

## Nastavenia

V prvom rade bolo potrebné nastaviť generovanie tokov. V našom prípade s jednalo o 4xTCP tok a 1xUDP tok o intenzite 12paketrov/sekundu pri 512B na paket to činilo cca 53kbps na tok, čo dokopy prekročilo kapacitu linky, ktorá bola 128kbps. V grafoch je UDP prevádzka ružovou farbou.

Na vstupe sme si pripravili taktiež značkovanie jednotlivých paketov v týchto tokoch príkazmi:

```
access-list 101 permit tcp any any eq 9001
access-list 102 permit tcp any any eq 9002
access-list 103 permit tcp any any eq 9003
access-list 104 permit tcp any any eq 9004
access-list 105 permit udp any any eq 9005
```

```
class-map match-all tok1
  match access-group 101
class-map match-all tok2
  match access-group 102
class-map match-all tok3
  match access-group 103
class-map match-all tok4
  match access-group 104
class-map match-all tok5
  match access-group 105
```

```
policy-map zn
  class tok1
    set dscp af11 // čierny tok
  class tok2
    set dscp af12 // červený tok
  class tok3
    set dscp af31 // zelený tok
  class tok4
    set dscp af33 // modrý tok
  class tok5
    set dscp af21 // ružový tok
```

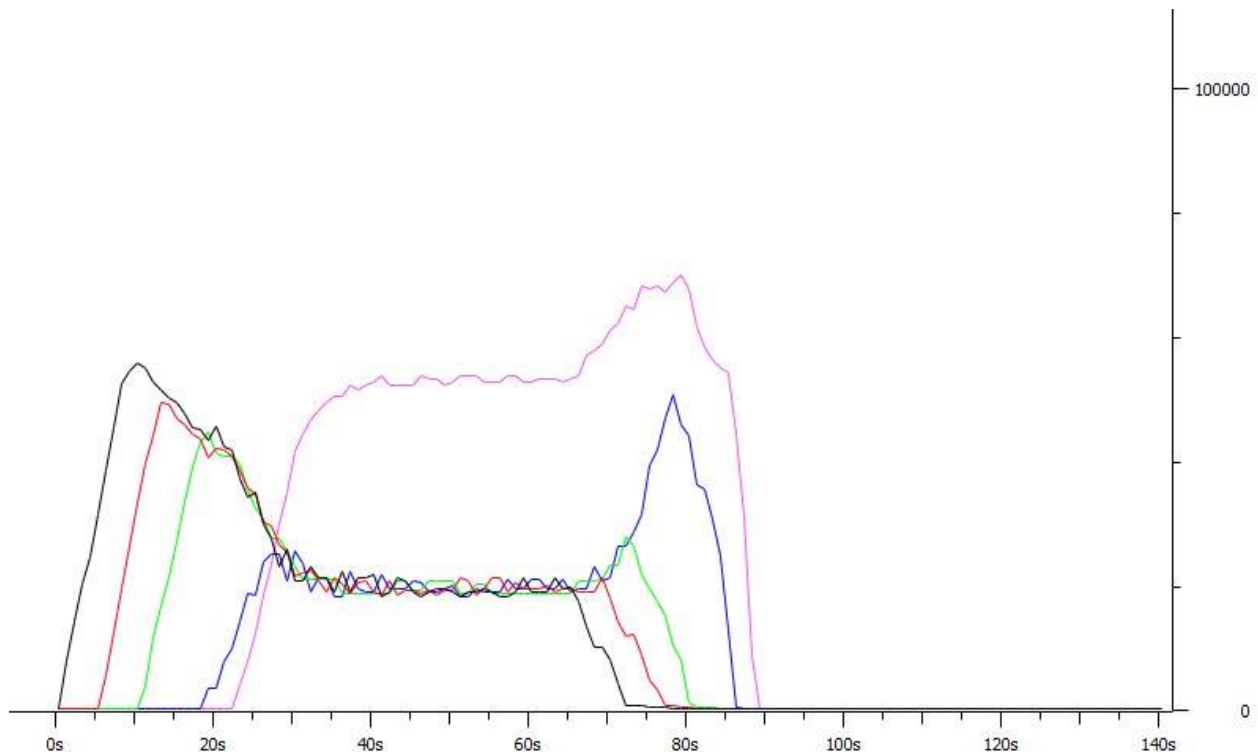
## Úloha č.1 – FIFO

V prvej úlohe bolo potrebné mať frontový režim nastavený na FIFO, čo bolo v našom prípade nastavené defaultne.

```

R1(config)#do sh int s0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is GT96K Serial
  Internet address is 10.0.12.1/24
  MTU 1500 bytes, BW 128 Kbit/sec, DLY 20000 usec,
    reliability 255/255, txload 67/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  CRC checking enabled
  Last input 00:00:01, output 00:00:03, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
    5202 packets input, 237520 bytes, 0 no buffer
    Received 236 broadcasts (0 IP multicasts)
    0 runs, 0 giants, 0 throttles
    3 input errors, 0 CRC, 0 frame, 3 overrun, 0 ignored, 0 abort
  12401 packets output, 8729498 bytes, 0 underruns
    0 output errors, 0 collisions, 14 interface resets
    0 unknown protocol drops
    0 output buffer failures, 0 output buffers swapped out
    3 carrier transitions
  DCD=up DSR=up DTR=up RTS=up CTS=up

