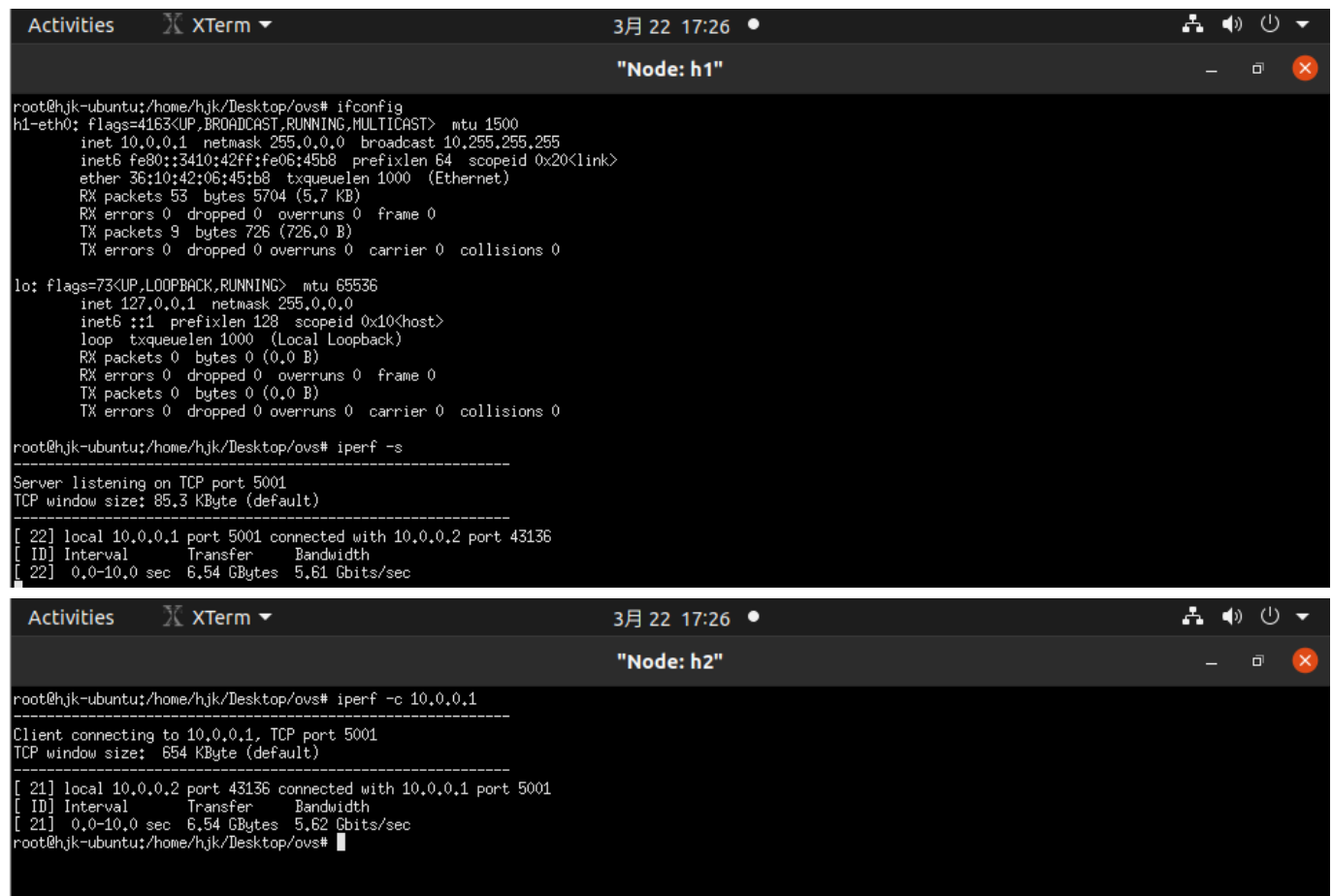


# Lab3: QoS Implementation with OvS

## Part1

### Task1



The image shows two terminal windows from an Ubuntu system, both titled "Node: h1" and "Node: h2".

