Infrastructure QoS support

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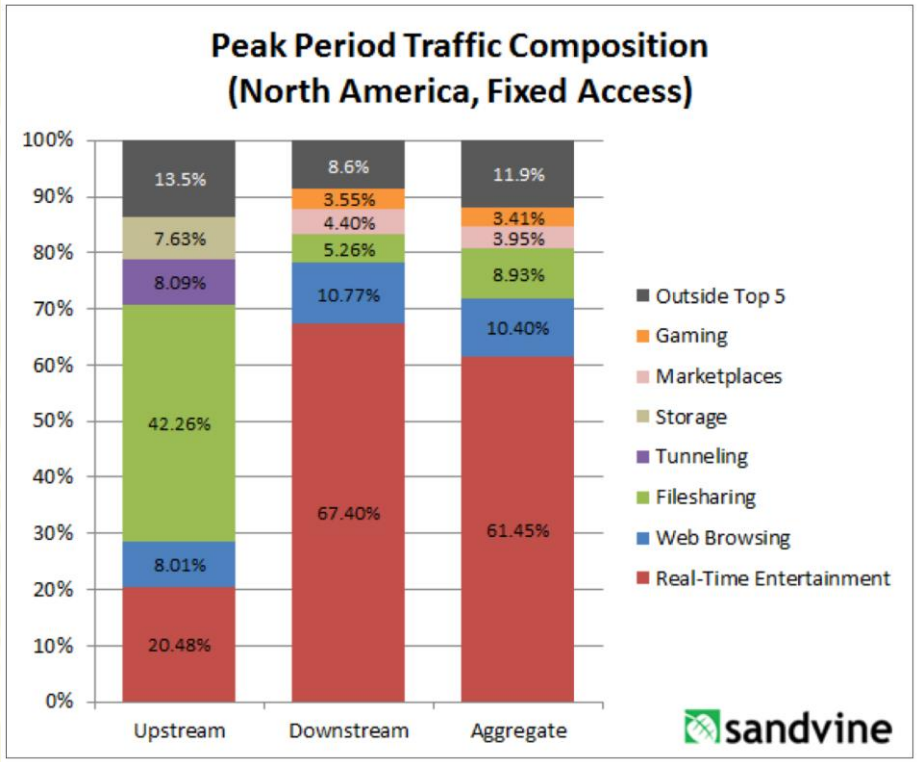
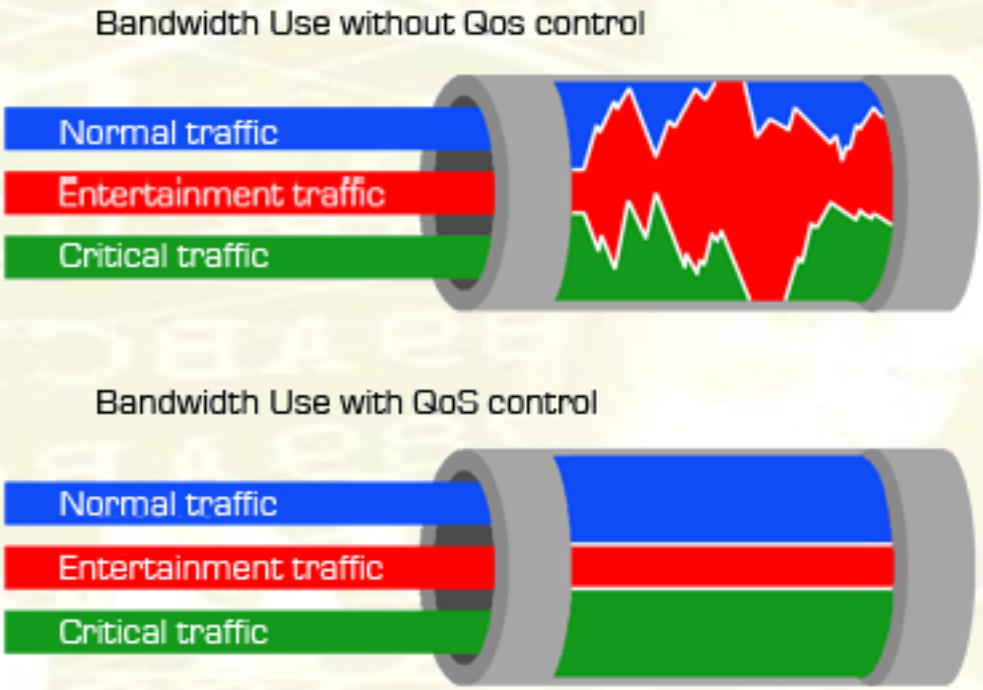


	Upstream		Downstream		Aggregate	
Rank	**Application**	**Share**	**Application**	**Share**	**Application**	**Share**
1	BitTorrent	36.35%	Netflix	31.62%	Netflix	28.18%
2	HTTP	6.03%	YouTube	18.69%	YouTube	16.78%
3	SSL	5.87%	HTTP	9.74%	HTTP	9.26%
4	Netflix	4.44%	BitTorrent	4.05%	BitTorrent	7.39%
5	YouTube	3.63%	iTunes	3.27%	iTunes	2.91%
6	Skype	2.76%	MPEG - Other	2.60%	SSL	2.54%
7	QVoD	2.55%	SSL	2.05%	MPEG - Other	2.32%
8	Facebook	1.54%	Amazon Video	1.61%	Amazon Video	1.48%
9	FaceTime	1.44%	Facebook	1.31%	Facebook	1.34%
10	Dropbox	1.39%	Hulu	1.29%	Hulu	1.15%
	Top 10	**66.00%**	**Top 10**	**76.23%**	**Top 10**	**73.35%**

