GTER

São Paulo

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Mecanismos de QoS

Alexandre Longo - alongo@cisco.com

Cisco Systems

Agenda

- What is QoS?
- QoS Service Types
- QoS Components
- Classification & Marking
- Traffic Shapping x Policing
- Queuing Algorithms
- Congestion Avoidance
- Link Efficiency Management
- QoS and MPLS
- QoS requirements of Voice, Video and Data

What is Quality of Service?

“

The Pragmatic Answer:
Managed Unfairness

The Technical Answer:
Set of techniques to manage delay, jitter, packet loss, and bandwidth for flows in a network

”

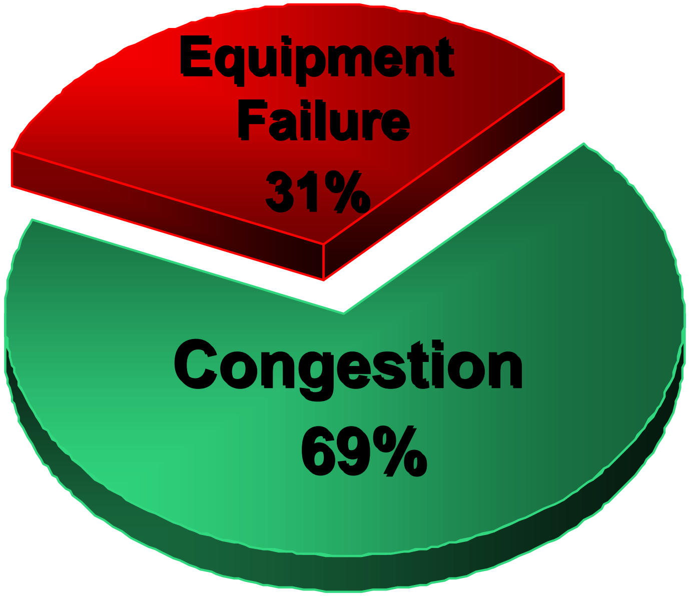
Who Cares ?

	Voice	FTP	ERP and Mission-Critical
Bandwidth	Low to Moderate	Moderate to High	Low
Random Drop Sensitive	Low	High	Moderate To High
Delay Sensitive	High	Low	Low to Moderate
Jitter Sensitive	High	Low	Moderate

Not All Traffic Is Equal

How Serious is Congestion?

Costs of Productivity Loss Due to Network Downtime



> Congestion-related performance degradation has been found to cause the majority of network downtime costs

Michael Howard
President, Infonetics Research

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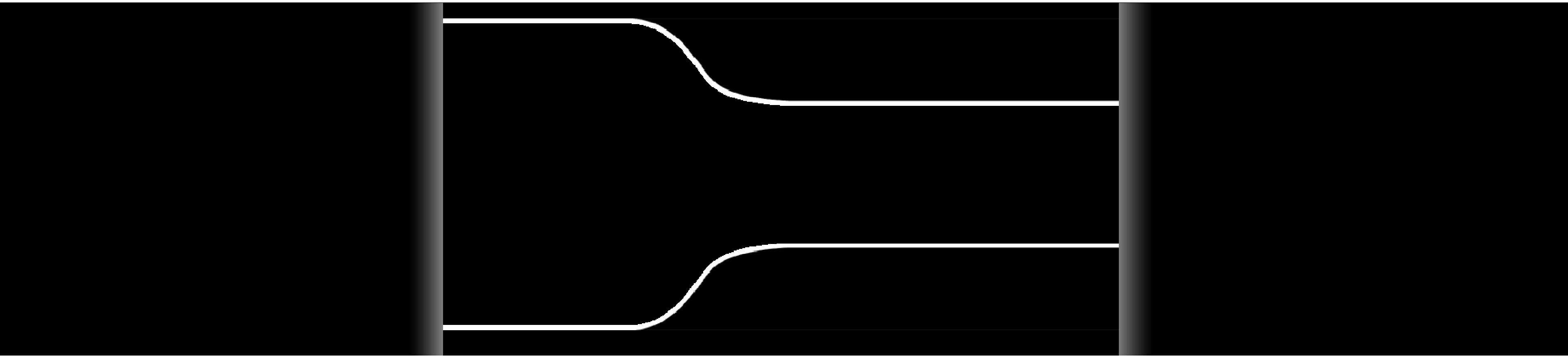
Business-Centric Network Management and Downtime Costs 1997

The Case for Quality of Service

What Happens Without QoS?



Traffic Bottlenecks

- Congested Internet uplinks
- Slowdowns at bandwidth mismatches

  LANs, WANs or VPNs

QoS Factors

Attributes Requiring Explicit Service Levels

Delay
(Latency)

Delay-Variation
(Jitter)

Packet Loss

Is More Bandwidth the Right Solution?

PROS

Increases capacity

Resolves immediate congestion problems

CONS

Short-term solution

Expensive $$$

Will not guarantee applications with low latency tolerance such as VoIP and video conferencing

All applications receive same service, no protection for mission-critical applications.

Abundant Bandwidth isn’t always Available

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QoS Service Types

- **Integrated Services (IntServ)**
- **Differentiated Services (DiffServ)**
- **Best Effort**

“IntServ” or ”DiffServ”

- Integrated Services (*RFC1633)*

  Request for resources per flow with a signalling protocol (i.e. RSVP)

- Differentiated Services (*RFC2475)*

  Manage available resources based on a “tag” associated per flow (IP prec or new DSCP)

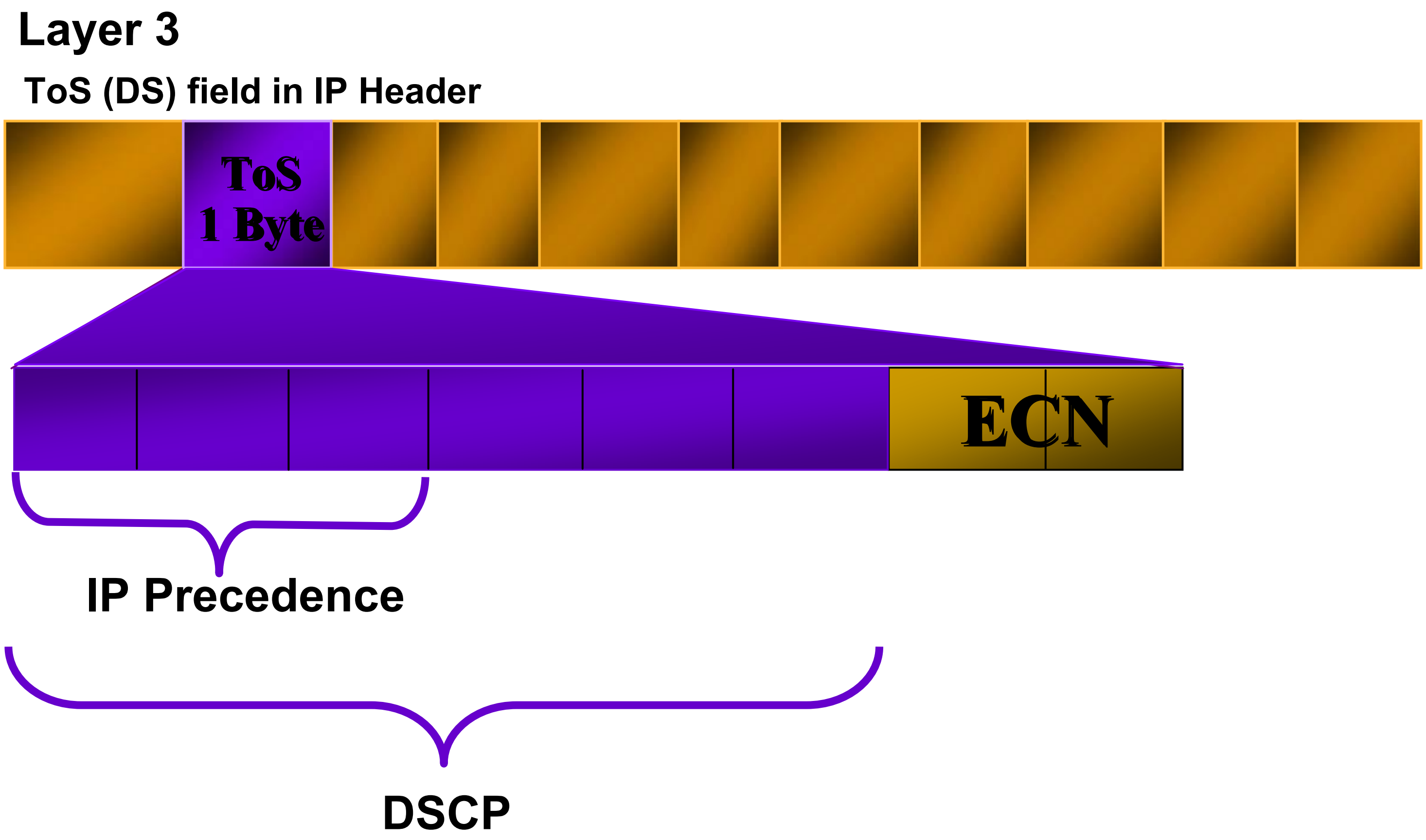
‘IntServ’ or ‘DiffServ’

- Integrated Services
  - Network needs to maintain each reservation
  - “all or nothing” mechanism
  - real time traffic oriented
- Differentiated Services
  - Define limited “flow classes”
  - more scalable, but provisioning

Differentiated Services 'DiffServ'

- **Technique for providing QoS in TCP/IP**
- **No need for per hop signaling and flow state maintenance as required by RSVP**
- **Each network device classifies, polices and schedules packets in a flow**
- **Uses the Type of Service (ToS) byte in the IP header to identify or set the priority level**
- **6 most significant bits of the ToS byte are called DSCP (DiffServ Code Point)**
- **3 of these DSCP bits identify the IP Precedence**

Layer 3 Marking – A Closer Look

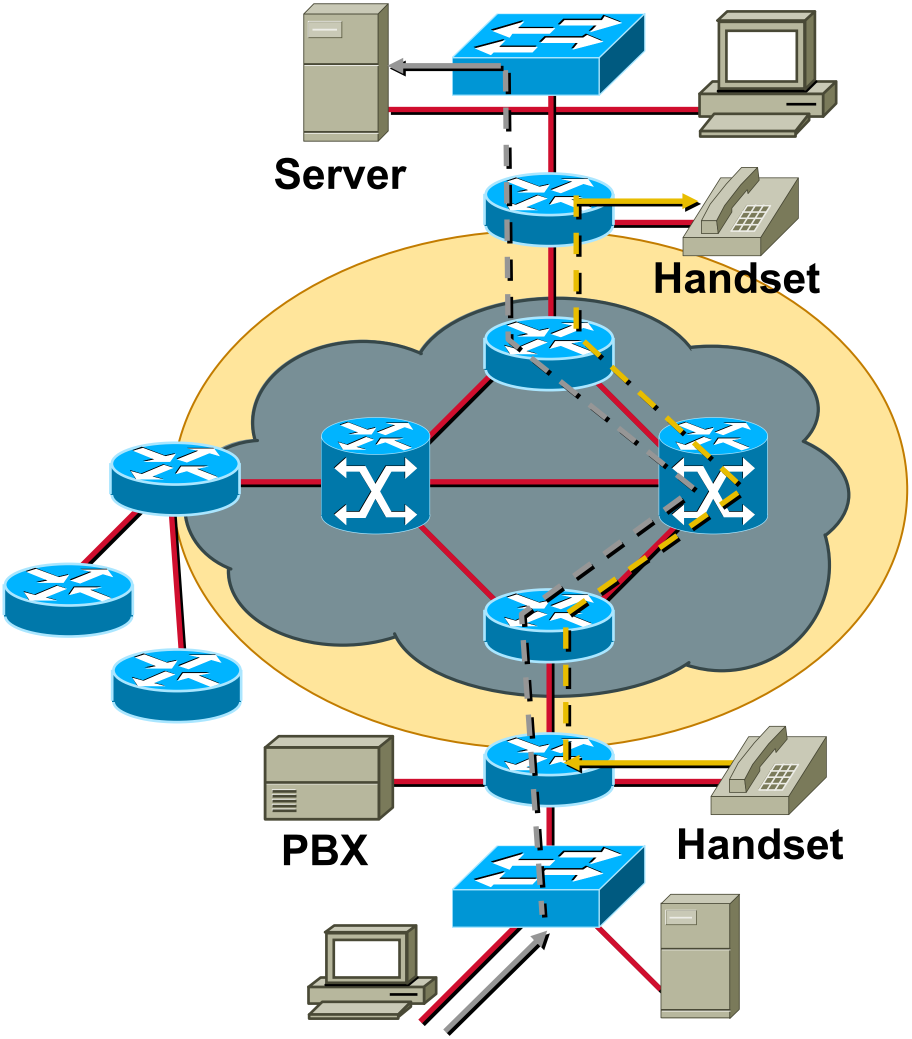


DiffServ Background Information

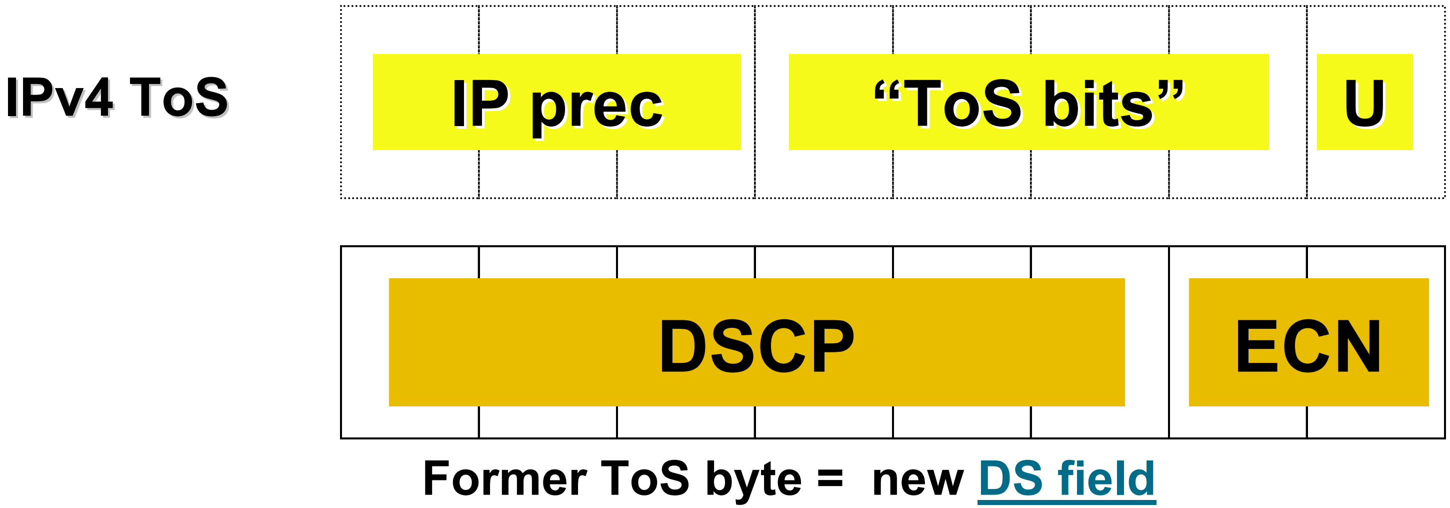
- IP Precedence marks packets into eight classes:

  0 = Best Effort
  1-5 = User Defined
  6-7 = Reserved (Network Control)

- DiffServ framework extends class model to 64 classes (DSCP)



Differentiated Service Code Point (DSCP)



Former ToS byte = new DS field

- **DS codepoint**: a specific value of the DSCP portion of the DS field, used to select a PHB
- **DS field (rfc2474)**: the IPv4 header TOS octet or the IPv6 Traffic Class octet when interpreted in conformance with the definition given in [DSFIELD]. The bits of the DSCP field encode the DS codepoint,
- ECN bits used for host Congestion Notification (RFC3168, cscdu83511)

DS field (RFC 2474, 2597, 2598)

Per-Hop Behaviours (PHB) | DiffServ Code Points (DSCP)

Expedited Forwarding	EF			46 101110		
Assured Forwarding						
	Low Drop Pref	Med Drop Pref	High Drop Pref			
Class 1	AF11	AF12		10 001010	12 001100	14 001110
Class 2	AF21	AF22		18 010010	20 010100	22 010110
Class 3	AF31	AF32		26 011010	28 011100	30 011110
Class 4	AF41	AF42		34 100010	36 100100	38 100110
Best Effort	BE			0 000000		

RFC 2598: Expedited Forwarding PHB

- **Semantic: “forward me first”**

- One recommended code point (101110) ← Notice: CSC = 5
- Characteristics: low-loss, low-latency, low-jitter
- Likely service: voice traffic
- Build up: VLL or “Premium Service”
    - –Looks like a “pipe”
    - –Uses strict ingress Policer (priority 128k = police 128k)
- Strict policer = Not TCP-friendly

RFC 2597: Assured Forwarding PHB

- **Semantic: “drop me last”**

- Uses 12 code points; 4 groups, 3 “drop preference” values in each
- AFij (i = “class”(1-4), j = “drop preference” (1-3))
- Loss probability – AFx1 <= AFx2 <=AFx3
- No reordering w/in a class (AF1y in same queue)
- Typically “mark down” within a class when out-of-profile, and use WRED to effect drop_probability
- Gradual transition to “dropping” → TCP friendly

AF PHB, An Example

AF Class 1: 001dd0

AF Class 2: 010dd0

AF Class 3: 011dd0

AF Class 4: 100dd0

dd=Drop Preference

AF12 = Class 1, Drop 2 = DSCP 001100
CSC = 001 Drop Preference = 10

Class-based Marking
DSCP and IP Prec

```
Router(config-pmap-c)#set ip dscp ?
  <0-63>   Differentiated services codepoint value
  af11     Match packets with AF11 dscp (001010)
  af12     Match packets with AF12 dscp (001100)
  af13     Match packets with AF13 dscp (001110)
  …
  af42     Match packets with AF42 dscp (100100)
  af43     Match packets with AF43 dscp (100110)
  cs1      Match packets with CS1(precedence 1) dscp (001000)
  cs2      Match packets with CS2(precedence 2) dscp (010000)
  …
  cs6      Match packets with CS6(precedence 6) dscp (110000)
  cs7      Match packets with CS7(precedence 7) dscp (111000)
  default  Match packets with default dscp (000000)
  ef       Match packets with EF dscp (101110)
```

- **Requires CEF on the interface**

RFCs to Remember

- **RFC 2475: Architecture**
  Overall intent of DiffServ Architecture and DiffServ Terminology

- **RFC 2474: DS Field**
  Details of the re-use of the ToS Byte, backward compatibility with IP Precedence, etc.

