56000
frame-relay fair-queue
```

Remote3640#

```
interface Serial0/0
no ip address
encapsulation frame-relay
bandwidth 56000
frame-relay traffic-shaping
!
interface Serial0/0.1 point-to-point
ip address 10.1.1.2 255.255.255.0
no ip directed-broadcast
bandwidth 56000
frame-relay class gene

map-class frame-relay gene
frame-relay fragment 70
no frame-relay adaptive-shaping
frame-relay bc 2000
frame-relay mincir 56000
frame-relay fair-queue
```

Note: Bc set lower than the default of 1/8th the CIR
Lower interval better on high speed links with low CIR (can result in quicker credit exhaustion)

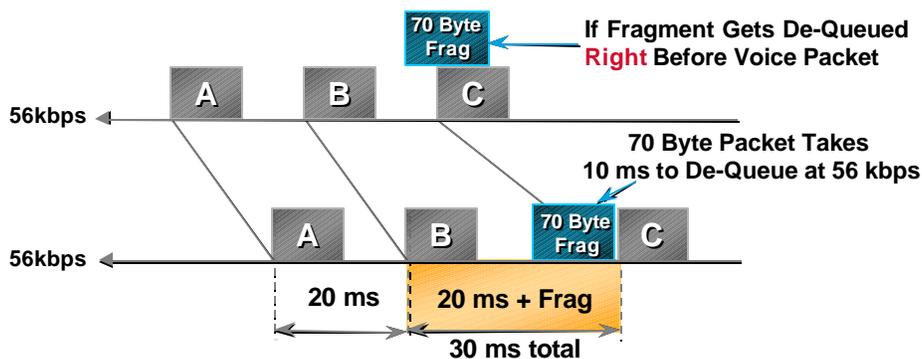
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Setting Fragment Size Based on Minimum Desired Blocking Delay



Note: Blocking delays are always present

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Fragment Size Matrix

Assuming 10 ms Blocking Delay per Fragment

Link Speed	Fragment Size
56 kbps	70 Bytes
64 kbps	80 Bytes
128 kbps	160 Bytes
256 kbps	320 Bytes
512 kbps	640 Bytes
768 kbps	1000 Bytes
1536 kbps	2000 Bytes

$$\text{Fragment Size} = \frac{10 \text{ ms}}{\text{Time for 1 Byte at BW}}$$

Example: 4 G.729 Calls on 128 kbps Circuit
Fragment Blocking Delay = 10 ms (160 bytes)

$$Q = (Pv * N / C) + LFI$$

$$Q = (480 \text{ bits} * 4 / 128000) + 10 \text{ ms} = 25 \text{ ms}$$

Worst Case Queuing Delay = 25 ms

Q = Worst Case Queuing Delay of Voice Packet in ms

Pv = Size of a Voice Packet in Bits (at Layer 1)

N = Number of Calls

C = Is the Link Capacity in bps

LFI = Fragment Size Queue Delay in ms

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When Is Fragmentation Needed?

Link Speed	Frame Size						
	1 Byte	64 Bytes	128 Bytes	256 Bytes	512 Bytes	1024 Bytes	1500 Bytes
56 kbps	143 us	9 ms	18 ms	36 ms	72 ms	144 ms	214 ms
64 kbps	125 us	8 ms	16 ms	32 ms	64 ms	128 ms	187 ms
128 kbps	62.5 us	4 ms	8 ms	16 ms	32 ms	64 ms	93 ms
256 kbps	31 us	2 ms	4 ms	8 ms	16 ms	32 ms	46 ms
512 kbps	15.5 us	1 ms	2 ms	4 ms	8 ms	16 ms	23 ms
768 kbps	10 us	640 us	1.28 ms	2.56 ms	5.12 ms	10.24 ms	15 ms
1536 kbps	5 us	320 us	640 us	1.28 ms	2.56 ms	5.12 ms	7.5 ms

- Depends on the queuing delay caused by large frames at a given speed—fragmentation generally not needed above 768 kbps

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RTP Header Compression

- **Overhead**

20 ms @ 8 kbps yields
20 byte payload

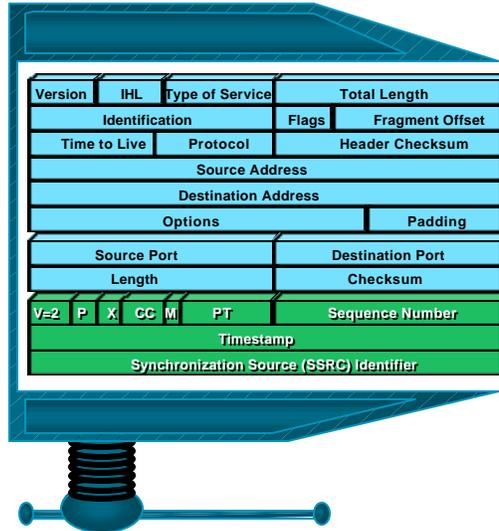
40bytes per packet IP
header 20; UDP header 8;
RTP header 12

2X payload!