SOURCE: SANDVINE NETWORK DEMOGRAPHICS

sandvine

QoS in the Internet



E.g. VoIP requires packets to be delivered with a delay which is in the worst case in the order of 150ms one-way

Basic Network

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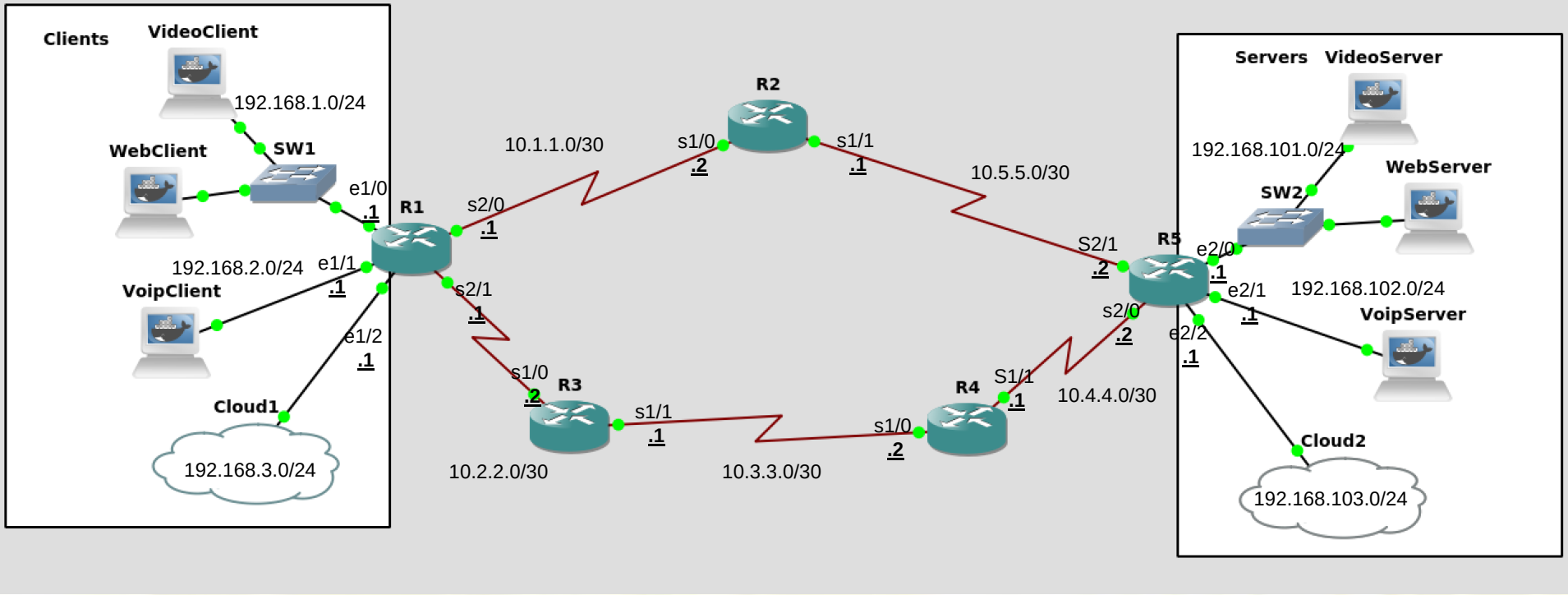
Network Architecture

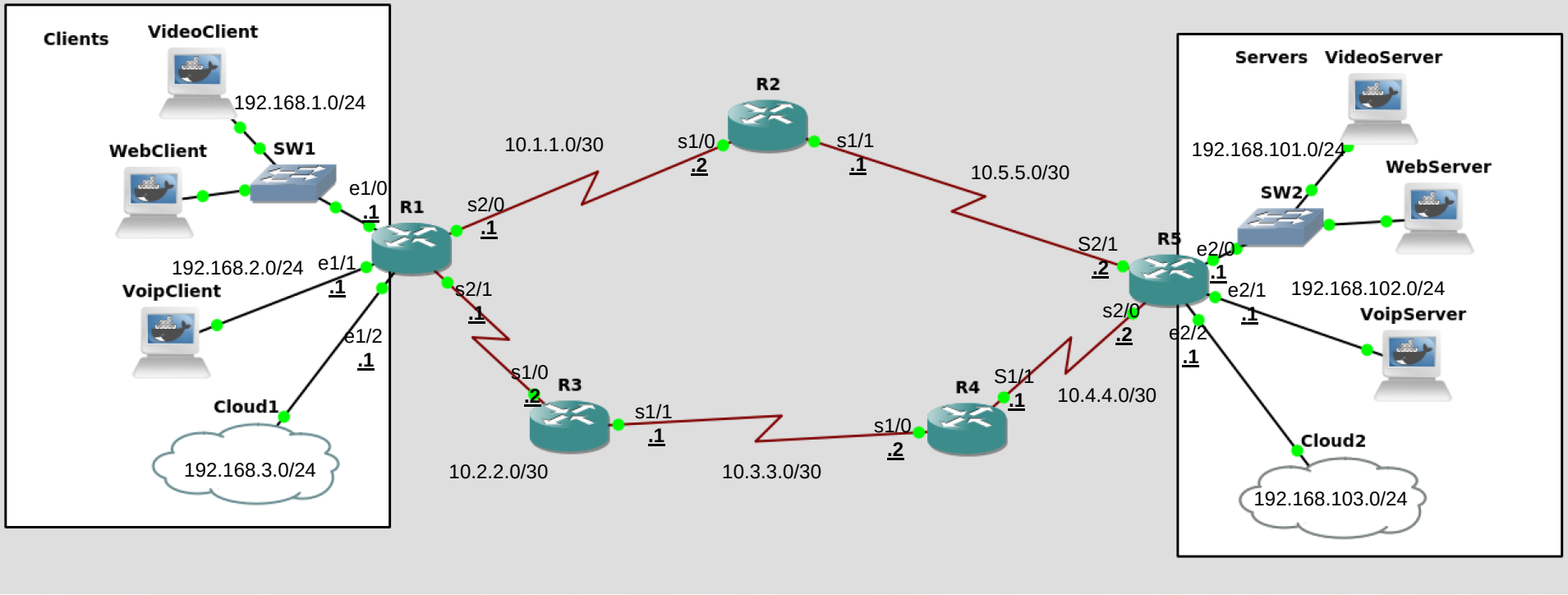


Linux OS tap0

tapX is a virtual network interface exposed on the Linux OS to provide a point of access to the emulated network