```



```

***** TOTAL RESULTS *****
Number of flows      =      5
Total time           =    79.856000 s
Total packets        =    2158
Minimum delay        =   -135.524000 s
Maximum delay        =   -129.532000 s
Average delay        =   -132.773060 s
Average jitter       =     0.129313 s
Delay standard deviation =    1.373343 s
Bytes received       =    1104896
Average bitrate      =   110.688840 Kbit/s
Average packet rate  =    27.023643 pkt/s
Packets dropped      =      0 (0.00 %)
Average loss-burst size =      0 pkt
Error lines          =      0

```

## Úloha č.2 - CBWFQ

V tejto úlohe sme v našej policy aktivovali v triede class-default frontový režim fair-queue a pozorovali sme zmeny. Pre každý tok sme taktiež nastavili 25% z bandwidthu.

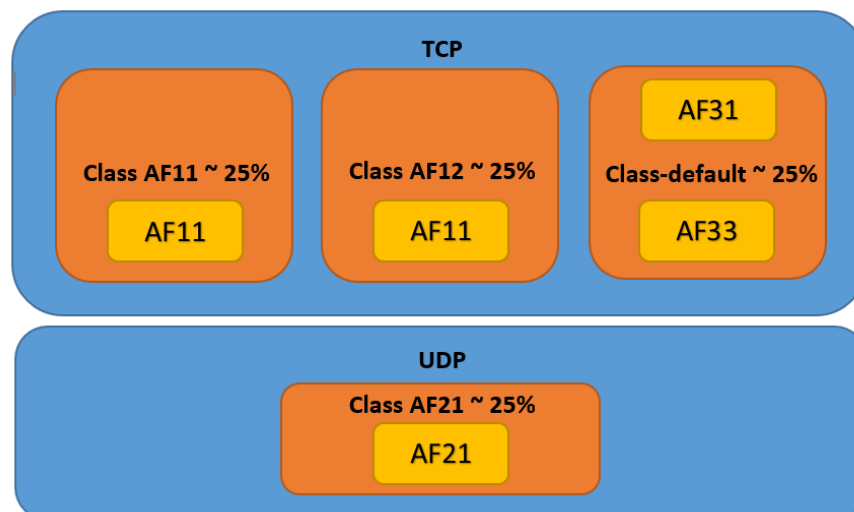
Použité príkazy:

```

policy-map prio
  class af11
    bandwidth percent 25
  class af12
    bandwidth percent 25
  class af21
    bandwidth percent 25
  class class-default
    fair-queue
    bandwidth percent 25

```

Značkovanie a rozdelenie do tried je teda nasledujúce.



```
R1#sh int s0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is GT96K Serial
  Internet address is 10.0.12.1/24
  MTU 1500 bytes, BW 128 Kbit/sec, DLY 20000 usec,
    reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  CRC checking enabled
  Last input 00:00:07, output 00:00:09, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes): Total output drops: 167
  Queueing strategy: Class-based queueing
  Output queue: 0/1000/167 (size/max total/drops)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
    6115 packets input, 286248 bytes, 0 no buffer
    Received 456 broadcasts (0 IP multicasts)
    0 runs, 0 giants, 0 throttles
    3 input errors, 0 CRC, 0 frame, 3 overrun, 0 ignored, 0 abort
    14259 packets output, 8821484 bytes, 0 underruns
    0 output errors, 0 collisions, 15 interface resets
    0 unknown protocol drops
    0 output buffer failures, 0 output buffers swapped out
    3 carrier transitions
  DCD=up DSR=up DTR=up RTS=up CTS=up
```

```
R1#sh policy-map int s0/0/0
Serial0/0/0
```

