

For Buffer size(limit) 10 kbits

1. Client-side node (h1)

```
root@mininet-vm: /usr/Test/Assignment# iperf3 -c 10.0.4.2
Connecting to host 10.0.4.2, port 5201
[ 20] local 10.0.1.2 port 46770 connected to 10.0.4.2 port 5201
[ ID] Interval      Transfer    Bandwidth  Retr  Cwnd
[ 20] 0.00-1.00    sec  77.8 KBytes  636 Kbits/sec    0   14.1 KBytes
[ 20] 1.00-2.00    sec  0.00 Bytes    0.00 bits/sec    1   1.41 KBytes
[ 20] 2.00-3.00    sec  0.00 Bytes    0.00 bits/sec    1   1.41 KBytes
[ 20] 3.00-4.00    sec  0.00 Bytes    0.00 bits/sec    0   1.41 KBytes
[ 20] 4.00-5.00    sec  0.00 Bytes    0.00 bits/sec    1   1.41 KBytes
[ 20] 5.00-6.00    sec  0.00 Bytes    0.00 bits/sec    0   1.41 KBytes
[ 20] 6.00-7.00    sec  0.00 Bytes    0.00 bits/sec    0   1.41 KBytes
[ 20] 7.00-8.00    sec  0.00 Bytes    0.00 bits/sec    0   1.41 KBytes
[ 20] 8.00-9.00    sec  0.00 Bytes    0.00 bits/sec    0   1.41 KBytes
[ 20] 9.00-10.00   sec  0.00 Bytes    0.00 bits/sec    1   1.41 KBytes
-----
[ ID] Interval      Transfer    Bandwidth  Retr
[ 20] 0.00-10.00   sec  77.8 KBytes  63.7 Kbits/sec    4
[ 20] 0.00-10.00   sec  0.00 Bytes    0.00 bits/sec
                                     sender
                                     receiver

iperf Done.
root@mininet-vm: /usr/Test/Assignment#
```

Server-side node (h2)

```
"Node: h2"
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
Accepted connection from 10.0.1.2, port 46768
[ 21] local 10.0.4.2 port 5201 connected to 10.0.1.2 port 46770
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.00-1.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 1.00-2.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 2.00-3.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 3.00-4.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 4.00-5.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 5.00-6.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 6.00-7.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 7.00-8.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 8.00-9.00    sec 0.00 Bytes 0.00 bits/sec
[ 21] 9.00-10.00   sec 0.00 Bytes 0.00 bits/sec
[ 21] 10.00-10.18  sec 0.00 Bytes 0.00 bits/sec
-----
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.00-10.18   sec 0.00 Bytes 0.00 bits/sec
[ 21] 0.00-10.18   sec 0.00 Bytes 0.00 bits/sec
-----
Server listening on 5201
-----
```

In this particular case, the buffer size is very small when compared to the flow rate. The burst size (or the bucket size) is 1 mbit but the queue size(limit) is only 10 Kbit, obviously whenever the bucket is freed, the queue size cannot hold all the packets, so it will drop packets instantaneously, which is translated in terms of cwnd decreasing in the first RTT itself. Every time the bucket(burst) is freed there will be drop in packets. As a result, the cwnd will never recover and it will be kind of stalled, which is evident from the above experiment.

Assuming that the RTT is 180 ms (30 ms delay at each router – 3 routers – to and fro is approx. 180 ms)

Confirmed using ping:

```
mininet> h1 ping h2
PING 10.0.4.2 (10.0.4.2) 56(84) bytes of data:
64 bytes from 10.0.4.2: icmp_seq=1 ttl=6 time=241 ms
64 bytes from 10.0.4.2: icmp_seq=2 ttl=6 time=182 ms
64 bytes from 10.0.4.2: icmp_seq=3 ttl=6 time=183 ms
64 bytes from 10.0.4.2: icmp_seq=4 ttl=6 time=181 ms
64 bytes from 10.0.4.2: icmp_seq=5 ttl=6 time=182 ms
64 bytes from 10.0.4.2: icmp_seq=6 ttl=6 time=182 ms
64 bytes from 10.0.4.2: icmp_seq=7 ttl=6 time=182 ms
64 bytes from 10.0.4.2: icmp_seq=8 ttl=6 time=181 ms
64 bytes from 10.0.4.2: icmp_seq=9 ttl=6 time=182 ms
64 bytes from 10.0.4.2: icmp_seq=10 ttl=6 time=181 ms
64 bytes from 10.0.4.2: icmp_seq=11 ttl=6 time=182 ms
64 bytes from 10.0.4.2: icmp_seq=12 ttl=6 time=182 ms
^C
--- 10.0.4.2 ping statistics ---
12 packets transmitted, 12 received, 0% packet loss, time 11007ms
rtt min/avg/max/mdev = 181.524/187.332/241.979/16.488 ms
```