Linux OS tap1

Network Architecture



Linux OS tap0

Each tap is attached to an ***isolated Network Namespace*** with its own network stack and routing table. Applications running on each namespace are forced to ***communicate through*** the emulated network

Linux OS tap1

Differentiated Services Architectures

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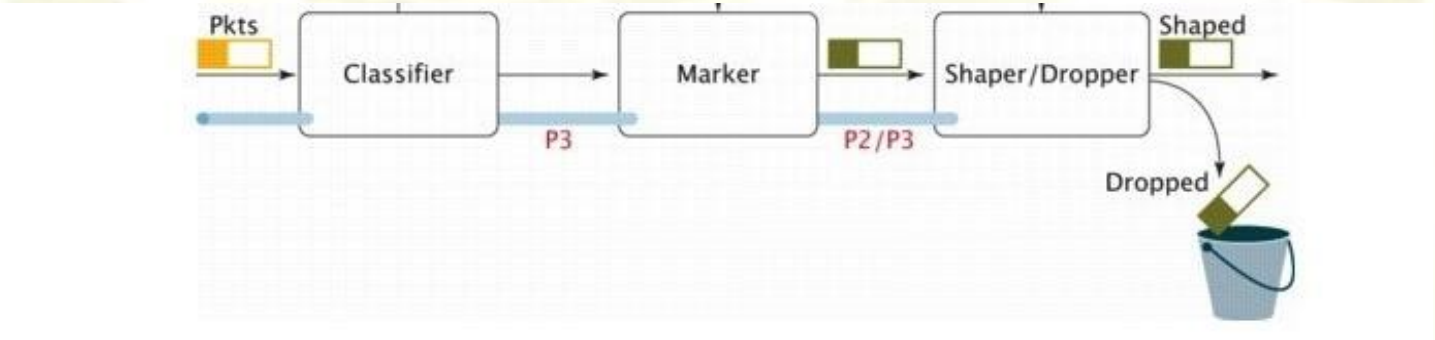
Intro

- Network Boundary
  - Classification & Marking
  - Shaping and Policing
- Per-Hop Behavior
  - Scheduling and Resource Allocation
  - Congestion Avoidance and Packet Drop Policy

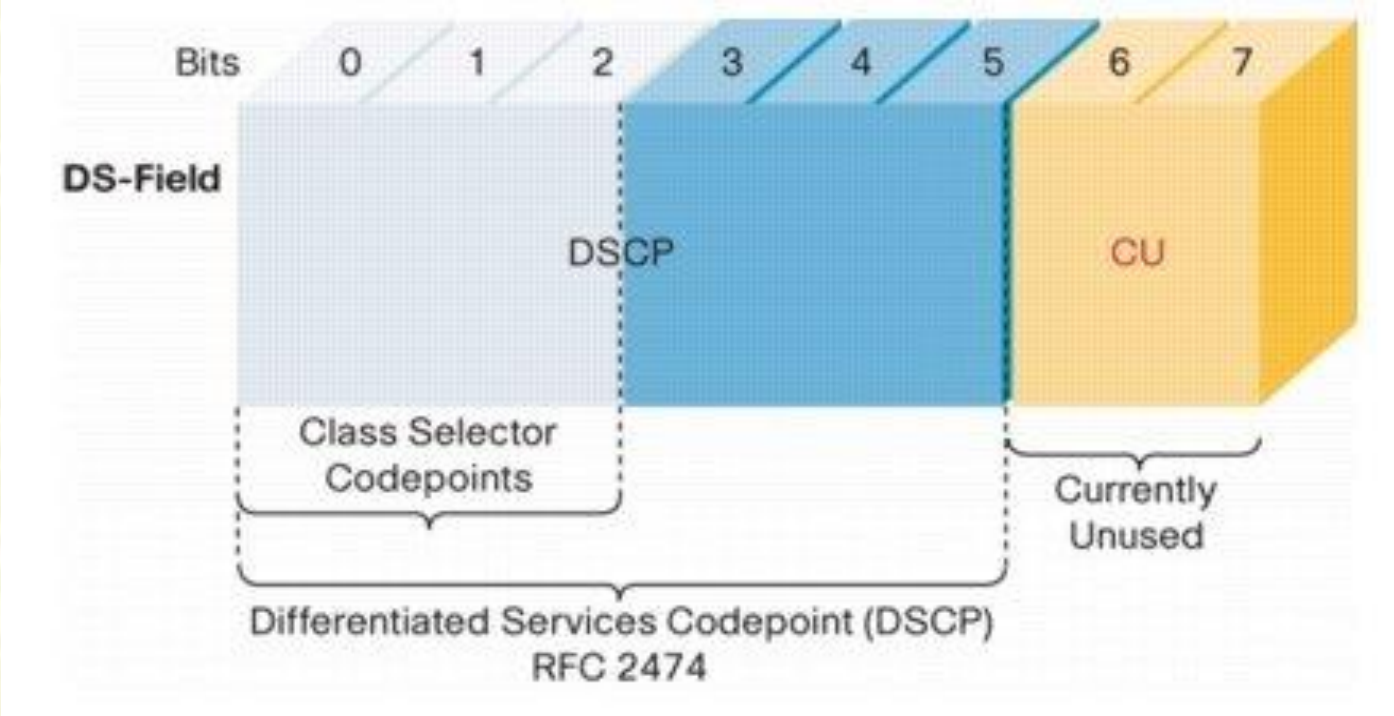
Network Ingress

- Routers at the network boundary perform ***Classifier*** functions to identify packets belonging to a certain traffic class based on one or more TCP/IP header fields
- A ***Marker*** is used to color the classified traffic
- A ***Shaper*** or ***Traffic Policing*** is used to regulate ingress rate



