

# Introduction To Quality of Service (QoS)

by

Luis Chanu

*On Site Network Solutions, Inc.*

Luis@OnSite.Com

# Disclaimer

- In developing the Enterprise QoS Policy, my main hardware focus was on 6500 and 4510R platforms running SUP720-3B and SUP-V, respectively. As such, that is the focus of my discussion, but I've tried to present concepts where possible.
- QoS is implemented differently on different platforms. Hence, not everything may apply for your platform, but the general concept should still apply.
- I don't know it all, and have done all I can to ensure this information is accurate. However, I'm sure Martin will find something in error with this presentation. 😊
- Please ASK QUESTIONS! I may not always have the answer, but I'll try my best. I've developed this information to share information with YOU, our members.

# QoS Models

- Differentiated Services
  - Referred to as “DiffServ”
  - Defined in RFC 2474
  - QoS defined at each hop
- Resource ReSerVation Protocol
  - Referred to as “RSVP”
  - Defined in RFC 2205
  - Bandwidth requested from “network”

# What is QoS?

- QoS – Unfair Fairness

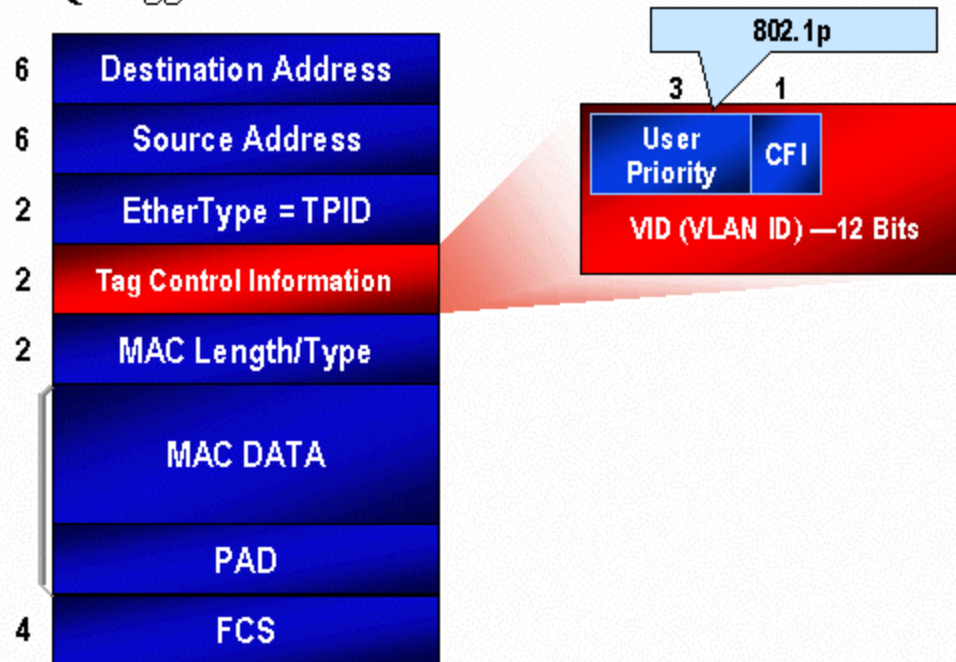
# Why is QoS Needed?

- To “prioritize” traffic
  - Voice traffic has higher priority than data traffic
- Minimize delay, jitter, etc.
- “Guarantee” bandwidth for certain traffic
- Help meet business SLAs

# Definitions

- CoS – Class of Service [Layer 2 QoS]
  - Only found in tagged frames (802.1Q or ISL)
  - 802.1p is 3 bits, and thus gives values from 0 - 7

802.1Q Tagged Ethernet Frame



# Definitions

- **Differentiated Services [Layer 3 QoS]**
  - Service model, NOT a technology/command
  - Defines a set of end-to-end QoS capabilities
  - Defines DS field which supersedes IPv4 Type of Service (ToS) byte

