eTourPlan: A Knowledge-Based Tourist Route and Activity Planner

Thesis Oral Defence for MCS Degree Program

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Outline

1.1 Motivation

-
- Tourism is the world's largest and fastest growing industry
- The World Tourism Organization predicts that one billion international tourists will travel by the year 2010
- A highly competitive business for tourism destinations all over the world
- There are many conventional tourism service providers which are competively trying to provide the best travel plans and recommendations to thier customers
-

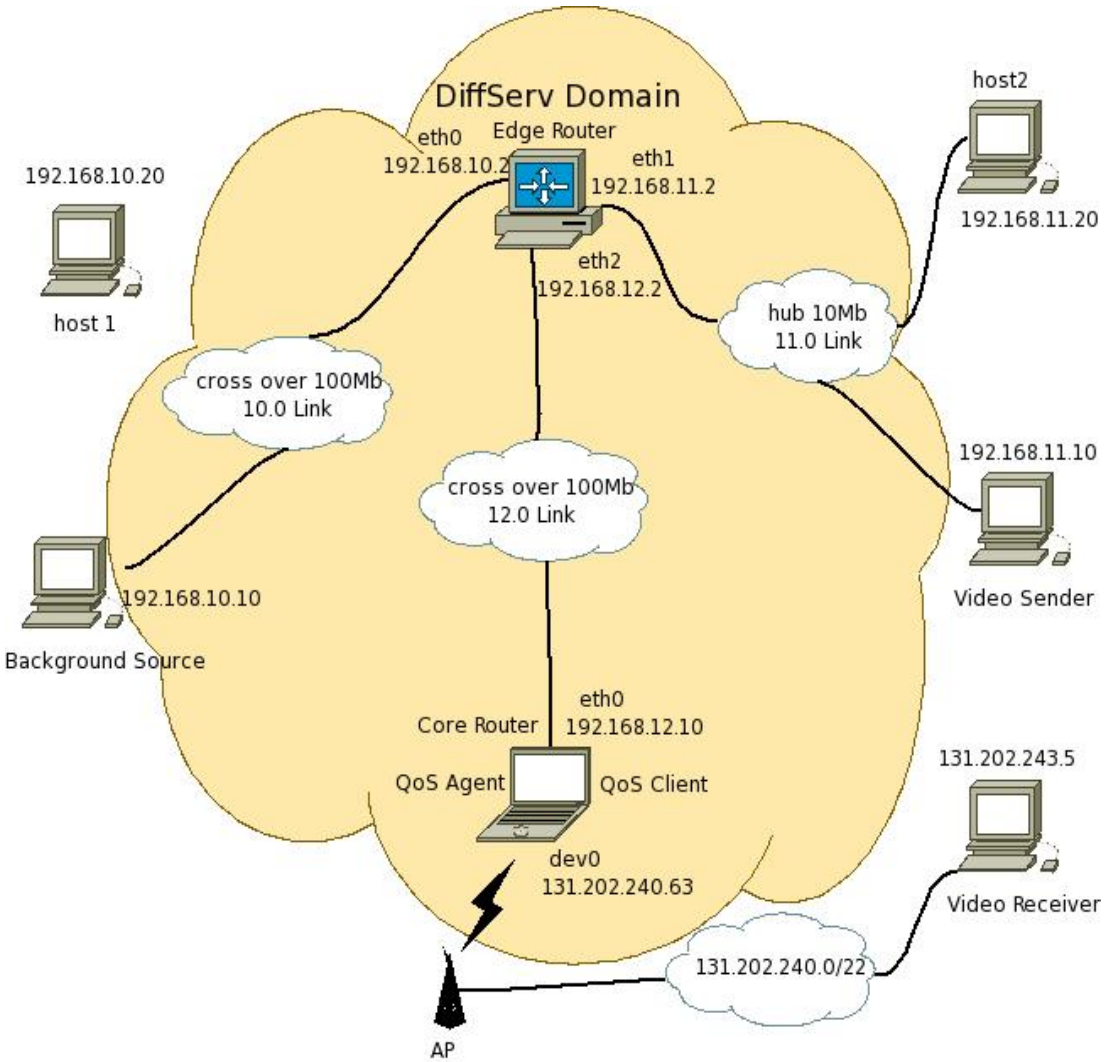
1.2 Goals

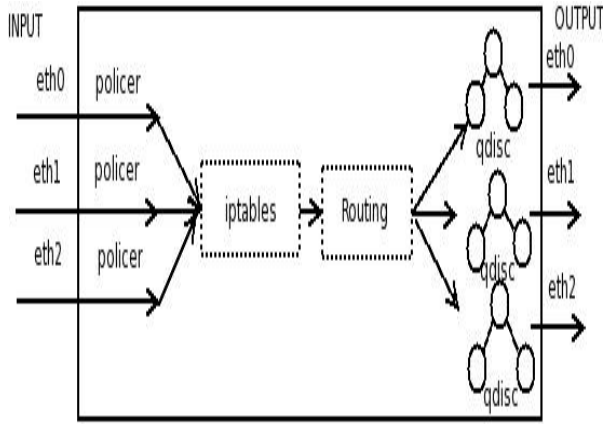
- To provide QoS test-bed and investigating characteristics of real-time Internet traffic on the heterogeneous networks.
- To investigate measurement techniques to measure performance.
- To configure what bandwidth and burst size is required to stream MPEG2 video through the DiffServ domain.

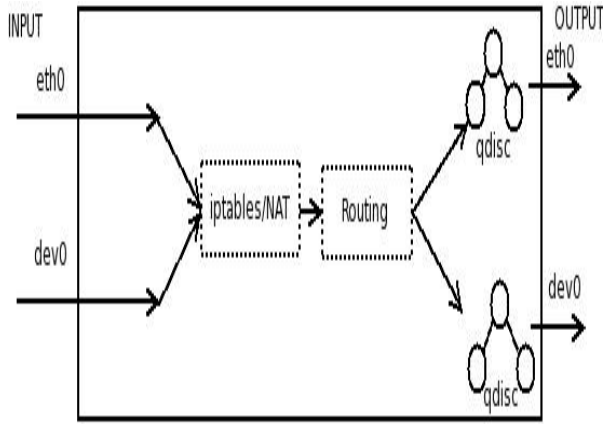
2.1 Methodology for QoS Mechanism

- Bandwidth Broker (BB):
  to manage heterogeneous network.
- TungaBaskaraRao's Thesis:
  End-to-End QoS Signaling for Real-Time Data Streams.
- Policer regulates packets
  - rate parameter
  - burst parameter
- Packet Marker categorizes packets
- Packet scheduler manages the bandwidth
  - Expedited Forwarding (EF) traffic
  - Best Effort (BE) traffic