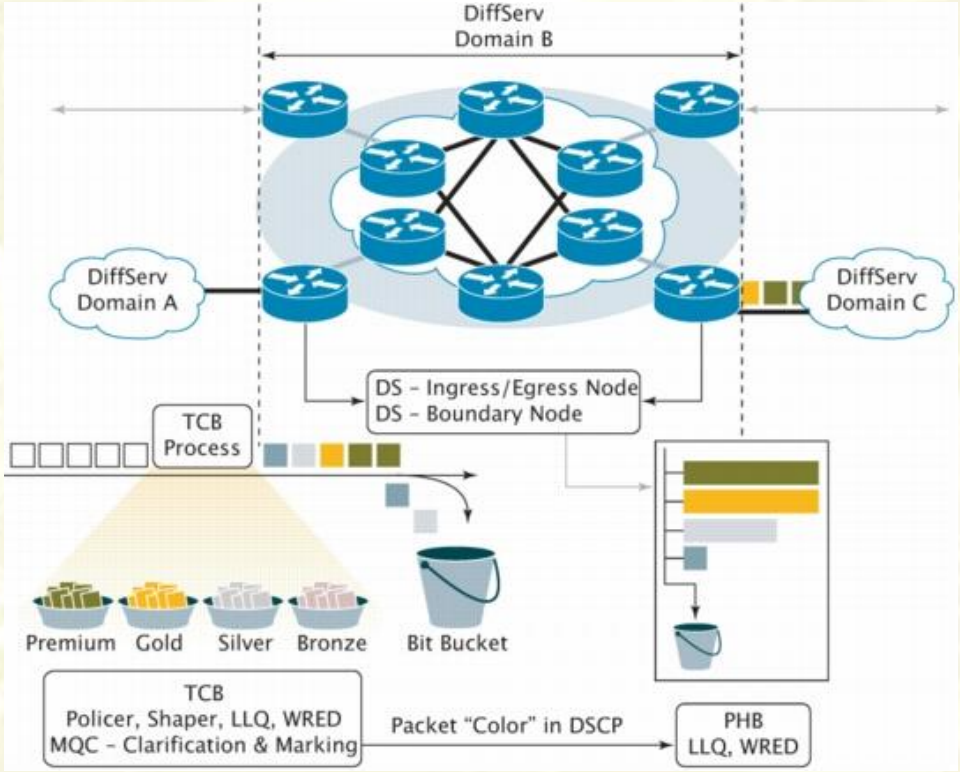
Packet Marker

- The marker set the Differentiated Services Code Point (DSCP) field



Per-Hop Behavior

- Within the network core, a per-hop behavior (PHB) is applied to the packets based on either the IP Precedence or the DSCP field marked in the packet header



Resulting Service

QoS Class Names	Layer 3 QoS Markings		IPP / CoS Markings
	PHB	DSCP	
Network Control	CS6	48	6
Voice Real-Time Transport	EF	46	5
Clinical Life Critical	CS5	40	5
Multimedia Conferencing	AF41	34	4
Real-Time Interactive	CS4	32	4
Multimedia Streaming	AF31	26	3
Call Signaling	CS3	24	3
Low-Latency Data	AF21	18	2
OAM (Net Mgmt)	CS2	16	2
High-Throughput Data	AF11	10	1
Low-Priority Data	CS1	8	1
Best Effort	0	0	0

Network Boundary

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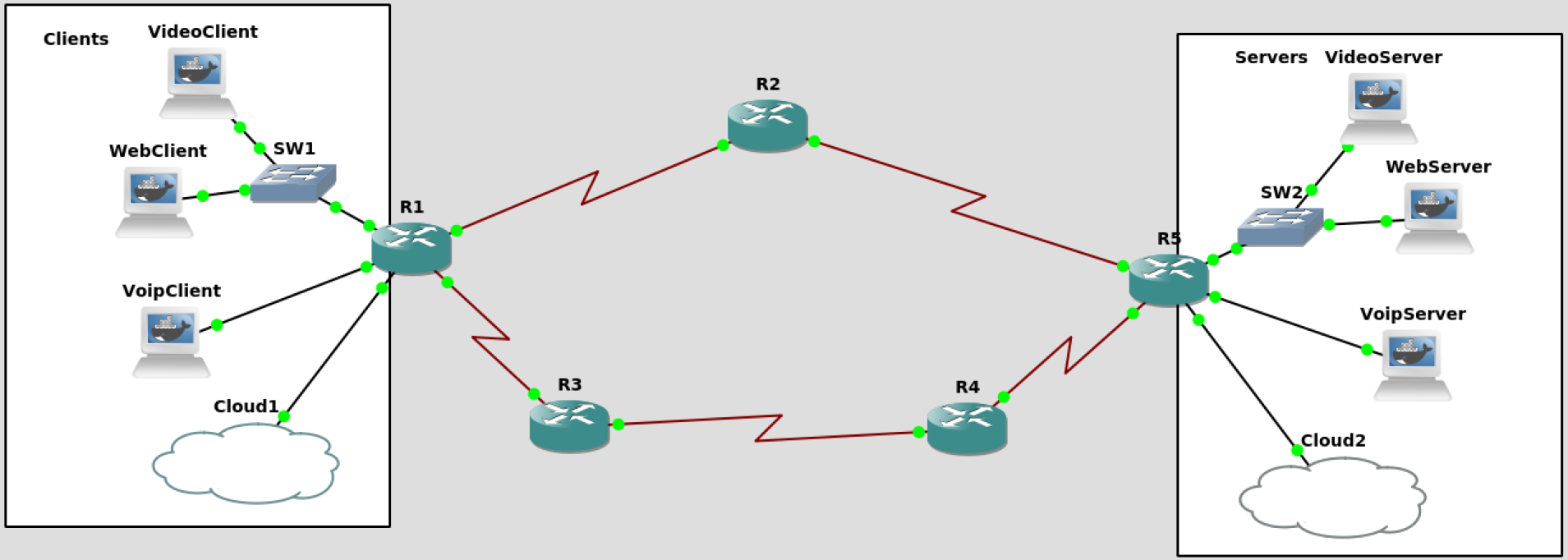
Application Scenario