Header compression
40 Bytes to 2–4 much
of the time

Hop-by-hop on slow links

CRTP—compressed
real-time protocol



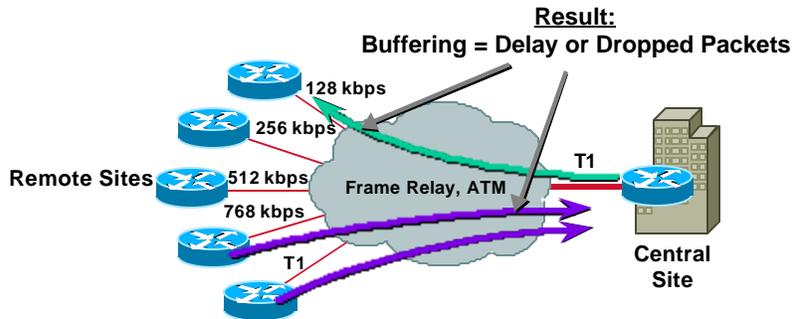
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Traffic Shaping Why?



- **Central to remote site speed mismatch**
- **Remote to central site over-subscription**
- **Prohibit bursting above committed rate**

What are you guaranteed above you committed rate?

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Understanding Shaping Parameters Frame Relay

Traffic Shaping

“Average” Traffic Rate Out of an Interface
Challenge—Traffic Still Clocked Out at **Line Rate**

CIR (Committed Information Rate)

Average Rate over Time, Typically in Bits per Second

Bc (Committed Burst)

Amount Allowed to Transmit in an Interval, in Bits

Be (Excess Burst)

Amount Allowed to Transmit Above Bc per Second

Interval

Equal Integer of Time Within 1 sec, Typically in ms. Number of Intervals per Second
Depends on Interval Length Bc and the Interval Are Derivatives of Each Other

$$\text{Interval} = \frac{Bc}{CIR} \quad \text{Example} \rightarrow 125 \text{ ms} = \frac{8000 \text{ bits}}{64 \text{ kbps}}$$

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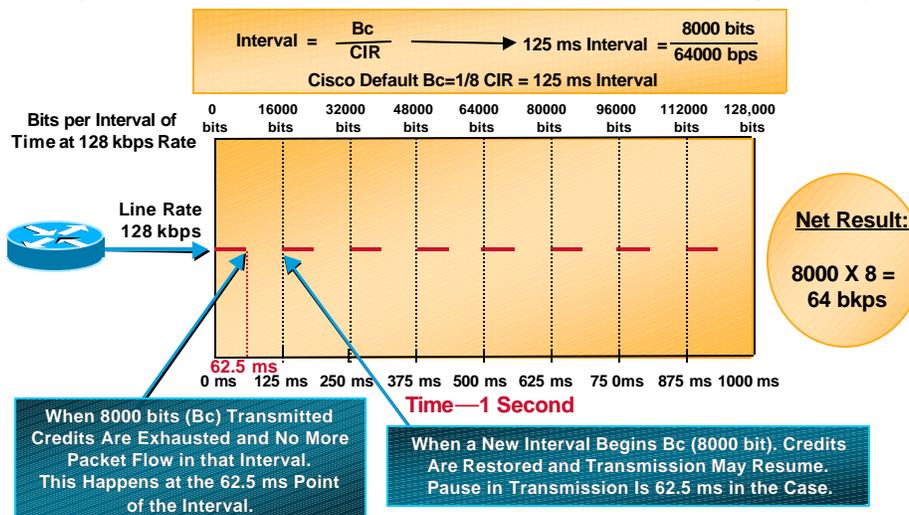
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Example—Traffic Shaping in Action

High Volume Data Flow Towards a 128 kbps Line Rate Shaping to 64 kbps



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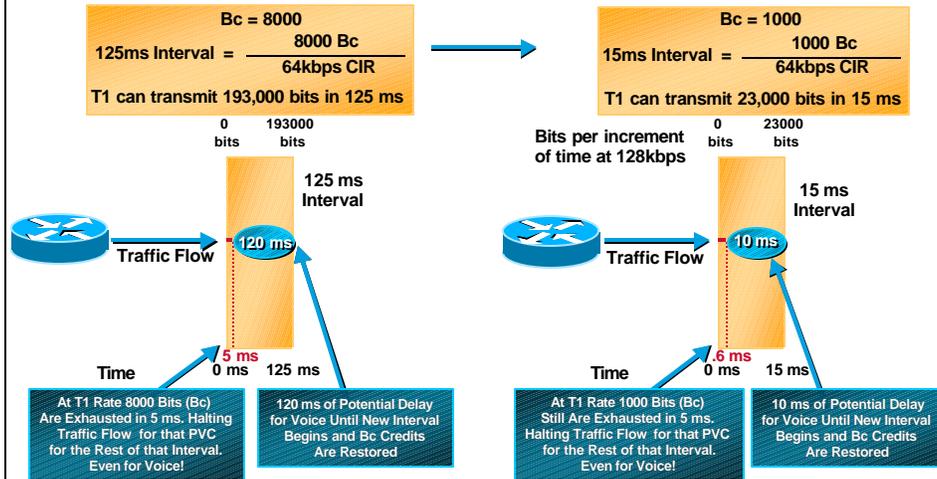
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Bc setting Considerations for VoIP

Set Bc Lower if Line Rate to CIR Ratio Is High
 Example: T1 Line Rate Shaping to 64 kbps



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Traffic Shaping Configuration Shaping to 56 kbps with No Bursting

FRTS#

```
interface Serial0/0
no ip address
encapsulation frame-relay
bandwidth 1300000
frame-relay traffic-shaping
!