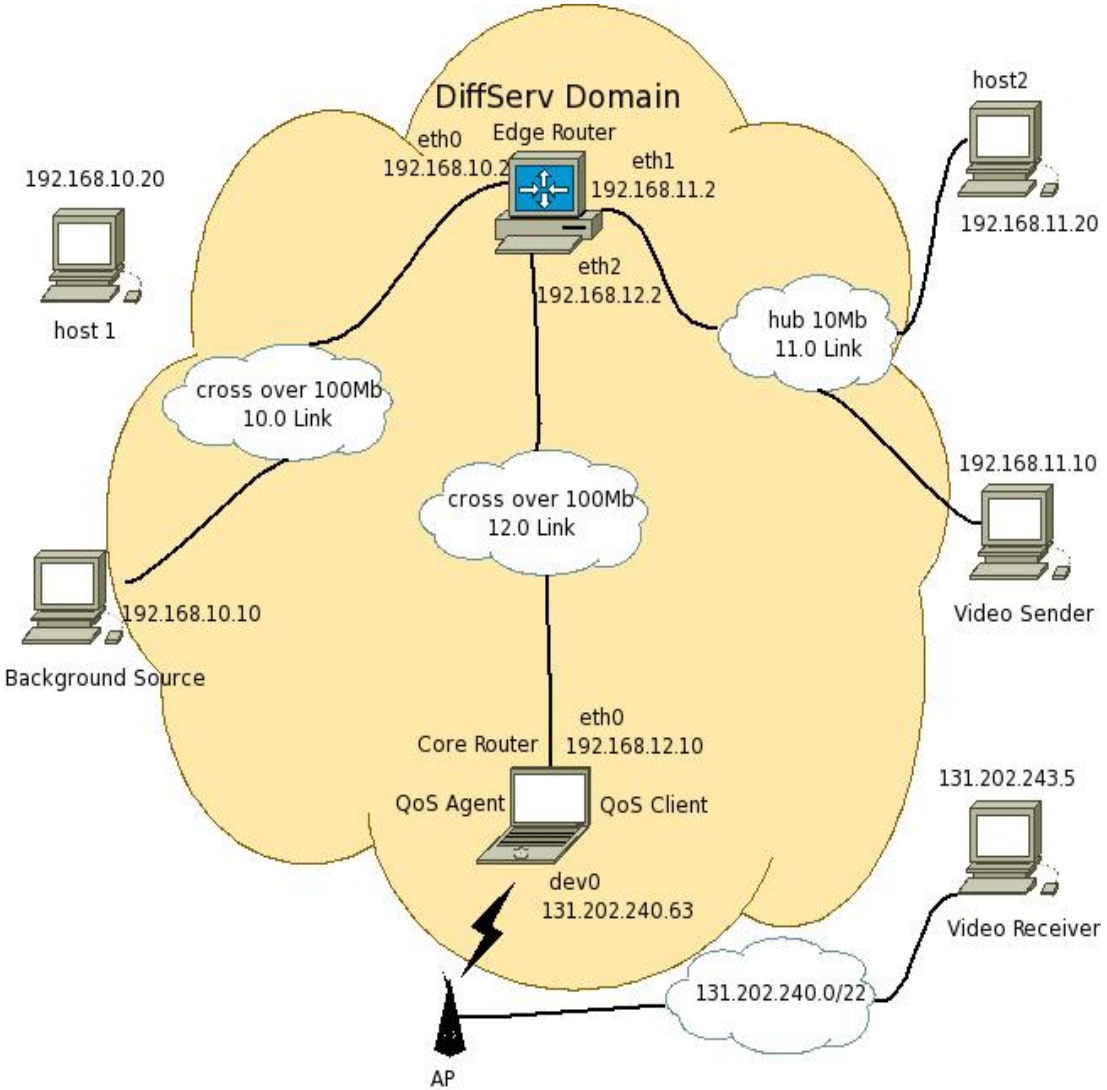
2.2 DiffServ Testbed Architecture







3.1.1 Testing the DiffServ domain



- Measurement tool : Iperf
- Video Sender transmits 3Mbits data to Video Receiver
- Background Srouce transmits 5Mbits to Video Reciever
- Wireless link's Total Throughput is 5.5 Mbits

3.1.2 Background Source 192.168.10.10 client report

```
[cnsr@localhost ˙ ]$ /usr/bin/iperf -c 131.202.243.5 -p 55555 -u -b 5M -t 30
------------------------------------------------------------
Client connecting to 131.202.243.5, UDP port 55555
Sending 1470 byte datagrams
UDP buffer size: 108 KByte (default)
------------------------------------------------------------
[ 3] local 192.168.10.10 port 32772 connected with 131.202.243.5 port 55555
[ 3] 0.0-30.0 sec 17.9 MBytes 5.00 Mbits/sec
[ 3] Sent 12757 datagrams
[ 3] WARNING: did not receive ack of last datagram after 10 tries.
[cnsr@localhost ˙ ]$
```

3.1.3 QoS client 192.168.11.10 client report

```
[cnsr@localhost videos]$ /usr/bin/iperf -c 131.202.243.5 -p 55556 -u -b 3M -t 30
------------------------------------------------------------
Client connecting to 131.202.243.5, UDP port 55556
Sending 1470 byte datagrams
UDP buffer size: 108 KByte (default)
------------------------------------------------------------
[ 3] local 192.168.11.10 port 32772 connected with 131.202.243.5 port 55556
[ 3] 0.0-30.0 sec 10.7 MBytes 3.00 Mbits/sec
[ 3] Sent 7655 datagrams
[ 3] Server Report:
[ 3] 0.0-30.0 sec 10.6 MBytes 2.96 Mbits/sec 0.109 ms 104/ 7654 (1.4%)
[ 3] 0.0-30.0 sec 1 datagrams received out-of-order
[cnsr@localhost videos]$
```

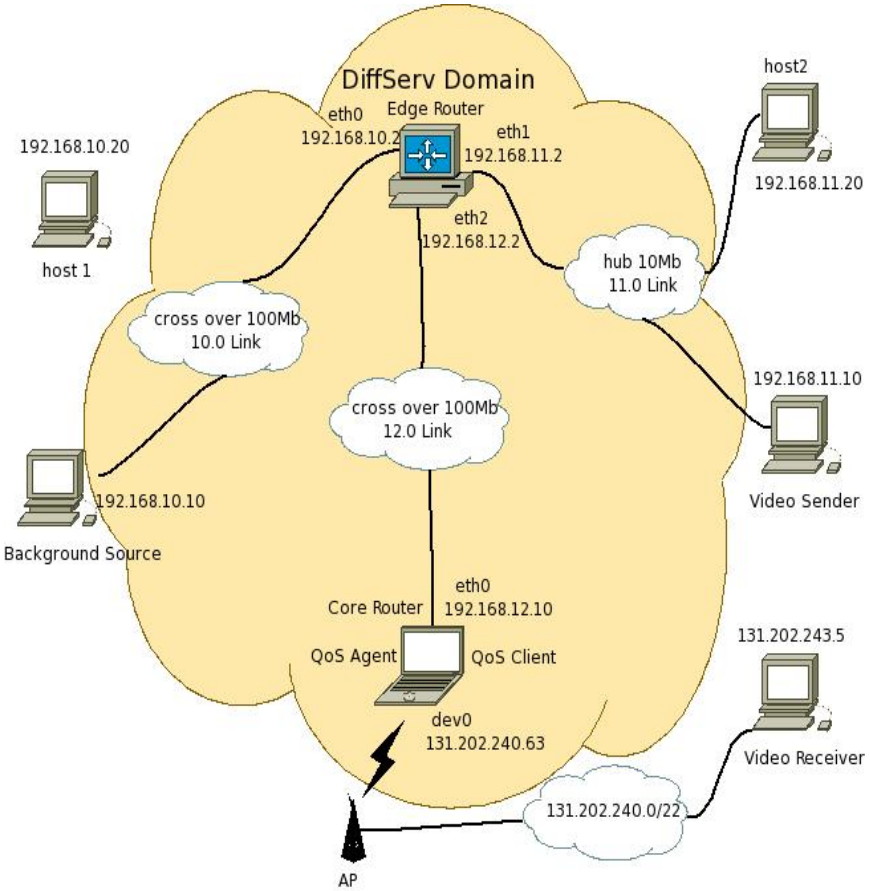
3.1.4 Server report for background traffic

```
[cnsr@ib214m05 ~]$ /usr/bin/iperf -s -p 55555 -u -i 5
------------------------------------------------------------
Server listening on UDP port 55555
Receiving 1470 byte datagrams
UDP buffer size: 108 KByte (default)
------------------------------------------------------------
[ 3] local 131.202.243.5 port 55555 connected with 131.202.240.63 port 32772
[ 3] 0.0- 5.0 sec 1.87 MBytes 3.14 Mbits/sec 0.706 ms 679/ 2012 (34%)
[ 3] 5.0-10.0 sec 3.08 MBytes 5.17 Mbits/sec 1.362 ms 44/ 2199 (2%)
[ 3] 5.0-10.0 sec 44 datagrams received out-of-order
[ 3] 10.0-15.0 sec 2.93 MBytes 4.92 Mbits/sec 6.334 ms 0/ 2093 (0%)
[ 3] 15.0-20.0 sec 1.39 MBytes 2.34 Mbits/sec 3.420 ms 938/ 1932 (49%)
[ 3] 15.0-20.0 sec 81 datagrams received out-of-order
[ 3] 20.0-25.0 sec 1.38 MBytes 2.32 Mbits/sec 4.098 ms 1128/ 2115 (53%)
[ 3] 25.0-30.0 sec 1.40 MBytes 2.36 Mbits/sec 4.541 ms 1131/ 2133 (53%)
[ 3] 0.0-30.6 sec 12.2 MBytes 3.35 Mbits/sec 2.948 ms 4020/12756 (32%)
[ 3] 0.0-30.6 sec 126 datagrams received out-of-order
read failed: Connection refused
```

3.1.5 Server report for EF traffic

```
[cnsr@ib214m05 ~]$ /usr/bin/iperf -s -p 55556 -u -i 5
------------------------------------------------------------
Server listening on UDP port 55556
Receiving 1470 byte datagrams
UDP buffer size: 108 KByte (default)
------------------------------------------------------------
[ 3] local 131.202.243.5 port 55556 connected with 131.202.240.63 port 32772
[ 3] 0.0- 5.0 sec 1.64 MBytes 2.75 Mbits/sec 2.036 ms 105/ 1276 (8.2%)
[ 3] 5.0-10.0 sec 1.77 MBytes 2.98 Mbits/sec 1.925 ms 0/ 1266 (0%)
[ 3] 10.0-15.0 sec 1.80 MBytes 3.02 Mbits/sec 1.671 ms 0/ 1286 (0%)
[ 3] 15.0-20.0 sec 1.79 MBytes 3.00 Mbits/sec 0.200 ms 0/ 1275 (0%)
[ 3] 20.0-25.0 sec 1.79 MBytes 3.00 Mbits/sec 0.129 ms 0/ 1276 (0%)
[ 3] 25.0-30.0 sec 1.79 MBytes 3.00 Mbits/sec 0.105 ms 0/ 1275 (0%)
[ 3] 0.0-30.0 sec 10.6 MBytes 2.96 Mbits/sec 0.109 ms 104/ 7654 (1.4%)
[ 3] 0.0-30.0 sec 1 datagrams received out-of-order
read failed: Connection refused
```

3.2.1 Configuring Packet Scheduler (HTB qdisc)



Clip2.mpeg
MPEG2 compression video,
320×240, 29.970 fps,
MPEG layer-2, duration 92s.
File size = 8043364 bytes.