3 Flows by priority:

1. VoIP Flow (UDP): LOW Latency, LOW Loss
2. Video Flow (UDP): MEDIUM Latency, LOW Loss
3. Web Flow (TCP): Delay and Loss tolerant

Packet Classification and Marking using Class Maps

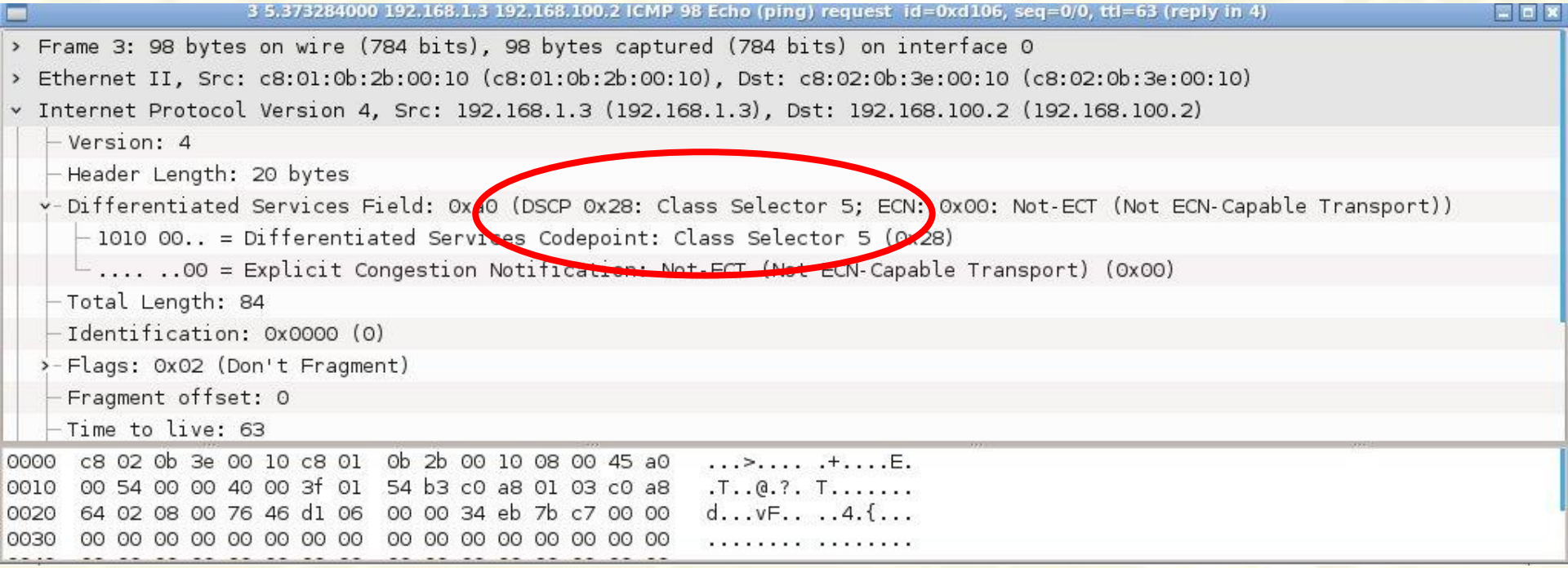
- Define Classification
  - `access-list 1 permit 192.168.102.0 0.0.0.255`
  - `class-map match-all VOIP`
  - `match access-group 1`
- Define Marking
  - `policy-map E11`
  - `class VOIP`
  - `set ip dscp ef`
  - `interface Ethernet 1/1`
  - `service-policy input E11`
- To disable
  - `no service-policy input E11`

Classify all the traffic from the network 192.168.102.0/24

Set DSCP field for this traffic as expedited forwarding

Test

- Test with ping and check that the precedence bit on the IP header is set correctly using wireshark!



Classification based on protocol

- Classify traffic based on transport protocol or application (e.g. video traffic on UDP):
  - `access-list 101 permit udp any any`
  - `class-map match-all VIDEO`
  - `match access-group 101`
- Define Marking:
  - `policy-map E10`
  - `class VIDEO`
  - `set ip dscp af13`

This add to the class VIDEO

Set DSCP field for this traffic as assured forwarding

Classification based on protocol

- Apply marking (marking is already applied in Ethernet 1/0):
  - `interface Ethernet 1/0`
  - `  service-policy input E10`

Test with iperf

- Iperf is a tool to generate traffic
- Generate TCP flow (data is generated from client to server)
  - `iperf -s -p 80 (to create the server)`
  - `iperf -c 192.168.1.2 -p 80 (to start the flow)`
- Generate UDP flow (data is generated from client to server)
  - `iperf -s -u (to create the server)`
  - `iperf -u -c 192.168.2.2 -b 2M (to start 2Mbps flow, by default the flow is 1Mbps)`

Test!