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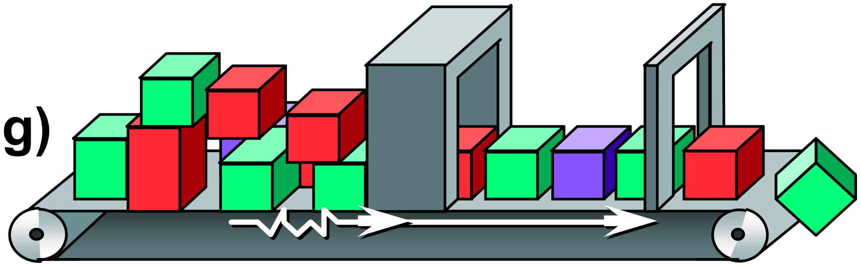
QoS components



- Classifier (ACL, NBAR,CB-marking)
- Conditioner

    Policy based Routing (PBR)

    Committed Access Rate (CAR, CB policing)

    Traffic Shaping (GTS, FTRS, CB-shaper)

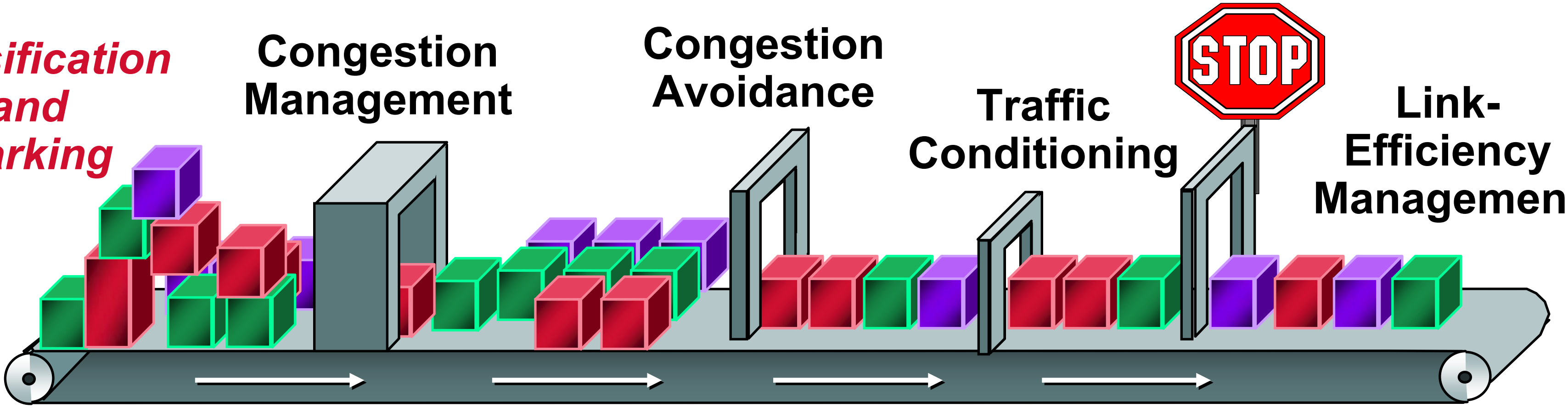
- Queuing/Scheduling

    Congestion management(PQ, CQ, WFQ, CBWFQ, LLQ)

    Congestion avoidance (wRED)

- Fragmentation and Interleaving (MLPPP, FRF11/12)

How Do We Determine What Goes Where?



Classification and Marking

Identify and/or Mark Traffic.

Congestion Management

Prioritize, Protect and Isolate Traffic, based on Markings

Congestion Avoidance

Discard specific packets to avoid congestion

Traffic Conditioning

Control bursts and conform traffic

Link-Efficiency Management

Fragment and compress for WAN efficiency

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What is Classification?

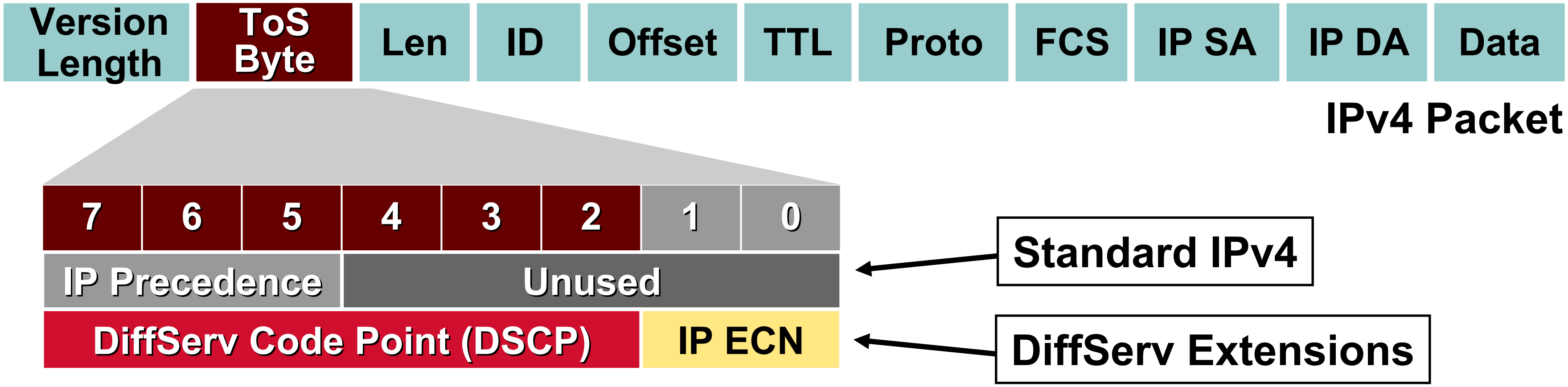
- The component of a QoS feature that recognizes and distinguishes between different traffic streams
- The most fundamental QoS Building Block
- Without classification all packets would be treated the same

What is Marking?

- The component of QoS that “colors” a packet (or frame) so that it can be identified and distinguished from other packets (or frames) in QoS treatment
- 802.1p/ISL CoS, IP Precedence, DSCP, etc.

Classification Tools

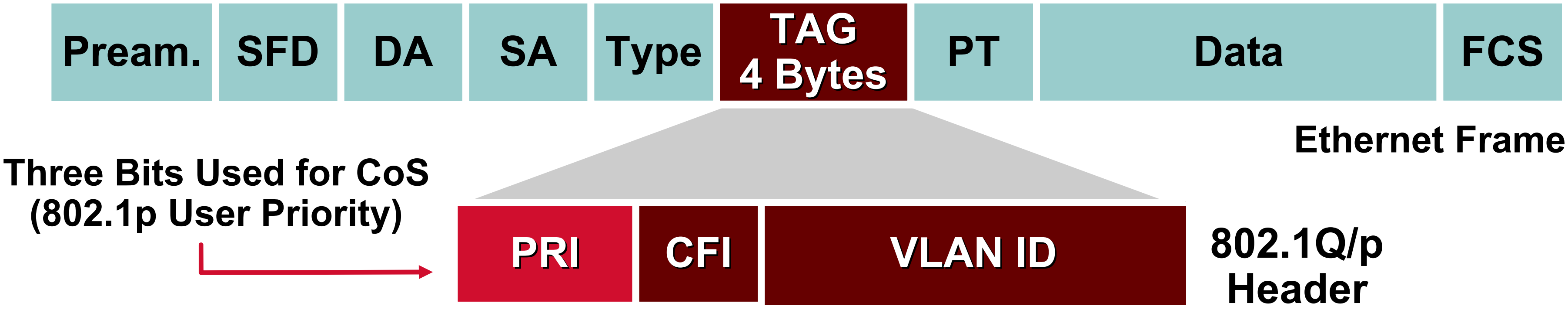
IP Precedence and DiffServ Code Points



- **IPv4**: Three most significant bits of ToS byte are called IP Precedence (IPP)—other bits unused
- **DiffServ**: Six most significant bits of ToS byte are called DiffServ Code Point (DSCP)—remaining two bits used for flow control
- DSCP is backward-compatible with IP precedence

Classification Tools

Ethernet 802.1Q Class of Service



Pream. | SFD | DA | SA | Type | TAG 4 Bytes | PT | Data | FCS

Ethernet Frame

Three Bits Used for CoS (802.1p User Priority)

PRI | CFI | VLAN ID

802.1Q/p Header

CoS	Application
7	Reserved
6	Routing
5	Voice
4	Video
3	Call Signaling
2	Critical Data
1	Bulk Data
0	Best Effort Data

- 802.1p user priority field also called Class of Service (CoS)
- Different types of traffic are assigned different CoS values
- CoS 6 and 7 are reserved for network use

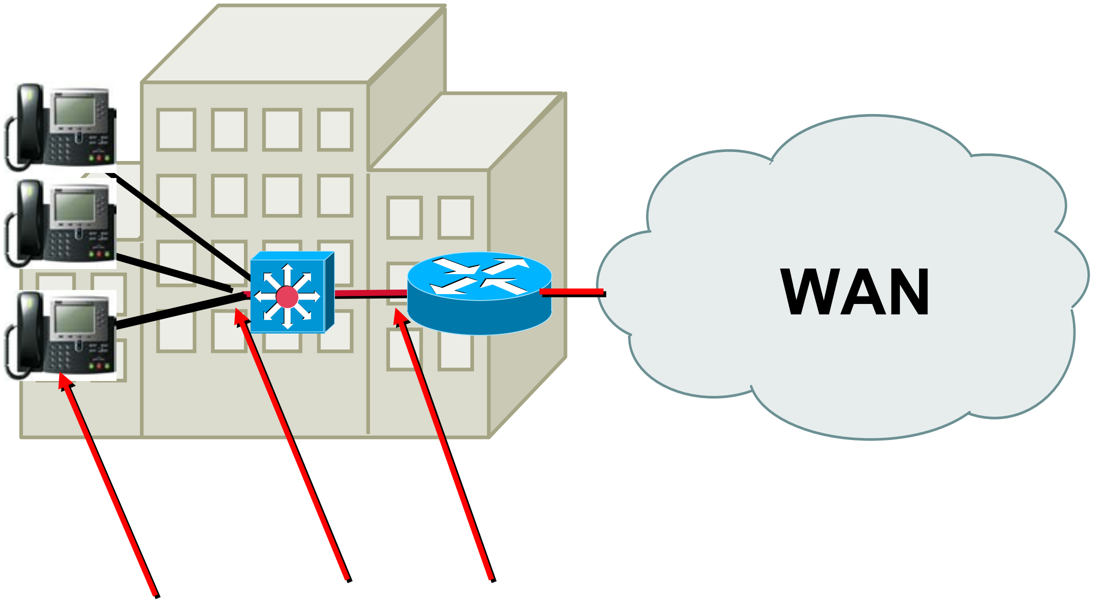
Quality of Service Operations
How Do QoS Tools Work?

CLASSIFICATION AND MARKING

QUEUEING AND
(SELECTIVE) DROPPING

SHAPING/COMPRESSION/
FRAGMENTATION/INTERLEAVE

Where Should Packets Be Marked?



As Close to the Traffic Source as Possible!

Per-Hop Behavior

- A Per-Hop Behavior (PHB) is a description of the externally observable forwarding behavior of a DS node applied to a set of packets with the same DSCP
- PHB may be defined in terms of their resources priority relative to others PHBs (Class A gets 50% more bandwidth than Class B) or the observable traffic characteristics (delay, loss, etc.)
- PHB defined in terms of behavior characteristics; does NOT mandate particular implementation mechanisms!

Classification & Marking Tools

- Class-Based Marking
- Network-Based Application Recognition (NBAR)
- Policy-Based Routing (PBR)
- Access Control List / Route-Map
- Dial Peers
- Committed Access Rate (CAR)

Basic Classification & Marking Using PBR

```
interface Ethernet0/0
        ip policy route-map lab
access-list 101 permit tcp any host 10.22.1.10
route-map lab permit 10
        match ip address 101
        set ip precedence 4
```

Committed Access Rate (CAR)*

- Two functions

  Combined Classification & Marking

  Access Bandwidth Management (Policing)
  through rate limiting
  (we will discuss this later)

* CAR is a “Legacy” QoS tool – Support with be available for several years, but no new development efforts.

Committed Access Rate (CAR)

- Rate Limiting (Policing)
- Packet Classification
- Similar to Traffic Shaping, but no Buffering

Matching specification:

- 1) All traffic
- 2) IP precedence
- 3) MAC address
- 4) IP access list

Conform Action:

- Drop, Transmit, Recolor

Exceed Action:

- Drop, Transmit, Recolor

Traffic Matching Specification

Traffic Measurement Instrumentation

Action Policy

CAR Configuration Example

```
interface Serial4/0
  bandwidth 2000
  ip address 23.1.0.1 255.255.0.0
  rate-limit output access-group 101 1544000 289500
   579000 conform-action set-prec-transmit 3 exceed-
   action set-prec-transmit 0
access-list 101 permit udp host 15.1.0.5 host 23.1.0.2
```

No packets will be dropped in this example!

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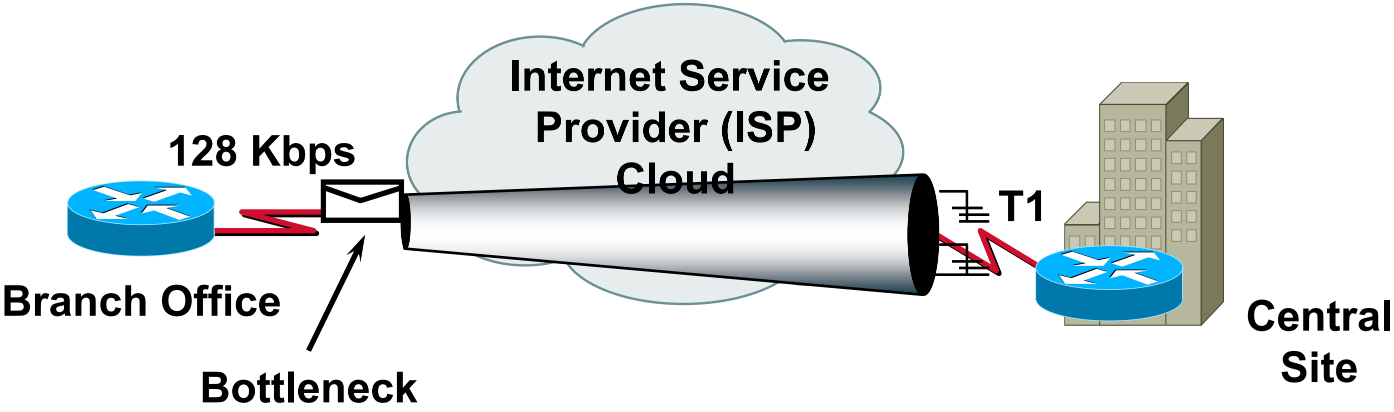
Traffic Shaping



- Reduces outbound traffic flow to avoid congestion (via buffering)
- Eliminates bottlenecks in topologies with data rate mismatch
- Provides mechanism to partition interfaces to match far-end requirements

Traffic shaping packet path

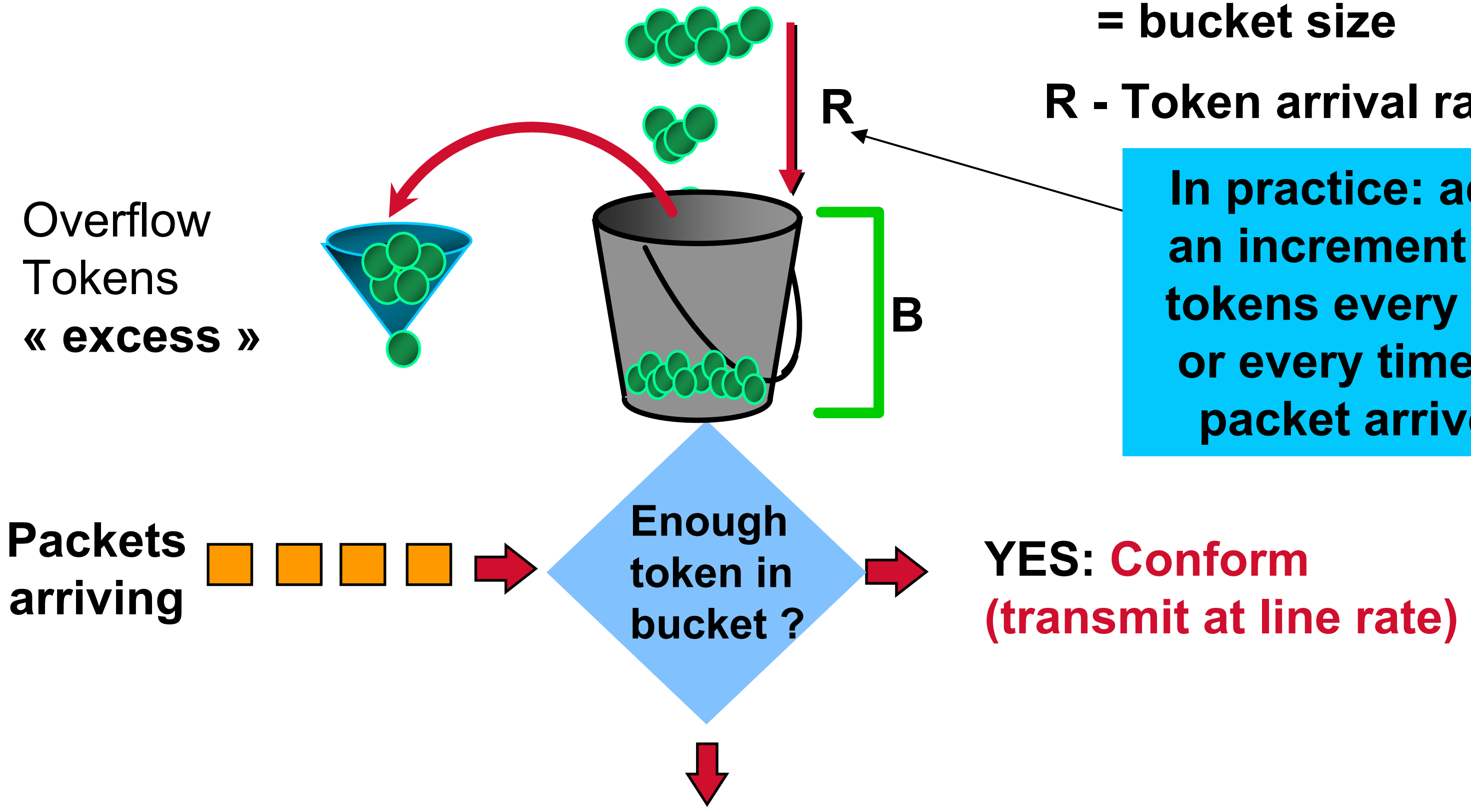
Packet path:

When a packet arrives at the interface for transmission, the following happens:

- **if the SHAPING queue is empty, the arriving packet is processed by the traffic shaper.**
  1. **If possible, the traffic shaper sends the packet to the OUTPUT queue. (Means if number of bits allowed during Tc is not reached)**
  2. **Otherwise, the packet is placed in the SHAPING queue and sent in next Tc.**
- **If the SHAPING queue is not empty, the packet is placed in the shaping queue.**

When there are packets in the SHAPING queue, the traffic shaper removes the number of packets it can transmit from the SHAPING queue every time interval.

Token/leaky bucket



B - Burst size max in bits
= bucket size

R - Token arrival rate.

In practice: add an increment of tokens every Tc or every time a packet arrive

Packets arriving

Enough token in bucket ?