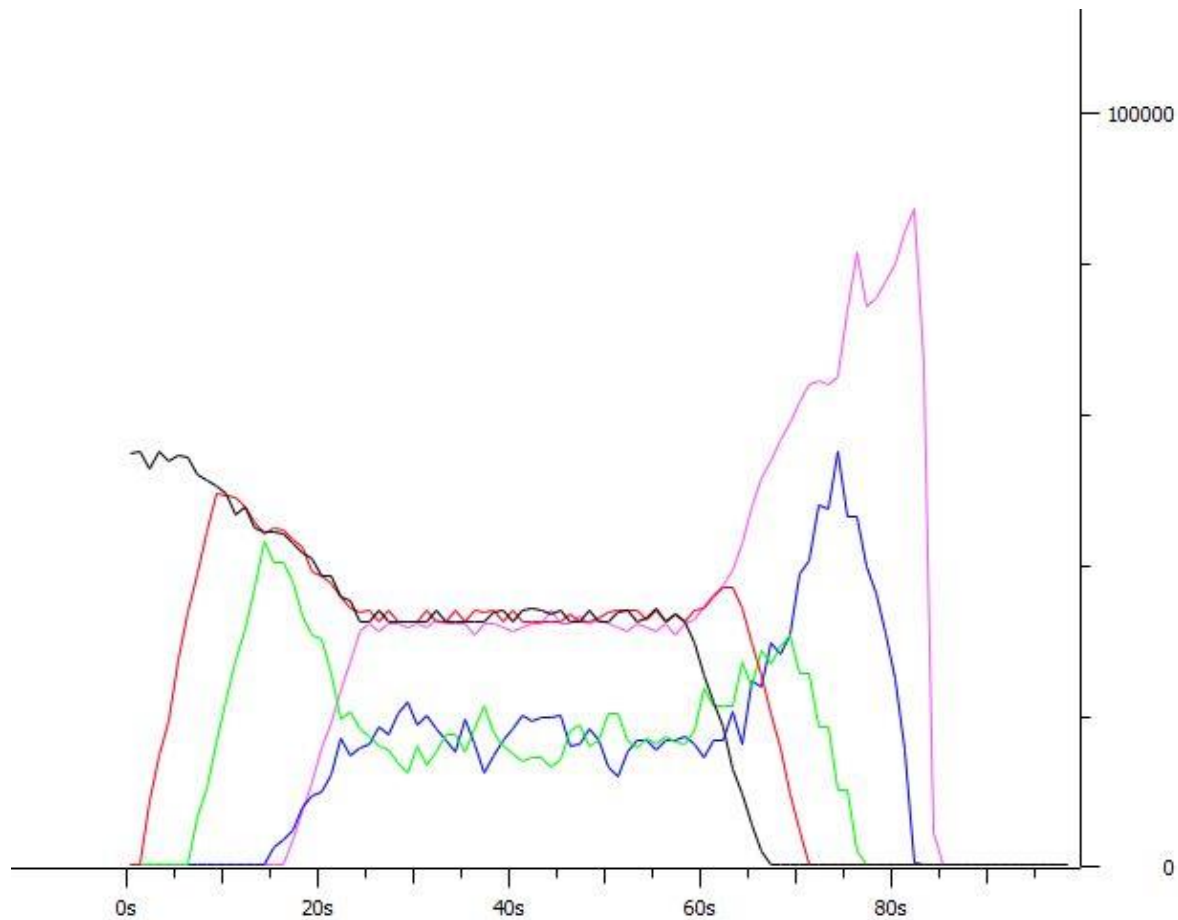
```
Service-policy output: prio
```

```
Class-map: af11 (match-all)
 342 packets, 282324 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
Match: dscp af11 (10)
Queueing
queue limit 64 packets
(queue depth/total drops/no-buffer drops) 0/0/0
(pkts output/bytes output) 342/282324
bandwidth 25% (32 kbps)
```

```
Class-map: af12 (match-all)
 330 packets, 273604 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
Match: dscp af12 (12)
Queueing
queue limit 64 packets
(queue depth/total drops/no-buffer drops) 0/0/0
(pkts output/bytes output) 330/273604
bandwidth 25% (32 kbps)
```

```
Class-map: af21 (match-all)
 720 packets, 391680 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
Match: dscp af21 (18)
Queueing
queue limit 64 packets
(queue depth/total drops/no-buffer drops) 0/150/0
(pkts output/bytes output) 570/310080
bandwidth 25% (32 kbps)
```

```
Class-map: class-default (match-any)
 482 packets, 339897 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
Match: any
Queueing
queue limit 64 packets
(queue depth/total drops/no-buffer drops/flowdrops) 0/17/0/17
(pkts output/bytes output) 465/333705
bandwidth 25% (32 kbps)
Fair-queue: per-flow queue limit 16 packets
```



```

***** TOTAL RESULTS *****
Number of flows      =          5
Total time           =      79.954000 s
Total packets        =      2171
Minimum delay        =     -124.070000 s
Maximum delay        =     -112.416000 s
Average delay        =     -119.247930 s
Average jitter       =       0.217364 s
Delay standard deviation =       1.968488 s
Bytes received       =      1111552
Average bitrate      =      111.219151 Kbit/s
Average packet rate  =       27.153113 pkt/s
Packets dropped      =       150 (6.46 %)
Average loss-burst size =       1.595745 pkt
Error lines          =          0

