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PART 1

A. Every host is able to send packets to every other host

```
mininet> pingall
*** Ping: testing ping reachability
d1 -> d2 d3 d4 d5 d6 r1 r2 r3
d2 -> d1 d3 d4 d5 d6 r1 r2 r3
d3 -> d1 d2 d4 d5 d6 r1 r2 r3
d4 -> d1 d2 d3 d5 d6 r1 r2 r3
d5 -> d1 d2 d3 d4 d6 r1 r2 r3
d6 -> d1 d2 d3 d4 d5 r1 r2 r3
r1 -> d1 d2 d3 d4 d5 d6 r2 r3
r2 -> d1 d2 d3 d4 d5 d6 r1 r3
r3 -> d1 d2 d3 d4 d5 d6 r1 r2
*** Results: 0% dropped (72/72 received)
mininet>
```

Topology Implementation:

```
mininet> net
d1 d1-eth0:s1-eth2
d2 d2-eth0:s1-eth3
d3 d3-eth0:s2-eth2
d4 d4-eth0:s2-eth3
d5 d5-eth0:s3-eth2
d6 d6-eth0:s3-eth3
r1 r1-eth1:s1-eth1 r1-eth2:r2-eth2 r1-eth3:r3-eth2
r2 r2-eth1:s2-eth1 r2-eth2:r1-eth2 r2-eth3:r3-eth3
r3 r3-eth1:s3-eth1 r3-eth2:r1-eth3 r3-eth3:r2-eth3
s1 lo: s1-eth1:r1-eth1 s1-eth2:d1-eth0 s1-eth3:d2-eth0
s2 lo: s2-eth1:r2-eth1 s2-eth2:d3-eth0 s2-eth3:d4-eth0
s3 lo: s3-eth1:r3-eth1 s3-eth2:d5-eth0 s3-eth3:d6-eth0
c0
```

B. Capture from wireshark for router r1 (r1-eth1)

Capturing from r1-eth1

File Edit View Go Capture Analyze Statistics Telephone Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
25	34.081419661	10.0.0.251	10.2.0.252	ICMP	98	Echo (ping) request id=0x431e, seq=8/2048, ttl=64 (req)
26	34.081489184	10.2.0.252	10.0.0.251	ICMP	98	Echo (ping) reply id=0x431e, seq=8/2048, ttl=62 (req)
27	34.860910854	fe80::9c35:e7ff:fe5... ff02::fb	MDNS	125	Standard query 0x0000 PTR _pgpkey-hkp._tcp.local, "QM"	
28	35.103998215	10.0.0.251	10.2.0.252	ICMP	98	Echo (ping) request id=0x431e, seq=9/2304, ttl=64 (req)
29	35.104058367	10.2.0.252	10.0.0.251	ICMP	98	Echo (ping) reply id=0x431e, seq=9/2304, ttl=62 (req)
30	35.584593295	fe80::98b1:e0ff:fe5... ff02::2	ICMPv6	70	Router Solicitation from 9a:b1:e0:59:7a:db	
31	36.130242151	10.0.0.251	10.2.0.252	ICMP	98	Echo (ping) request id=0x431e, seq=10/2560, ttl=64 (req)
32	36.130299103	10.2.0.252	10.0.0.251	ICMP	98	Echo (ping) reply id=0x431e, seq=10/2560, ttl=62 (req)
33	37.152264035	10.0.0.251	10.2.0.252	ICMP	98	Echo (ping) request id=0x431e, seq=11/2816, ttl=64 (req)
34	37.152318716	10.2.0.252	10.0.0.251	ICMP	98	Echo (ping) reply id=0x431e, seq=11/2816, ttl=62 (req)
35	37.636660774	fe80::1c5c:e9ff:feb... ff02::2	ICMPv6	70	Router Solicitation from 1e:5c:e9:bb:9b:a3	
36	37.637819577	fe80::94c3:37ff:fe6... ff02::2	ICMPv6	70	Router Solicitation from 96:c3:37:65:78:df	
37	38.177092977	10.0.0.251	10.2.0.252	ICMP	98	Echo (ping) request id=0x431e, seq=12/3072, ttl=64 (req)

Frame 1: 70 bytes on wire (560 bits), 70 bytes captured (560 bits) on interface r1-eth1, id 0

Ethernet II, Src: 9e:35:e7:5b:7a:a5 (9e:35:75:b7:a5:a5), Dst: IPv6mcast_02 (33:33:00:00:00:02)

Internet Protocol Version 6, Src: fe80::9c35:e7ff:fe5b:7aa5, Dst: ff02::2

 0110 = Version: 6

 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)