Figure: clip2.mpg specification

Estimated average rate (bps): file size/duration.
Estimated average rate for clip2.mpeg is 699kbits/sec

- VLC at the Video Sender,
- VLC at the CR,

3.2.2 HTB to manage the bandwidth

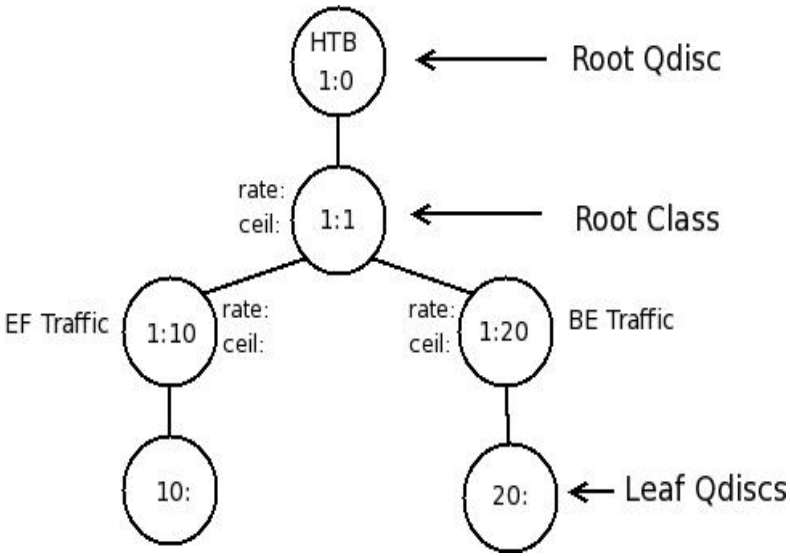


Figure: The qdisc-class hierarchy of the configuration used for the research

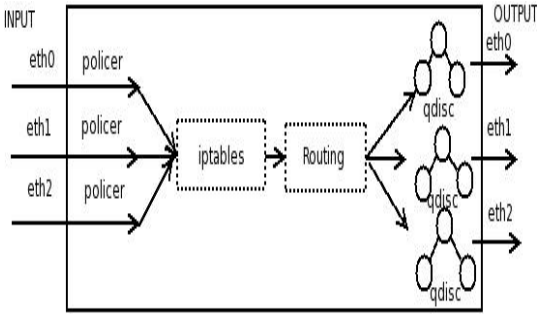
Table: Link Specification at the Edge Router

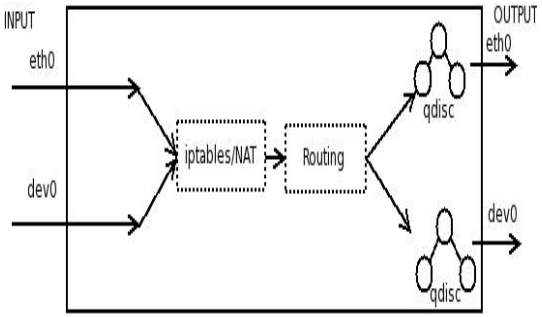
Link	BW(Mbps)	EF	BE
192.168.10.0/24	94.5	44.5	50
192.168.11.0/24	9.5	4.5	5
192.168.12.0/24	94.5	44.5	50

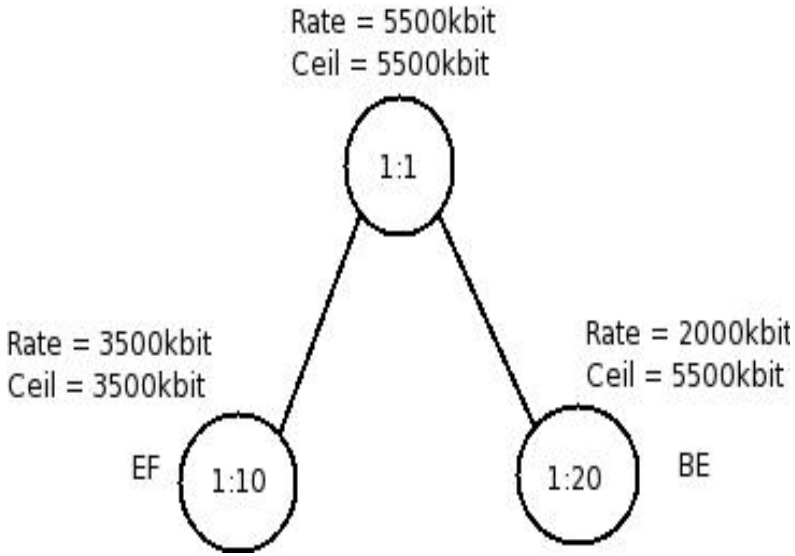
Table: Link Specification at the Core Router

Link	BW(Mbps)	EF	BE
192.168.12.0/24	94.5	44.5	50
131.202.240.0/22	5.5	3.5	2

3.2.3 Characteristic of Packet Scheduler (HTB qdisc)







Rate of 699 Kbits and ceil of 699 Kbits : quality of video was low (unwatchable)

Rate of 699 Kbits and ceil of 1000 Kbits : video quality was high

3.3.1 Testing to Find the Minimum Bandwidth with HTB

- poor: scene stoppage during playing time, or scene breaks,
- acceptable: some missing pixels, and a few scenes blurry but watchable,
- good : a few missing pixels, but overall scenes are clean,
- excellent: no scene stops or missing pixels.

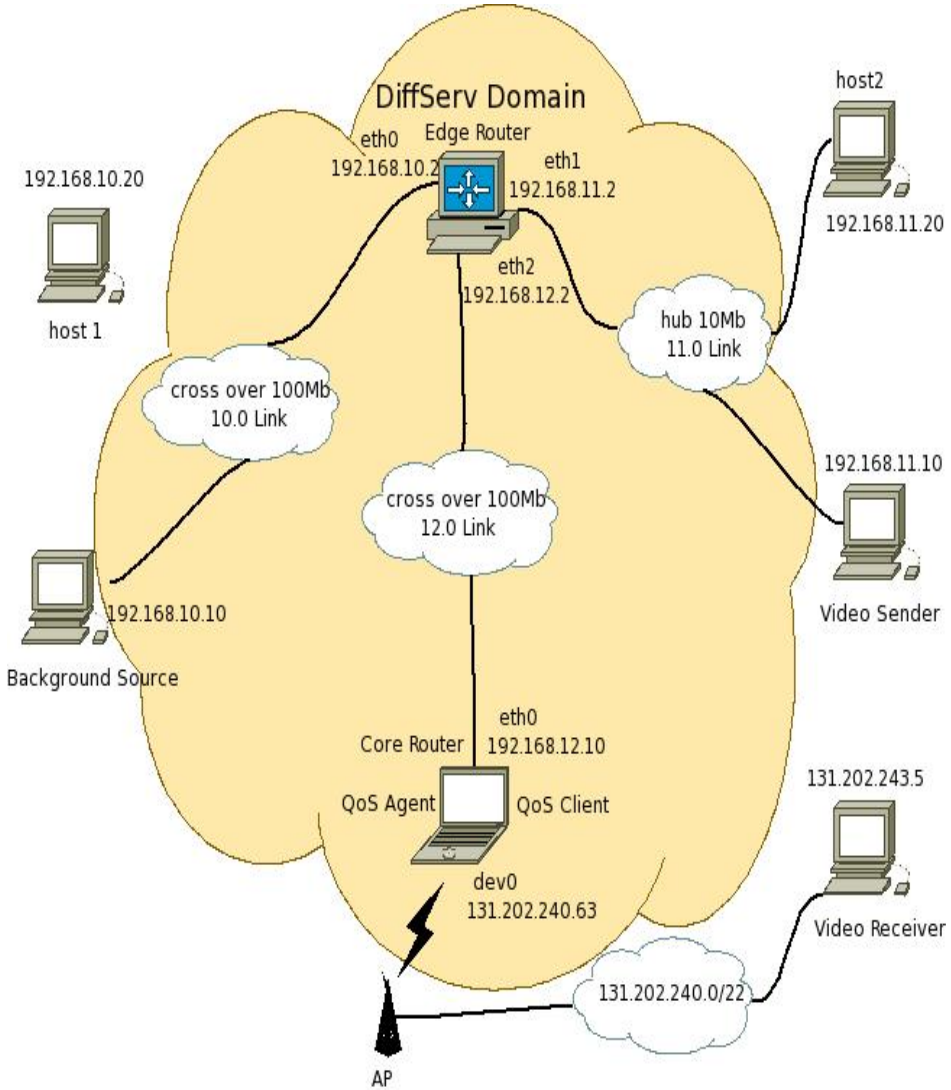
Table: Video quality with the same rate and ceil at HTB

Rate = Ceil = 750 Kbit :	Quality of view is poor.
Rate = Ceil = 760 Kbit :	Quality of view is poor.
Rate = Ceil = 765 Kbit :	Quality of view is acceptable.
Rate = Ceil = 770 Kbit :	Quality of view is excellent.
Rate = Ceil = 800 Kbit :	Quality of view is excellent.