**Node: h1**

```
root@hjk-ubuntu:/home/hjk/Desktop/ovs# ifconfig
h1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.1 netmask 255.0.0.0 broadcast 10.255.255.255
    inet6 fe80::3410:42ff:fe06:45b8 prefixlen 64 scopeid 0x20<link>
    ether 36:10:42:06:45:b8 txqueuelen 1000 (Ethernet)
    RX packets 53 bytes 5704 (5.7 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 9 bytes 726 (726.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -s
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)

[ 22] local 10.0.0.1 port 5001 connected with 10.0.0.2 port 43136
[ ID] Interval      Transfer    Bandwidth
[ 22] 0.0-10.0 sec  6.54 GBytes  5.61 Gbits/sec
```

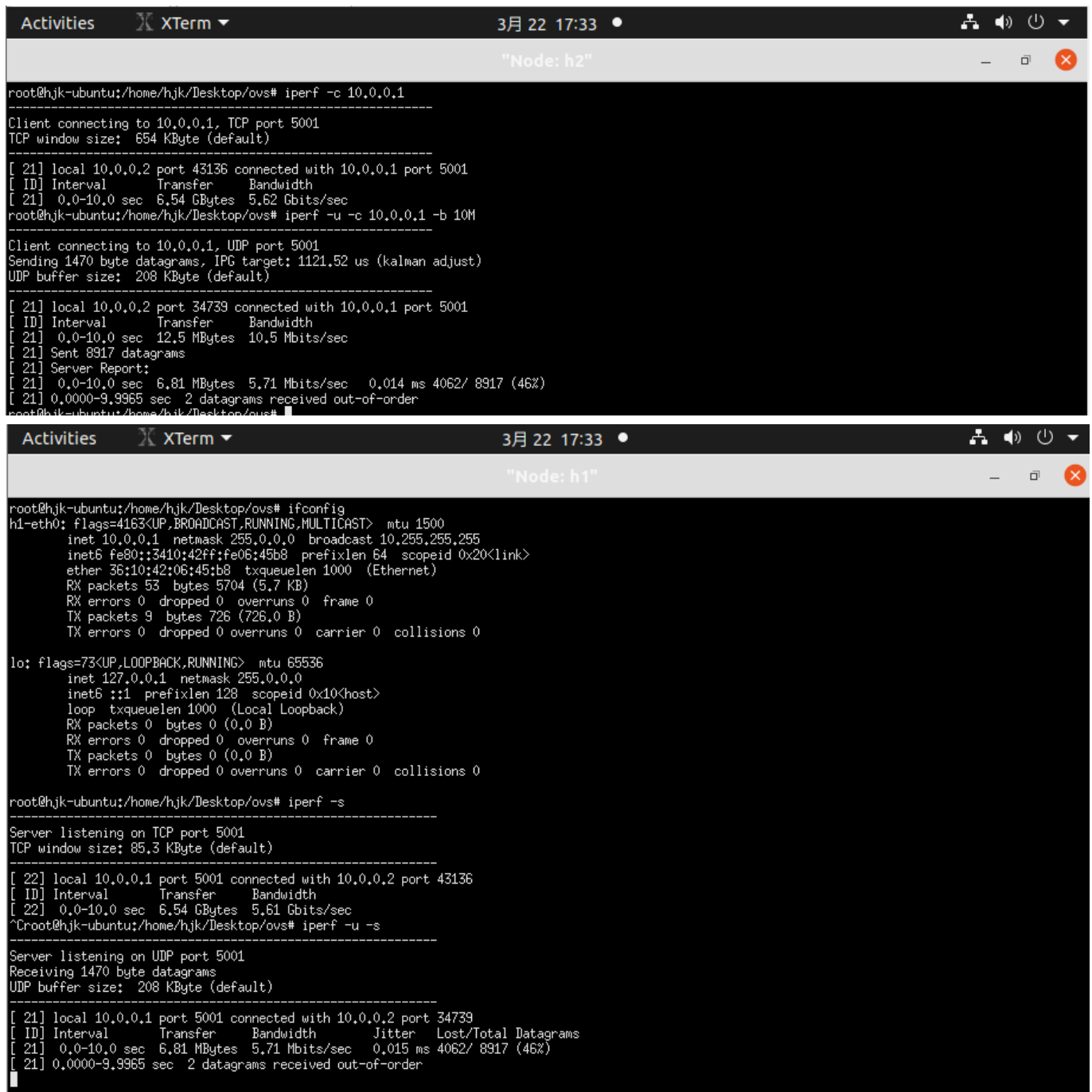
**Node: h2**

```
root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -c 10.0.0.1
Client connecting to 10.0.0.1, TCP port 5001
TCP window size: 654 KByte (default)

[ 21] local 10.0.0.2 port 43136 connected with 10.0.0.1 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.0-10.0 sec  6.54 GBytes  5.62 Gbits/sec
root@hjk-ubuntu:/home/hjk/Desktop/ovs#
```

## Part2

### Task2.1



The image shows two terminal windows from an Ubuntu system, both titled "Node: h2" and "Node: h1".