 0000 0000 0000 0000 0000 = Flow Label: 0x00000

 Payload Length: 16

 Next Header: ICMPv6 (58)

 Hop Limit: 255

 Source Address: fe80::9c35:e7ff:fe5b:7aa5

Offset	Hex	Dec	Printable
0000	33 33 00 00 00 02 9e 35 e7 5b 7a a5 86 dd 60	3333000000029e35e75b7aa586dd605.[z.....]
0010	00 00 00 10 3a ff fe 80 00 00 00 00 00 9c 35	000000103afffe800000000009c35:.....5
0020	e7 ff fe 5b 7a a5 ff 02 00 00 00 00 00 00 00	e7fffe5b7aa5ff02000000000000	...[z.....]
0030	00 00 00 00 00 02 85 00 7e c0 00 00 00 00 01 01	00000000000285007ec000000000101~.....
0040	9e 35 e7 5b 7a a5	9e35e75b7aa5	5.[z..]

C. Default route of packet from h1 to h6 (h1 -> ra ->rc ->h6)

```
mininet> d1 ping d6
PING 10.2.0.252 (10.2.0.252) 56(84) bytes of data.
64 bytes from 10.2.0.252: icmp_seq=1 ttl=62 time=2.02 ms
64 bytes from 10.2.0.252: icmp_seq=2 ttl=62 time=2.66 ms
64 bytes from 10.2.0.252: icmp_seq=3 ttl=62 time=0.570 ms
64 bytes from 10.2.0.252: icmp_seq=4 ttl=62 time=0.089 ms
64 bytes from 10.2.0.252: icmp_seq=5 ttl=62 time=0.083 ms
64 bytes from 10.2.0.252: icmp_seq=6 ttl=62 time=1.76 ms
64 bytes from 10.2.0.252: icmp_seq=7 ttl=62 time=0.098 ms
64 bytes from 10.2.0.252: icmp_seq=8 ttl=62 time=0.125 ms
64 bytes from 10.2.0.252: icmp_seq=9 ttl=62 time=0.076 ms
64 bytes from 10.2.0.252: icmp_seq=10 ttl=62 time=0.111 ms
64 bytes from 10.2.0.252: icmp_seq=11 ttl=62 time=0.110 ms
64 bytes from 10.2.0.252: icmp_seq=12 ttl=62 time=0.077 ms
^C
--- 10.2.0.252 ping statistics ---
12 packets transmitted, 12 received, 0% packet loss, time 11300ms
rtt min/avg/max/mdev = 0.076/0.647/2.661/0.894 ms
mininet> iperf d1 d6
*** Iperf: testing TCP bandwidth between d1 and d6
*** Results: ['15.8 Gbits/sec', '15.7 Gbits/sec']
```

Time taken in Ping = 2.02 ms

Bandwidth = 15.8 Gbits/sec

Different routing path for packet from **h1** to **h6** (**h1->ra->rb->rc->h6**)

```
mininet> d1 ping d6
PING 10.2.0.252 (10.2.0.252) 56(84) bytes of data.
64 bytes from 10.2.0.252: icmp_seq=1 ttl=62 time=7.21 ms
64 bytes from 10.2.0.252: icmp_seq=2 ttl=62 time=0.652 ms
64 bytes from 10.2.0.252: icmp_seq=3 ttl=62 time=0.000 ms
64 bytes from 10.2.0.252: icmp_seq=4 ttl=62 time=0.167 ms
64 bytes from 10.2.0.252: icmp_seq=5 ttl=62 time=0.088 ms
64 bytes from 10.2.0.252: icmp_seq=6 ttl=62 time=0.258 ms
64 bytes from 10.2.0.252: icmp_seq=7 ttl=62 time=0.086 ms
64 bytes from 10.2.0.252: icmp_seq=8 ttl=62 time=0.134 ms
64 bytes from 10.2.0.252: icmp_seq=9 ttl=62 time=0.124 ms
^C
--- 10.2.0.252 ping statistics ---
9 packets transmitted, 9 received, 0% packet loss, time 8234ms
rtt min/avg/max/mdev = 0.000/0.968/7.208/2.213 ms
mininet> iperf d1 d6
*** Iperf: testing TCP bandwidth between d1 and d6
*** Results: ['24.4 Gbits/sec', '24.3 Gbits/sec']
mininet> █
```