interface Serial0/0.1 point-to-point
ip address 10.1.1.1 255.255.255.0
bandwidth 56000
frame-relay class gene

map-class frame-relay gene
frame-relay fragment 70
no frame-relay adaptive-shaping
frame-relay bc 2000
frame-relay cir 56000
frame-relay mincir 56000
frame-relay fair-queue
```

Frame Relay Traffic Shaping

GTS#

```
interface Serial0/0
ip address 10.1.1.2 255.255.255.0
bandwidth 512
traffic-shape rate 56000 2000 0
```

Can Work on "Non" Frame Relay Interfaces
 Anywhere Throttling Needs to Occur

traffic shape rate [average] [interval] [burst]

Generic Traffic Shaping

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Verifying Traffic Shaping Operation

```
HUB3640#sho frame pvc 100
```

```
PVC Statistics for interface Serial0/0 (Frame Relay DTE)
```

```
DLCI = 100, DLCI USAGE = LOCAL, PVC STATUS = STATIC, INTERFACE = Serial0/0.1
```

```
input pkts 149427      output pkts 835851    in bytes 9948250
out bytes 1042695469  dropped pkts 622090  in FECN pkts 0
in BECN pkts 0        out FECN pkts 0      out BECN pkts 0
in DE pkts 0          out DE pkts 0
out bcast pkts 1325   out bcast bytes 110227
pvc create time 013442, last time pvc status changed 013145
fragment type end-to-end  fragment size 70
cir 56000  bc 2000  be 0  limit 250  interval 35
mincir 56000  byte increment 250  BECN response no