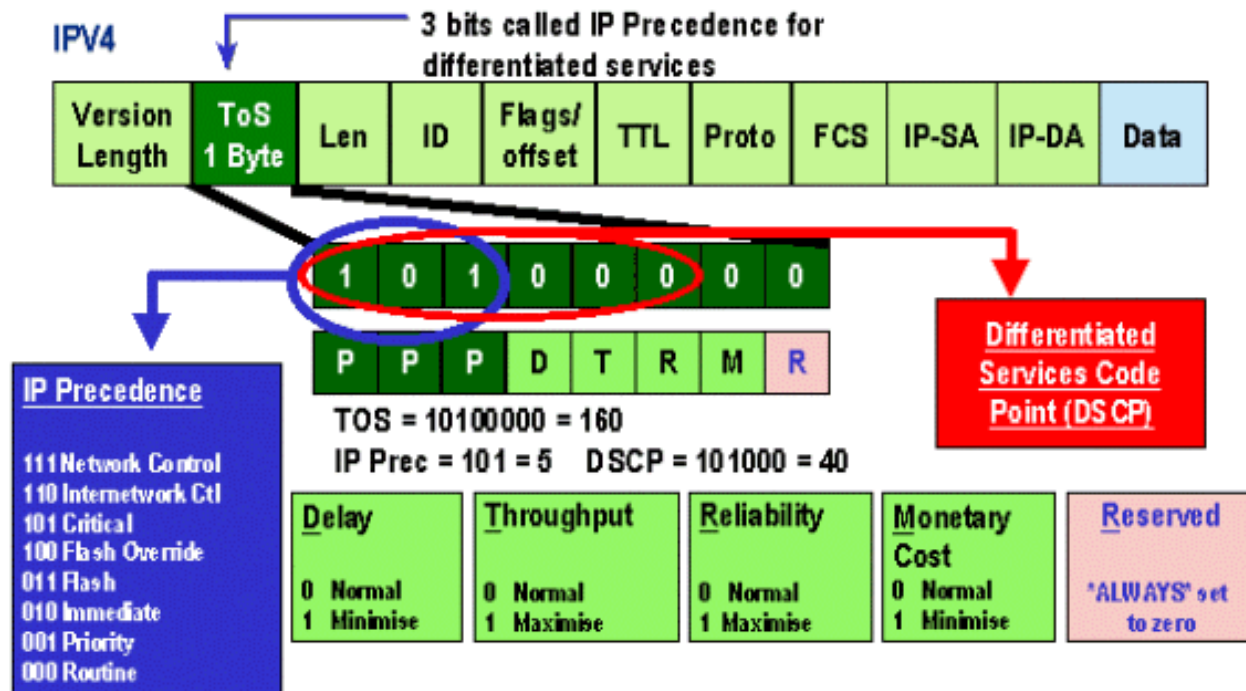
# Definitions

- **DiffServ Code Point (DSCP)**
  - Found in every IP packet, and is comprised of the first six (6) bits within the Type of Service (TOS) byte. These six (6) bits give DSCP 64 possible values: 0 through 63.
  - Remaining two (2) bits in the ToS byte are reserved for Explicit Congestion Notification (ECN), and is not covered in this discussion
  - Marking is the process of setting the DSCP value



# Definitions

- DiffServ Code Point (DSCP) Field



# Definitions

- **PHB: Per Hop Behavior**

- Differentiation of traffic determined on a hop-by-hop basis as apposed to maintaining end-to-end flow states (i.e. RSVP) that consume network resources.
- Traffic is classified and then marked with a an appropriate DSCP value in the DS field. The DSCP then triggers a per-hop behavior (PHB) of how the traffic is treated from the components in the network.

# Definitions

- Four (4) Standard PHBs:
  - Default PHB or “Best Effort” (RFC 2474)
    - DSCP = 0 = 000000
  - Class Selector (RFC 2474)
    - Backward compatibility with IP Prec bits (xxx000)
  - Assured Forwarding (AF<sub>n</sub>y) (RFC 2597)
    - n=Class, y=Drop Probability (Details To Come)
  - Expedited Forwarding (EF) (RFC 2598)
    - Implemented a Low Latency Priority Queue

# Assured Forwarding (AFny)

Drop Probability	AF1y (Class 1)	AF2y (Class 2)	AF3y (Class 3)	AF4y (Class 4)
Low (AFn1)	001010 (10)	010010 (18)	011010 (26)	100010 (34)
Medium (AFn2)	001100 (12)	010100 (20)	011100 (28)	100100 (36)
High (AFn3)	001110 (14)	010110 (22)	011110 (30)	100110 (38)

## Important Notes

1. For example in the AF1 class, packets that are marked AF13 with a DiffServ value of 14 **will be dropped before** those that are marked AF11 with a DiffServ value of 10. This is brought up to stress the fact that **DiffServ code values cannot be considered by numerical value only.**
2. The DiffServ standard does **NOT** specify a precise definition of “Low”, “Medium”, and “High” drop probability.