**Node: h2 terminal:**

```

root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -c 10.0.0.1
-----
Client connecting to 10.0.0.1, TCP port 5001
TCP window size: 654 KByte (default)
-----
[ 21] local 10.0.0.2 port 43136 connected with 10.0.0.1 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.0-10.0 sec  6.54 GBytes  5.62 Gbits/sec
root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -c 10.0.0.1 -b 10M
-----
Client connecting to 10.0.0.1, UDP port 5001
Sending 1470 byte datagrams, IPG target: 1121.52 us (kalman adjust)
UDP buffer size: 208 KByte (default)
-----
[ 21] local 10.0.0.2 port 34739 connected with 10.0.0.1 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.0-10.0 sec  12.5 MBytes  10.5 Mbits/sec
[ 21] Sent 8917 datagrams
[ 21] Server Report:
[ 21] 0.0-10.0 sec  6.81 MBytes  5.71 Mbits/sec    0.014 ms 4062/ 8917 (46%)
[ 21] 0.0000-9.9955 sec  2 datagrams received out-of-order

```

**Node: h1 terminal:**

```

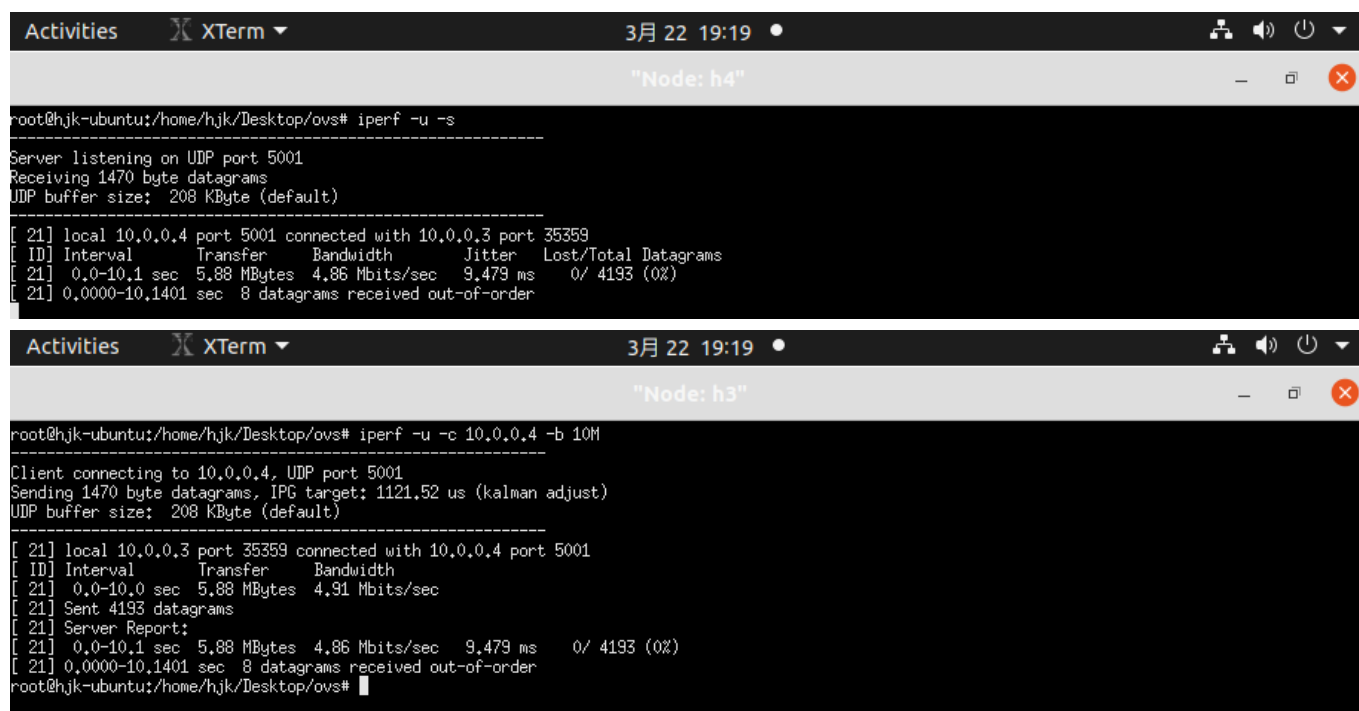
root@hjk-ubuntu:/home/hjk/Desktop/ovs# ifconfig
h1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.1 netmask 255.0.0.0 broadcast 10.255.255.255
    inet6 fe80::3410:42ff:fe06:45b8 prefixlen 64 scopeid 0x20<link>
    ether 36:10:42:06:45:b8 txqueuelen 1000 (Ethernet)
    RX packets 53 bytes 5704 (5.7 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 9 bytes 726 (726.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -s
-----
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
-----
[ 22] local 10.0.0.1 port 5001 connected with 10.0.0.2 port 43136
[ ID] Interval      Transfer    Bandwidth
[ 22] 0.0-10.0 sec  6.54 GBytes  5.61 Gbits/sec
^Croot@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -s
-----
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 208 KByte (default)
-----
[ 21] local 10.0.0.1 port 5001 connected with 10.0.0.2 port 34739
[ ID] Interval      Transfer    Bandwidth      Jitter  Lost/Total Datagrams
[ 21] 0.0-10.0 sec  6.81 MBytes  5.71 Mbits/sec    0.015 ms 4062/ 8917 (46%)
[ 21] 0.0000-9.9955 sec  2 datagrams received out-of-order