pkts 48669  bytes 4146936  pkts delayed 24334  bytes delayed 2072716
shaping active
```

Byte Increment = Bc

Amount to be Credited to Bc for Next Upcoming Interval.

Value Gets Decreased Upon Receipt of BECN or CLLM Messages. This Is How Router Gets Throttled Back Due to Congestion Indication.

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Cisco IOS Support

- WFQ—11.0
- IP Precedence—11.0
- RSVP—11.2
- MLPPP + Frag—11.3
- Traffic Shaping—11.2
- FRF.12—12.0(4)T
- WRED—12.0
- DWFQ—12.0(3)T
- IP to ATM QoS—12.0(3)T

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Agenda

- VoIP Requirements and Challenges
- Router/Switch Egress QoS Study
- **WAN QoS Design Considerations**
- Tuning—Audio Level and Echo
- Best Practice Recommendations

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WAN QoS Considerations

- High-speed to low circuits
- Remote to central site over subscription
- Over subscription—carrier
- To burst or not to burst?

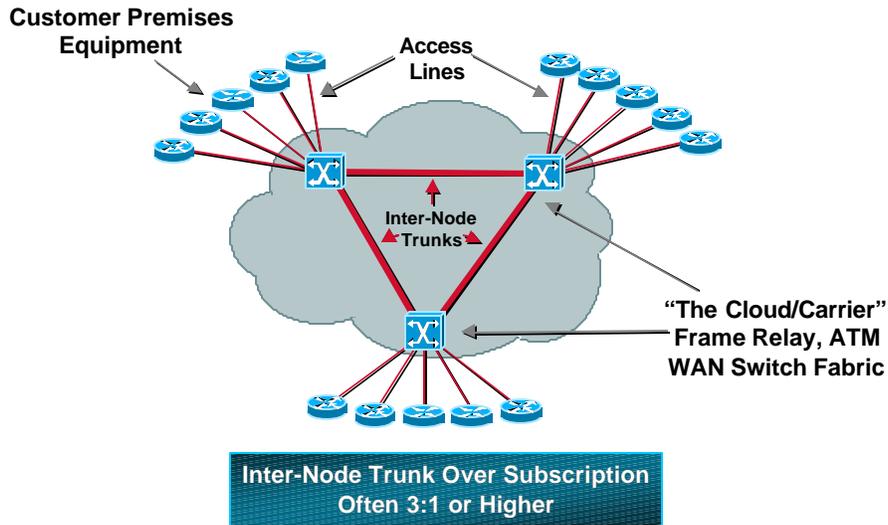
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Anatomy of a Carrier



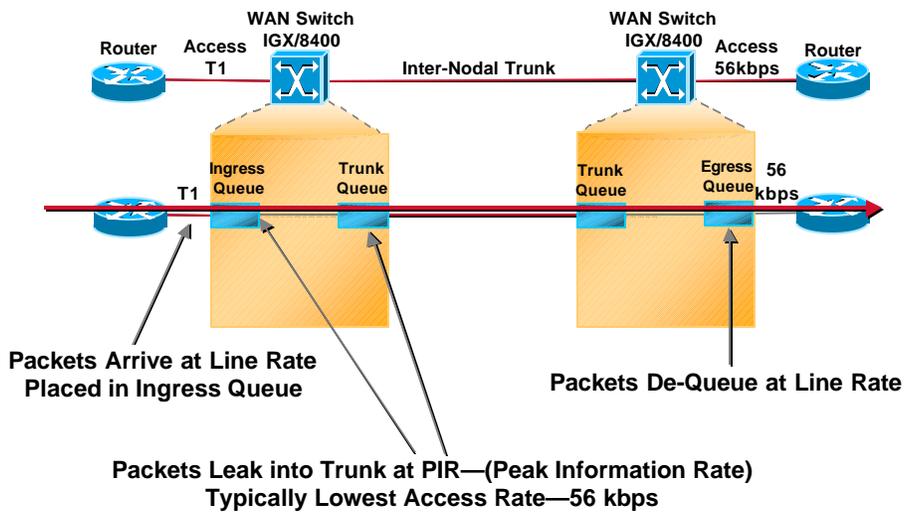
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WAN Queuing and Buffering



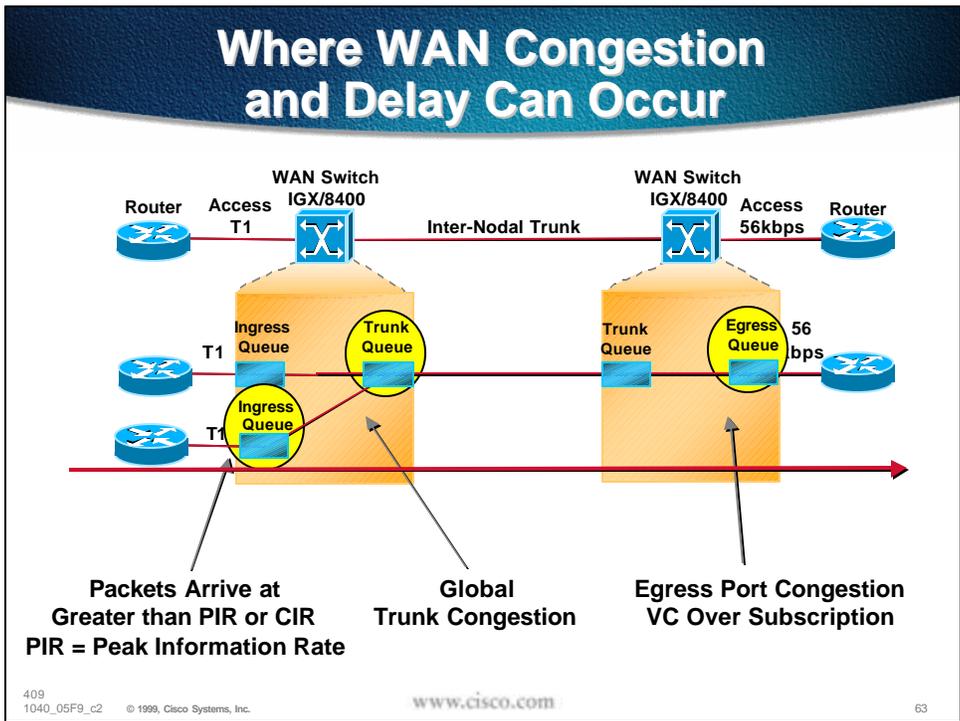