YES: Conform
(transmit at line rate)

NO: Exceed (drop, enqueue or use excess)

Token/leaky bucket

- bucket is filled at defined rate with ‘tokens’ (at each Tc or elapsed time between incoming pkts)
- Incoming Packets take available tokens in bucket
- Packets can to take up to ‘burst’ bits (excess burst is just a 2nd bucket mechanism)
- If no credits in bucket, packet gets dropped (policer) or queued (shaper)

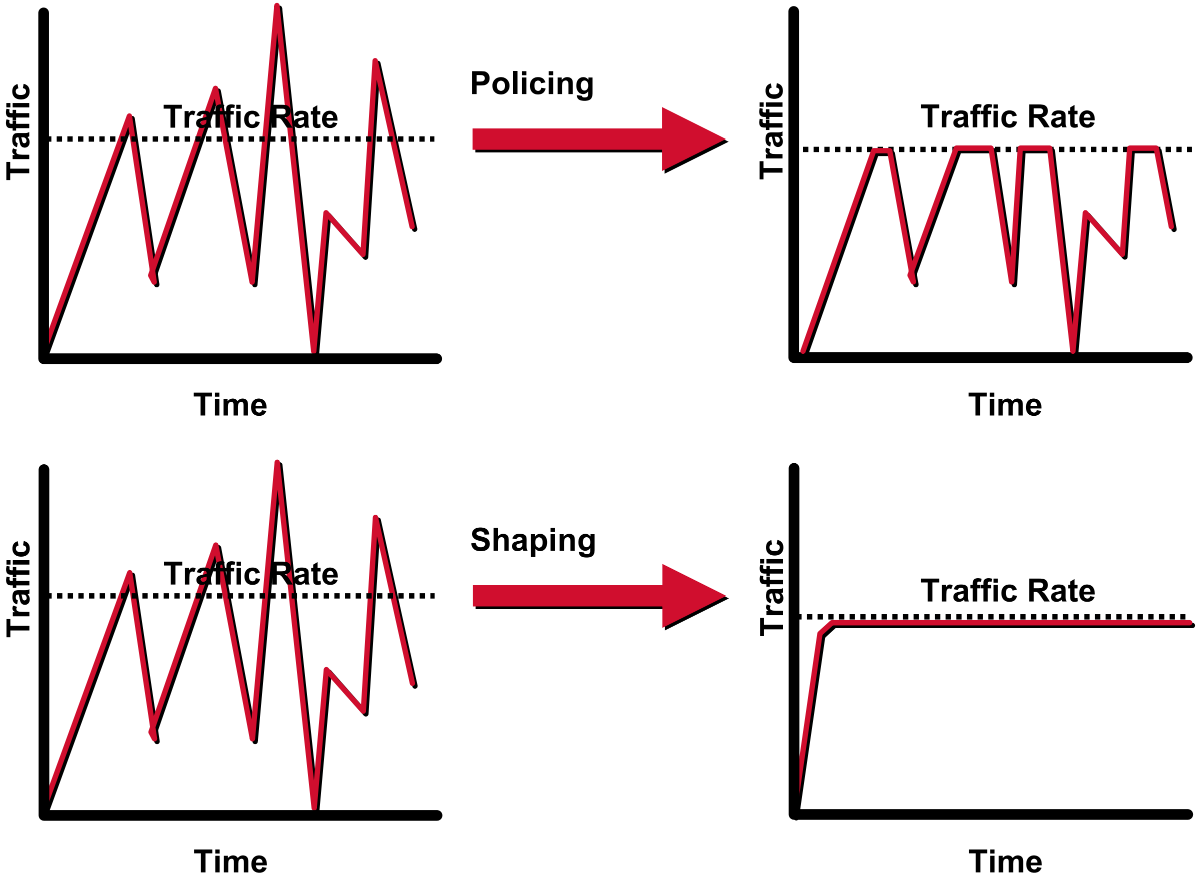
Policing vs. Traffic Shaping

- Both ensure that traffic does not exceed a (contracted) BW limit
- Both limit BW but with different impact on traffic
  - Policing drops more often - more retransmits
  - Shaping adds variable delay (buffering)
- Policer causes TCP Retransmits
  - Oscillation of Windows in TCP
- Policer can be a Marker also

Policing vs. Traffic Shaping

- Policer on input or output interface; Shaper on output interface
- Shaper ‘smooth’ traffic, policer allows bursts
- Shaper can adapt to Network congestion (BECN, FECN)
- Shaper ‘create’ shaping queues (can be use as a congestion mechanism in virtual intf like tunnel)

Policing vs. Traffic Shaping



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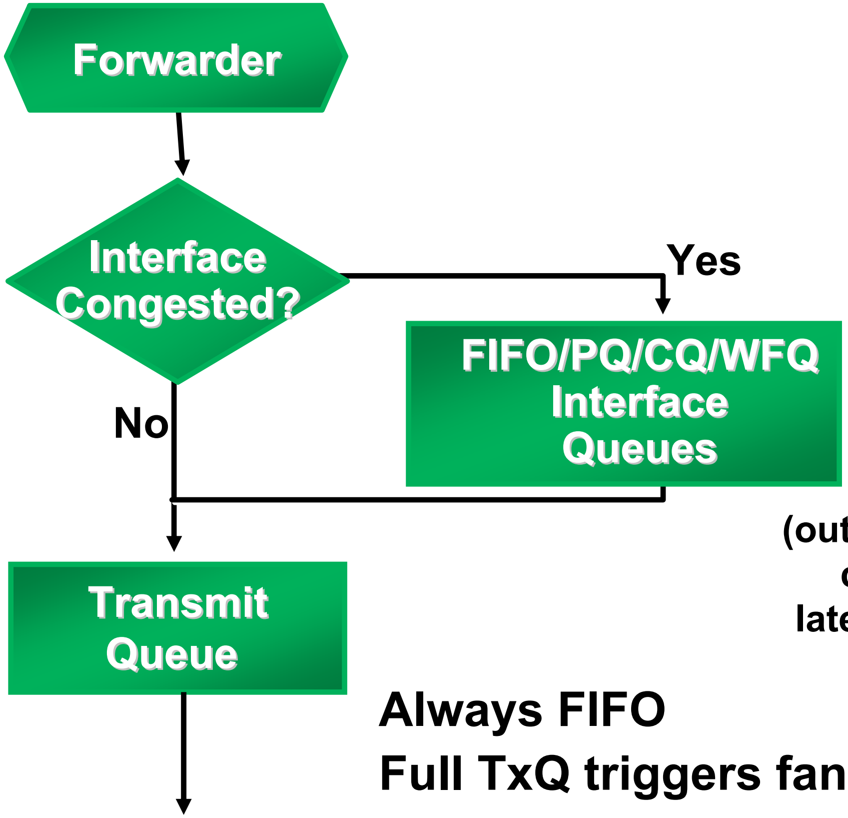
Queuing Algorithms

- First In, First Out (FIFO)
- Priority Queuing (PQ)
- Custom Queuing (CQ)
- Weighted Fair Queuing (WFQ)
- Class-Based Weighted Fair Queuing (CBWFQ)
- Low Latency Queuing (LLQ)

Transmit Queue vs. Interface Queue

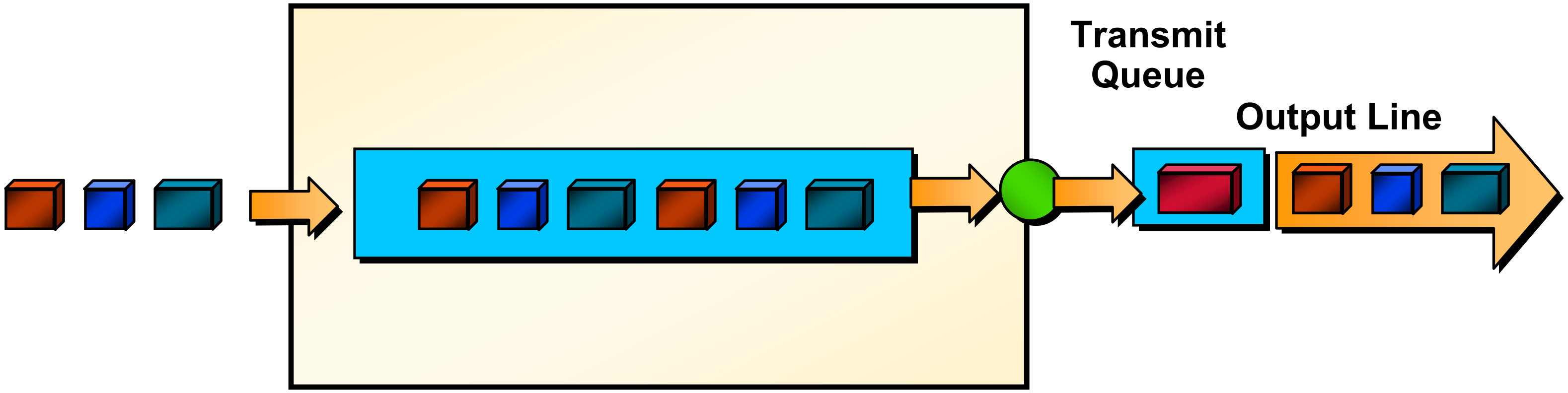


(output hold-queue compromise latency/buffering)

Always FIFO

Full TxQ triggers fancy queuing

First In First Out (FIFO)

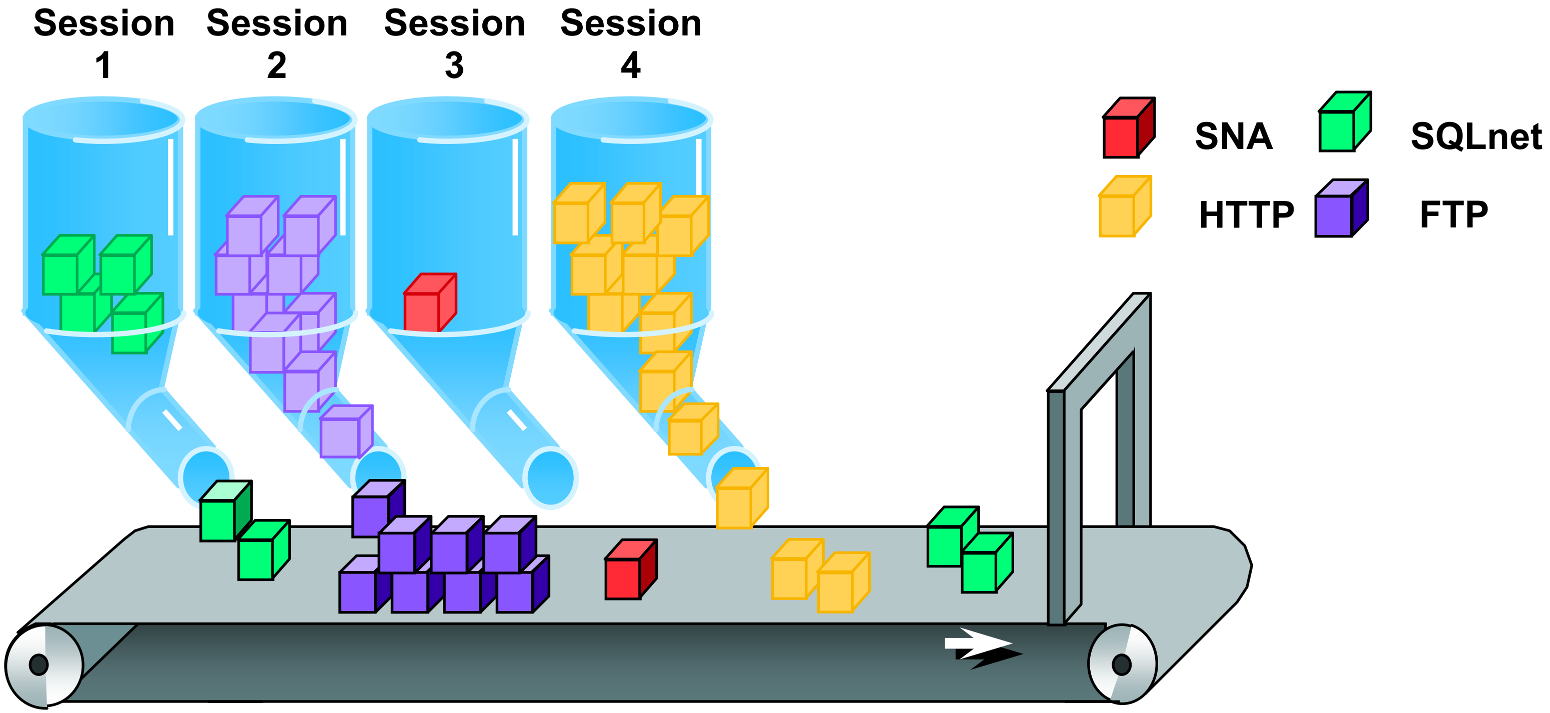


- Simplest Queuing Algorithm
- “packets leave in order of arrival”
- Fixed Queue Lengths (default 40)

  Result in dropping from tail of queue under load

Congestion Management

Prioritize traffic by re-ordering buffers on congested interfaces



Congestion Management (Queuing,CBWFQ,LLQ)

Queuing and Scheduling

The QoS feature component that determines how output queues are serviced

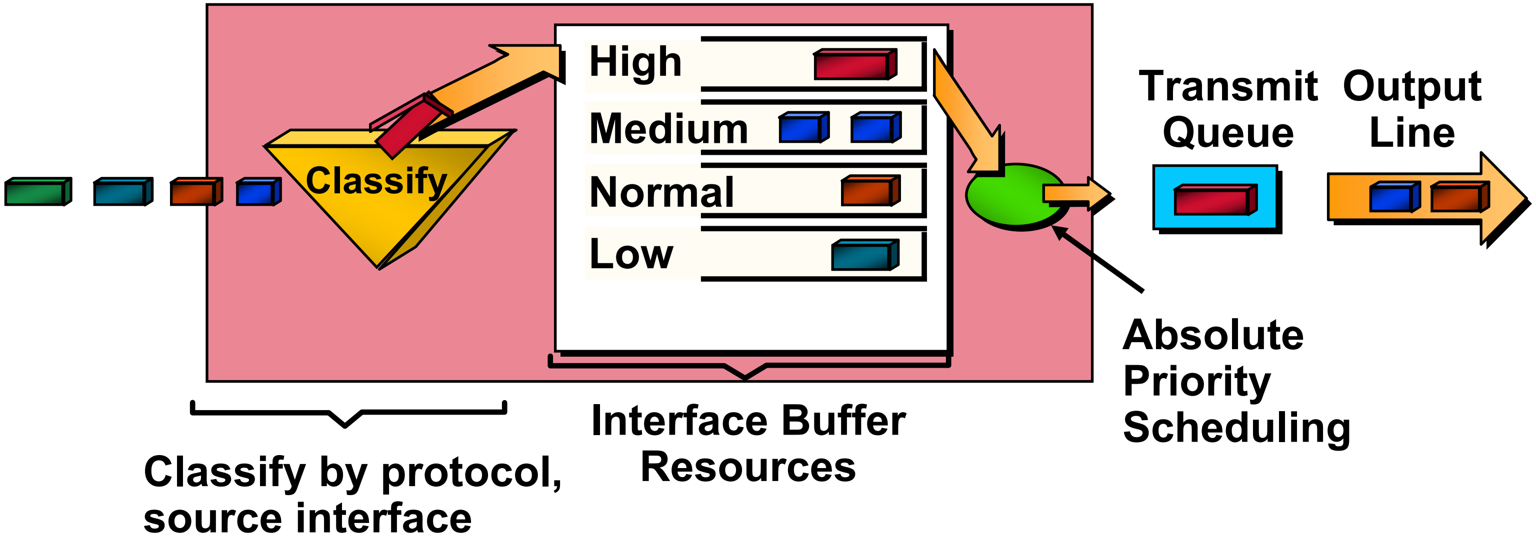
Scheduling algorithms re-order transmit queues to offer priority service to specified flows

When there is no congestion, the net effect is simply FIFO

When there is congestion, scheduling is the primary QoS action component

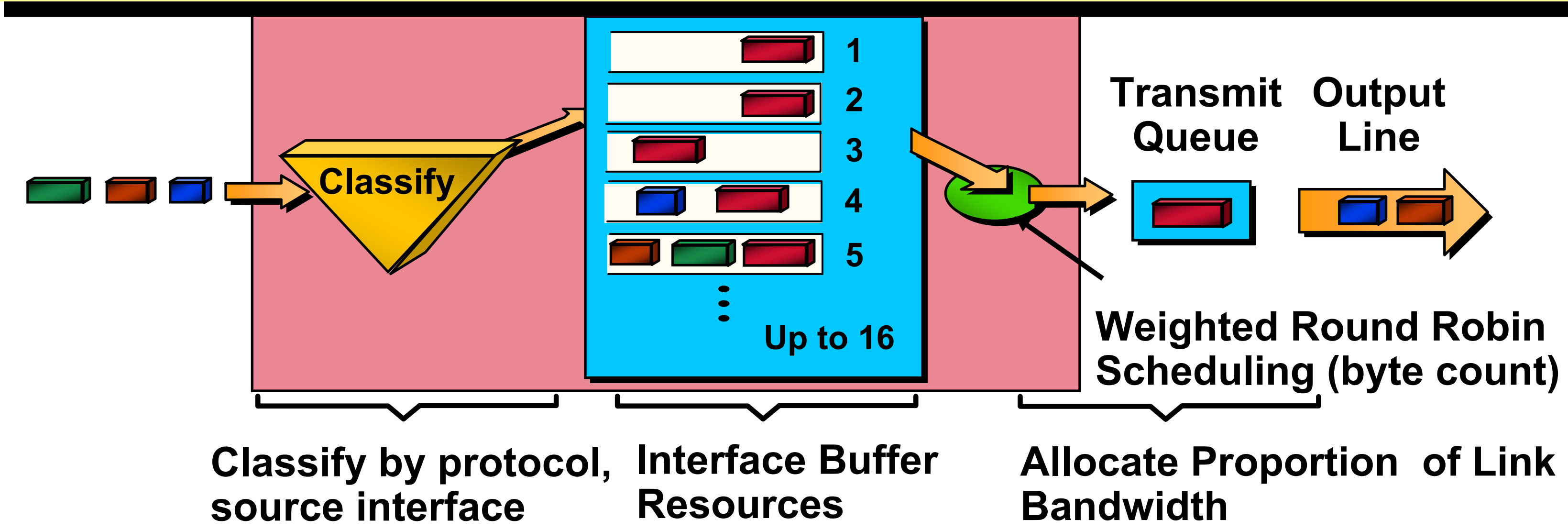
Priority Queuing (PQ)

- Rigid traffic prioritization scheme with 4 queues—high, medium, normal, low
- Unclassified packets to the normal queue
- Can result in "protocol starvation" (lower priority traffic might never be serviced)