```

## Task2.2



```
root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -s
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 208 KByte (default)
-----
[ 21] local 10.0.0.4 port 5001 connected with 10.0.0.3 port 35359
[ ID] Interval      Transfer    Bandwidth   Jitter    Lost/Total Datagrams
[ 21] 0.0-10.1 sec  5.88 MBytes  4.86 Mbits/sec  9.479 ms  0/ 4193 (0%)
[ 21] 0.0000-10.1401 sec  8 datagrams received out-of-order

root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -c 10.0.0.4 -b 10M
Client connecting to 10.0.0.4, UDP port 5001
Sending 1470 byte datagrams, IPG target: 1121.52 us (kalman adjust)
UDP buffer size: 208 KByte (default)
-----
[ 21] local 10.0.0.3 port 35359 connected with 10.0.0.4 port 5001
[ ID] Interval      Transfer    Bandwidth   Jitter    Lost/Total Datagrams
[ 21] 0.0-10.0 sec  5.88 MBytes  4.91 Mbits/sec
[ 21] Sent 4193 datagrams
[ 21] Server Report:
[ 21] 0.0-10.1 sec  5.88 MBytes  4.86 Mbits/sec  9.479 ms  0/ 4193 (0%)
[ 21] 0.0000-10.1401 sec  8 datagrams received out-of-order
root@hjk-ubuntu:/home/hjk/Desktop/ovs#
```

## Question1

```
$ ovs-ofctl add-flow s1 in_port=5,action=meter:1,output:6 -O openflow13
```

作用:下发流表

- **ovs-ofctl**是流表操作指令
- **add-flow**表示添加流表
- **s1**表示向switch s1添加流表
- **in\_port=5, action=meter:1,output:6**描述了要添加的流表项, 具体表示数据包从5号端口进入, 使用1号meter表, 然后从2号端口转发出去
- **-O openflow13**表示使用的OpenFlow版本为openflow13

```
$ ovs-ofctl dump-flows s1 -O openflow13
```

作用:查看流表

- **ovs-ofctl**是流表操作指令
- **dump-flows**表示查看当前流表
- **s1**表示对应的switch为s1
- **-O openflow13**表示使用的OpenFlow版本为openflow13

## Task2.3

Activities

XTerm

3月 22 20:10

Node: h5

```
root@hjk-ubuntu:/home/hjk/Desktop/ovs# ethtool -K h5-eth0 tx off
Actual changes:
tx-checksumming: off
    tx-checksum-ip-generic: off
    tx-checksum-sctp: off
tcp-segmentation-offload: off
    tx-tcp-segmentation: off [requested on]
    tx-tcp-ecn-segmentation: off [requested on]
    tx-tcp-mangleid-segmentation: off [requested on]
    tx-tcp6-segmentation: off [requested on]
root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -c 10.0.0.6 -b 10M
-----
Client connecting to 10.0.0.6, UDP port 5001
Sending 1470 byte datagrams, IPG target: 1121.52 us (kalman adjust)
UDP buffer size: 208 KByte (default)
-----
[ 21] local 10.0.0.5 port 53798 connected with 10.0.0.6 port 5001
[ 21] WARNING: did not receive ack of last datagram after 10 tries.
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.0-10.0 sec  12.5 MBytes  10.5 Mbits/sec
[ 21] Sent 8917 datagrams
root@hjk-ubuntu:/home/hjk/Desktop/ovs#
```