```



## Úloha č.3 – WRED

Frontový režim WRED zahadzuje pakety náhodne a v predstihu. Zapneme ho v triede class-default príkazom *random-detect*.

```
R1(config-pmap-c)#do sh int s0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is GT96K Serial
  Internet address is 10.0.12.1/24
  MTU 1500 bytes, BW 128 Kbit/sec, DLY 20000 usec,
    reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  CRC checking enabled
  Last input 00:00:04, output 00:00:06, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes): Total output drops: 316
  Queueing strategy: Class-based queueing
  Output queue: 0/1000/316 (size/max total/drops)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
    6934 packets input, 325234 bytes, 0 no buffer
    Received 539 broadcasts (0 IP multicasts)
    0 runts, 0 giants, 0 throttles
    3 input errors, 0 CRC, 0 frame, 3 overrun, 0 ignored, 0 abort
    15978 packets output, 8903168 bytes, 0 underruns
    0 output errors, 0 collisions, 15 interface resets
    0 unknown protocol drops
    0 output buffer failures, 0 output buffers swapped out
    3 carrier transitions
  DCD=up DSR=up DTR=up RTS=up CTS=up
```

```
R1(config-pmap-c)#do sh policy-map int s0/0/0
Serial0/0/0
```

```
Service-policy output: prio
```

```
Class-map: af11 (match-all)
  673 packets, 564676 bytes
  5 minute offered rate 0000 bps, drop rate 0000 bps
  Match: dscp af11 (10)
  Queueing
    queue limit 64 packets
    (queue depth/total drops/no-buffer drops) 0/0/0
    (pkts output/bytes output) 673/564676
    bandwidth 25% (32 kbps)
```

```
Class-map: af12 (match-all)
  651 packets, 545788 bytes
  5 minute offered rate 0000 bps, drop rate 0000 bps
  Match: dscp af12 (12)
  Queueing
    queue limit 64 packets
    (queue depth/total drops/no-buffer drops) 0/0/0
    (pkts output/bytes output) 651/545788
    bandwidth 25% (32 kbps)
```

```
Class-map: af21 (match-all)
  1440 packets, 783360 bytes
  5 minute offered rate 0000 bps, drop rate 0000 bps
  Match: dscp af21 (18)
  Queueing
    queue limit 64 packets
    (queue depth/total drops/no-buffer drops) 0/299/0
    (pkts output/bytes output) 1441/620704
    bandwidth 25% (32 kbps)
```