- Start two flows, one UDP and one TCP, the first between the VideoServer and the VideoClient, the other between the WebServer and the WebClient
  - Check with wireshark the DSCP value

Classification based on port

- Classify traffic based on the specific service (e.g. web traffic on TCP port 80):
  - `access-list 102 permit tcp any any range www 81`
  - `class-map match-all WEB`
  - `match access-group 102`
- Define Marking:
  - `policy-map E10`
  - `class WEB`
  - `set ip dscp af33`

This add to the class WEB

Set DSCP field for this traffic as assured forwarding

Test!

- Test again with two flows, one UDP and one TCP, the first between the VideoServer and the VideoClient, the other between the WebServer and the WebClient
  - Check with wireshark the DSCP value

Policing/Shaping

Table 3-3. Comparison Between Policing and Shaping Functions	
Policing Function (CAR)	**Shaping Function (TS)**
Sends conforming traffic up to the line rate and allows bursts.	Smoothes traffic and sends it out at a constant rate.
When tokens are exhausted, it can drop packets.	When tokens are exhausted, it buffers packets and sends them out later, when tokens are available.
Works for both input and output traffic.	Implemented for output traffic only.
Transmission Control Protocol (TCP) detects the line at line speed but adapts to the configured rate when a packet drop occurs by lowering its window size.	TCP can detect that it has a lower speed line and adapt its retransmission timer accordingly. This results in less scope of retransmissions and is TCP-friendly.

To limit ingress traffic rate

Smooth traffic flow on an interface to avoid link congestion

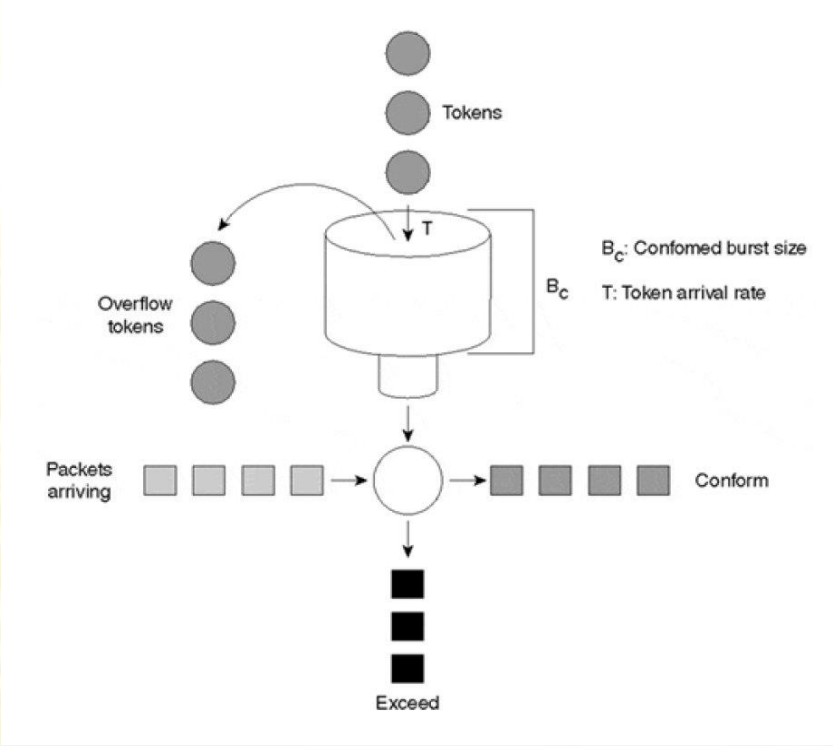
CAR (Committed Access Rate)

- CAR is a traffic Classifier/Marker/Policing
- Usually adopted at the ingress router to limit ingress traffic of a flow
- It performs Traffic Policing with additional Classification & Marking, if needed

CAR (Committed Access Rate)

- Rate limit statement:
  - `rate-limit {access-group num} <input/output> "CIR" "conformed burst" "extended burst" "conformed-action" "action desired" exceed-action "action desired"`

CIR, Committed Information Rate, *bit per second*, average traffic rate
Conformed burst size, *bytes*, amount of traffic allowed to exceed the bucket on an instantaneous basis
Extended burst size, *bytes*, bonus instantaneous rate based on token borrowing mechanism, if set equal to conformed burst size is disabled



Packet C/M/P using CAR

- Define policing function:
  - `interface Ethernet 1/1`
  - `rate-limit input 10000000 5000 5000 conform-action continue exceed-action drop`
    - *Limit all the traffic to 10Mpbs (continue -> check other rules)*

Packet C/M/P using CAR

- Use a classifier
  - `access-list 101 permit udp any any`
    - *Policing only udp traffic to limit the VIDEO traffic*
- Define policing function:
  - `interface Ethernet 1/0`
  - `rate-limit input access-group 101 1000000 2000 2000 conform-action transmit exceed-action set-dscp-transmit 38`
    - *Limit the VIDEO traffic 1Mbps, remark exceeded traffic*