Activities

XTerm

3月 22 20:10

Node: h6

```
root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -s
-----
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 208 KByte (default)
-----
[ 21] local 10.0.0.6 port 5001 connected with 10.0.0.5 port 53798
[ ID] Interval      Transfer    Bandwidth   Jitter  Lost/Total Datagrams
[ 21] 0.0-10.2 sec   6.37 MBytes  5.22 Mbits/sec  15.698 ms  4373/ 8918 (49%)

```

Question2

限速方式	带宽/(Mb/s)	抖动/ms	丢包率
网卡限速	5.71	0.015	46%
队列限速	4.86	9.479	0
Meter表限速	5.22	15.698	49%

- 丢包率:网卡限速和Meter表限速都是通过丢弃多于数据包实现限速, 因此丢包率相近, 且接近于(发送带宽(10M)-实际测量带宽)/发送带宽(50%),队列限速通过缓存数据包实现限速, 不会丢弃包, 因此丢包率为0;
- 带宽:三者带宽接近, 约等于限制的最大带宽, 其中网卡限速测量带宽最大, 队列限速测量带宽最小, 网卡限速偏离最大限速带宽最多, 表明网卡的限速准确度最低, 队列限速的准确度最高;带宽控制准确率的不同可能与不同速度测量方式和控制方式有关, 队列限速直接控制发送队列的速率, 比Meter表限速在switch控制和网卡限速在网卡限速控制更加精准, 受传输等其他因素影响更小, 对网速的测量可能也更准确.
- 抖动: 抖动描述了最大端到端延迟和最小端到端延迟的极差; Meter表限速抖动最高, 网卡限速抖动最低; 网卡限速由于在发送端、switch和接收端都几乎没有任何处理工作和拥塞而抖动几乎为0; Meter表限速由于数据包要被switch处理(由于进程调度和switch处理能力限制不同数据包处理时间可能差异较大)而抖动最高; 队列限速由于不同包在队列中的延迟时间不同也具有较高抖动, 但仍小于Meter表限速.

Task3

限速方式: 队列限速

```
sudo ovs-vsctl set port s1-eth1 qos=@newqos -- --id=@newqos create qos
type=linux-htb queues=0=@q0 -- --id=@q0 create queue other-config:max-
rate=10000000
```