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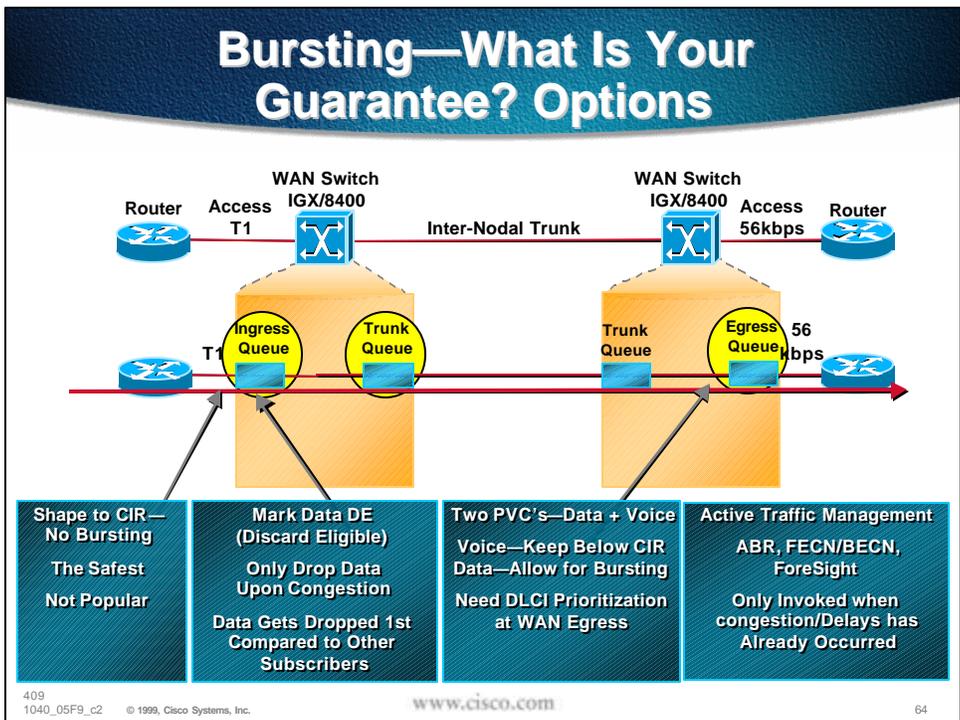
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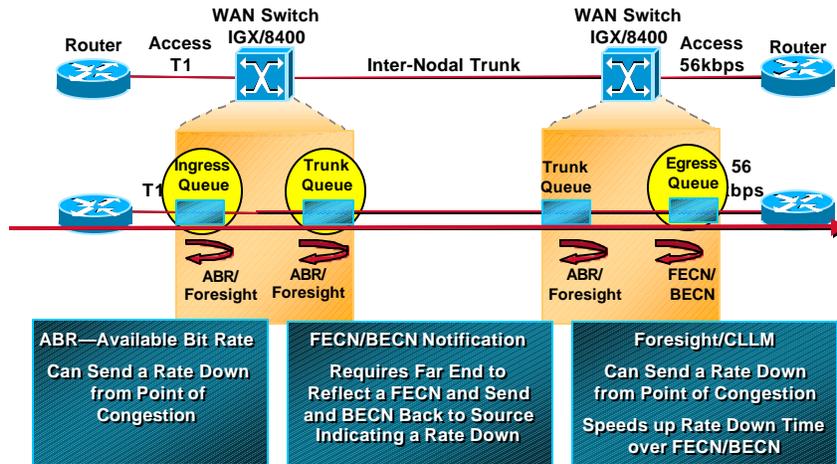
Where WAN Congestion and Delay Can Occur



Bursting—What Is Your Guarantee? Options



Congestion Detection and Feedback Effectiveness Depends on Round Trip Delay



Congestion Must Occur to Invoke, Congestion Relief Can be as Long as One Round Trip Time

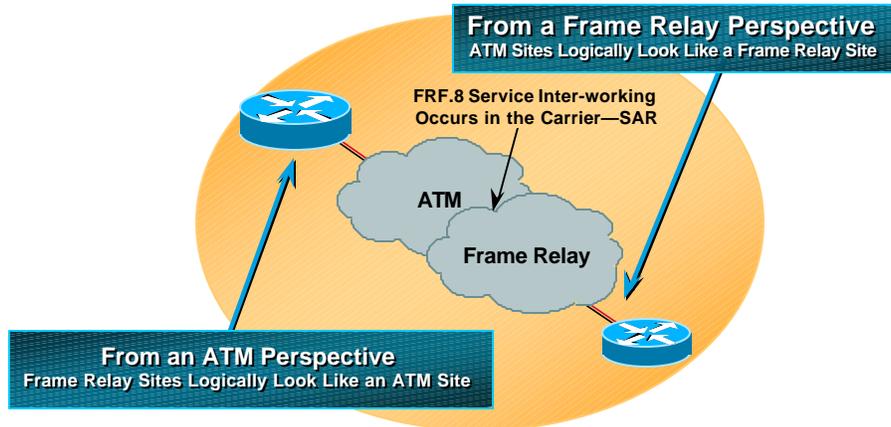
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FRF.8 ATM/FR Service Interworking



**Caution: If FRF.12 needed at remote then its fragment re-assembly must occur before SAR in carrier
Two PVC's required for Interleaving ATM must not interleave cells from different packets**

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- Best Practice Recommendations

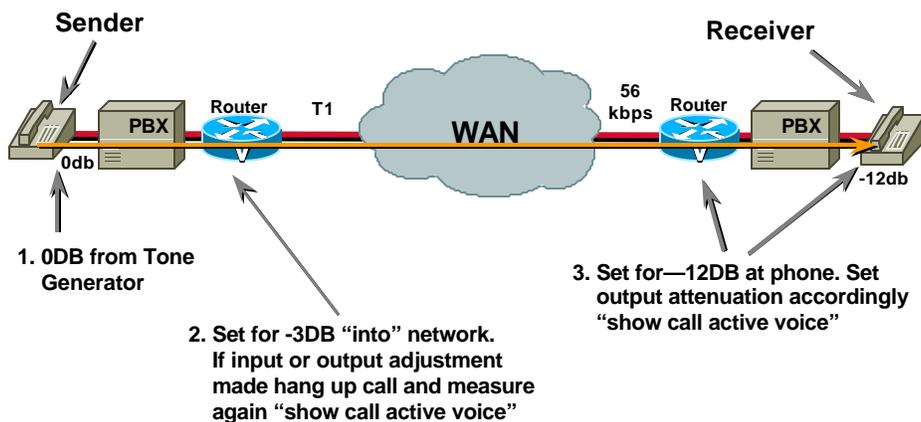
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Audio Level Adjustment/Tuning



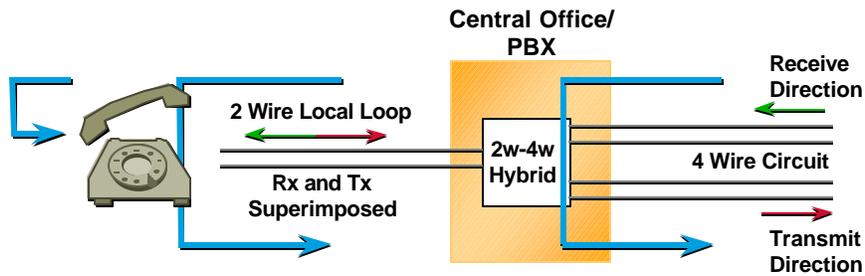
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Echo—How Does it Happen? Echo Is Due to a Reflection



- Impedance mismatch at the 2w-4w hybrid is the most common source of echo
- Echo is always present. A function of the echo delay, and the magnitude of the echo

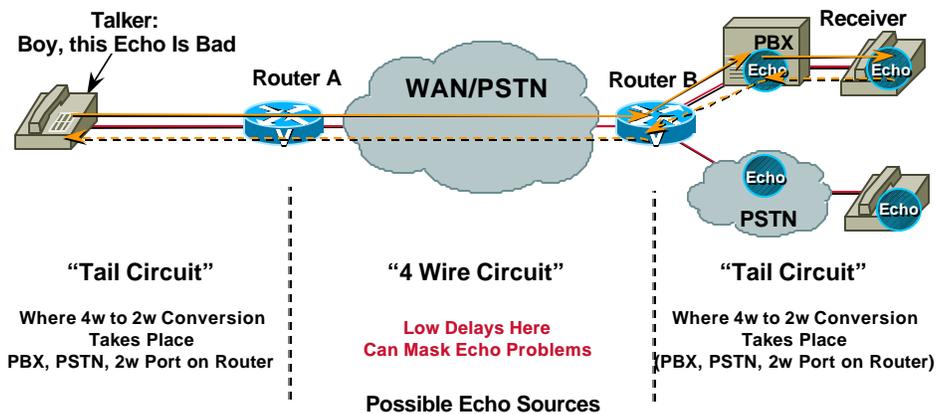