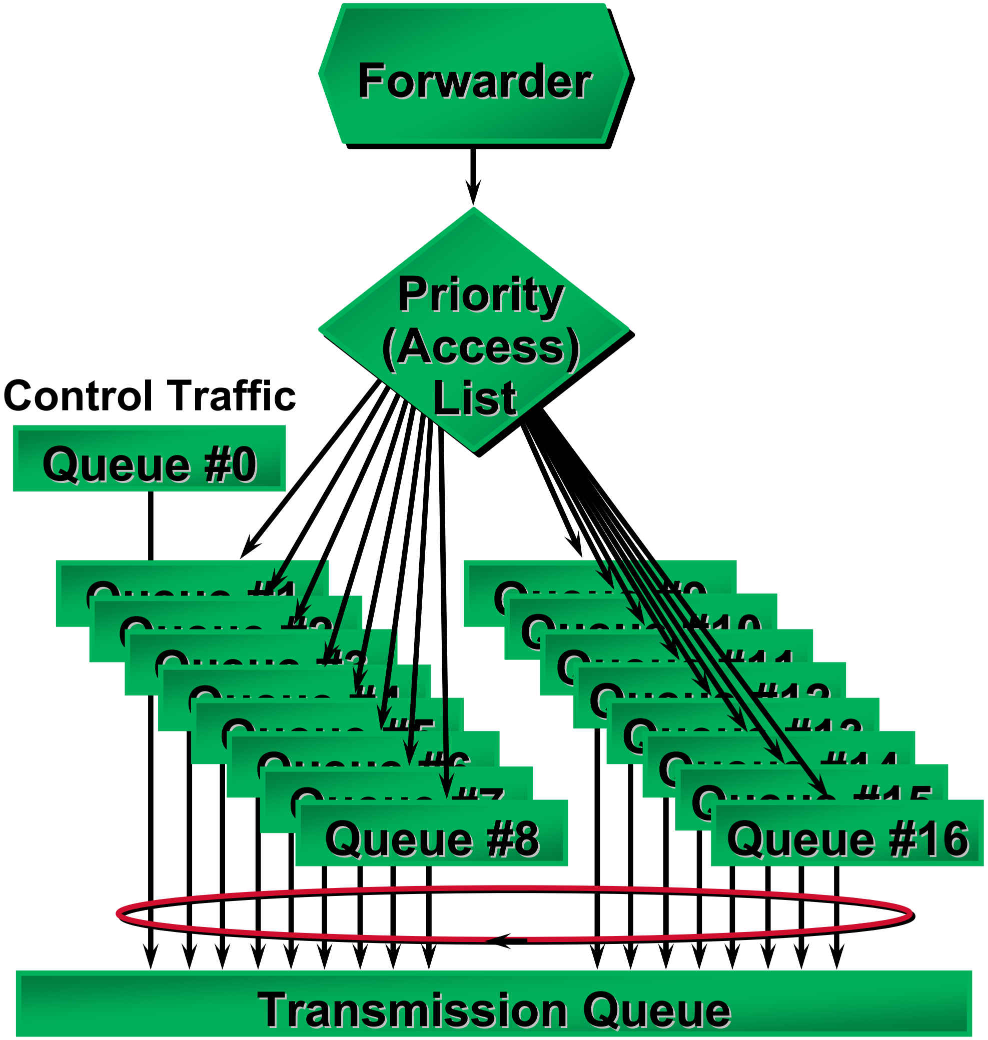


Custom Queuing (CQ)

- Flexible traffic prioritization scheme allocates minimum bandwidth to specific classes of traffic
- Up to 16 queues available
- Queues serviced in round-robin fashion
- Bandwidth specified in terms of byte count and queue length



Custom Queuing - Queues



Custom Queuing – Things to Consider

- **The average packet size of the protocol in the queue**

    If all FTP traffic goes to queue 3 with an average packet size of 600 bytes then you will want your byte count for queue 3 to be a multiple of 600

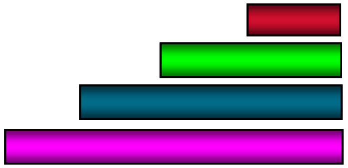
- **Once the byte count value is exceeded, the frame that is currently being transmitted will be completely sent**

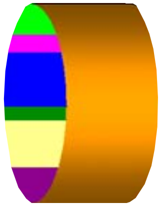
    If the byte count is 100 and the average packet size for the protocol in the queue is 1024, then the queue is actually servicing 1024 each time, not 100

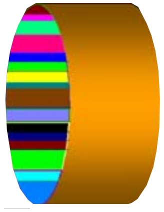
- **Large byte counts (> 10K) may result in jerky distribution much like priority queuing**

    If queue 1 has a byte count of 100K then queue 2 may wait a long time before it is serviced

Queuing and Scheduling Algorithms

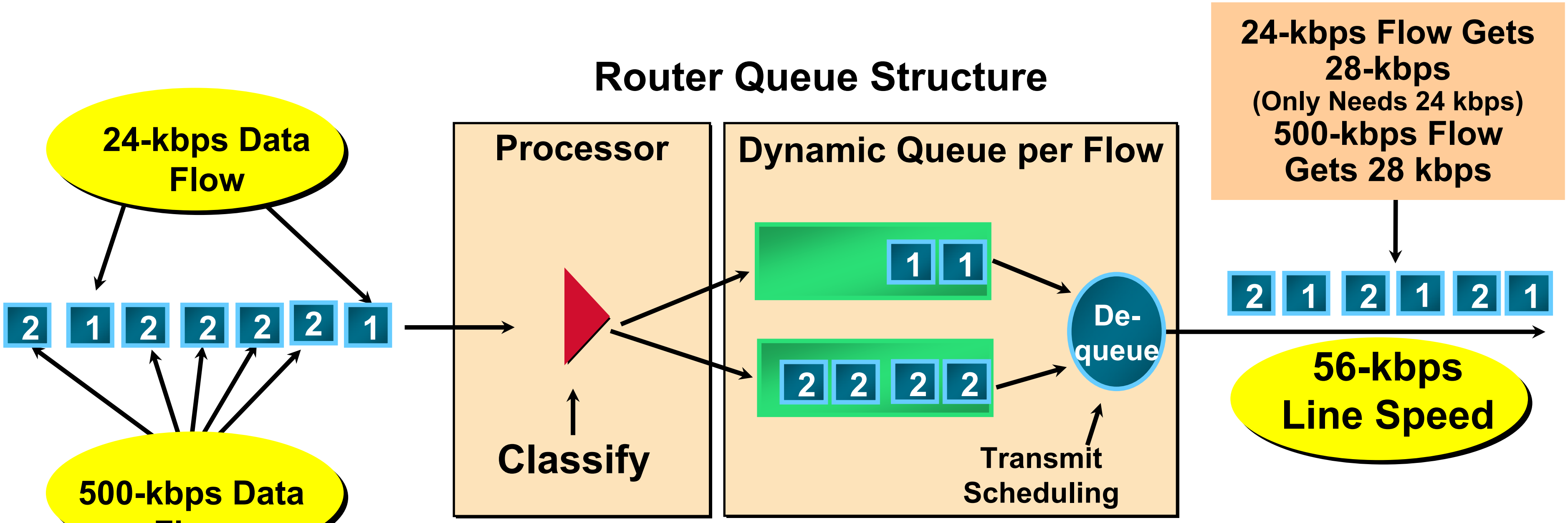






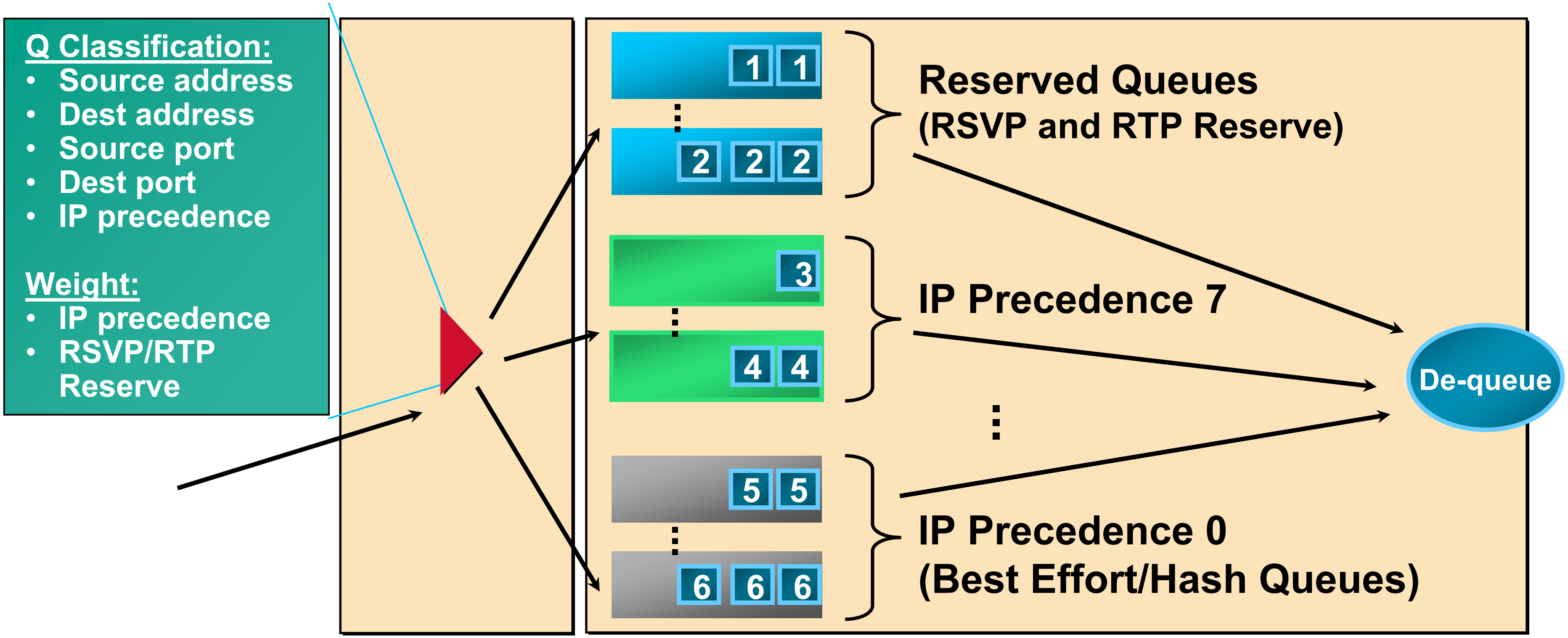
- Three Basic Queuing Algorithms
  - Priority Queuing
  - Custom Queuing
  - Weighted-Fair Queuing

Fair Queuing



- Source address
- Dest address
- Source port
- Dest port
- IP precedence

Weighted Fair Queuing



Q Classification:
- Source address
- Dest address
- Source port
- Dest port
- IP precedence

Weight:
- IP precedence
- RSVP/RTP Reserve

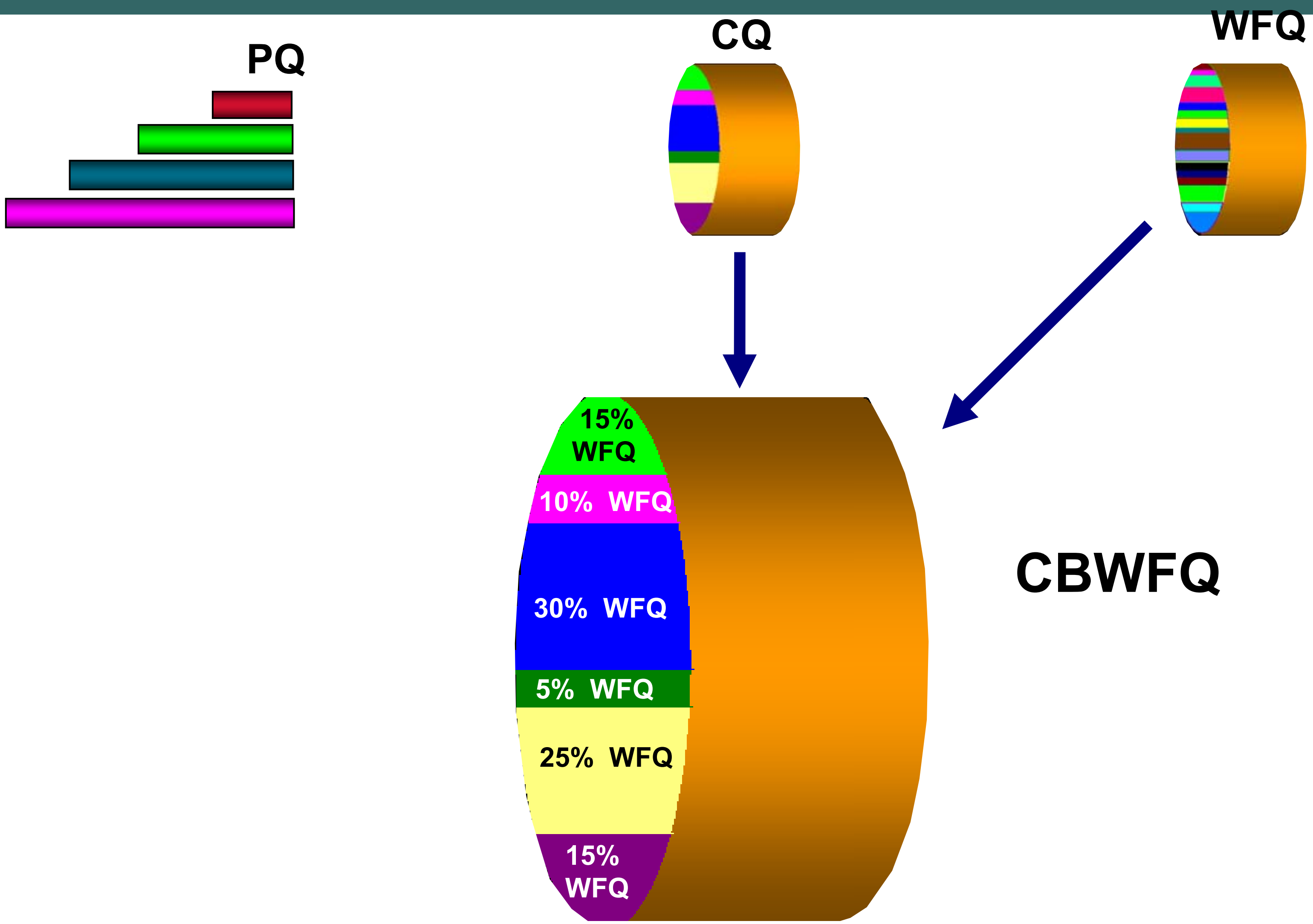
Packets within the same weight are scheduled based on arrival time

Routing protocols and LMI bypass WFQ algorithm

ALL RSVP traffic queued at weight 4, not just voice

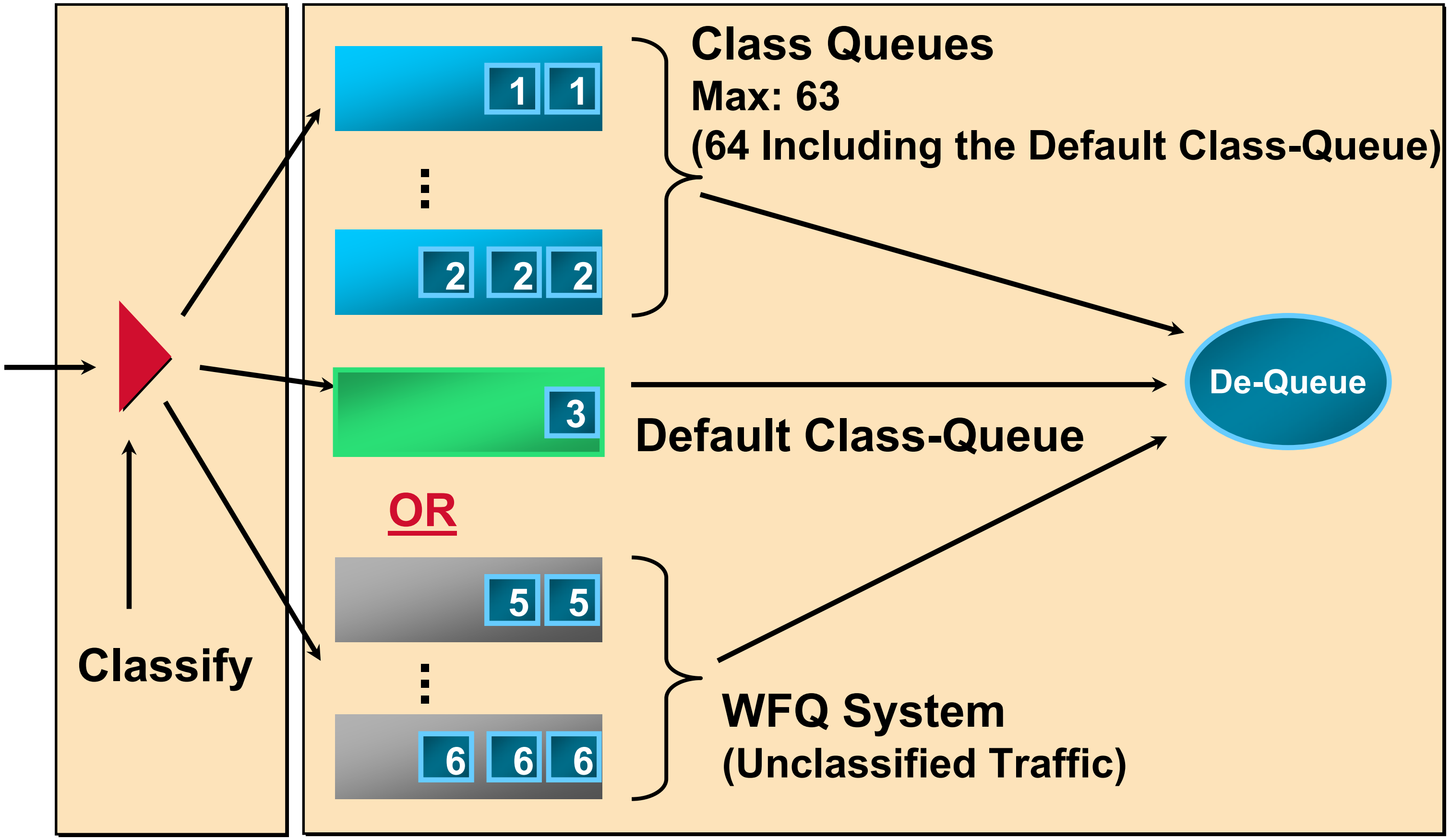
Default on serial links E1 or less

Queuing - Hybrid: CBWFQ



CBWFQ

Class-Based WFQ (CBWFQ)



Class Queues
Max: 63
(64 Including the Default Class-Queue)

Default Class-Queue

WFQ System
(Unclassified Traffic)

Classify

CBWFQ Feature Summary

- MQC interface - Classes created via match criteria
  - Protocol, interface, or access lists
- Class policies can provide:
  - *Guaranteed BW during congestion*
  - Tail drop (w/queue-limit) or WRED
- Up to 64 classes (including default class)
- Unclassified traffic to default class:
  - Fixed allocated BW, or
  - WFQ