# Class Selector & Expedited Forwarding

DiffServ Name	DS Field	DSCP Value	IP Precedence
CS0	<b>000000</b>	0	0
CS1	<b>001000</b>	8	1
CS2	<b>010000</b>	16	2
CS3	<b>011000</b>	24	3
CS4	<b>100000</b>	32	4
CS5	<b>101000</b>	40	5
CS6	<b>110000</b>	48	6
CS7	<b>111000</b>	56	7
EF	101110	46	5

# DiffServ Categories

"Priority"	DiffServ Category	CoS	IP Prec	DSCP Range
Higher	Link Layer And Routing Protocol Keep Alives	7	7	56 – 63
	IP Routing Protocols	6	6	48 – 55
<b>Priority (LLQ)</b>	<b>EF - Expedited Forwarding (*)</b>	<b>5</b>	<b>5</b>	<b>40 – 47</b>
	AF4y (Class 4)	4	4	32 – 39
	AF3y (Class 3)	3	3	24 – 31
	AF2y (Class 2)	2	2	16 – 23
	AF1y (Class 1)	1	1	8 – 15
Lower	BE - Best Effort	0	0	0 – 7

(\*) EF is usually implemented via a Low-Latency Strict Priority Queue (LLQ), which means it's forwarded before ANY other traffic.

# Internal DSCP/CoS Values

- When a switch makes a QoS policy decision, it does NOT directly use the CoS/DSCP value of the arriving frame, but rather, it uses an internal value within the switch. The internal value is derived from the frame, but it may be different due to various CoS->DSCP and DSCP->CoS mapping functions, which are configurable.
- As we'll see in a later slide, by default, these values are used again when the frame egresses the switch.

# It's All About Trust...

- **CoS**
  - If CoS is trusted, then the internal DSCP value is derived from the CoS->DSCP mapping function
- **DSCP**
  - If DSCP is trusted, then the internal CoS value is derived from the DSCP->CoS mapping function
- **None**
  - Both internal CoS and DSCP values are set to zero (0)



# QoS Re-Writes

- **Default Action**

- As a frame is ready to be queued up to egress a switch, the CoS and DSCP values within the frame are re-written using the Internal CoS/DSCP values.
- Could be problematic if your Enterprise QoS policy leverages granular DSCP values.

# DSCP Transparency

- End-To-End DSCP Values
  - If you want to ensure that DSCP values are maintained end-to-end in your network, you'll need to enable DSCP Transparency at each PHB.
- Enabling DSCP Transparency
  - 6509: no mls qos rewrite ip dscp
  - 4510R: Trusts DSCP by default

# Definitions

- **Weighted Random Early Detection (WRED)**
  - WRED can prevent an output queue from ever filling to capacity, which would result in packet loss for all incoming packets.
  - WRED should only be applied to TCP flows
  - WRED should NEVER be applied to VoIP flows
  - WRED's purpose is to prevent TCP synchronization by "randomly" dropping packets from a flow based DSCP/Precedence. TCP then goes into "Slow Start", which sets the TCP window size to 1, thereby temporarily throttling that TCP flow down.

# Queuing

- **Priority Queuing (PQ)**
  - Traffic sitting in a PQ gets serviced before ALL other traffic.
  - Primary drawback is that it can starve out other valid traffic.
- **Ideal For Time Critical Traffic**
  - Voice

# Queuing

- **Class-Based Weighted Fair Queuing (CBWFQ)**
  - Classes of traffic may be defined by a variety of criteria including IP precedence, port, IP subnet information, DSCP value, etc.
  - Each defined class of traffic is **required to have a bandwidth statement**. The statement defines a minimum guaranteed bandwidth for this class **during times of congestion**.
  - All traffic that is not defined by a class statement is assigned to class default. Class default may then be defined to apply weights within the class based on ip precedence for flow-based queuing or drop mechanisms such as weighted random early detection (WRED).
- **Ideal For Non-Latency Dependent Traffic**