## 测量结果

```

root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -s
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 208 KByte (default)
-----
[ 21] local 10.0.0.1 port 5001 connected with 10.0.0.2 port 37919
[ 22] local 10.0.0.1 port 5001 connected with 10.0.0.4 port 48742
[ 23] local 10.0.0.1 port 5001 connected with 10.0.0.3 port 33273
[ 10] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[ 21] 0.0-20.3 sec 8.37 MBytes 3.46 Mbits/sec 15.167 ms 0/ 5972 (0%)
[ 22] 0.0-20.2 sec 8.00 MBytes 3.32 Mbits/sec 15.270 ms 0/ 5707 (0%)
[ 23] 0.0-20.170 sec 2 datagrams received out-of-order
[ 21] 0.0-19.9 sec 8.08 MBytes 3.41 Mbits/sec 4.683 ms 0/ 5761 (0%)
[ 23] 0.0-19.8905 sec 1 datagrams received out-of-order
[ 21] 1.0- 2.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 2.0- 3.0 sec 425 KBytes 3.48 Mbits/sec
[ 21] 3.0- 4.0 sec 345 KBytes 2.82 Mbits/sec
[ 21] 4.0- 5.0 sec 392 KBytes 3.21 Mbits/sec
[ 21] 5.0- 6.0 sec 434 KBytes 3.55 Mbits/sec
[ 21] 6.0- 7.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 7.0- 8.0 sec 346 KBytes 2.83 Mbits/sec
[ 21] 8.0- 9.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 9.0-10.0 sec 405 KBytes 3.32 Mbits/sec
[ 21] 10.0-11.0 sec 357 KBytes 2.93 Mbits/sec
[ 21] 11.0-12.0 sec 375 KBytes 3.07 Mbits/sec
[ 21] 12.0-13.0 sec 452 KBytes 3.70 Mbits/sec
[ 21] 13.0-14.0 sec 418 KBytes 3.42 Mbits/sec
[ 21] 14.0-15.0 sec 346 KBytes 2.83 Mbits/sec
[ 21] 15.0-16.0 sec 418 KBytes 3.42 Mbits/sec
[ 21] 16.0-17.0 sec 347 KBytes 2.85 Mbits/sec
[ 21] 17.0-18.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 18.0-19.0 sec 353 KBytes 2.89 Mbits/sec
[ 21] 0.0-20.1 sec 8.37 MBytes 3.49 Mbits/sec
[ 21] Sent 5972 datagrams
[ 21] Server Report:
[ 21] 0.0-20.3 sec 8.37 MBytes 3.46 Mbits/sec 15.166 ms 0/ 5972 (0%)
[ 21] 0.0000-20.3264 sec 2 datagrams received out-of-order
root@hjk-ubuntu:/home/hjk/Desktop/ovs#

"Node: h3"
[ 21] 1.0- 2.0 sec 396 KBytes 3.25 Mbits/sec
[ 21] 2.0- 3.0 sec 419 KBytes 3.43 Mbits/sec
[ 21] 3.0- 4.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 4.0- 5.0 sec 347 KBytes 2.85 Mbits/sec
[ 21] 5.0- 6.0 sec 415 KBytes 3.40 Mbits/sec
[ 21] 6.0- 7.0 sec 346 KBytes 2.83 Mbits/sec
[ 21] 7.0- 8.0 sec 406 KBytes 3.33 Mbits/sec
[ 21] 8.0- 9.0 sec 428 KBytes 3.50 Mbits/sec
[ 21] 9.0-10.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 10.0-11.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 11.0-12.0 sec 346 KBytes 2.83 Mbits/sec
[ 21] 12.0-13.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 13.0-14.0 sec 346 KBytes 2.83 Mbits/sec
[ 21] 14.0-15.0 sec 401 KBytes 3.28 Mbits/sec
[ 21] 15.0-16.0 sec 432 KBytes 3.54 Mbits/sec
[ 21] 16.0-17.0 sec 418 KBytes 3.42 Mbits/sec
[ 21] 17.0-18.0 sec 346 KBytes 2.83 Mbits/sec
[ 21] 18.0-19.0 sec 418 KBytes 3.42 Mbits/sec
[ 21] 0.0-20.0 sec 8.08 MBytes 3.39 Mbits/sec
[ 21] Sent 5761 datagrams
[ 21] Server Report:
[ 21] 0.0-19.9 sec 8.08 MBytes 3.41 Mbits/sec 4.682 ms 0/ 5761 (0%)
[ 21] 0.0000-19.8905 sec 1 datagrams received out-of-order
root@hjk-ubuntu:/home/hjk/Desktop/ovs#

[ 21] 1.0- 2.0 sec 446 KBytes 3.66 Mbits/sec
[ 21] 2.0- 3.0 sec 382 KBytes 3.13 Mbits/sec
[ 21] 3.0- 4.0 sec 418 KBytes 3.42 Mbits/sec
[ 21] 4.0- 5.0 sec 352 KBytes 2.88 Mbits/sec
[ 21] 5.0- 6.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 6.0- 7.0 sec 418 KBytes 3.42 Mbits/sec
[ 21] 7.0- 8.0 sec 352 KBytes 2.88 Mbits/sec
[ 21] 8.0- 9.0 sec 425 KBytes 3.48 Mbits/sec
[ 21] 9.0-10.0 sec 401 KBytes 3.28 Mbits/sec
[ 21] 10.0-11.0 sec 419 KBytes 3.43 Mbits/sec
[ 21] 11.0-12.0 sec 345 KBytes 2.82 Mbits/sec
[ 21] 12.0-13.0 sec 416 KBytes 3.41 Mbits/sec
[ 21] 13.0-14.0 sec 415 KBytes 3.40 Mbits/sec
[ 21] 14.0-15.0 sec 345 KBytes 2.82 Mbits/sec
[ 21] 15.0-16.0 sec 422 KBytes 3.46 Mbits/sec
[ 21] 16.0-17.0 sec 406 KBytes 3.33 Mbits/sec
[ 21] 17.0-18.0 sec 431 KBytes 3.53 Mbits/sec
[ 21] 18.0-19.0 sec 346 KBytes 2.83 Mbits/sec
[ 21] 0.0-20.2 sec 8.00 MBytes 3.33 Mbits/sec
[ 21] Sent 5707 datagrams
[ 21] Server Report:
[ 21] 0.0-20.2 sec 8.00 MBytes 3.32 Mbits/sec 15.269 ms 0/ 5707 (0%)
[ 21] 0.0000-20.2170 sec 2 datagrams received out-of-order
root@hjk-ubuntu:/home/hjk/Desktop/ovs#