CBWFQ: Capabilities and Benefits

- **Capabilities:**

  User-defined traffic classes based on match criteria

  Classes assigned minimum bandwidth, queue limits or drop policy

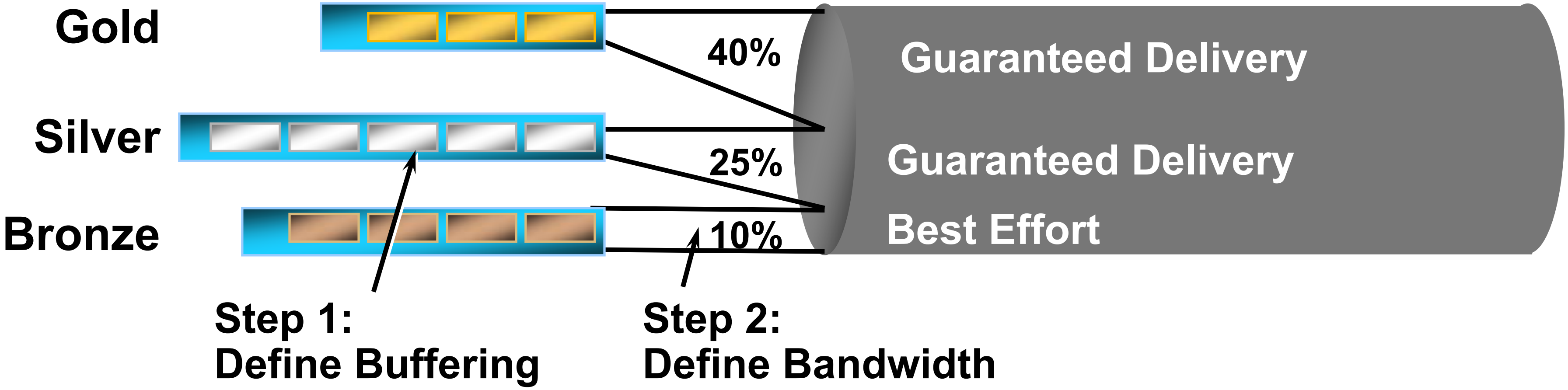
- **Benefits:**

  Minimum bandwidth allocation

  Finer granularity and scalability

  MQC interface is easy to use

CBWFQ: QoS Guarantees and Bandwidth Efficiency



- **Benefits:**
  - Maximize transport of priority traffic
  - No wasted bandwidth as with PVCs
  - Bandwidth allocation
  - Finer granularity and scalability
  - Modular QoS CLI (MQC) is easier to use

Weights guarantee minimum bandwidth

Unused capacity is shared among the other classes

Each queue can be separately configured for QoS

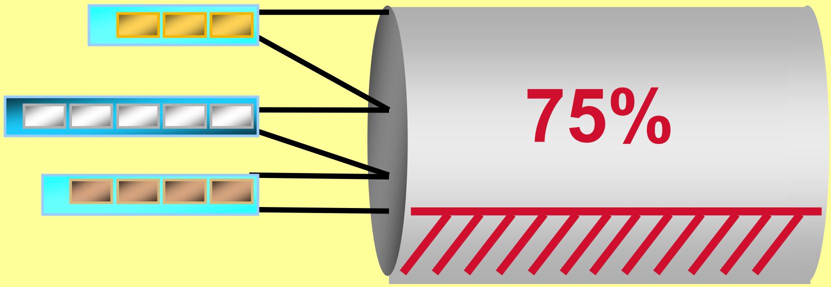
WFQ vs. CBWFQ

- All traffic within a class treated equally
  - *derived*
  - *No BW guarantee*
  - No limit on incoming traffic
  - No configuration required (default on serial thru E1)
  - Better service to interactive traffic w/ small packets
  - With many flows, can be "too fair"
  - Weighted w/IP Precedence

- Specify traffic classes
  - Tail-drop/WRED
  - *BW given; weights derived*
  - *Minimum BW guarantee*
  - Policing on incoming traffic
  - Easy MQC configuration
  - Default: 75% of BW allocatable
  - Classify by ACL, protocol, interface
  - Unused BW shared

75 Percent Rule

- Add up:
  - Class bandwidths
  - RSVP maximum reserved bandwidth



- Result must be less than or equal to 75% of interface bandwidth (or FR DLCI MinCIR)
  - Leaves headroom for call signaling, SNMP, management (LMI) and routing traffic

- *Max-reserved-bandwidth* command overrides 75% limit, but be careful!

CBWFQ Configuration Example

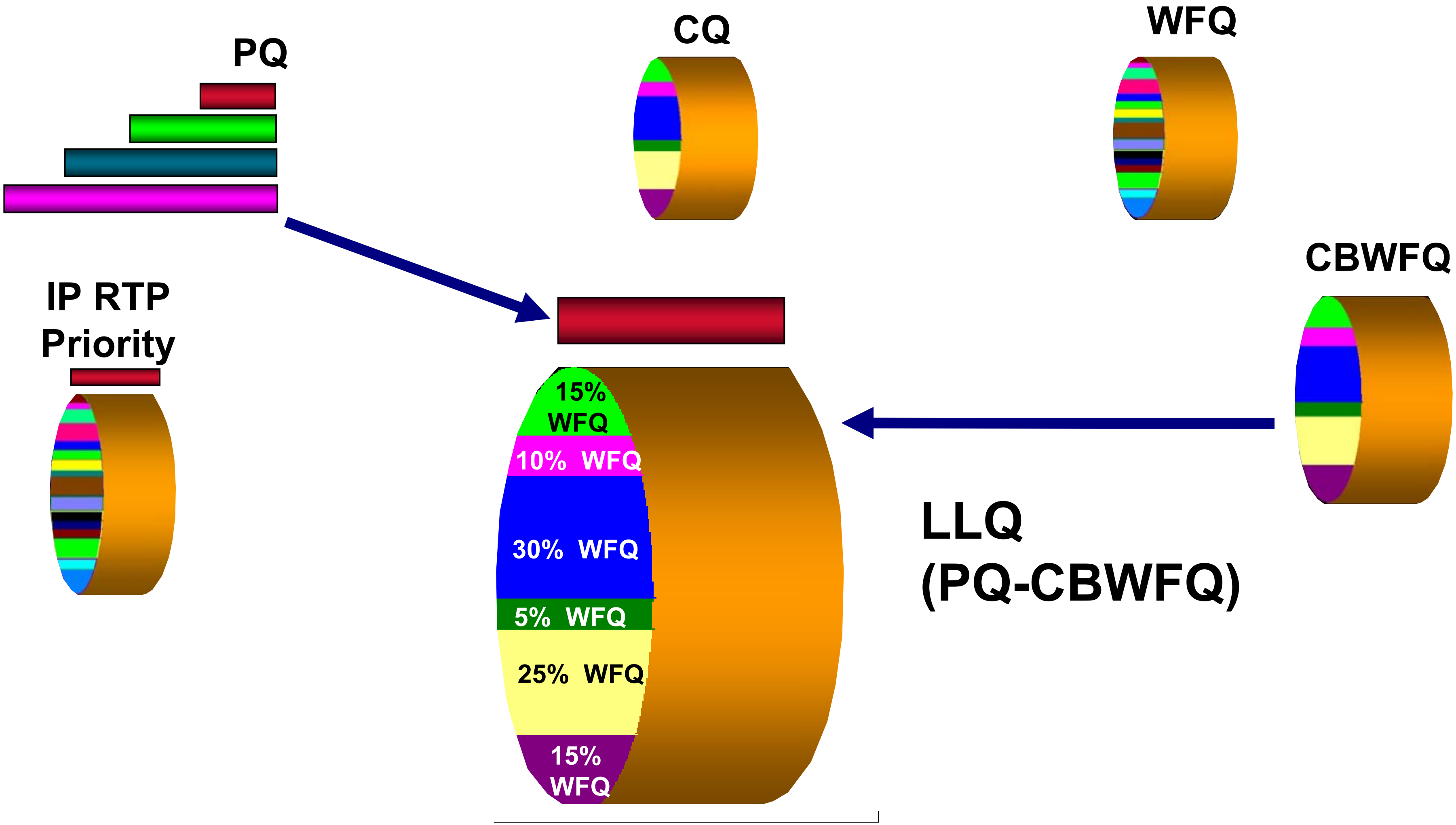
This is the traffic we care about

```
Router(config)# class-map class1
Router(config-cmap)# match input-interface FastEthernet0/1
!
Router(config)# policy-map policy1
Router(config-pmap)# class class1
Router(config-pmap-c)# bandwidth 1000
Router(config-pmap-c)# random-detect
!
Router(config)# interface serial0/0
Router(config-if)# service-policy output policy1
```

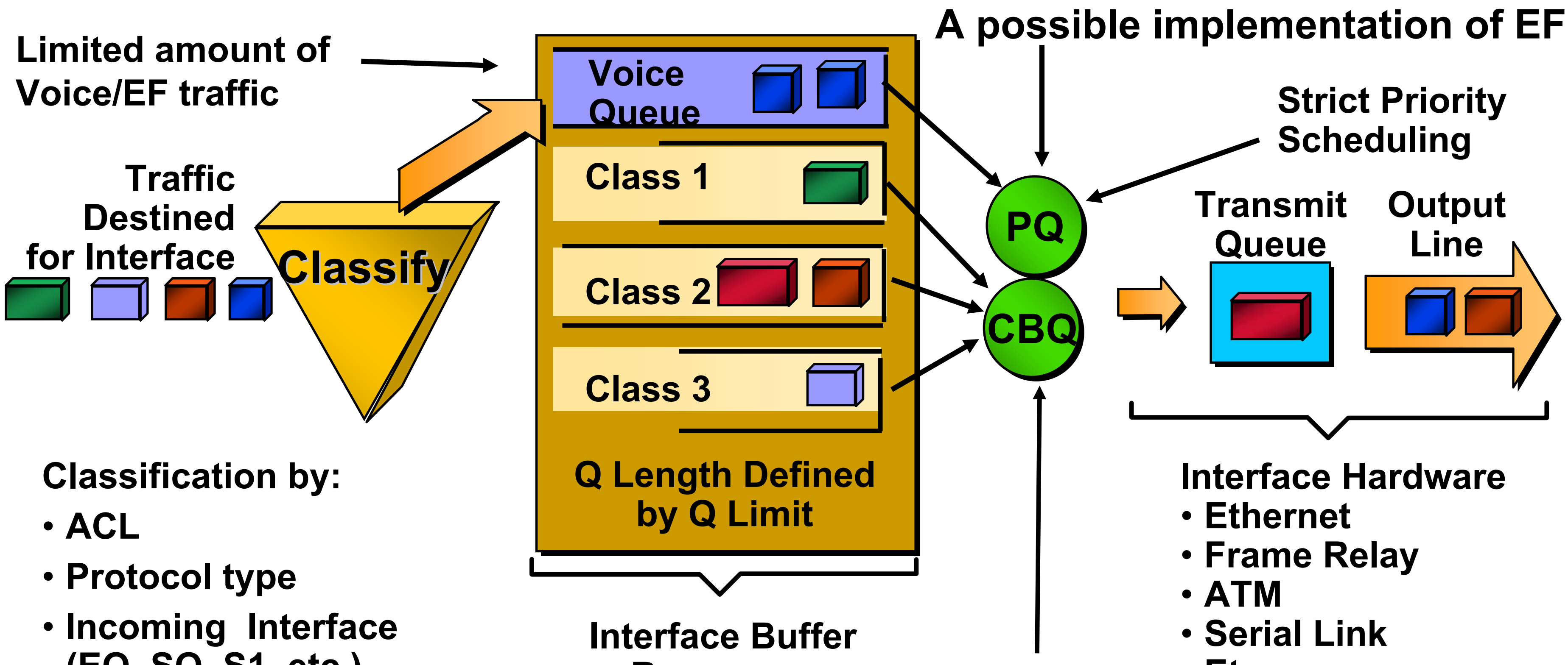
This is the policy for the traffic we care about.

This is where we enforce the policy.

Queuing - LLQ – Low Latency Queuing (PQ-CBWFQ)



Low Latency Queuing (LLQ)



A possible implementation of EF

Limited amount of Voice/EF traffic

Traffic Destined for Interface

Classify

Voice Queue

Class 1

Class 2

Class 3

Q Length Defined by Q Limit

PQ

CBQ

Strict Priority Scheduling

Transmit Queue

Output Line

Interface Buffer Resources

CBWFQ

Classification by:
- ACL
- Protocol type
- Incoming Interface (EO, SO, S1, etc.)
- MPLS EXP field

Interface Hardware
- Ethernet
- Frame Relay
- ATM
- Serial Link
- Etc.

Provides low latency and reduced jitter for Voice

LLQ Benefits

- Consistent configuration and operation across all media types
  - Frame Relay
  - Leased lines
  - ATM
- Entrance criteria to a class can be defined by an ACL
  - Not limited to UDP ports as with IP RTP priority
  - Use of IP RTP priority should be phased out
  - Ensure trust boundary is defined to ensure simple classification and entry to a queue

Configuration Example:
Low Latency Queuing (LLQ)

```
Router(config)# policy-map wan_policy
Router(config-pmap)# class Gold
Router(config-pmap-c)# priority 512
Router(config-pmap)# exit
Router(config-pmap)# class Silver
Router(config-pmap-c)# bandwidth 256
Router(config-pmap)# exit
Router(config-pmap)# class class-default
Router(config-pmap-c)# fair-queue 10
```

LLQ – Notable Points

- One Priority Queue (PQ)
- Multiple Priority Classes
- PQ – min b/w guarantee + rate limiting

Queuing Methods: Pros and Cons

Method	Advantages	Disadvantages
PQ	Absolute priority for one traffic class	Potential protocol starvation
CQ	Guaranteed bandwidth to a few critical applications	Must create policy statements on the interface
WFQ	User classification not required; on by default	Cannot guarantee bandwidth for any class; too fair if many flows
CBWFQ	Bandwidth-defined traffic classes (up to 64)	No priority queue
IP RTP Priority	Suitable for voice; PQ without protocol starvation	Limited to UDP/RTP ports; no per-call call admission
LLQ	Suitable for voice; guaranteed b/w and latency; not just UDP ports	Classification not automatic

Queuing Summary

	PQ	CQ	WFQ	CBWFQ	IP RTP Priority (PQ-WFQ)	LLQ (PQ-CBWFQ)
Classification	Protocol, interface	Protocol, interface	IP Prec, RSVP, protocol, port	Mod CLI	VoFR and IP RTP Priority	VoFR and Mod CLI
# queues	4	16	Per flow	64 classes	1 PQ + WFQ	1 PQ + CBWFQ
Scheduling	Strict priority	Round-robin	Fair (weight, arrival time)	Fair: weight and BW	PQ: Strict WFQ: Fair	PQ: Strict CBWFQ: Fair/BW
Delay guarantee	Yes	No	No	No	Yes	Yes
BW Guarantee	No	No	No	Yes	PQ: yes WFQ: No	Yes
Used for Voice	No	No	Last resort	No	Yes	Yes

Agenda

- What is QoS?
- QoS Service Types
- QoS Components
- Classification & Marking
- Traffic Shapping x Policing
- Queuing Algorithms
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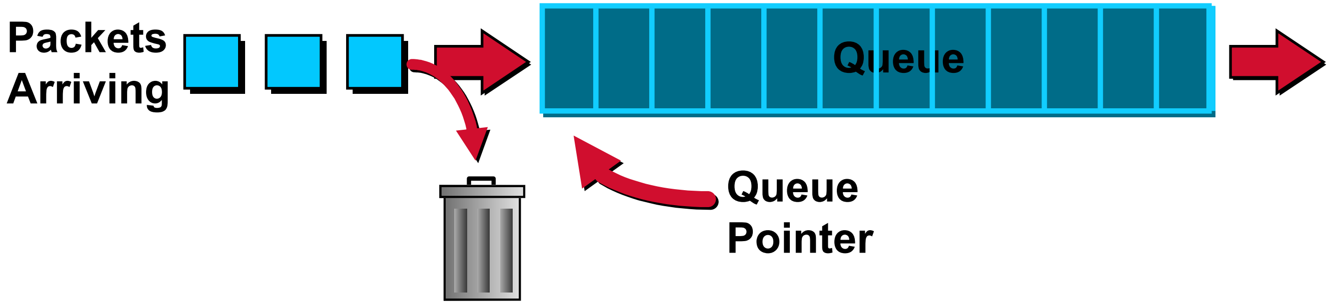
- QoS and MPLS
- QoS requirements of Voice, Video and Data

Congestion Avoidance Random Early Detection (RED)



- **Without RED when the queue fills up ALL packets that arrive are dropped—Tail drop**
- **With RED as oppose to doing a tail drop the router monitors the average queue size and using randomization choose connections to notify that a congestion is impending**

RED

- **The average queue size is calculated based on the previous average and the current size of the queue**

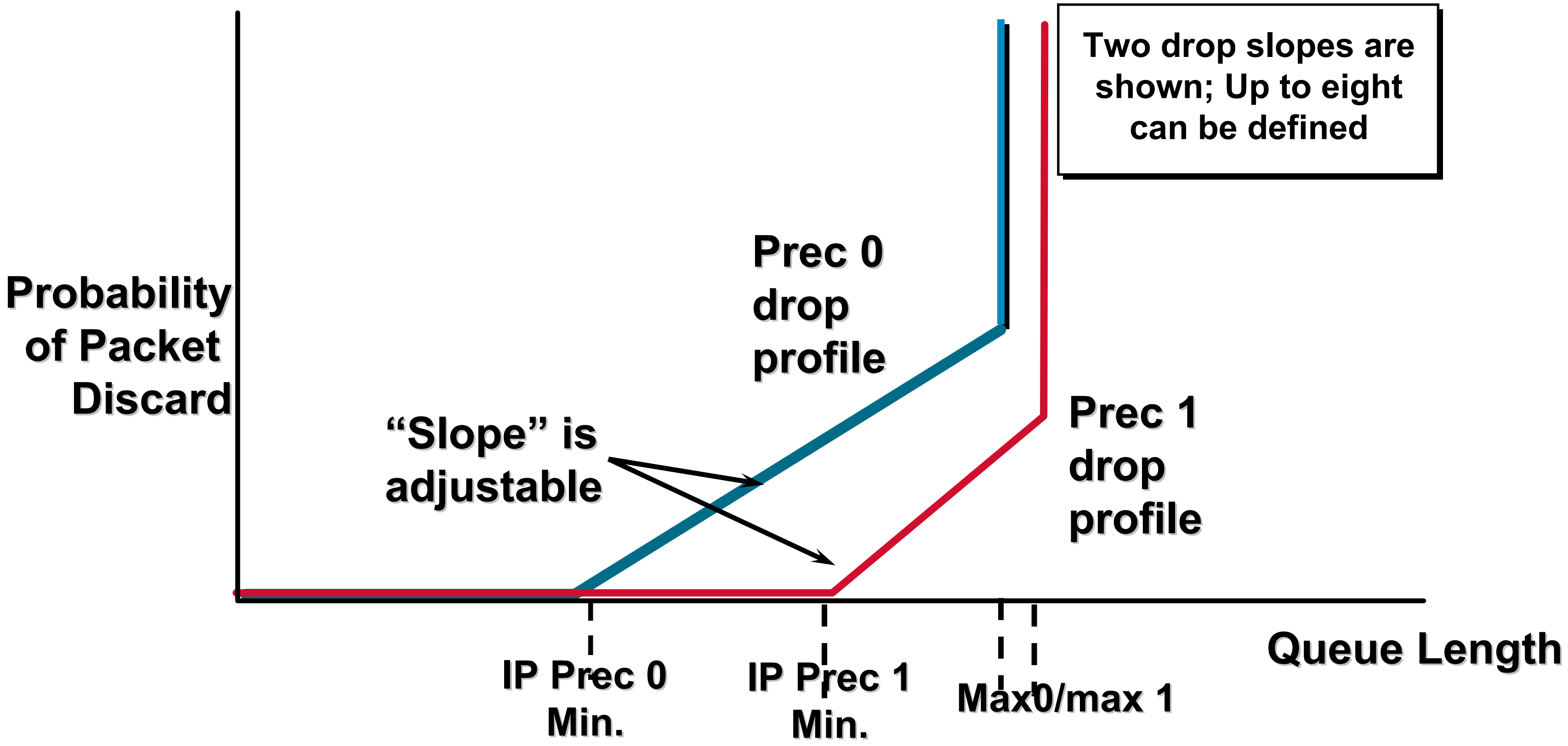
Avg = (old_avg * (1 - 1/2^n)) +
current_queue_size * 1/2^n)