BDP (Bandwidth Delay Product) = Bandwidth * RTT

BDP (limit = 10 kbits) = 63.7 kbits/s * 180 ms = 11.4 kbits

For Buffer size(limit) is 5 mbits

1. Client side

```

"Node: h1"
root@mininet-virtual-machine:~# iperf3 -c 10.0.4.2
Connecting to host 10.0.4.2, port 5201
[ 20] local 10.0.1.2 port 46802 connected to 10.0.4.2 port 5201
[ ID] Interval           Transfer     Bandwidth       Retr   Cwnd
[ 20] 0.00-1.00   sec    141 KBytes  1.16 Mbits/sec    1   29.7 KBytes
[ 20] 1.00-2.00   sec    7.85 MBytes  65.9 Mbits/sec    0   1.23 MBytes
[ 20] 2.00-3.00   sec   13.8 MBytes  115 Mbits/sec   982   2.17 MBytes
[ 20] 3.00-4.00   sec   12.5 MBytes  105 Mbits/sec    33   2.01 MBytes
[ 20] 4.00-5.00   sec   11.2 MBytes  94.4 Mbits/sec     0   2.11 MBytes
[ 20] 5.00-6.00   sec   11.2 MBytes  94.4 Mbits/sec     0   2.19 MBytes
[ 20] 6.00-7.00   sec   11.2 MBytes  94.4 Mbits/sec     0   2.24 MBytes
[ 20] 7.00-8.00   sec   11.2 MBytes  94.4 Mbits/sec     0   2.28 MBytes
[ 20] 8.00-9.00   sec   11.2 MBytes  94.4 Mbits/sec     0   2.30 MBytes
[ 20] 9.00-10.00  sec   11.2 MBytes  94.4 Mbits/sec     0   2.32 MBytes
-----
[ ID] Interval           Transfer     Bandwidth       Retr
[ 20] 0.00-10.00  sec   102 MBytes  85.3 Mbits/sec  1016
[ 20] 0.00-10.00  sec    92.1 MBytes  77.2 Mbits/sec
sender
receiver

iperf Done.
root@mininet-virtual-machine:~#
```

2. Server side

```
"Node: h2"
Server listening on 5201
-----
Accepted connection from 10.0.1.2, port 46800
[ 21] local 10.0.4.2 port 5201 connected to 10.0.1.2 port 46802
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.00-1.00    sec 15.6 KBytes 127 Kbits/sec
[ 21] 1.00-2.00    sec 1.20 MBytes 10.1 Mbits/sec
[ 21] 2.00-3.00    sec 7.83 MBytes 65.7 Mbits/sec
[ 21] 3.00-4.00    sec 12.5 MBytes 105 Mbits/sec
[ 21] 4.00-5.00    sec 11.2 MBytes 94.0 Mbits/sec
[ 21] 5.00-6.00    sec 11.4 MBytes 95.6 Mbits/sec
[ 21] 6.00-7.00    sec 11.4 MBytes 95.7 Mbits/sec
[ 21] 7.00-8.00    sec 11.4 MBytes 95.6 Mbits/sec
[ 21] 8.00-9.00    sec 11.4 MBytes 95.7 Mbits/sec
[ 21] 9.00-10.00   sec 11.4 MBytes 95.6 Mbits/sec
[ 21] 10.00-10.20  sec 2.30 MBytes 95.3 Mbits/sec
-----
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.00-10.20   sec 0.00 Bytes 0.00 bits/sec
[ 21] 0.00-10.20   sec 92.1 MBytes 75.7 Mbits/sec
-----
Server listening on 5201
-----
```

In this case, as the buffer size (limit) is increase to 5 mbits, which is greater than the bucket size (1 mbits), we can see a considerable increase the throughput and there is only drop in the cwnd, when the interface/router tried to go overboard than the allowed bandwidth, which is where the packets were dropped, other than that, when the interface/router is working within the limits of the set bandwidth, it is working as expected. There are minor losses which I think can be attributed to the delay we introduced into the router. Here, we can also see that the cwnd is almost consistent, as the buffer size(limit) and the burst size are having similar capacity, the feedback between dropping the packets and the cwnd correction is very responsive.