```

client对三个server的带宽基本相同, 由于三个网路流优先级相同, 限速算法的公平性和丢包的随机性保证了三者带宽相同

## Task4

```

# 使用队列限制client带宽为10M
$ sudo ovs-vsctl set port s1-eth1 qos=@newqos -- --id=@newqos create qos
type=linux-htb queues=0=@q0 -- --id=@q0 create queue other-config:max-
rate=10000000

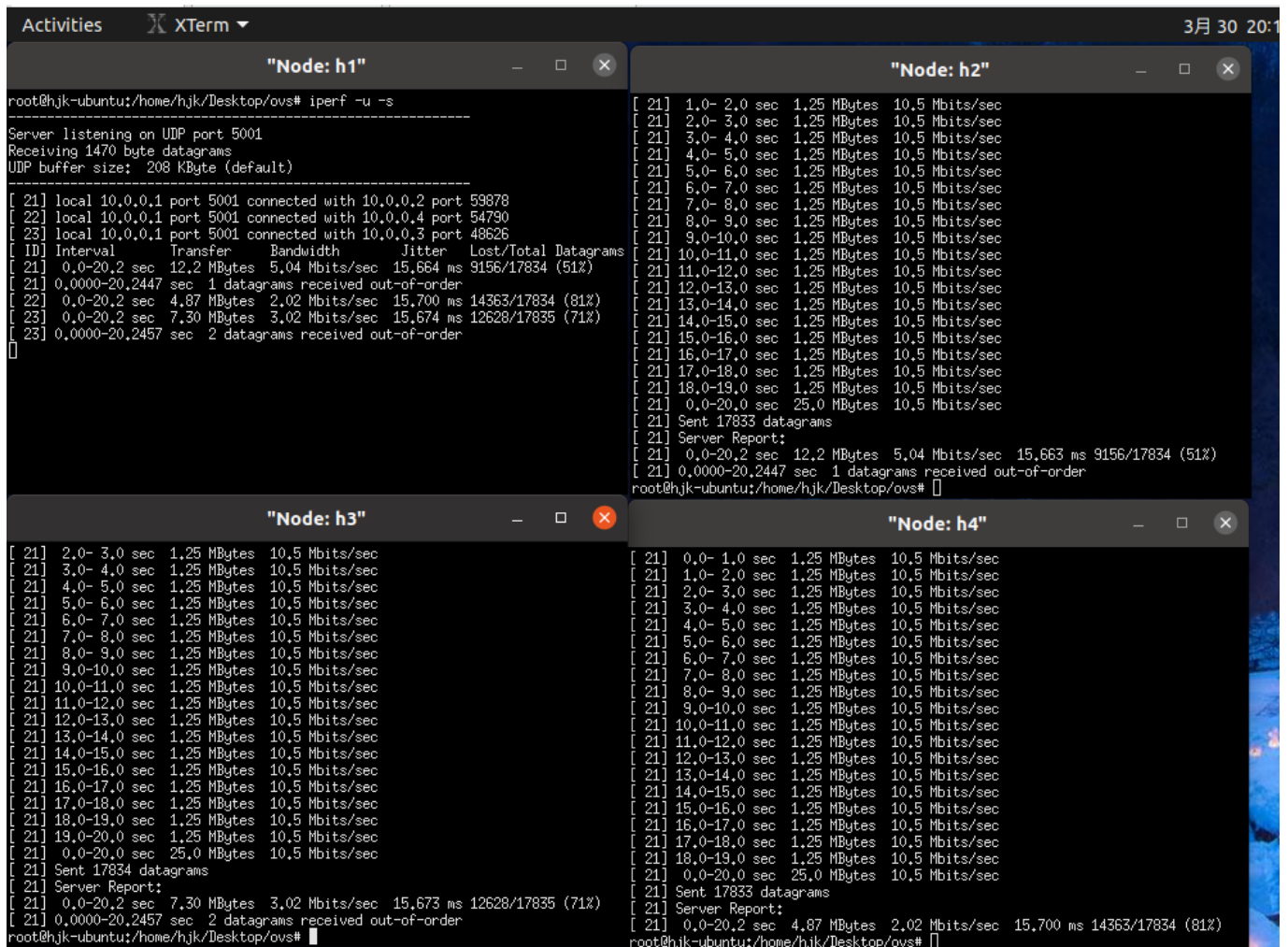
# 添加2号端口进入转发到1号端口的meter表, 带宽限制为5M
$ sudo ovs-ofctl add-meter s1 meter=1,kbps,band=type=drop,rate=5000 -O OpenFlow13
$ sudo ovs-ofctl add-flow s1 in_port=2,action=meter:1,output:1 -O openflow13

# 添加3号端口进入转发到1号端口的meter表, 带宽限制为3M
$ sudo ovs-ofctl add-meter s1 meter=2,kbps,band=type=drop,rate=3000 -O OpenFlow13
$ sudo ovs-ofctl add-flow s1 in_port=3,action=meter:2,output:1 -O openflow13