- **'n'** *exponential-weight-constant* keyword
- **'P': drop probability**

prob = mark_prob * (avg - min_th) / (max_th - min_th)

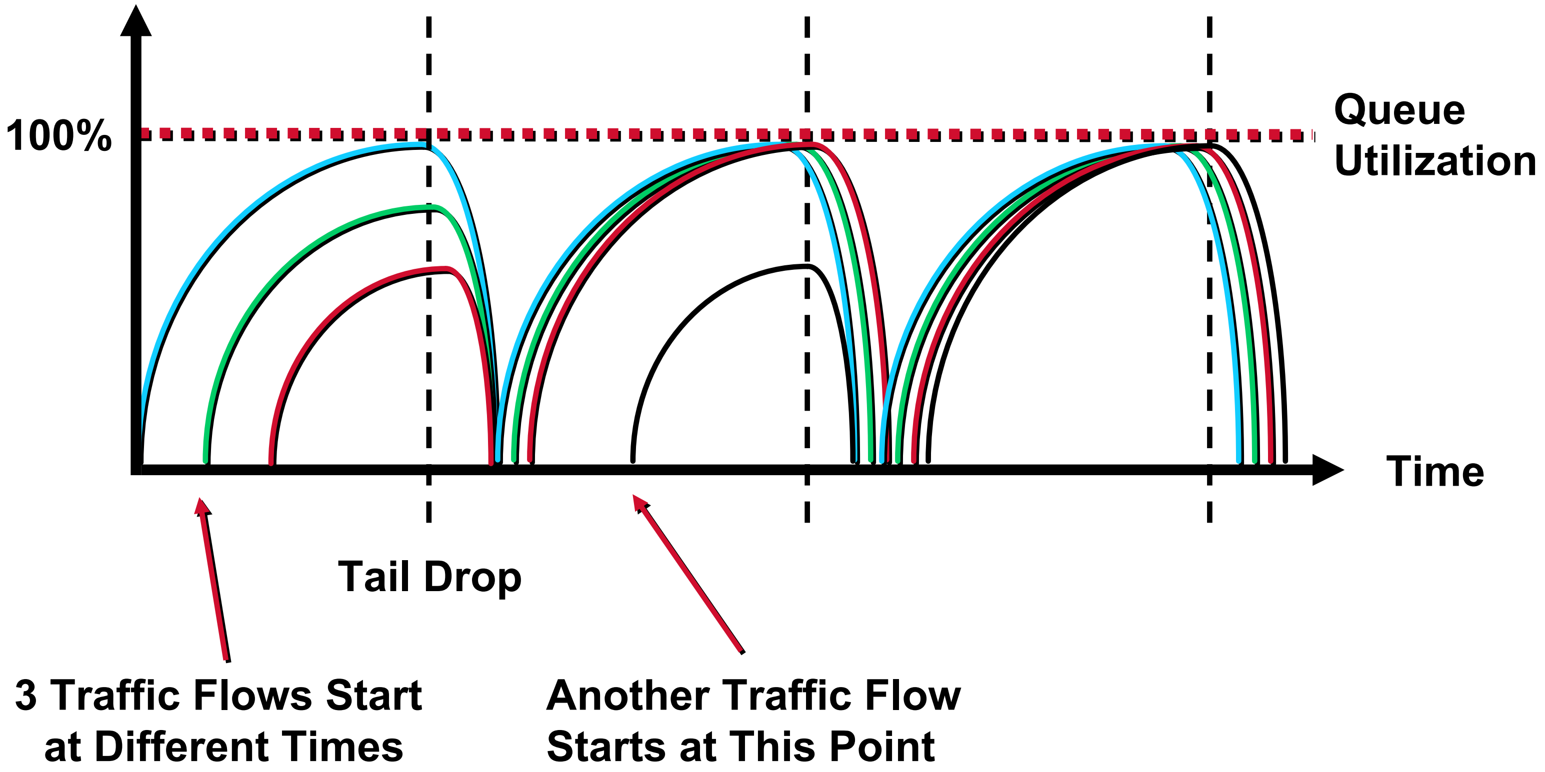
default *mark_prob* = 1/10

weighted RED



- Configure min and max threshold per IPprec (or per DSCP drop pref)

TCP and tail drop
‘global synchronization’



3 Traffic Flows Start at Different Times

Another Traffic Flow Starts at This Point

wRED

- Dropping a message is a way of telling the sender to slow down
- Randomly drop (instead of tail drop) avoid ‘global synchronization’
- Weighted drop thresholds based on IP Prec
- Good for TCP traffic

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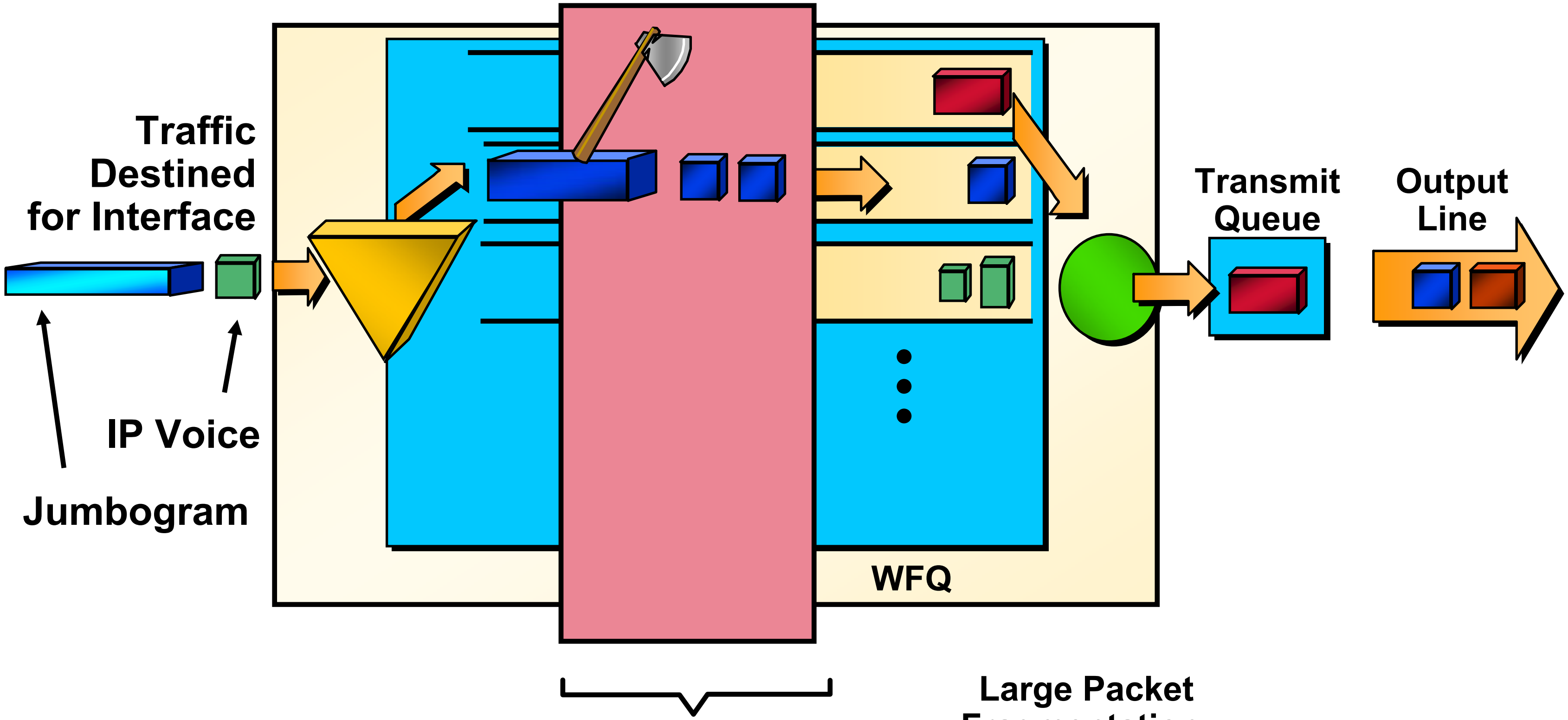
Link Efficiency Management

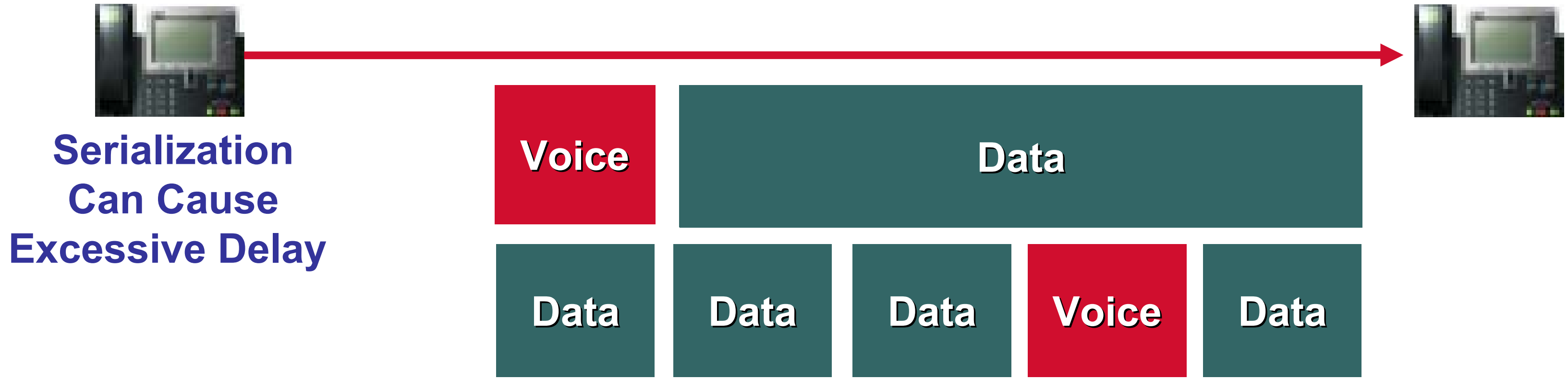


Multlink PPP
with LFI
Or Frame
Realy with
FRF 11/12

Large Packet
Fragmentation:
Fragment Size Based
on Required Delay

Link-Specific Tools

Link-Fragmentation and Interleaving

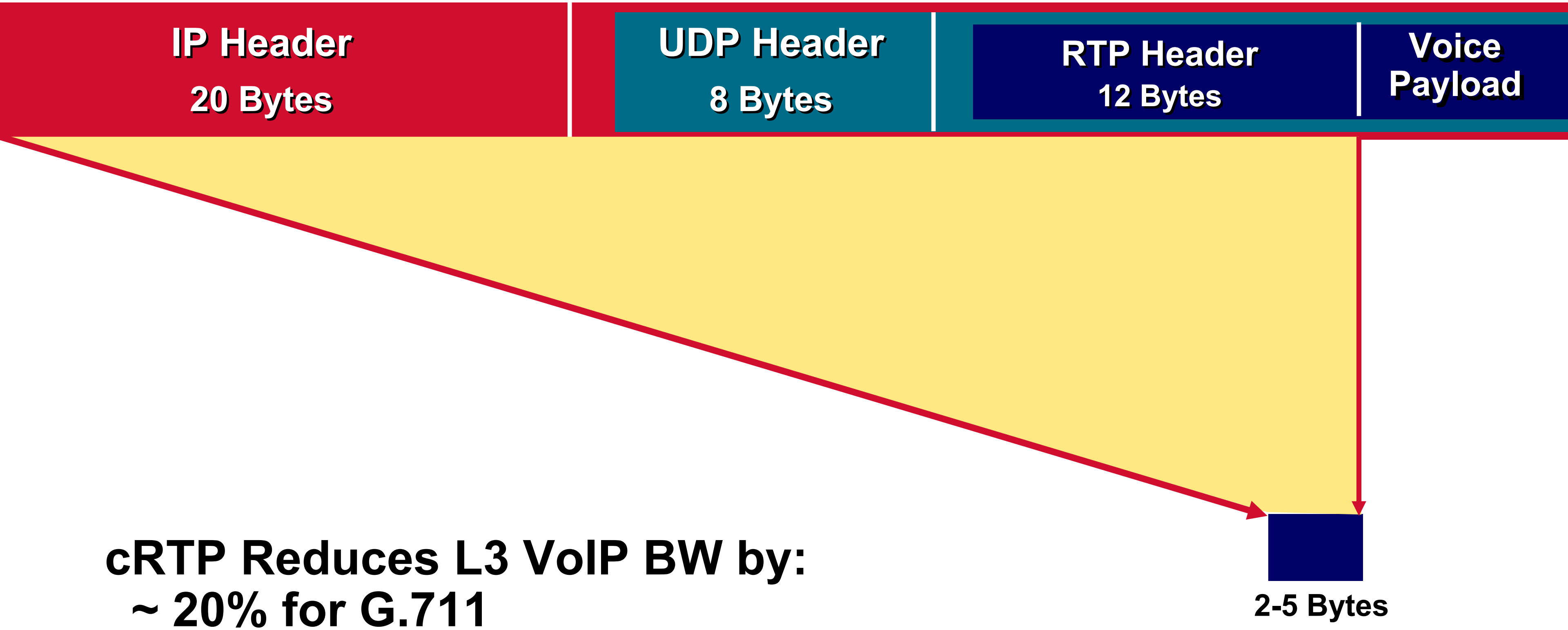


With Fragmentation and Interleaving Serialization Delay Is Minimized

- Serialization delay is the finite amount of time required to put frames on a wire
- For links ≤ 768 kbps serialization delay is a major factor affecting latency and jitter
- For such slow links, large data packets need to be fragmented and interleaved with smaller, more urgent voice packets

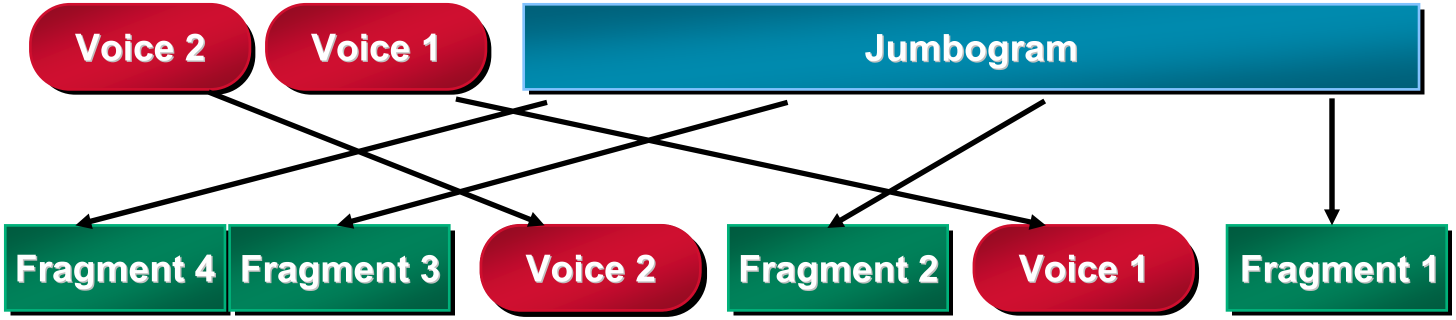
Link-Specific Tools

IP RTP Header Compression



cRTP Reduces L3 VoIP BW by:
~ 20% for G.711
~ 60% for G.729

Multilink PPP / FRF.11 & .12



- Line overhead
- Segmentation/reassembly overhead (ppp multilink or FRF12 overhead)
- Fragment all packets greater than fragment size defined
- Interleave packets from OTHER queues

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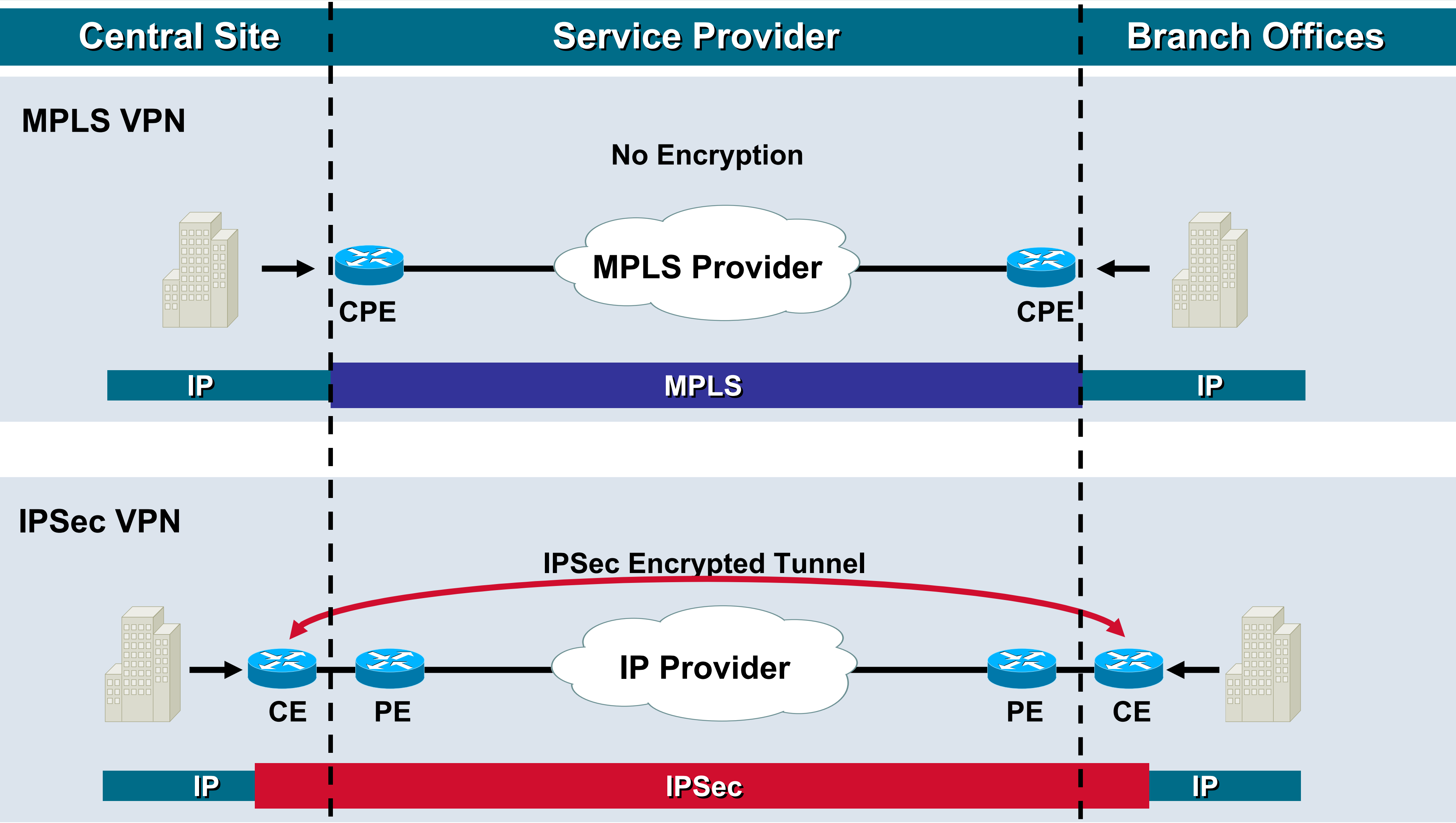
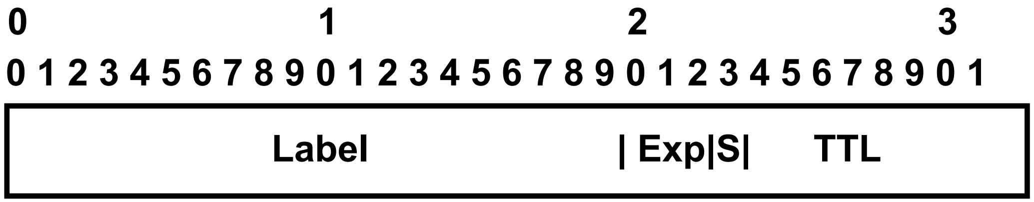
Layer 3 Virtual Private Network Options