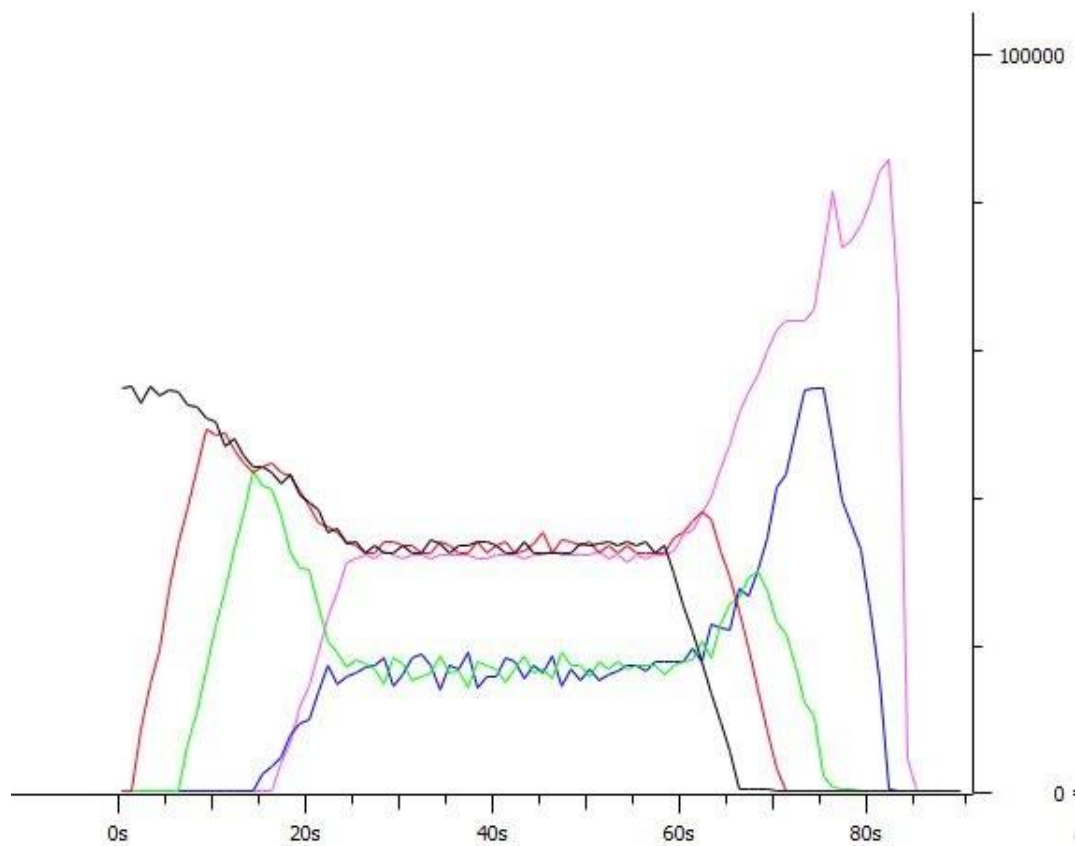
```
Class-map: class-default (match-any)
  981 packets, 676883 bytes
  5 minute offered rate 0000 bps, drop rate 0000 bps
  Match: any
  Queueing
    queue limit 64 packets
    (queue depth/total drops/no-buffer drops) 0/17/0
    (pkts output/bytes output) 983/670667
    bandwidth 25% (32 kbps)
```

```
Exp-weight-constant: 9 (1/512)
```

```
Mean queue depth: 0 packets
```

class	Transmitted	Random drop	Tail drop	Minimum	Maximum	M
	pkts/bytes	pkts/bytes	pkts/bytes	thresh	thresh	pro
0	79/5615	0/0	0/0	20	40	1/10
1	0/0	0/0	0/0	22	40	1/10
2	0/0	0/0	0/0	24	40	1/10
3	388/328933	0/0	0/0	26	40	1/10
4	0/0	0/0	0/0	28	40	1/10
5	0/0	0/0	0/0	30	40	1/10
6	0/0	0/0	0/0	32	40	1/10
7	0/0	0/0	0/0	34	40	1/10