3.4.1 Video quality with the rate and burst at the policer

Test	Rate(Kbits)	burst(KB)	result
1	700	90	poor
2	700	100	poor
3	700	150	poor
4	770	90	excellent
5	770	80	excellent
6	770	70	excellent
7	770	60	excellent
8	770	30	excellent
9	770	25	excellent
10	770	10	excellent
11	770	5	excellent but beginning of scene has broken
12	770	4	excellent but beginning of scene has broken
13	770	1	not playing
14	760	100	excellent
15	760	70	excellent
16	760	60	good
17	760	50	good

3.4.2 Measuring packet loss with the rate and burst at the policer



- Measure Pakcet Loss
  - Wireshark
  - Tc Linux traffic control statistics
- VLC at the Video Sender and Video Reciever.

3.4.3 Measuring packet loss using Wireshark

Test No	Rate Kbit	Burst KB	Packet Count					
			Sender Out	ER In	ER Out	CR In	CR Out	Receiver In
1	760	40	6458	6458	6458	6458	6458	6458
2	760	30	6458	6458	6456	6456	6456	6456
3	760	5	6458	6458	6422	6422	6422	6422
4	760	33	6458	6458	6458	6458	6458	6458
5	760	31	6458	6458	6457	6457	6457	6456
6	760	32	6458	6458	6457	6457	6457	6456
7	700	32	6458	6458	5959	5959	5959	5959
8	700	90	6458	6458	6002	6002	6002	6002
9	700	150	6458	6458	6048	6048	6048	6048
10	700	200	6458	6458	6086	6086	6086	6086
11	700	400	6458	6458	6237	6237	6237	6237
12	1000	20	6458	6458	6457	6457	6457	6456
13	1000	15	6458	6458	5953	5953	5953	5953
14	1500	15	6458	6458	5954	5954	5954	5954

3.4.4 Measuring packet loss using tc Linux traffic control statistics at the video sender

Table: tc Linux traffic control statistics

At the video sender:	/sbin/tc -s -d qdisc show dev eth0
At the edge router:	/sbin/tc -s -d filter show dev eth1 parent ffff:
At the edge router:	/sbin/tc -s -d qdisc show dev eth2
At the core router:	/sbin/tc -s -d qdisc show dev dev0

```
[root@localhost ~] /sbin/tc -s -d qdisc show dev eth0
qdisc pfifo_fast 0: root bands 3 priomap 1 2 2 2 1 2 0 0 1 1 1 1 1 1 1 1
Sent 8847628 bytes 6462 pkt (dropped 0, overlimits 0 requeues 0)
rate 0bit 0pps backlog 0b 0p requeues 0
```

Figure: tc statistic at the egress interface of the Video Sender

3.4.5 Measuring packet loss at the incoming interface of ER

```
[root@localhost ~] /sbin/tc -s -d filter show dev eth1 parent ffff:0
filter protocol ip pref 1 u32
filter protocol ip pref 1 u32 fh 800: ht divisor 1
filter protocol ip pref 1 u32 fh 800::800 order 2048 key ht 800 bkt 0 flowid :1
(rule hit 6458 success 6458)
match c0a80b0a/ffffffff at 12 (success 6458 )
match 83caf305/ffffffff at 16 (success 6458 )
match 00110000/00ff0000 at 8 (success 6458 )
match 000004d2/0000ffff at 20 (success 6458 )
police 0xf rate 760000bit burst 5Kb mtu 2Kb action drop ref 1 bind 1

Sent 8757048 bytes 6458 pkts (dropped 0, overlimits 36 )
```

Figure: tc statistic at the ingress interface (eth1) of the edge router

3.4.6 Measuring packet loss at the outgoing interface of ER

```
[root@localhost ~] /sbin/tc -s -d qdisc show dev eth2
qdisc htb 1: r2q 10 default 20 direct_packets_stat 0 ver 3.17
Sent 8860766 bytes 7292 pkt (dropped 0, overlimits 0 requeues 0)
rate 0bit 0pps backlog 0b 0p requeues 0
qdisc sfq 10: parent 1:10 limit 128p quantum 1514b flows
128/1024 perturb 10sec
Sent 8798140 bytes 6422 pkt (dropped 0, overlimits 0 requeues 0)
rate 0bit 0pps backlog 0b 0p requeues 0
qdisc sfq 20: parent 1:20 limit 128p quantum 1514b flows
128/1024 perturb 10sec
Sent 62626 bytes 870 pkt (dropped 0, overlimits 0 requeues 0)
rate 0bit 0pps backlog 0b 0p requeues 0
```

Figure: tc statistic at egress interface (eth2) of the edge router

3.4.7 Measuring packet loss at the outgoing interface of CR

```
[root@sleepyw ~] /sbin/tc -s -d qdisc show dev dev0
qdisc htb 1: r2q 10 default 20 direct_packets_stat 0 ver 3.17
Sent 8865629 bytes 7318 pkt (dropped 0, overlimits 0 requeues 0)
rate 0bit 0pps backlog 0b 0p requeues 0
qdisc sfq 10: parent 1:10 limit 128p quantum 1514b flows
128/1024 perturb 10sec
Sent 8798140 bytes 6422 pkt (dropped 0, overlimits 0 requeues 0)
rate 0bit 0pps backlog 0b 0p requeues 0
qdisc sfq 20: parent 1:20 limit 128p quantum 1514b flows
128/1024 perturb 10sec
Sent 67489 bytes 896 pkt (dropped 0, overlimits 0 requeues 0)
rate 0bit 0pps backlog 0b 0p requeues 0
```

Figure: tc statistic at the egress interface (dev0) of the core router

3.5.1 Characteristics of Policer

- Packet loss for each rate and burst.
- How the VLC video sender transmits packets.
- How the policer works.

	30KB burst	20KB burst
760kbit	2,2,2,2,2	10,10,10,10,10
740kbit	163,163,163,163,163	170,170,170,170,170
720kbit	332,332,332,332,332	340,340,340,340,340
700kbit	501,501,501,501,501	509,509,509,509,509

	10KB burst	5KB burst
760kbit	17,17,17,17,17	36,36,36,36,36
740kbit	178,178,178,178,178	186,186,186,186,186
720kbit	347,347,347,347,347	353,353,353,353,353
700kbit	516,516,516,516,516	522,522,522,522,522

3.6.1 Packet Loss (36) Distribution with high bandwidth and small size of burst

Table: Packet loss with a rate of 760 Kbits/sec and 5 KB burst

start 8589 end 15046	packets lost	packets lost	packets lost
	8621	8635	9565
	8622	8678	10898
	8623	8684	10943
	8624	8689	12381
	8625	8712	12840
	8626	8719	12865
	8627	8763	13013
	8628	8834	14037
	8629	8857	14741
	8630	8863	14987
	8631	8908	14998
	8633	9276	15015

3.6.2 Packet Loss (522) Distribution with low bandwidth and large size of burst

Table: Packet loss with 700 Kbits/sec rate, 30KB burst

start 29627 end 36084	packets lost	packets lost	packets lost
	29724	33346	35813
	29728	33360	35830
	29743	33375	35844
	29748	33383	35856
	29753	33390	35869
	29757	33403	35883
	29787	33412	35897
	29791	33420	35911
	29796	33447	35921
	29800	33455	35931
	29819	33470	36009
	29824	33482	36015
	29829	33492	36020
	29860	33505	36025
	.	.	.