BDP (Bandwidth Delay Product) = Bandwidth * RTT

BDP (limit = 5 mbits) = 85.3 mbits/s * 180 ms = 15.35 mbits

For Buffer Size (limit) is 25 mbits

1. Client side

```
"Node: h1"
[ 20] 0.00-10.00 sec 23.8 MBytes 19.9 Mbits/sec receiver
iperf Done.
root@mininet-vm:/usr/Test/Assignment# iperf3 -c 10.0.4.2
Connecting to host 10.0.4.2, port 5201
[ 20] local 10.0.1.2 port 46824 connected to 10.0.4.2 port 5201
[ ID] Interval          Transfer      Bandwidth    Retr  Cwnd
[ 20] 0.00-1.00 sec      375 KBytes   3.07 Mbits/sec    0   59.4 KBytes
[ 20] 1.00-2.00 sec     10.5 MBytes  88.1 Mbits/sec    0   1.81 MBytes
[ 20] 2.00-3.00 sec     11.2 MBytes  94.3 Mbits/sec  1029   4.58 MBytes
[ 20] 3.00-4.00 sec     13.8 MBytes  115 Mbits/sec    86   4.73 MBytes
[ 20] 4.00-5.00 sec     11.2 MBytes  94.4 Mbits/sec    0   5.05 MBytes
[ 20] 5.00-6.00 sec      7.50 MBytes  62.9 Mbits/sec   168   1.98 MBytes
[ 20] 6.00-7.00 sec     15.0 MBytes  126 Mbits/sec    0   2.62 MBytes
[ 20] 7.00-8.00 sec     11.2 MBytes  94.4 Mbits/sec    0   2.75 MBytes
[ 20] 8.00-9.00 sec     11.2 MBytes  94.4 Mbits/sec    0   2.85 MBytes
[ 20] 9.00-10.00 sec    12.5 MBytes  105 Mbits/sec    0   2.93 MBytes
-----
[ ID] Interval          Transfer      Bandwidth    Retr
[ 20] 0.00-10.00 sec     105 MBytes  87.8 Mbits/sec  1283
[ 20] 0.00-10.00 sec     94.8 MBytes  79.6 Mbits/sec
sender
receiver
iperf Done.
root@mininet-vm:/usr/Test/Assignment#
```

2. Server Side

```
"Node: h2"
Server listening on 5201
-----
Accepted connection from 10.0.1.2, port 46822
[ 21] local 10.0.4.2 port 5201 connected to 10.0.1.2 port 46824
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.00-1.00    sec  45.2 KBytes  371 Kbits/sec
[ 21] 1.00-2.00    sec  1.75 MBytes  14.7 Mbits/sec
[ 21] 2.00-3.00    sec  8.25 MBytes  69.2 Mbits/sec
[ 21] 3.00-4.00    sec  13.7 MBytes  115 Mbits/sec
[ 21] 4.00-5.00    sec  11.4 MBytes  95.7 Mbits/sec
[ 21] 5.00-6.00    sec  7.23 MBytes  60.7 Mbits/sec
[ 21] 6.00-7.00    sec  15.3 MBytes  129 Mbits/sec
[ 21] 7.00-8.00    sec  11.4 MBytes  95.5 Mbits/sec
[ 21] 8.00-9.00    sec  11.4 MBytes  95.6 Mbits/sec
[ 21] 9.00-10.00   sec  11.4 MBytes  95.7 Mbits/sec
[ 21] 10.00-10.26  sec  2.92 MBytes  95.2 Mbits/sec
-----
[ ID] Interval      Transfer    Bandwidth
[ 21] 0.00-10.26   sec  0.00 Bytes  0.00 bits/sec
[ 21] 0.00-10.26   sec  94.8 MBytes  77.6 Mbits/sec
-----
Server listening on 5201
-----
```

BDP (Bandwidth Delay Product) = Bandwidth * RTT

BDP (limit = 25 mbits) = 87.8 mbits/s * 180 ms = 15.8 mbits

In this case, the buffer size is almost 25 times the bucket size, so there is a very little chance of dropping the packets because the buffer capacity. So here most of the retransmissions are happening because the concerned packet is staying the queue for long, but not due to packet drop (as we have enough buffer capacity). Here also the throughput is similar to the previous version, mainly due to the fact that it tries to pump way over set bandwidth, because of this it observes reasonably high re-transmissions, because of which the cwnd get down and it has to start afresh which kind off balances the extremes and gives a throughput similar to the previous setting.