MPLS VPNs and IPSec VPNs



QoS and MPLS



```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                 Label                  | Exp|S|      TTL
```

Label = 20 bits
Exp = Experimental, 3 bits
S = Bottom of stack, 1bit
TTL = Time to live, 8 bits

- Two methods are possible
  - Single LSP per ‘QoS’ FEC: E-LSP

    use EXP field in MPLS header to select Diff-Serv queue

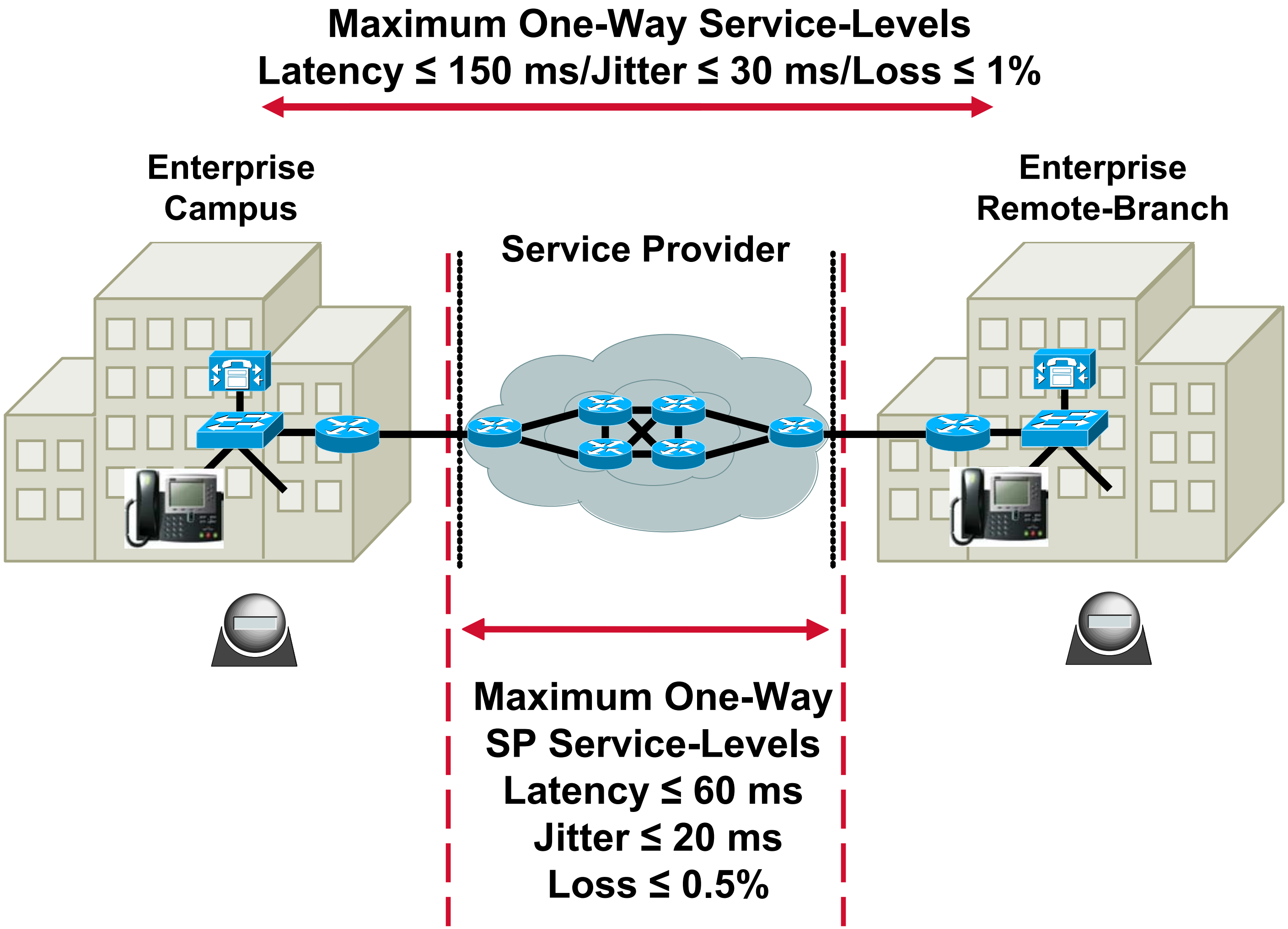
    By default IP prec copied in EXP labels (cisco)

    By default exp is not copied ‘down’ (in label below or prec)
  - Multiple LSPs per ‘QoS’ FEC: L-LSP

    use Label to select Diff-Serv queue

CPN IP Multiservice VPN Service Providers

Service-Level Agreements



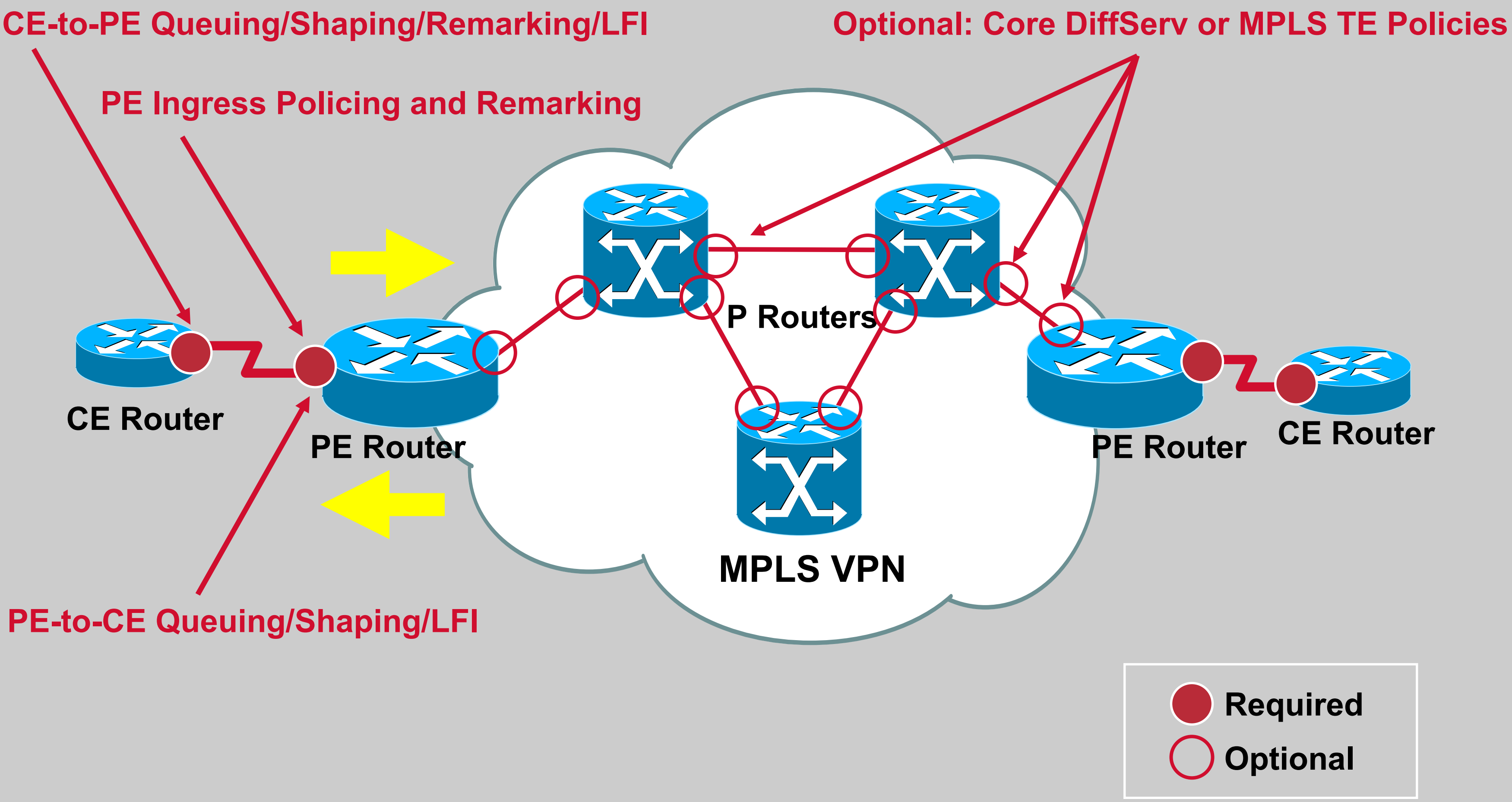
What Are the QoS Implications of MPLS VPNs?

Bottom Line:

Enterprises Must Co-Manage QoS with Their MPLS VPN Service Providers; Their Policies Must Be Both Consistent and Complementary

MPLS VPN QoS Design

Where QoS Is Required in MPLS VPN Architectures?



CE-to-PE Queuing/Shaping/Remarking/LFI

Optional: Core DiffServ or MPLS TE Policies

PE Ingress Policing and Remarking

PE-to-CE Queuing/Shaping/LFI

● Required

○ Optional

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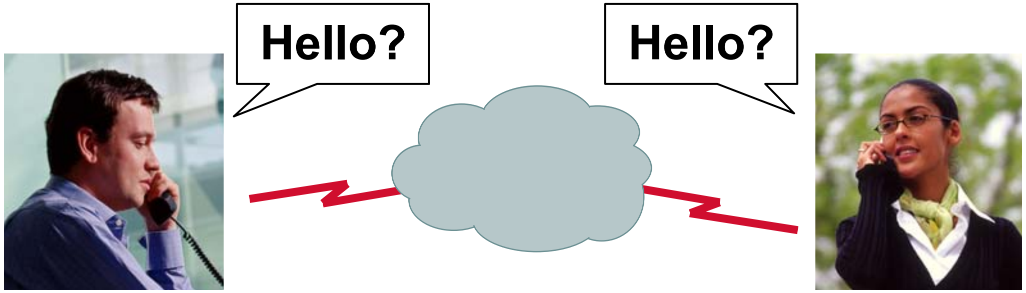
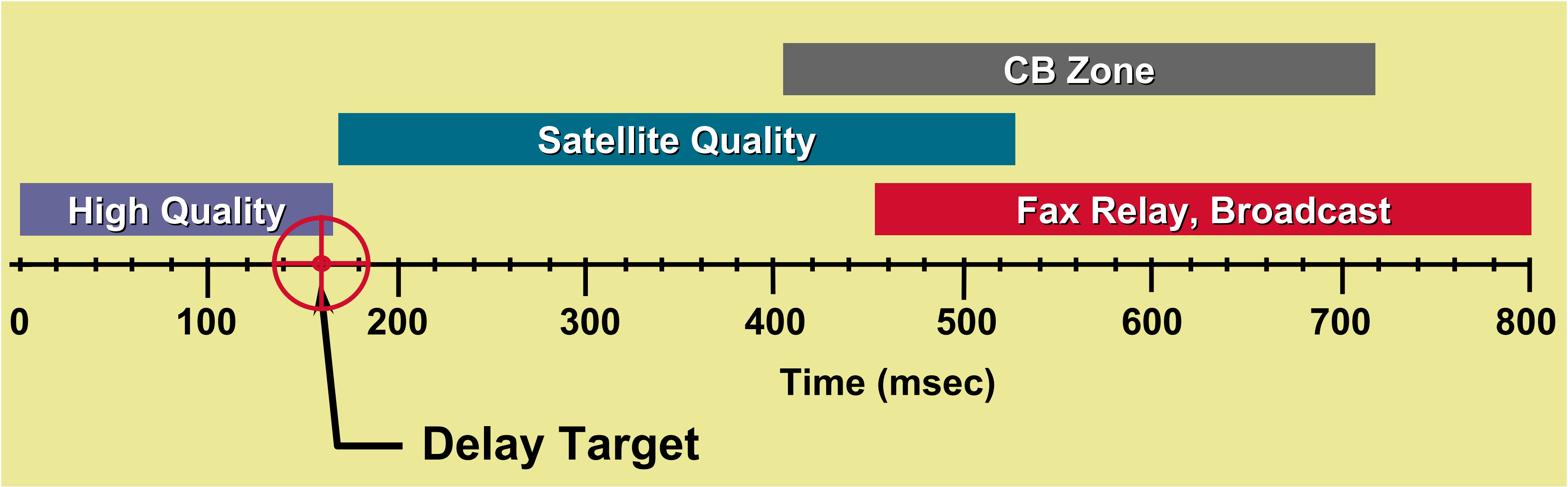
Voice QoS Requirements

End-to-End Latency

Avoid the "Human Ethernet"

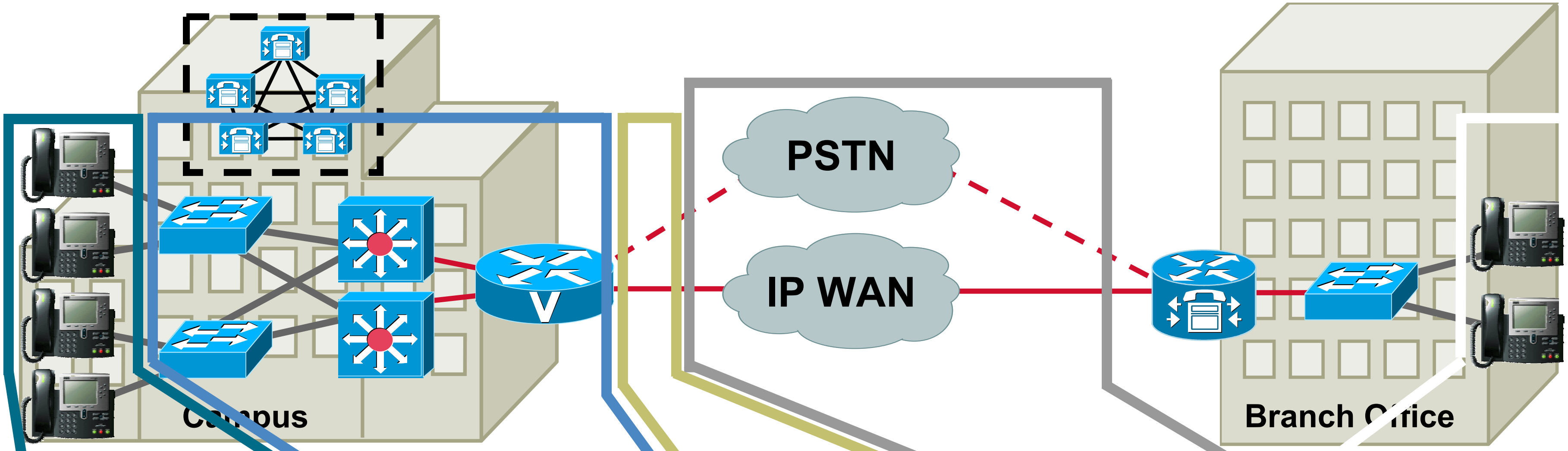




ITU's G.114 Recommendation: ≤ 150msec One-Way Delay

Voice QoS Requirements

Elements That Affect Latency and Jitter

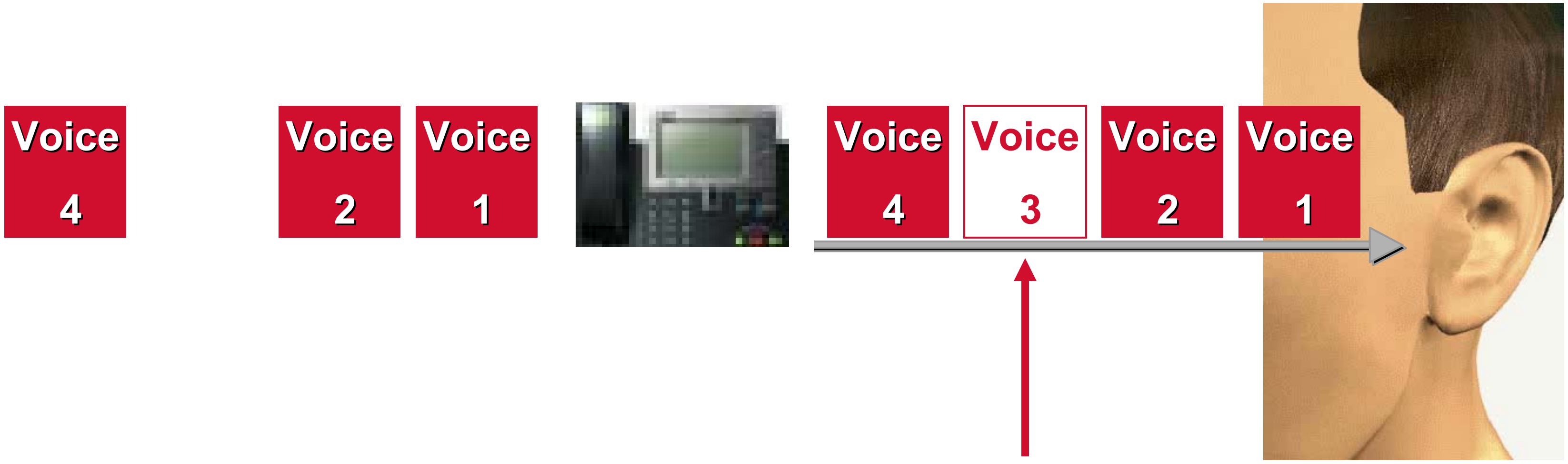


CODEC	Queuing	Serialization	Propagation and Network	Jitter Buffer
G.729A: 25 ms	Variable	Variable	Fixed (6.3 µs/Km) + Network Delay (Variable)	20–50 ms

End-to-End Delay (Must Be ≤ 150 ms)