```

```
# 添加4号端口进入转发到1号端口的meter表, 带宽限制为2M
$ sudo ovs-ofctl add-meter s1 meter=3,kbps,band=type=drop,rate=2000 -O OpenFlow13
$ sudo ovs-ofctl add-flow s1 in_port=4,action=meter:3,output:1 -O openflow13
```

### 实验结果:



```
Activities XTerm 3月 30 20:1

"Node: h1"
root@hjk-ubuntu:/home/hjk/Desktop/ovs# iperf -u -s
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 208 KByte (default)

[ 21] local 10.0.0.1 port 5001 connected with 10.0.0.2 port 59878
[ 22] local 10.0.0.1 port 5001 connected with 10.0.0.4 port 54790
[ 23] local 10.0.0.1 port 5001 connected with 10.0.0.3 port 48626
[ ID] Interval      Transfer      Bandwidth      Jitter    Lost/Total Datagrams
[ 21] 0.0-20.2 sec  12.2 MBytes  5.04 Mbits/sec  15.664 ms  9156/17834 (51%)
[ 21] 0.0000-20.2447 sec  1 datagrams received out-of-order
[ 22] 0.0-20.2 sec  4.87 MBytes  2.02 Mbits/sec  15.700 ms  14363/17834 (81%)
[ 23] 0.0-20.2 sec  7.30 MBytes  3.02 Mbits/sec  15.674 ms  12628/17835 (71%)
[ 23] 0.0000-20.2457 sec  2 datagrams received out-of-order

"Node: h2"
[ 21] 1.0- 2.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 2.0- 3.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 3.0- 4.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 4.0- 5.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 5.0- 6.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 6.0- 7.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 7.0- 8.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 8.0- 9.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 9.0-10.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 10.0-11.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 11.0-12.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 12.0-13.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 13.0-14.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 14.0-15.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 15.0-16.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 16.0-17.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 17.0-18.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 18.0-19.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 0.0-20.0 sec 25.0 MBytes  10.5 Mbits/sec
[ 21] Sent 17833 datagrams
[ 21] Server Report:
[ 21] 0.0-20.2 sec  12.2 MBytes  5.04 Mbits/sec  15.663 ms  9156/17834 (51%)
[ 21] 0.0000-20.2447 sec  1 datagrams received out-of-order
root@hjk-ubuntu:/home/hjk/Desktop/ovs#

"Node: h3"
[ 21] 2.0- 3.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 3.0- 4.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 4.0- 5.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 5.0- 6.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 6.0- 7.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 7.0- 8.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 8.0- 9.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 9.0-10.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 10.0-11.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 11.0-12.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 12.0-13.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 13.0-14.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 14.0-15.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 15.0-16.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 16.0-17.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 17.0-18.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 18.0-19.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 19.0-20.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 0.0-20.0 sec 25.0 MBytes  10.5 Mbits/sec
[ 21] Sent 17834 datagrams
[ 21] Server Report:
[ 21] 0.0-20.2 sec  7.30 MBytes  3.02 Mbits/sec  15.673 ms  12628/17835 (71%)
[ 21] 0.0000-20.2457 sec  2 datagrams received out-of-order
root@hjk-ubuntu:/home/hjk/Desktop/ovs#

"Node: h4"
[ 21] 0.0- 1.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 1.0- 2.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 2.0- 3.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 3.0- 4.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 4.0- 5.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 5.0- 6.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 6.0- 7.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 7.0- 8.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 8.0- 9.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 9.0-10.0 sec  1.25 MBytes  10.5 Mbits/sec
[ 21] 10.0-11.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 11.0-12.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 12.0-13.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 13.0-14.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 14.0-15.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 15.0-16.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 16.0-17.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 17.0-18.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 18.0-19.0 sec 1.25 MBytes  10.5 Mbits/sec
[ 21] 0.0-20.0 sec 25.0 MBytes  10.5 Mbits/sec
[ 21] Sent 17833 datagrams
[ 21] Server Report:
[ 21] 0.0-20.2 sec  4.87 MBytes  2.02 Mbits/sec  15.700 ms  14363/17834 (81%)
root@hjk-ubuntu:/home/hjk/Desktop/ovs#
```

### 注:

题目要求保证h2和h3的带宽下限, 但使用上述三种限速方式只能设置带宽上限, 但是在发送带宽大于switch限制带宽的情况下, 限速的带宽上限应等于实际保证的带宽下限, 因此使用限速手段可以实现题目需求。