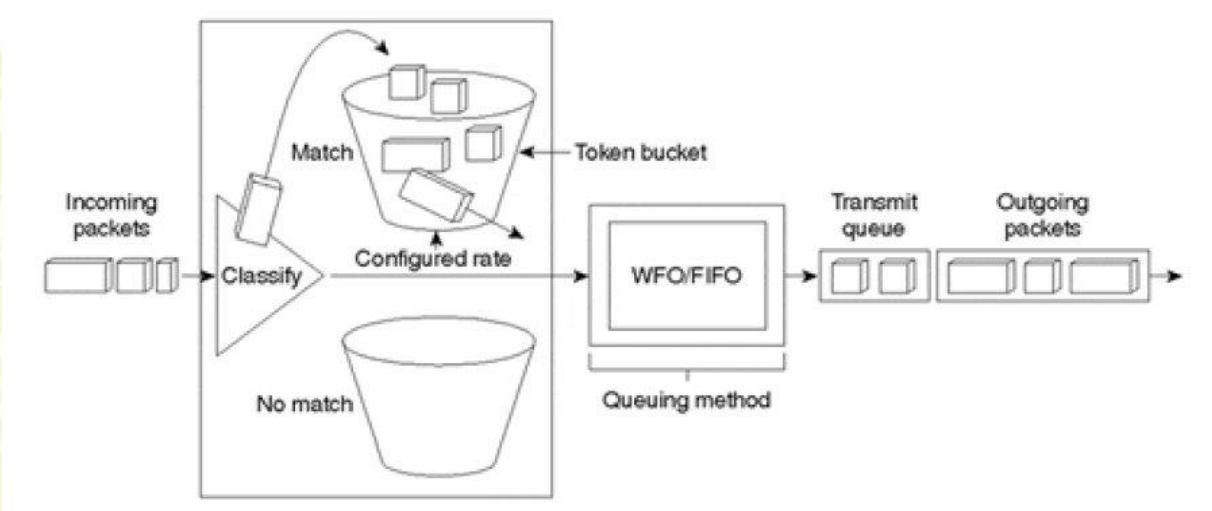
Packet C/M/P using CAR

- Try to add policing to limit VIDEO traffic, check with wireshark traffic re-marking!
- Show status
  - `show interfaces Ethernet 1/1 rate`

```
Ethernet0/0
  Input
    matches: access-group 101
      params:  1000000 bps, 200000 limit, 200000 extended limit
      conformed 2039 packets, 2885550 bytes; action: set-prec-transmit 2
      exceeded 393 packets, 518162 bytes; action: drop
      last packet: 358299ms ago, current burst: 199897 bytes
      last cleared 00:06:39 ago, conformed 57000 bps, exceeded 10000 bps
R1#
```

Traffic Shaping (TS)

- TS smoothes bursty traffic to meet the configured CIR by queuing or buffering packets exceeding the mean rate (*outbound traffic only*)
- Queued packets are transmitted as tokens become available (*Packets are not discarded*)
- Shaper is usually used at the core to avoid link congestion



Generic Traffic Shaping

- I want to shape outgoing traffic on a certain interface (e.g. to avoid link saturation)
- Traffic class for shaping
  - `class-map match-all OUT_ES21`
  - `match any`
- Add shaper as policy-map
  - `policy-map SHAPER`
  - `class OUT_S21`
  - `shape average 2000000`

Generic Traffic Shaping

- Apply the policy-map to Serial 2/1
  - `interface Serial2/1`
  - `service-policy output SHAPER`

- Check the status of the policy-map
  - `show policy-map interface s2/1`

Test!

- Add a shaper to the outgoing interface e0/0 of R5 and test it with iperf using TCP traffic

Per Hop Behavior

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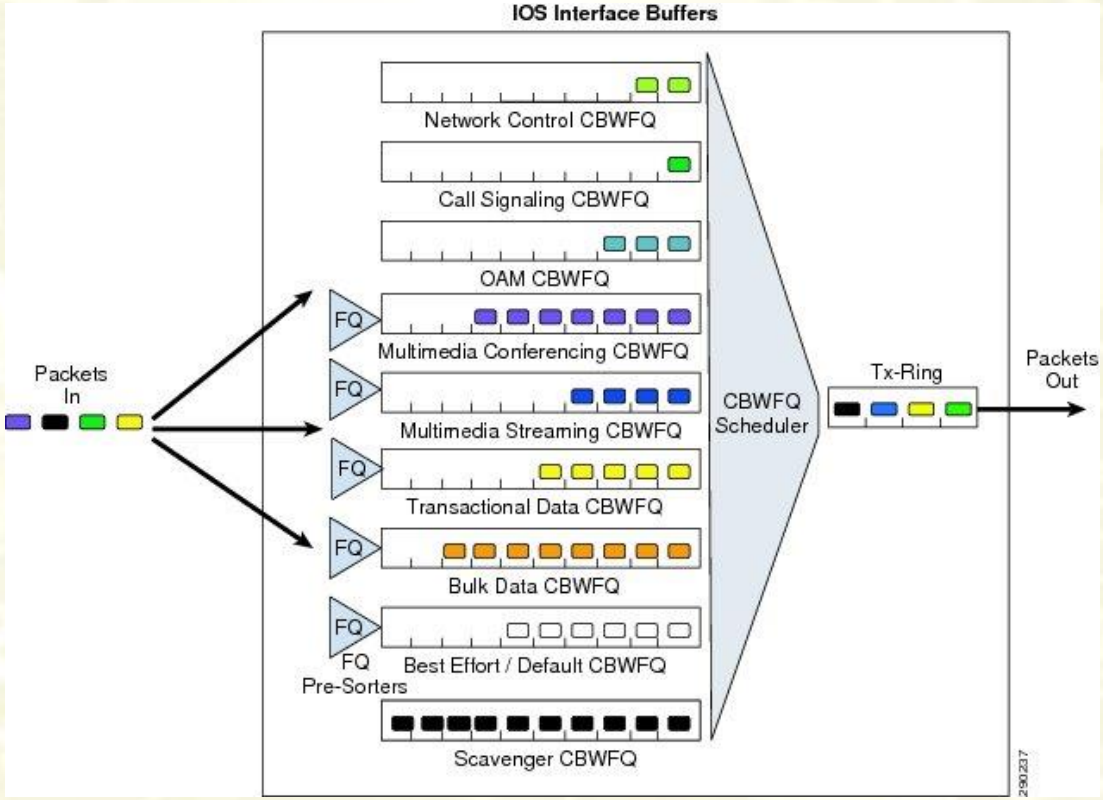
Class-Based WFQ