3.7.1 Characteristics of VLC

Repetition at 760kbits/sec and 5KB

first test	second test	third test	fourth test	fifth test
3346	38348	10022	39134	63496
⋮	⋮	⋮	⋮	⋮
3377	38379	10053	39165	63527
· · · 12pkt loss	· · · llpkt loss	· · · 12pkt loss	· · · 12pkt loss	· · · 12pkt loss
3390	38391	10066	39187	63540
3391 loss	38392 loss	loss 10067	loss 39179	loss 63541
3392	38393 loss	10068	39180	63542
⋮	38294	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮

3.7.2 Characteristics of Burst Packet

Table: Video Sender

packet	timestamp	inter time
63496	43.720858	
63497	43.734237	0.013379
63498	43.747404	0.013167
63499	43.761112	0.013708
⋮		
63515	43.982744	0.014146
63516	43.996884	0.01414
63517	44.011112	0.014228
63518	44.025196	0.014084
63519	44.039413	0.014217
63520	44.053551	0.014138
63521	44.067726	0.014175
63522	44.081818	0.014092
63523	44.096036	0.014218
63524	44.110123	0.014087

Table: Outgoing interface of ER

packet	timestamp	inter time
63496	56.546947	
63497	56.560232	0.013285
63498	56.573374	0.013142
63499	56.5871	0.013726
⋮		
63515	56.808745	0.014129
63516	56.822885	0.01414
63517	56.837129	0.014244
63518	56.851205	0.014076
63519	56.865435	0.01423
63520	56.879571	0.014136
63521	56.893753	0.014182
63522	56.907833	0.01408
63523	56.922057	0.014224
63524	56.936143	0.014086

3.7.2 Characteristics of Burst Packet Cont.

63525	44.120266	0.010143
63526	44.120438	0.000172
63527	44.120507	0.000069
63528	44.120595	0.000088
63529	44.120661	0.000066
63530	44.120715	0.000054
63531	44.120767	0.000052
63532	44.120818	0.000051
63533	44.120876	0.000058
63534	44.120929	0.000053
63535	44.120983	0.000054
63536	44.121037	0.000054
63537	44.121093	0.000056
63538	44.121148	0.000055
63539	44.121202	0.000054
63540	44.121256	0.000054
63541	44.126909	0.005653
63542	44.155789	0.02888

63525	56.946293	0.01015
63526	56.947409	0.001116
63527	56.948523	0.001114
loss		
loss		
loss		
loss		
loss		
loss		
loss		
loss		
loss		
loss		
loss		
loss		
loss		
loss		
63540	56.963036	0.014513
loss		
63542	56.981838	0.018802

3.7.3 Results and Analysis

- Single packet throughput rate = size of single packet / inter packet time

(1 pkt $\times$ (1356 bytes+8(UDP header)+20(IP header)) / pkt $\times$8 bits/byte) / (13×10^{-3}s) = 851×10^{3}bits/s = 851 Kbits/sec.

(1 pkt $\times$ (1356 bytes+8(UDP header)+20(IP header)) / pkt $\times$ 8 bits/byte) / (5×10^{-5}s) = 221.4×10^{6}bits/sec = 221 Mbits/s.

- Single packet's transmission time over 10 Mbits/sec link

(1 pkt $\times$ (1356 bytes+8(UDP header)+20(IP header))/pkt $\times$ 8bits/byte) / 10×10^{6} bits/s = 11072×10^{-7}s = 1.1072×10^{-3}s = 0.0011072 s.

3.8.1 Characteristics of Tcpdump

Table: Timestamp at the video sender with FIFO

packet	timestamp	inter time
18350	22.95287	
18351	22.965926	0.013056
18352	22.979686	0.01376
18353	22.993447	0.013761
18354	23.007206	0.013759
⋮		
18372	23.257524	0.0141
18373	23.271695	0.014171
18374	23.285849	0.014154
18375	23.300078	0.014229
18376	23.314176	0.014098
18377	23.328364	0.014188
18378	23.342485	0.014121
18379	23.352598	0.010113

Table: Timestamp at the Video Sender with TBF

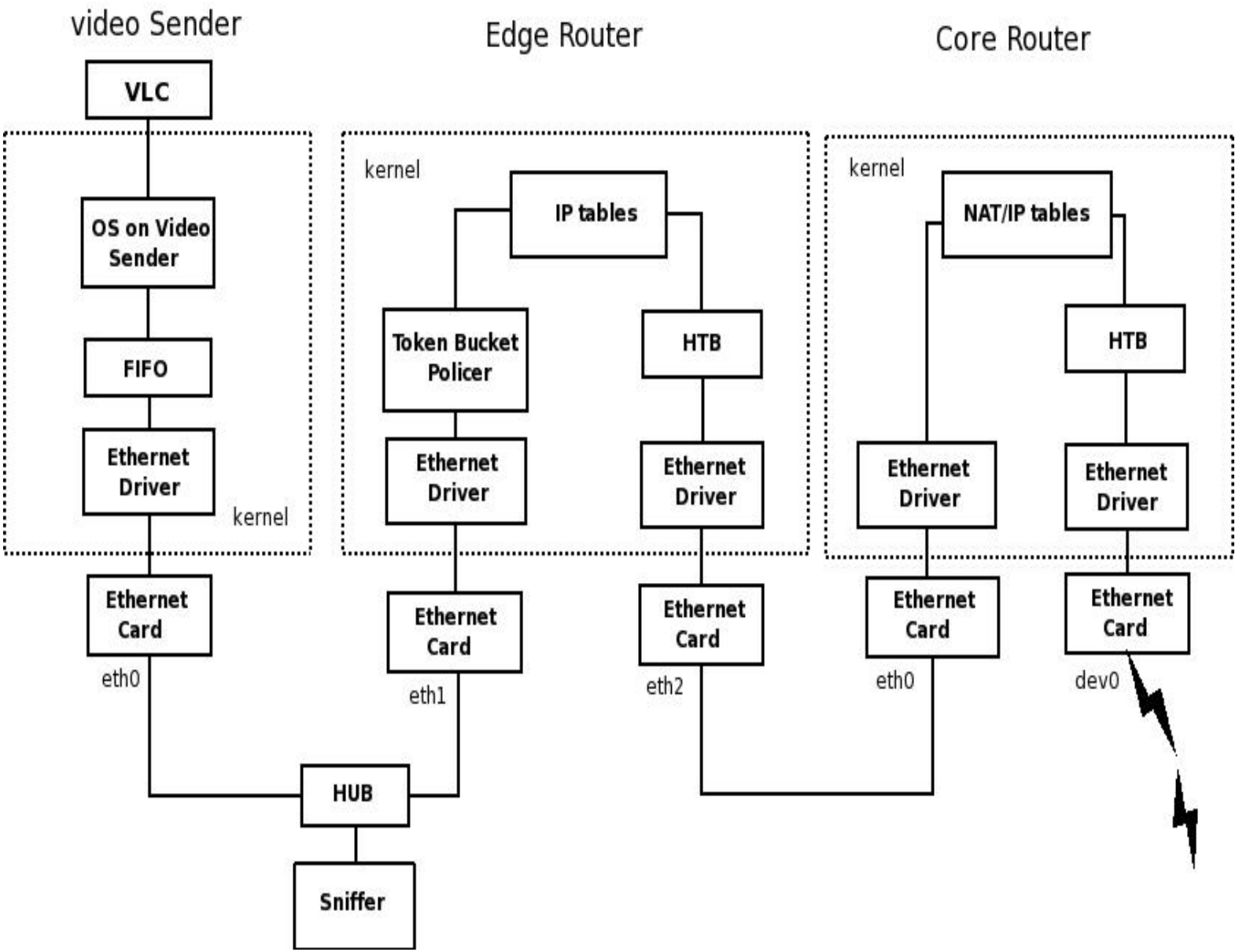
packet	timestamp	inter time
43567	48.870502	
43568	48.884743	0.014241
43569	48.897967	0.013224
43570	48.911683	0.013716
43571	48.925436	0.013753
⋮		
43589	49.17576	0.014133
43590	49.189986	0.014226
43591	49.204144	0.014158
43592	49.218305	0.014161
43593	49.232388	0.014083
43594	49.246594	0.014206
43595	49.260696	0.014102
43596	49.271052	0.010356

3.8.1 Characteristics of Tcpdump cont.

18380	23.352767	0.000169
18381	23.352839	0.000072
18382	23.35289	0.000051
18383	23.352946	0.000056
18384	23.352995	0.000049
18385	23.353046	0.000051
18386	23.353094	0.000048
18387	23.353147	0.000053
18388	23.353198	0.000051
18389	23.353252	0.000054
18390	23.353304	0.000052
18391	23.353357	0.000053
18392	23.353406	0.000049
18393	23.353456	0.00005
18394	23.353502	0.000046
18395	23.359234	0.005732
18396	23.391656	0.032422
⋮		