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If “I” Hear Echo, its “Your” Problem



- **ERL (Echo Return Loss)**
ITU-T G.131 states ERL of a device should be greater than 15 dbmo
Echo cancellers typically give 25 db additional echo reduction

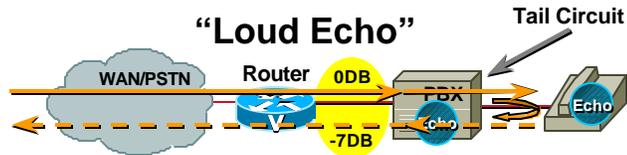
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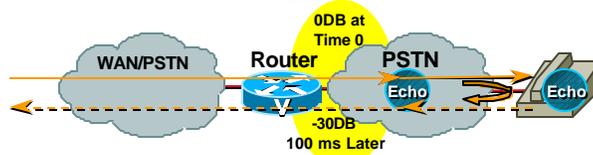
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Types of Echo



- ERL should be greater than 15 DB
- Typical echo canceller adds about 25 DB of echo reduction
- Solution—fix echo source

“Long Echo”



- Echo exceeds coverage range—Cisco echo coverage is 32 ms

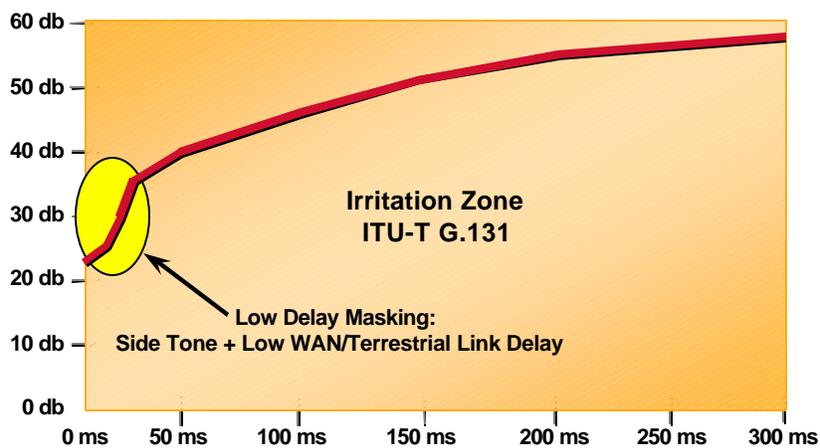
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Echo Loudness to Echo Delay Relationship



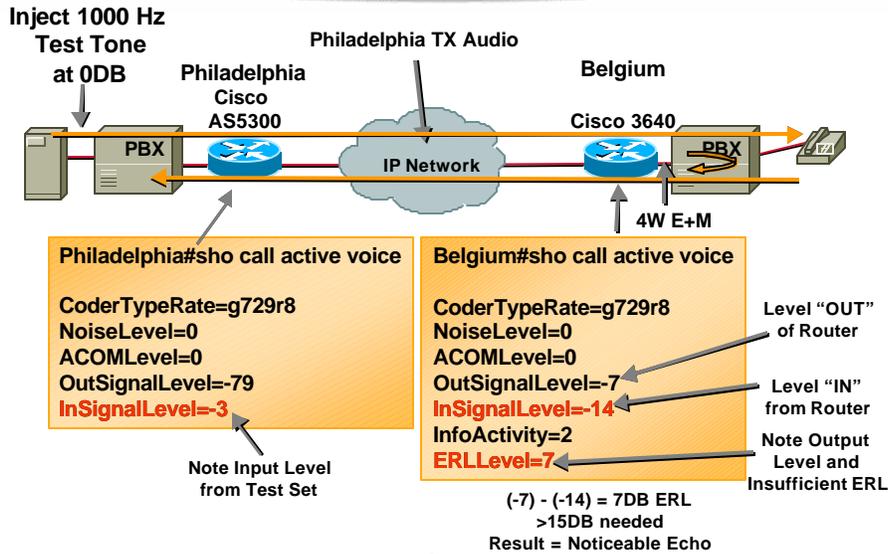
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Echo Troubleshooting Example "Loud Echo"



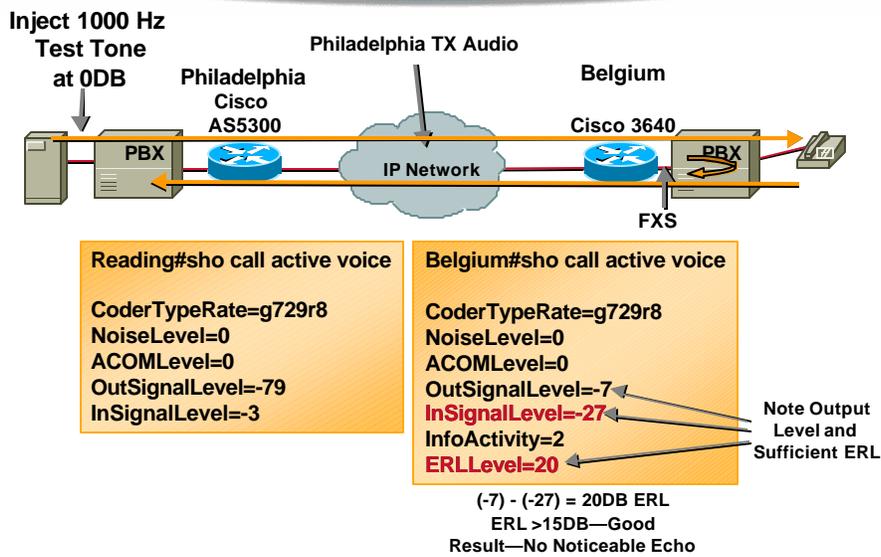
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Solution: Router Performs 4w to 2W Conversion



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Agenda

- VoIP Requirements and Challenges
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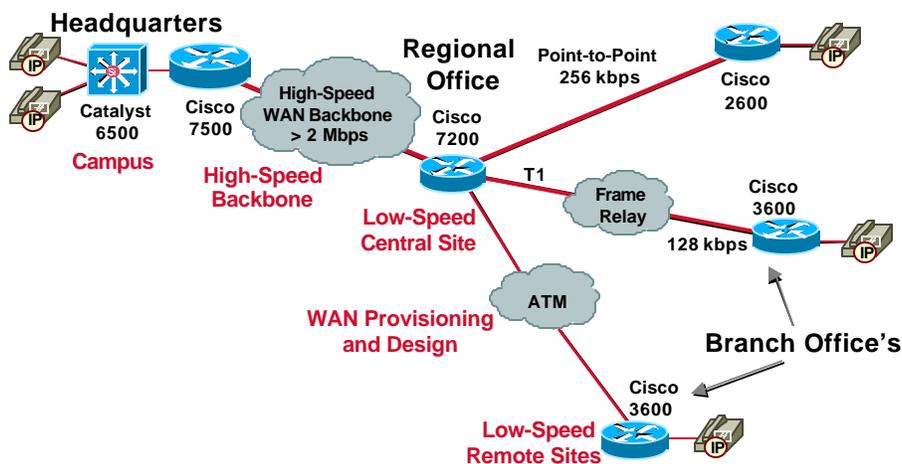
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Summary: QoS Best Practice Example