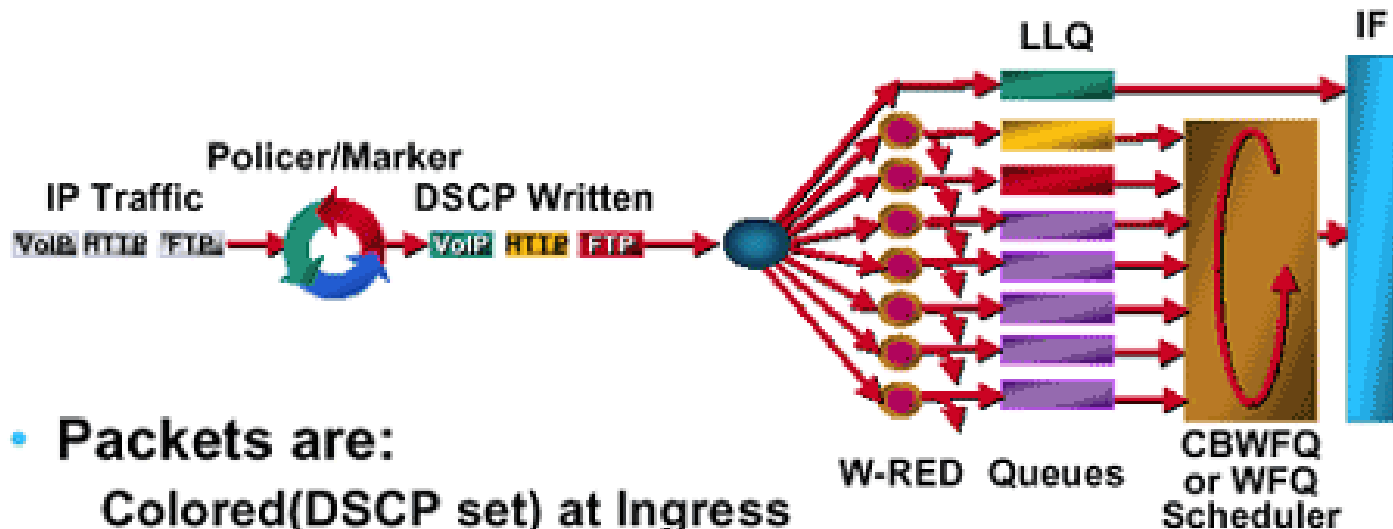
# Queuing

- **Low Latency Queuing (LLQ)**
  - LLQ is actually a combination of Priority Queuing (PQ) and Class-Based Weighted Fair Queuing (CBWFQ)
  - One (1) queue is defined as the Strict Priority Queue, which is where latency sensitive traffic is placed
  - Remaining traffic is put into various classes, each of which has a certain minimal bandwidth requirement in case of congestion
- **Best Of Both Queuing Strategies...**

# Congestion Avoidance

- Tail Drop Thresholds
  - Method of discarding traffic based on how full a queue is
  - Ability to have multiple thresholds which drop certain traffic classes before others

# Putting it All Together



- **Packets are:**
  - Colored(DSCP set) at Ingress**
  - Classified and potentially discarded by W-RED (Congestion Management)**
  - Assigned to the appropriate outgoing queue**
  - Scheduled for transmission by CBWFQ**



# Cisco VoIP Changes

- Cisco VoIP Phones – Call Control
  - Early CCM Version: DSCP 26
  - CCM v4.x and later: DSCP 24
  - DSCP 24 is the recent IETF Recommended Setting
- AutoQoS
  - Older IOS AutoQoS assumes DSCP 26 is used, and changes CoS->DSCP mappings accordingly.
  - Current IOS AutoQoS uses DSCP 24.
  - Care needs to be taken when you upgrade CCM and IOS.
- Reserve **BOTH** DSCP 24 & 26 for VoIP Control

# Lessons Learned...

- Catalyst 6500 (SUP720-3B)
  - Must trust CoS to leverage Hardware ASICs
  - Default is to re-write CoS/DSCP values, so needed to enable DSCP Transparency to prevent the re-write
  - NBAR limited to non-platform specific commands when used with QoS
  - SUP720-3B and high-end line cards provide different XpYqZt support. Threw a wrench in deploying the QoS policy over LACP channels.
  - Output Queuing based on CoS value

# Lessons Learned...

- **Catalyst 6500 (SUP720-3B) (Cont...)**
  - High-end line-cards provided high tail-drop counts, which were used to provide finer granularity of congestion avoidance within a particular Code Segment (CS) DSCP range.
  - If an interface is configured to use VLAN-BASED QoS policies, the VLAN QoS policies over-ride port defined QoS policies.

# Lessons Learned...

## ● Catalyst 4510R

- Ended up trusting DSCP on all ports, so no need to enable DSCP Transparency as DSCP->CoS mapping was active
- NBAR not supported
- Output Queuing based on DSCP
- Queue #3 is the Strict Priority LLQ
- Guaranteed minimum bandwidth during congestion specified on a port-by-port basis for each queue

# Lessons Learned...

- **Peer Review**

- As I was developing the Enterprise QoS Strategy, I brought in a CCIE “with QoS experience” to review my design. But, the CCIE’s QoS experience was mainly with VoIP. Be sure to get someone that has developed an Enterprise QoS policy, and not just implemented VoIP.

# Lessons Learned...

## ● Cisco TAC

- The answer was “Most people just keep it simple and use AutoQoS. Sounds like you’re leveraging many advanced features...”
- Only 2 of my questions were ever answered by TAC.
- They know QoS for VoIP, but you may be on your own with anything beyond simple VoIP deployments.

## ● SVCUG

- Several individuals within our group helped get answers to my questions... Thank You!

# References

- **CiscoPress**

- Cisco Catalyst QoS: Quality of Service in Campus Networks  
By Richard Froom, Mike Flannagan, Kevin Turek  
ISBN: 1587051206

# Any Questions?