43597	49.285575	0.014523
43598	49.300545	0.01497
43599	49.314549	0.014004
43600	49.32854	0.013991
43601	49.343547	0.015007
43602	49.35754	0.013993
43603	49.372551	0.015011
43604	49.386556	0.014005
43605	49.400548	0.013992
43606	49.415541	0.014993
43607	49.429543	0.014002
43608	49.443862	0.014319
43609	49.458547	0.014685
43610	49.472541	0.013994
43611	49.487536	0.014995
43612	49.501538	0.014002
43613	49.516536	0.014998
⋮		

3.9.1 An extra queue exists eithet in the Kernel or in the Ethernet card?



3.9.2 Inter Packet Times at the video sender vs at the HUB

Table: At the sender

packet	timestamp	inter time
18350	22.95287	
18351	22.965926	0.013056
18352	22.979686	0.01376
18353	22.993447	0.013761
18354	23.007206	0.013759
18355	23.020993	0.013787
⋮		
18372	23.257524	0.0141
18373	23.271695	0.014171
18374	23.285849	0.014154
18375	23.300078	0.014229
18376	23.314176	0.014098
18377	23.328364	0.014188
18378	23.342485	0.014121
18379	23.352598	0.010113

Table: At the hub

packet	timestamp	inter time
18350	58.569553	
18351	58.582612	0.013059
18352	58.59638	0.013768
18353	58.610152	0.013772
18354	58.623915	0.013763
18355	58.637707	0.013792
⋮		
18372	58.874314	0.014096
18373	58.888496	0.014182
18374	58.902651	0.014155
18375	58.916896	0.014245
18376	58.93099	0.014094
18377	58.945193	0.014203
18378	58.95931	0.014117
18379	58.969429	0.010119

3.9.2 Inter Packet Times at the video sender vs at the HUB cont

18380	23.352767	0.000169
18381	23.352839	7.2E-05
18382	23.35289	5.1E-05
18383	23.352946	5.6E-05
18384	23.352995	4.9E-05
18385	23.353046	5.1E-05
18386	23.353094	4.8E-05
18387	23.353147	5.3E-05
18388	23.353198	5.1E-05
18389	23.353252	5.4E-05
18390	23.353304	5.2E-05
18391	23.353357	5.3E-05
18392	23.353406	4.9E-05
18393	23.353456	5E-05
18394	23.353502	4.6E-05
18395	23.359234	0.005732
18396	23.391656	0.032422

18380	58.970546	0.001117
18381	58.971661	0.001115
18382	58.972778	0.001117
18383	58.973896	0.001118
18384	58.975011	0.001115
18385	58.976127	0.001116
18386	58.977252	0.001125
18387	58.97836	0.001108
18388	58.979476	0.001116
18389	58.980595	0.001119
18390	58.981709	0.001114
18391	58.982825	0.001116
18392	58.983944	0.001119
18393	58.985058	0.001114
18394	58.986175	0.001117
18395	58.987292	0.001117
18396	59.008512	0.02122

3.9.3 Results and Analysis

- Single packet throughput rate = size of single packet / inter packet time

(1 pkt $\times$ (1356 bytes+8(UDP header)+20(IP header)) / pkt $\times$ 8 bits/byte) / (5×10^{-5}s) = 221.4×10^{6}bits/s = 221 Mbits/s.

- Single packet throughput rate = size of single packet / inter packet time

(1 pkt $\times$ (1356 bytes+8(UDP header)+20(IP header)) / pkt $\times$ 8 bits/byte) / (1108×10^{-6}s) = 9.9×10^{6}bits/s = 9.9 Mbits/s.

- Single packet's transmission time over 10 Mbits/sec link

(1 pkt $\times$ (1356 bytes+8(UDP header)+20(IP header))/pkt $\times$ 8 bits/byte) / 10×10^{6} bits/s = 11072×10^{-7}s = 1.1072×10^{-3}s = 0.0011072 s.

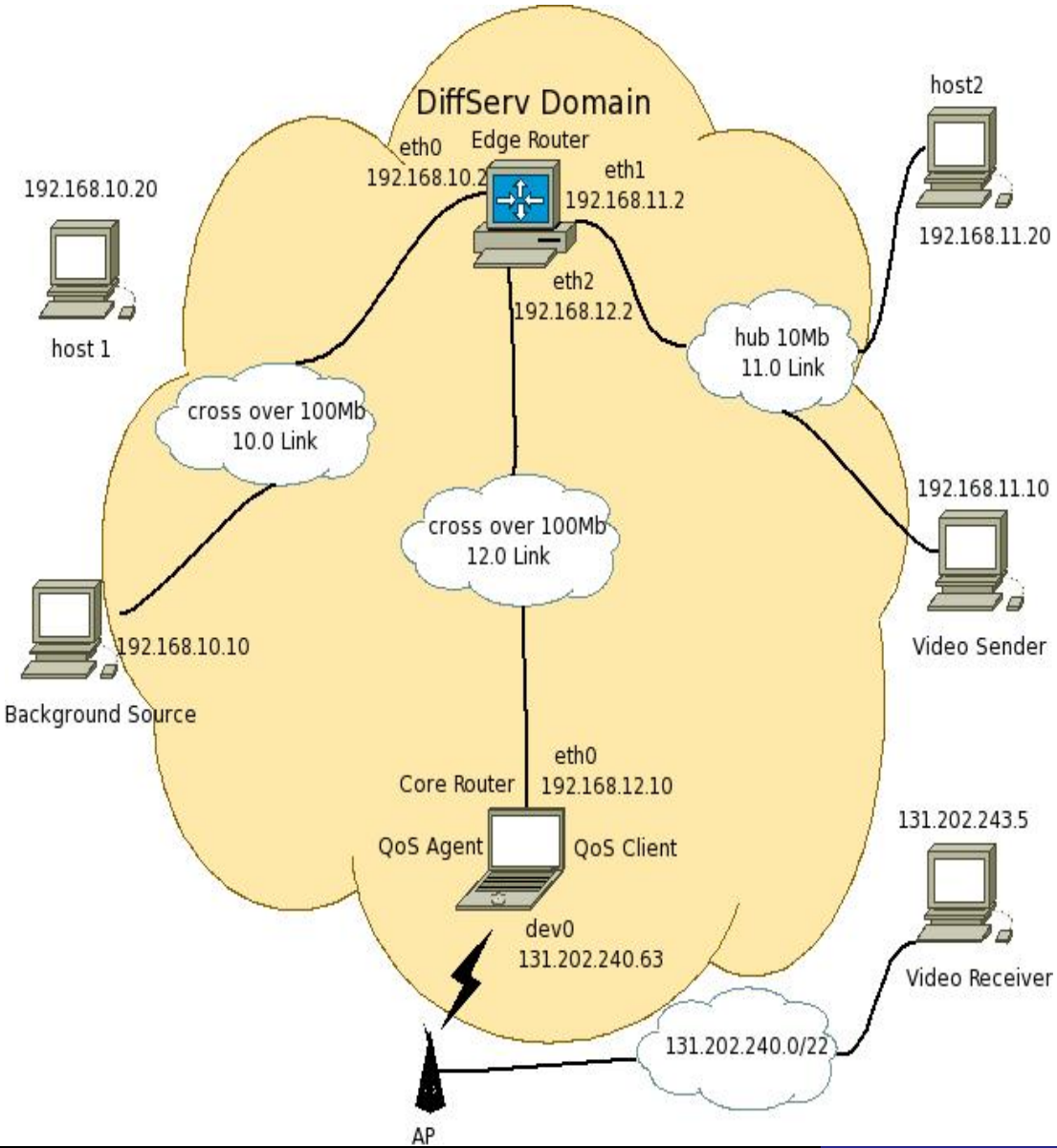
3.10.1 Characteristics of VLC vs RealMedia Player (clip6.mpeg)

packet	timestamp	inter time		packet	timestamp	inter time
6117	3.292816			6151	3.664136	0.013162
6118	3.302461	0.009645		6152	3.67543	0.011294
6119	3.312419	0.009958		6153	3.687796	0.012366
6120	3.322348	0.009929		6154	3.699057	0.011261
6121	3.332277	0.009929		6155	3.709669	0.010612
6122	3.342303	0.010026		6156	3.720306	0.010637
6123	3.352165	0.009862		6157	3.730909	0.010603
6124	3.362195	0.01003		6158	3.741628	0.010719
6125	3.372048	0.009853		6159	3.752149	0.010521
6126	3.381982	0.009934		6160	3.763979	0.01183
6127	3.391984	0.010002		6161	3.773467	0.009488
6128	3.401868	0.009884		6162	3.784063	0.010596
6129	3.411804	0.009936		6163	3.794655	0.010592
6130	3.421783	0.009979		6164	3.805239	0.010584
6131	3.431687	0.009904		6165	3.815857	0.010618
6132	3.44163	0.009943		6166	3.826507	0.01065
6133	3.451603	0.009973		6167	3.837094	0.010587