Voice QoS Requirements

Packet Loss Limitations



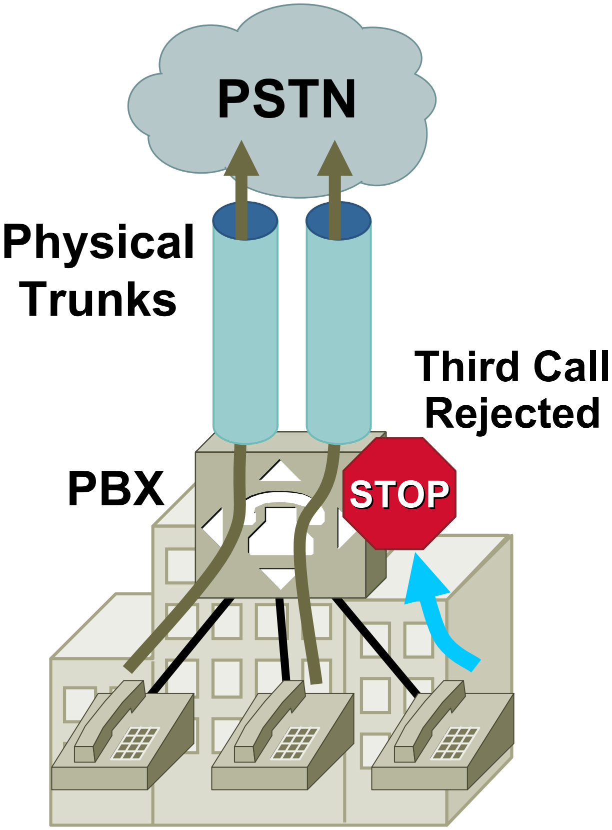
Reconstructed Voice Sample

- Cisco DSP codecs can use predictor algorithms to compensate for a single lost packet in a row
- Two lost packets in a row will cause an audible clip in the conversation

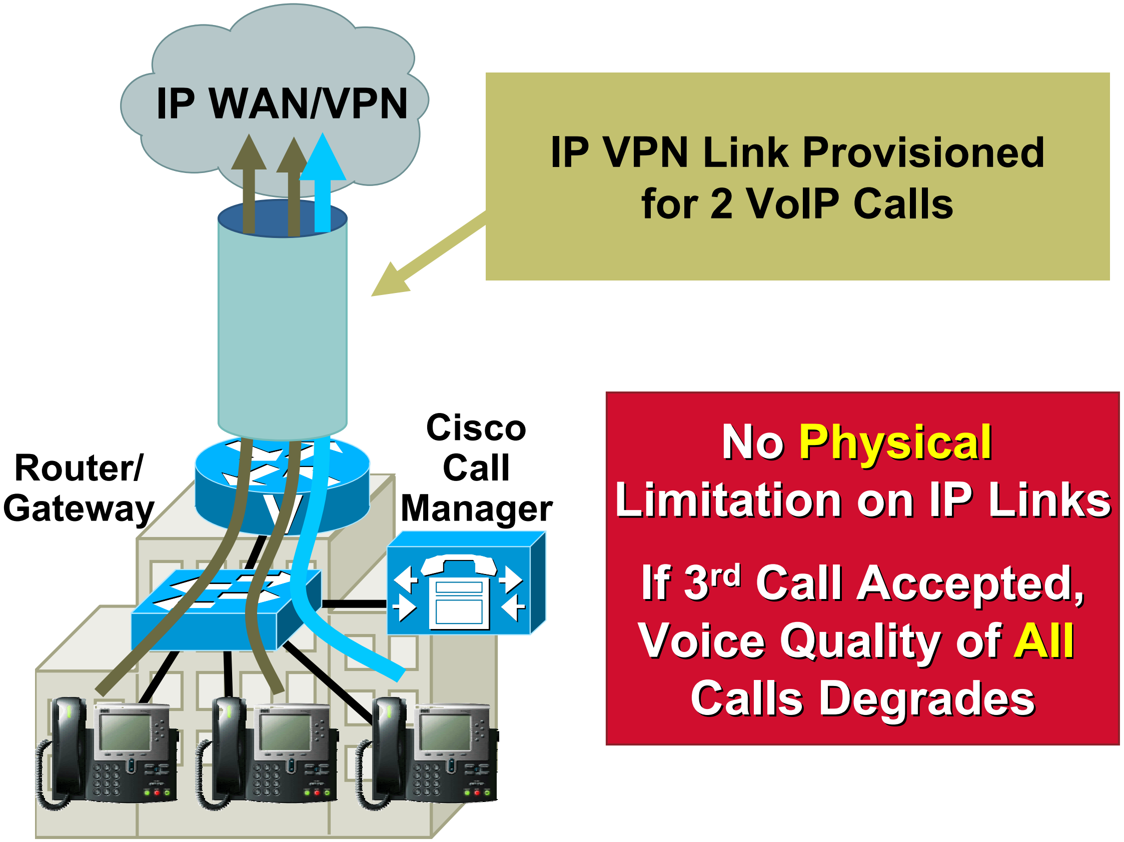
Voice QoS Requirements

Call Admission Control (CAC): Why Is It Needed?

Circuit-Switched Networks



Packet-Switched Networks



IP VPN Link Provisioned for 2 VoIP Calls

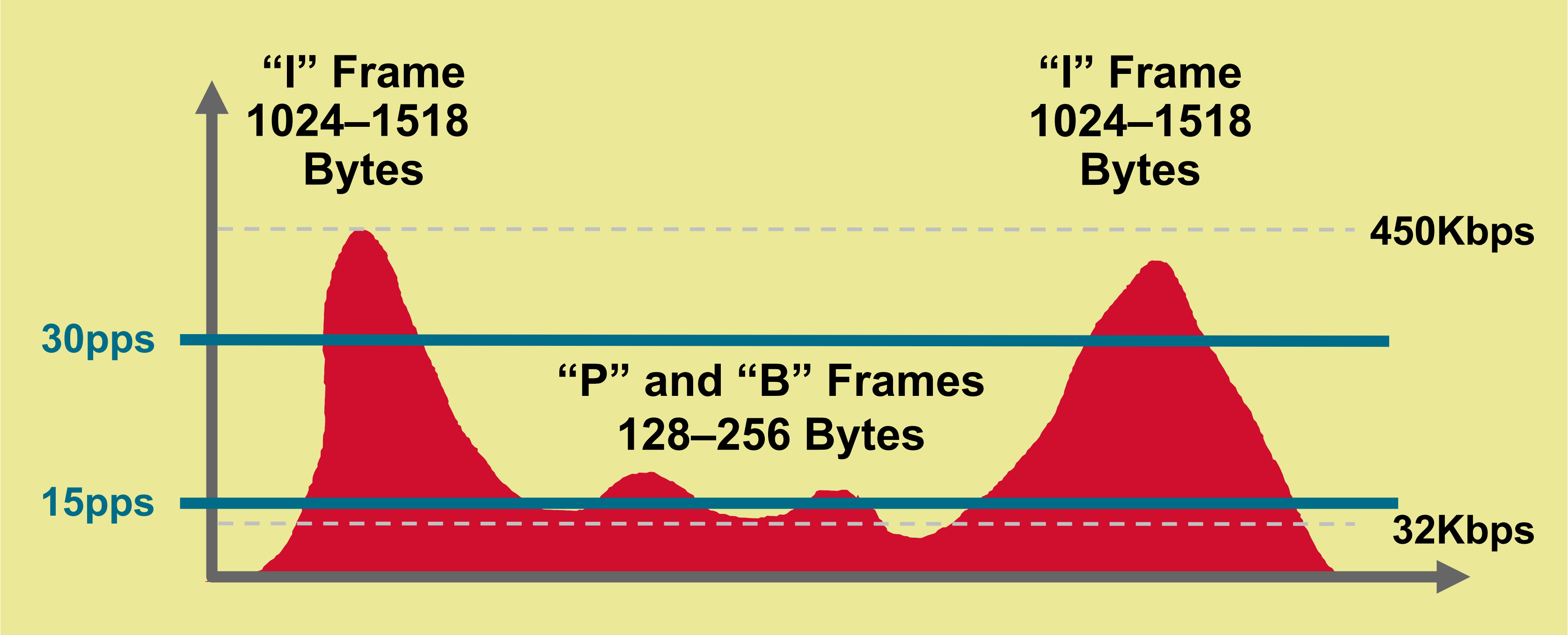
No Physical Limitation on IP Links

If 3rd Call Accepted, Voice Quality of All Calls Degrades

CAC Limits Number of VoIP Calls on Each VPN Link

Video QoS Requirements

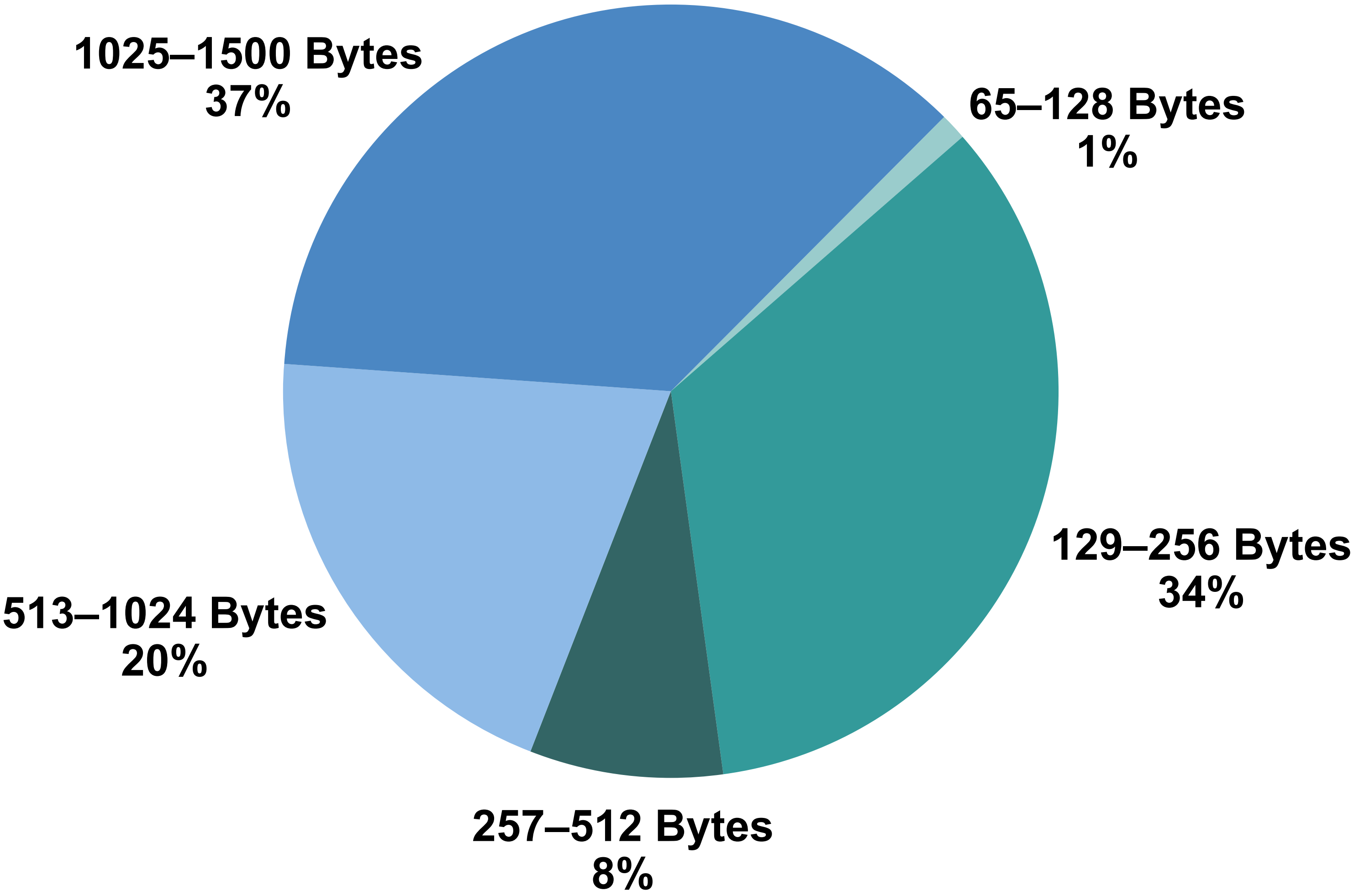
Video Conferencing Traffic Example (384 kbps)



- "I" frame is a full sample of the video
- "P" and "B" frames use quantization via motion vectors and prediction algorithms

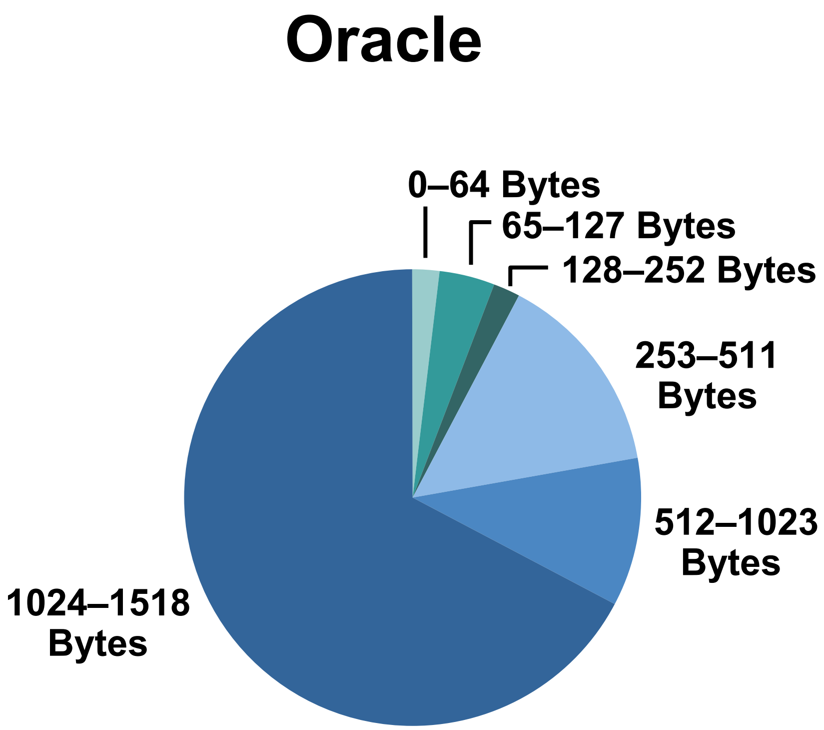
Video QoS Requirements

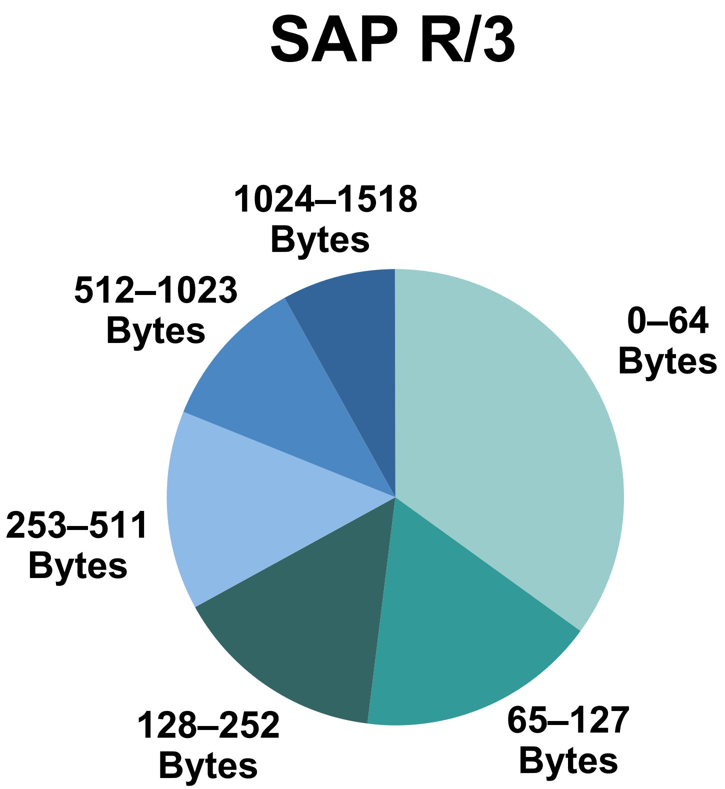
Video Conferencing Traffic Packet Size Breakdown



Data QoS Requirements

Application Differences





Data QoS Requirements

Version Differences

SAP Sales Order Entry Transaction

Client Version	VA01 # of Bytes
SAP GUI Release 3.0 F	14,000
SAP GUI Release 4.6C, No Cache	57,000
SAP GUI Release 4.6C, with Cache	33,000
SAP GUI for HTML, Release 4.6C	490,000

- **Same transaction takes over 35 times more traffic from one version of an application to another**

Voice QoS Requirements
Provisioning for Voice

- Latency ≤ 150 ms
- Jitter ≤ 30 ms
- Loss ≤ 1%

One-Way Requirements

- 17–106 kbps guaranteed priority bandwidth per call
- 150 bps (+ Layer 2 overhead) guaranteed bandwidth for Voice-Control traffic per call
- CAC must be enabled

Voice

- Smooth
- Benign
- Drop sensitive
- Delay sensitive
- UDP priority

Video QoS Requirements

Provisioning for Interactive Video

- Latency ≤ 150 ms
- Jitter ≤ 30 ms
- Loss ≤ 1%

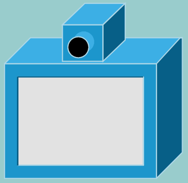
One-Way Requirements

- Minimum priority bandwidth guarantee required is:

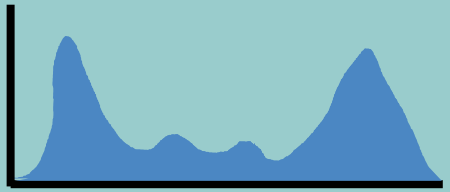
  Video-stream + 20%

  e.g. a 384 kbps stream would require 460 kbps of priority bandwidth

- CAC must be enabled



Video

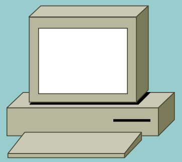


- Bursty
- Greedy
- Drop sensitive
- Delay sensitive
- UDP priority

Data QoS Requirements

Provisioning for Data

- Different applications have different traffic characteristics
- Different versions of the same application can have different traffic characteristics
- Classify data into four/five data classes model:
    - Mission-critical apps
    - Transactional/interactive apps
    - Bulk data apps
    - Best effort apps



Data

- Smooth/bursty
- Benign/greedy
- Drop insensitive
- Delay insensitive
- TCP retransmits

Data QoS Requirements
Provisioning for Data (Cont.)

- Use four/five main traffic classes:
  - Mission-critical apps—business-critical client-server applications
  - Transactional/interactive apps—foreground apps: client-server apps or interactive applications
  - Bulk data apps—background apps: FTP, e-mail, backups, content distribution
  - Best effort apps—(default class)
  - Optional: Scavenger apps—peer-to-peer apps, gaming traffic
- Additional optional data classes include internetwork-control (routing) and network-management
- Most apps fall under best-effort, make sure that adequate bandwidth is provisioned for this default class

Conclusions

- QoS not inherent to network
- no BW creation, requires provisioning
- Requires for each flow:

  Classification, metering,

  and congestion control

Questions?

Obrigado !!