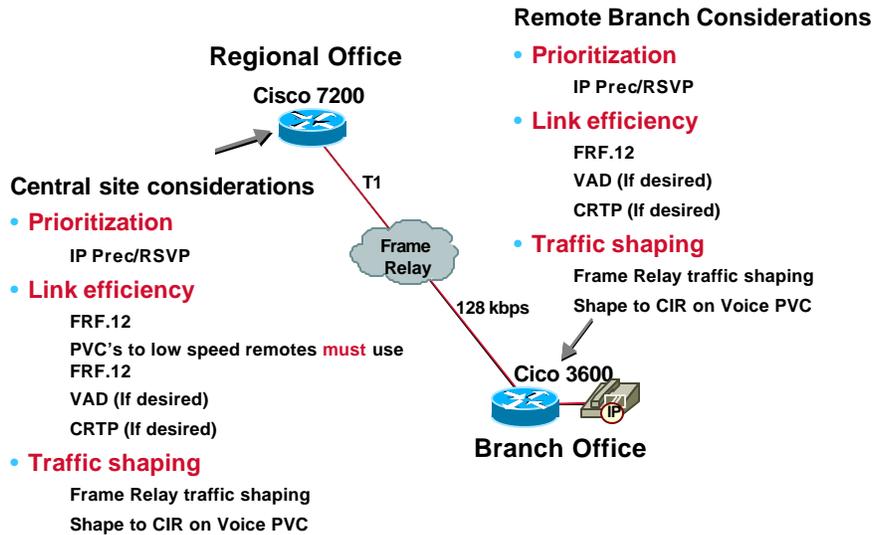
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Low-Speed WAN Frame Relay Example



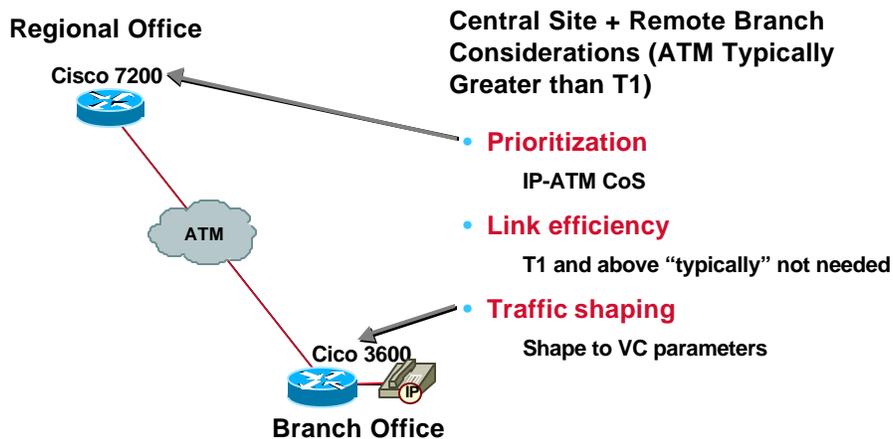
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Low Speed WAN ATM Example



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Low Speed WAN Pt to Pt Example

Regional Office

Cisco 7200



256 kbps



Branch Office

Point-to-Point Considerations

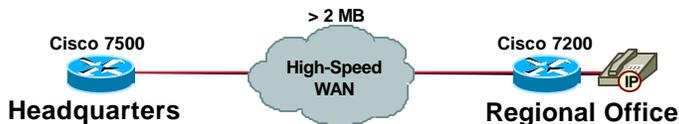
- **Prioritization**
IP Prec/RSVP
- **Link efficiency**
MLPPP with fragmentation and interleave
VAD (if desired)
CRTP (if desired)
- **Traffic shaping**
N/A

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High Speed WAN Backbone Frame Relay/ATM Example



ATM

- **Prioritization**
IP-ATM CoS
- **Link efficiency**
N/A
- **Traffic shaping**
Shape to VC parameters

Frame Relay

- **Prioritization**
IP Prec/RSVP
- **Link efficiency**
FRF.12 if remote low-speed
- **Traffic shaping**
Frame Relay traffic shaping
Shape to CIR

Point to Point

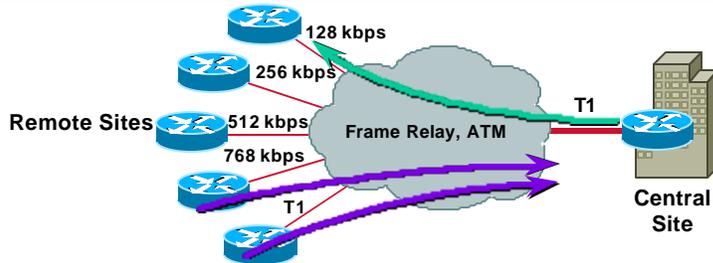
- **Prioritization**
IP Prec/RSVP
- **Link efficiency**
N/A
- **Traffic shaping**
N/A

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WAN Provisioning/ Design Considerations



Central to Remote Speed Mismatch