- Traffic Class are defined
- CBWFQ allocates a different subqueue for each traffic class



CBWFQ

- Classification based on DSCP
  - `class-map match-all VOIP`
  - `  match dscp ef`
  - `class-map match-all EXCESS`
  - `  match dscp af43`
  - `class-map match-all WEB`
  - `  match dscp af33`
  - `class-map match-all VIDEO`
  - `  match dscp af13`

Classify traffic based on the DSCP value

CBWFQ

- Allocate bandwidth
  - policy-map OUT
  - class VOIP
  - bandwidth percent 30
  - queue-limit 100 packets
  - class VIDEO
  - bandwidth percent 60
  - class WEB
  - bandwidth percent 5
  - queue-limit 20 packets
  - class EXCESS
  - bandwidth percent 4

Set the bandwidth share for this traffic

Limit the number of packets that can be enqueued for that class

CBWFQ

- Apply the configuration
  - `interface Serial1/0`
  - `service-policy output OUT`

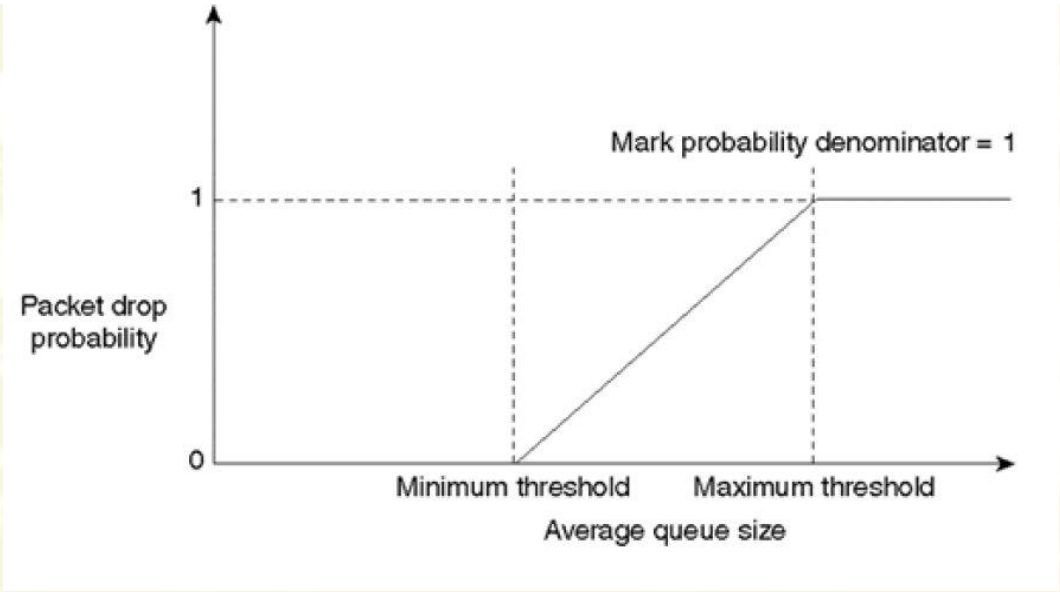
CBWFQ - Test

- Test! Activate all the traffic at once
- VoIP
  - `iperf -u -c 192.168.2.2 -i 1 -b 100K`
  - `iperf –u -s`
- VIDEO
  - `iperf -u -c 192.168.1.3 -i 1 -b 500K`
  - `iperf –u -s`
- WEB
  - `iperf -c 192.168.1.2 -i 1 -p 80 -t 30`
  - `iperf -s`
- Get statistics
  - `show policy-map interface`

Proactive Queue Management for Congestion Avoidance - RED

- RED is a congestion avoidance mechanism
- RED takes a ***proactive approach***, instead of waiting until the queue is full, it starts dropping packets with ***a non-zero drop probability*** when the average size is above a threshold

$$\text{packet drop probability} = \left(\frac{\text{(average queue length} - \text{minimum threshold)}}{\text{denominator}}\right) \times \text{mark probability}$$



Mark probability denominator is the fraction of packets dropped when the average queue depth is at the maximum threshold. If the mark probability denominator is 10, for example, 1 out of every 10 packets is dropped

Configuring RED

- Enabling RED
  - `policy-map OUT`
  - `  class VOIP`
  - `  random-detect`
  - `  no random-detect precedence-based`
- Tuning RED based on IP dscp
  - `random-detect dscp-based`
  - `random-detect dscp <dscp-value> <minimum-threshold> <maximum-threshold> <mark-prob-den>`
  - `random-detect dscp 46 40 60 10`
- Check RED status
  - `show policy-map interface`

References

- Committed Access Rate: http://www.cisco.com/c/en/us/td/docs/ios/12_2/qos/configuration/guide/fqos_c/qcfcar.html
- Generic Traffic Shaping: http://www.cisco.com/c/en/us/td/docs/ios/12_2/qos/configuration/guide/fqos_c/qcfgts.html
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- Class Based WFQ: http://www.cisco.com/c/en/us/td/docs/ios/12_0s/feature/guide/fswfq26.html
- RED: http://www.cisco.com/c/en/us/td/docs/ios/12_2/qos/configuration/guide/fqos_c/qcfwred.html