\*\*\*\*\* TOTAL RESULTS \*\*\*\*\*

Number of flows	=	5
Total time	=	79.929000 s
Total packets	=	2198
Minimum delay	=	-135.492000 s
Maximum delay	=	-126.262000 s
Average delay	=	-132.395429 s
Average jitter	=	0.179914 s
Delay standard deviation	=	2.393845 s
Bytes received	=	1125376
Average bitrate	=	112.637566 Kbit/s
Average packet rate	=	27.499406 pkt/s
Packets dropped	=	149 (6.35 %)
Average loss-burst size	=	1.366972 pkt
Error lines	=	0

## Úloha č.4 – WRED + ECN

Pre zapnutie mechanizmu ECN bolo na oboch koncoch v OS Windows zadať do príkazového riadka príkaz: `netsh int tcp set global ecncapability=enabled`. V policy mape bolo taktiež potrebné v triede class default zadať príkaz `random-detect ecn`. Po zadaní týchto príkazov by sme mali vidieť vo výpisoch z Wiresharku v IP hlavičke paketov v poli ECN vidieť hodnoty 10 alebo 01.

```
R1#sh int s0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is GT96K Serial
  Internet address is 10.0.12.1/24
  MTU 1500 bytes, BW 128 Kbit/sec, DLY 20000 usec,
    reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  CRC checking enabled
  Last input 00:00:02, output 00:00:05, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes): Total output drops: 873
  Queueing strategy: Class-based queueing
  Output queue: 0/1000/873 (size/max total/drops)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
    9898 packets input, 476936 bytes, 0 no buffer
    Received 729 broadcasts (0 IP multicasts)
    0 runts, 0 giants, 0 throttles
    3 input errors, 0 CRC, 0 frame, 3 overrun, 0 ignored, 0 abort