3.10.1 Characteristics of VLC vs RealMedia Player (clip6.mpeg) cont.

6134	3.46265	0.011047		6168	3.847763	0.010669
6135	3.471565	0.008915		6169	3.85839	0.010627
6136	3.481425	0.00986		6170	3.868956	0.010566
6137	3.491381	0.009956		6171	3.879615	0.010659
6138	3.503313	0.011932		6172	3.890226	0.010611
6139	3.51562	0.012307		6173	3.903689	0.013463
6140	3.527907	0.012287		6174	3.918253	0.014564
6141	3.540174	0.012267		6175	3.932932	0.014679
6142	3.552479	0.012305		6176	3.947448	0.014516
6143	3.564815	0.012336		6177	3.962152	0.014704
6144	3.577088	0.012273		6178	3.97671	0.014558
6145	3.589384	0.012296		6179	3.991311	0.014601
6146	3.601649	0.012265		6180	4.005856	0.014545
6147	3.613963	0.012314		6181	4.020516	0.01466
6148	3.626244	0.012281		6182	4.035088	0.014572
6149	3.638613	0.012369		6183	4.049658	0.01457
6150	3.650974	0.012361		6184	4.064331	0.014673

3.11.1 Adding Shaper (TBF) mechanism to the QoS domain



Shaper at the Video Sender

Policer at the Edge Router

3.11.2 Characteristics of shaper with soccer.mpg

Table: policer without shaper

rate (kbits)	burst (KB)	packets loss
1400	30	109
1500	30	0
1450	30	0
1350	30	383
1450	25	0
1450	20	0
1450	15	0
1450	10	1

Table: policer with shaper

rate (kbits)	limit (Bytes)	burst (Bytes)	change loss at policer
1400	230520	3000	109⇒0
1450	6780	3000	

3.11.2 Characteristics of shaper with soccer.mpg

Table: policer without shaper

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1400	30	109
1500	30	0
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1350	30	383
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1450	20	0
1450	15	0
1450	10	1

Table: policer with shaper

rate (kbits)	limit (Bytes)	burst (Bytes)	change loss at policer
1400	230520	3000	109⇒0
1450	6780	3000	

3.11.3 Investigating the shaper (soccer.mpg has total 7802 packets)

Table: Capturing soccer.mpg packets at the egress interface of the video sender

rate(Kbits)	limit(B)	burst(B)	packets sent	packet loss	latency
1400	230520	3000	7746	0	1.3s
1400	300000	3000	7746	0	1.7s
1400	400000	3000	7747	0	2.3s
1400	500000	3000	7747	0	2.8s
1400	600000	3000	7748	0	3.4s
1400	700000	3000	7746	0	4.0s

Table: Capturing soccer.mpg packets at the egress interface of the Edge Router

1400	230520	3000	7750	52	1.3s
1400	300000	3000	7800	2	1.7s
1400	400000	3000	7802	0	2.3s
1400	500000	3000	7802	0	2.8s
1400	600000	3000	7802	0	3.4s
1400	700000	3000	7802	0	4.0s

3.11.3 Investigating the shaper (soccer.mpg has total 7802 packets)

Table: Capturing soccer.mpg packets at the egress interface of the video sender

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1400	230520	3000	7746	0	1.3s
1400	300000	3000	7746	0	1.7s
1400	400000	3000	7747	0	2.3s
1400	500000	3000	7747	0	2.8s
1400	600000	3000	7748	0	3.4s
1400	700000	3000	7746	0	4.0s

Table: Capturing soccer.mpg packets at the egress interface of the Edge Router

1400	230520	3000	7750	52	1.3s
1400	300000	3000	7800	2	1.7s
1400	400000	3000	7802	0	2.3s
1400	500000	3000	7802	0	2.8s
1400	600000	3000	7802	0	3.4s
1400	700000	3000	7802	0	4.0s

4.1.1 MPEG2 Videos

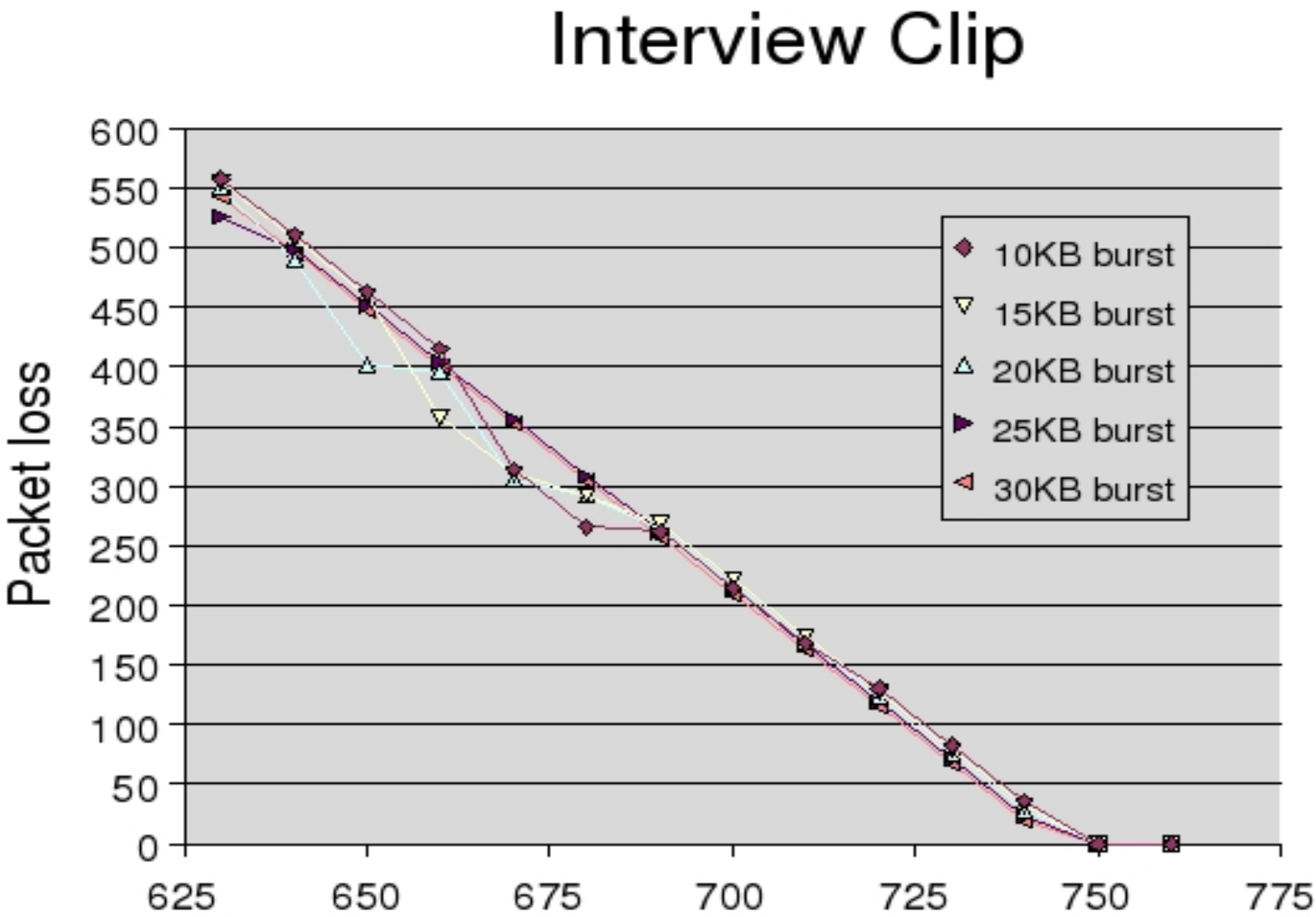
Interview clip (interview.mpg)

- MPEG 1/2 Video decoder,
- Resolution = 320 $\times$ 240,
- Frame rate = 25.000 fps,
- File size = 3.92 MB,
- Duration = 52.2s,
- Estimated average rate = 626 kbits/sec.