Traffic Shaping—Prevents Delay or Loss in WAN—**A Must**

Remote to Central Over Subscription—**Do Not**

Add additional T1's at Central Site, or
Traffic Shaping—from Remotes at Reduced Rate (< Line Rate)

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Bursting Considerations “Guidelines”

- **Single PVC—limit bursting to committed rate (CIR)**
The safest—you are guaranteed what you pay for
- **Single PVC—mark data discard eligible**
Your data gets dropped first upon network congestion
- **Single PVC—utilize BECN's, foresight or ABR**
Only invoked when congestion has already occurred
Round trip delays—Congestion indication must get back to source
- **Dual PVCs—one for voice and one for data**
One for **data** (may burst), one for **voice** (keep below CIR)
Must Perform PVC prioritization in frame cloud (Cisco WAN gear does)
Fragmentation rules still apply for data PVC

Moral of the Story—“Know Your Carrier”

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In Conclusion

- **Prioritization**
- **Link efficiency mechanisms**
- **Traffic shape**
- **Know your WAN!**

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**Please Complete Your
Evaluation Form**

Session 409

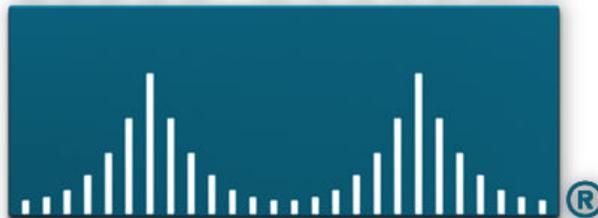
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