    22509 packets output, 9357096 bytes, 0 underruns
    0 output errors, 0 collisions, 15 interface resets
    0 unknown protocol drops
    0 output buffer failures, 0 output buffers swapped out
    3 carrier transitions
  DCD=up DSR=up DTR=up RTS=up CTS=up
```

```

R1#sh policy-map int s0/0/0
Serial0/0/0

Service-policy output: prio

Class-map: af11 (match-all)
 1986 packets, 1670556 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
 Match: dscp af11 (10)
 Queueing
  queue limit 64 packets
  (queue depth/total drops/no-buffer drops) 0/0/0
  (pkts output/bytes output) 1986/1670556
  bandwidth 25% (32 kbps)

Class-map: af12 (match-all)
 1872 packets, 1593348 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
 Match: dscp af12 (12)
 Queueing
  queue limit 64 packets
  (queue depth/total drops/no-buffer drops) 0/0/0
  (pkts output/bytes output) 1872/1593348
  bandwidth 25% (32 kbps)

Class-map: af21 (match-all)
 4320 packets, 2350080 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
 Match: dscp af21 (18)
 Queueing
  queue limit 64 packets
  (queue depth/total drops/no-buffer drops) 0/856/0
  (pkts output/bytes output) 3464/1884416
  bandwidth 25% (32 kbps)

Class-map: class-default (match-any)
 2640 packets, 1869554 bytes
 5 minute offered rate 0000 bps, drop rate 0000 bps
 Match: any
 Queueing
  queue limit 64 packets
  (queue depth/total drops/no-buffer drops) 0/17/0
  (pkts output/bytes output) 2622/1863338
  bandwidth 25% (32 kbps)
  Exp-weight-constant: 9 (1/512)
  Mean queue depth: 0 packets

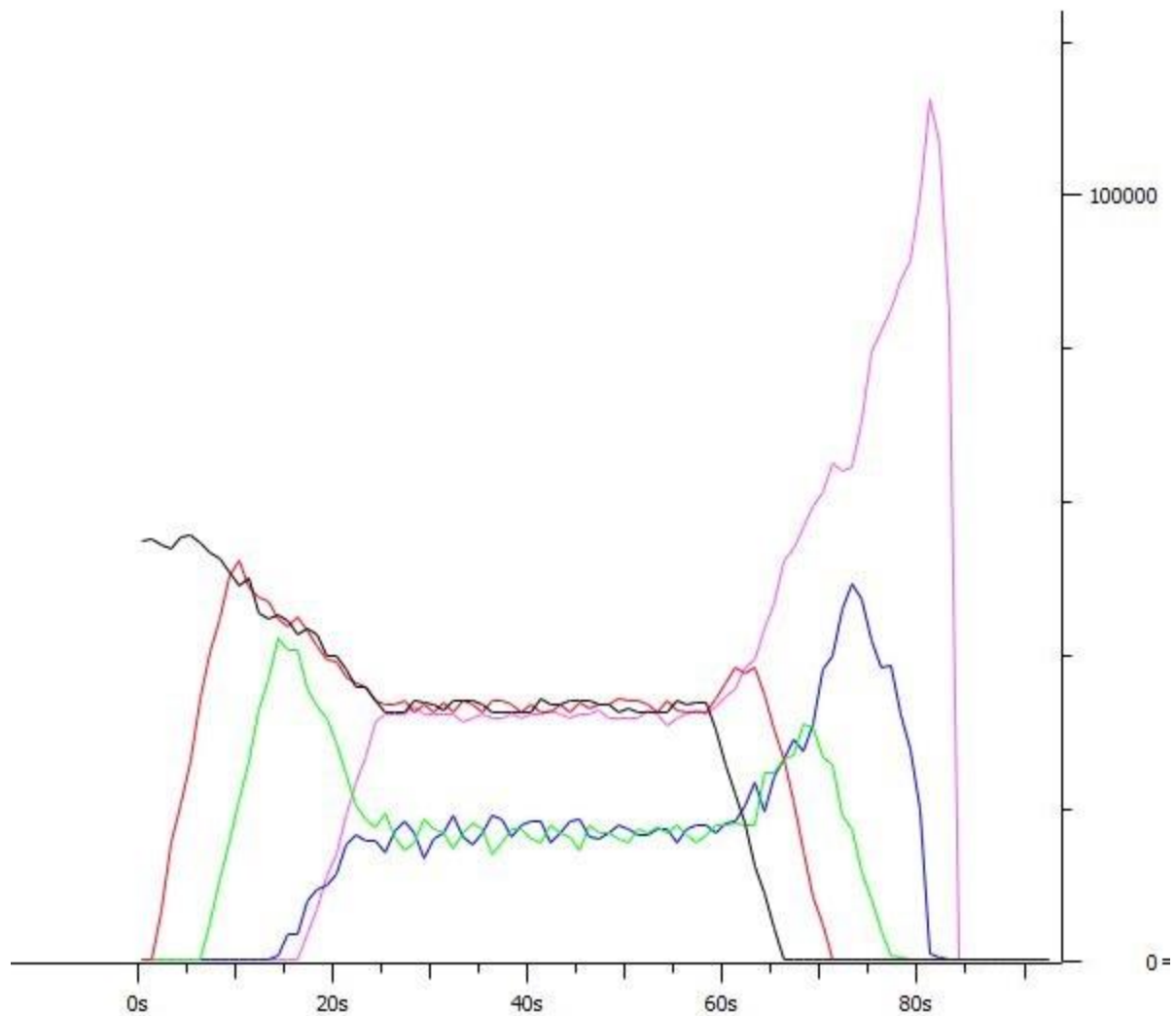
```