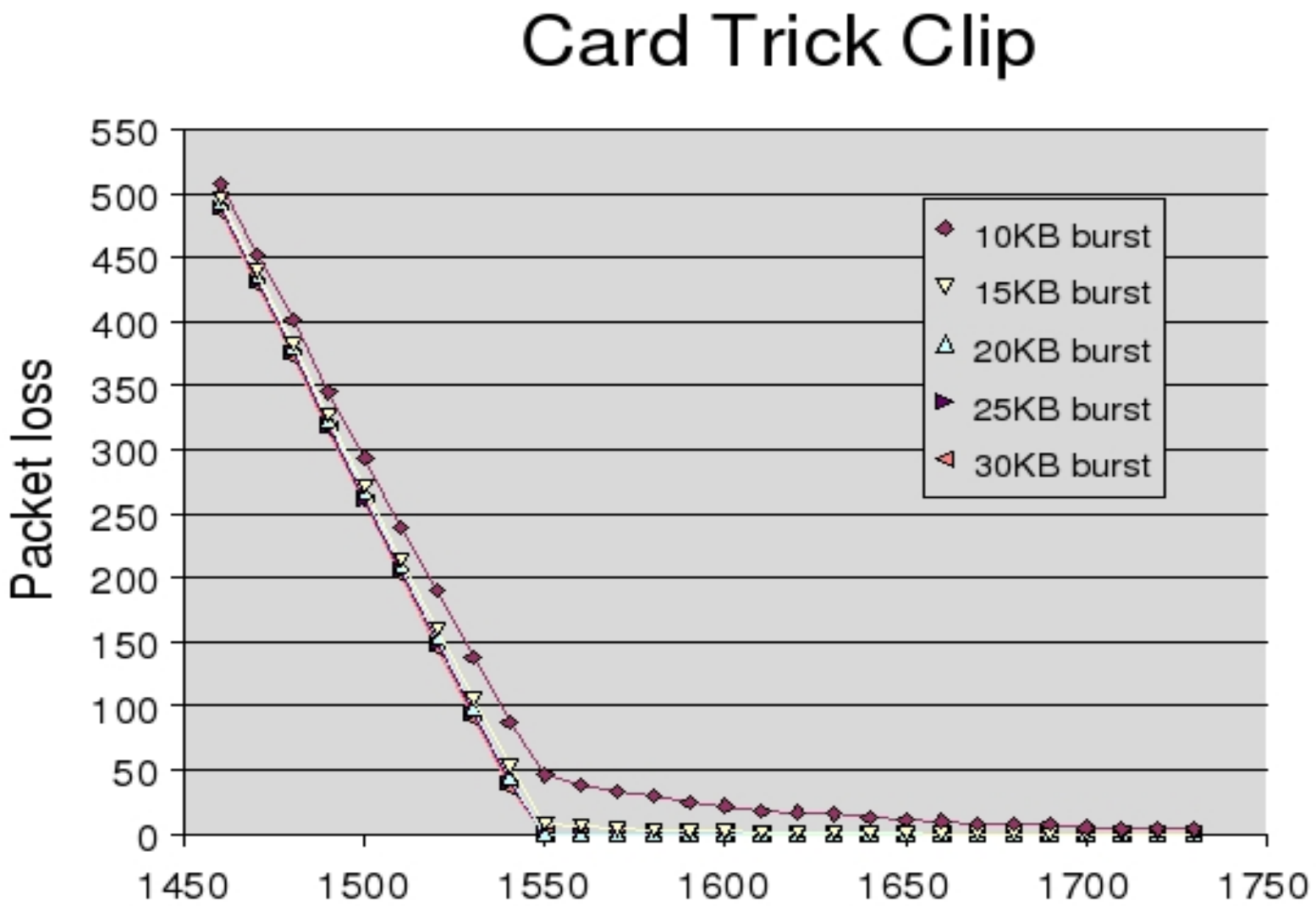
Entertainment Clip (card.mpg)

- MPEG 1/2 Video decoder,
- Resolution = 320 $\times$ 240,
- Frame rate = 29.970 fps,
- File size = 10.8 MB,
- Duration = 62.6s,
- Estimated average rate = 1,448 Kbits/sec.

4.1.2 interview.mpg (Estimated average rate = 626 kbits/sec)



4.1.3 card.mpg (Estimated average rate = 1,448 Kbits/sec)



4.1.4 interview vs card.mpg

Interview clip (interview.mpg)

- Estimated average rate = 626 kbits/sec,
- 120 Kbits/sec (750 Kbits/sec - 630 Kbits/sec) needs to be added to the estimated average rate with any burst size.

Entertainment Clip (card.mpg)

- Estimated average rate = 1,448 Kbits/sec,
- 100 Kbits/sec (1,550 Kbits/sec - 1,450 Kbits/sec) need to be added
  to the estimated average rate with 20 Kbytes burst.,

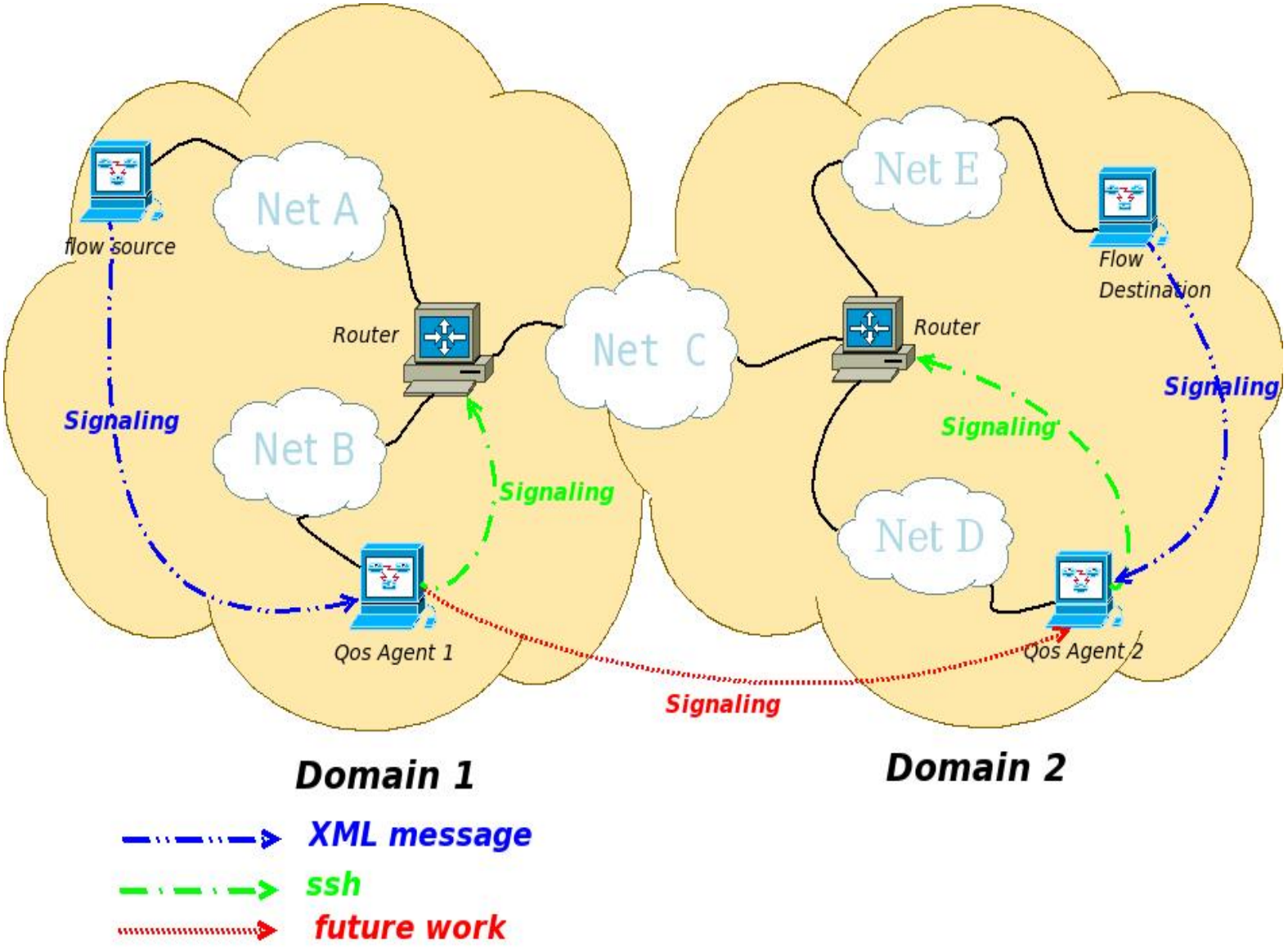
5.1 Work done

- The DiffServ domain provided QoS.
- Observed characteristics of burst traffic.
- Observed characteristics of HTB.
- Observed characteristics of Policer mechansim.
- Observed characteristics of VLC.
- Observed characteristics of Tcpdump timestamps.
- Observed An extra queue exists.
- Observed characteristics of Shaper (TBF).
- Observed characteristics of MPEG2 videos.

5.2 Future Work

- QoS performance with different compression schemes (MPEG4), and with different video applications (RealMedia Player)
- IPv4-IPv6 QoS performance.
- Signaling for multi-QoS domains

5.2 Future Work cont



Thank You

Thanks

Questions?