class	Transmitted pkts/bytes	ECN marked	Random drop pkts/bytes	Tail drop pkts/bytes	Minimum thresh	Maximum thresh	Mark prob
0	251/16897	0	0/0	0/0	20	40	1/10
1	0/0	0	0/0	0/0	22	40	1/10
2	0/0	0	0/0	0/0	24	40	1/10
3	1398/1175200	0	0/0	0/0	26	40	1/10
4	0/0	0	0/0	0/0	28	40	1/10
5	0/0	0	0/0	0/0	30	40	1/10
6	0/0	0	0/0	0/0	32	40	1/10
7	0/0	0	0/0	0/0	34	40	1/10

```

R1#

```



```

***** TOTAL RESULTS *****
Number of flows      =      5
Total time           =    79.850000 s
Total packets        =    2191
Minimum delay        =   -135.552000 s
Maximum delay        =   -126.281000 s
Average delay        =   -132.455562 s
Average jitter       =    0.184381 s
Delay standard deviation =    2.418063 s
Bytes received       =   1121792
Average bitrate      =   112.389931 Kbit/s
Average packet rate  =    27.438948 pkt/s
Packets dropped      =    150 (6.41 %)
Average loss-burst size =    1.456311 pkt
Error lines          =      0

```

No.	Time	Source	Destination	Protocol	Length	Info
85	4.23880000	10.0.1.2	10.0.2.2	TCP	130	1258-9001 [PSH, ACK] Seq=25525 Ack=1 Win=65536 Len=76
86	4.23883200	10.0.2.2	10.0.1.2	TCP	54	9001-1258 [ACK] Seq=1 Ack=25601 Win=65536 Len=0
87	4.27860200	10.0.1.2	10.0.2.2	TCP	566	1258-9001 [PSH, ACK] Seq=25601 Ack=1 Win=65536 Len=512
88	4.48248100	10.0.2.2	10.0.1.2	TCP	54	9001-1258 [ACK] Seq=1 Ack=26113 Win=65024 Len=0
89	4.56356300	10.0.1.2	10.0.2.2	TCP	1514	1258-9001 [ACK] Seq=26113 Ack=1 Win=65536 Len=1460
90	4.57124100	10.0.1.2	10.0.2.2	TCP	130	1258-9001 [PSH, ACK] Seq=27573 Ack=1 Win=65536 Len=76
91	4.57127900	10.0.2.2	10.0.1.2	TCP	54	9001-1258 [ACK] Seq=1 Ack=27649 Win=65536 Len=0
92	4.61076700	10.0.1.2	10.0.2.2	TCP	566	1258-9001 [PSH, ACK] Seq=27649 Ack=1 Win=65536 Len=512
93	4.80371000	10.0.2.2	10.0.1.2	TCP	54	9001-1258 [ACK] Seq=1 Ack=28161 Win=65024 Len=0
94	4.89746300	10.0.1.2	10.0.2.2	TCP	1514	1258-9001 [ACK] Seq=28161 Ack=1 Win=65536 Len=1460
[+] Frame 90: 130 bytes on wire (1040 bits), 130 bytes captured (1040 bits) on interface 0						
[+] Ethernet II, Src: Cisco_c0:60:d0 (00:15:fa:c0:60:d0), Dst: 7a:b3:01:02:01:01 (7a:b3:01:02:01:01)						
[+] Internet Protocol Version 4, Src: 10.0.1.2 (10.0.1.2), Dst: 10.0.2.2 (10.0.2.2)						
Version: 4						
Header Length: 20 bytes						
[+] Differentiated Services Field: 0x2a (DSCP 0x0a: Assured Forwarding 11; ECN: 0x02: ECT(0) (ECN-Capable Transport))						
0010 10.. = Differentiated Services Codepoint: Assured Forwarding 11 (0x0a)						
.... ..10 = Explicit Congestion Notification: ECT(0) (ECN-Capable Transport) (0x02)						
Total Length: 116						
Identification: 0x5204 (20996)						
[+] Flags: 0x02 (Don't Fragment)						
Fragment offset: 0						
Time to live: 126						
Protocol: TCP (6)						
[+] Header checksum: 0x9352 [validation disabled]						
Source: 10.0.1.2 (10.0.1.2)						
Destination: 10.0.2.2 (10.0.2.2)						
[Source GeoIP: Unknown]						
[Destination GeoIP: Unknown]						
[+] Transmission Control Protocol, Src Port: 1258 (1258), Dst Port: 9001 (9001), Seq: 27573, Ack: 1, Len: 76						
[+] Data (76 bytes)						

Čo sa týka zmeny veľkosti okna, zaznamenali sme tieto prípady:

- [+] .... 0000 0001 0000 = Flags: 0x010 (ACK)  
window size value: 252  
[Calculated window size: 64512]  
[window size scaling factor: 256]
- [+] .... 0000 0001 0000 = Flags: 0x010 (ACK)  
window size value: 256  
[Calculated window size: 65536]  
[window size scaling factor: 256]

Paket mal jednotlivé príznaky nastavené takto:

- [+] .... 0000 0001 1000 = Flags: 0x018 (PSH, ACK)
  - 000. .... = Reserved: Not set
  - ...0 .... = Nonce: Not set
  - .... 0... = Congestion window Reduced (CWR): Not set
  - .... .0.. = ECN-Echo: Not set
  - .... ..0. = Urgent: Not set
  - .... ...1 .... = Acknowledgment: Set
  - .... .... 1... = Push: Set
  - .... .... .0.. = Reset: Not set
  - .... .... ..0. = Syn: Not set
  - .... .... ...0 = Fin: Not set