Ping Time = 7.21ms

Bandwidth = 24.4Gbits/sec

D. Routing table of routers with default routing

```
mininet> r1 route
Kernel IP routing table
Destination     Gateway         Genmask        Flags Metric Ref  Use Iface
10.0.0.0        0.0.0.0        255.255.255.0 U     0      0      0  r1-eth1
10.1.0.0        10.100.0.2    255.255.255.0 UG    0      0      0  r1-eth2
10.2.0.0        10.100.1.2    255.255.255.0 UG    0      0      0  r1-eth3
10.100.0.0      0.0.0.0        255.255.255.0 U     0      0      0  r1-eth2
10.100.1.0      0.0.0.0        255.255.255.0 U     0      0      0  r1-eth3
mininet> r2 route
Kernel IP routing table
Destination     Gateway         Genmask        Flags Metric Ref  Use Iface
10.0.0.0        10.100.0.1    255.255.255.0 UG    0      0      0  r2-eth2
10.1.0.0        0.0.0.0        255.255.255.0 U     0      0      0  r2-eth1
10.2.0.0        10.100.2.2    255.255.255.0 UG    0      0      0  r2-eth3
10.100.0.0      0.0.0.0        255.255.255.0 U     0      0      0  r2-eth2
10.100.2.0      0.0.0.0        255.255.255.0 U     0      0      0  r2-eth3
mininet> r3 route
Kernel IP routing table
Destination     Gateway         Genmask        Flags Metric Ref  Use Iface
10.0.0.0        10.100.1.1    255.255.255.0 UG    0      0      0  r3-eth2
10.1.0.0        10.100.2.1    255.255.255.0 UG    0      0      0  r3-eth3
10.2.0.0        0.0.0.0        255.255.255.0 U     0      0      0  r3-eth1
10.100.1.0      0.0.0.0        255.255.255.0 U     0      0      0  r3-eth2
10.100.2.0      0.0.0.0        255.255.255.0 U     0      0      0  r3-eth3
mininet> █
```

Routing table of routers with different routing paths

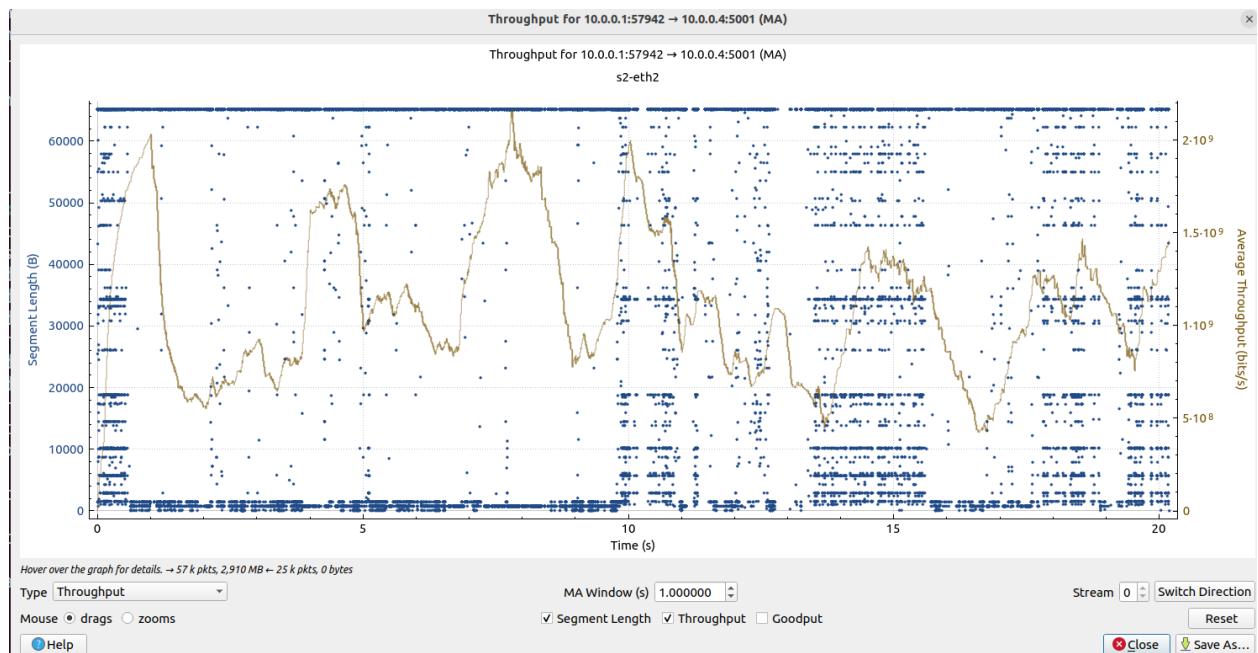
```
mininet> r1 route
Kernel IP routing table
Destination     Gateway         Genmask        Flags Metric Ref  Use Iface
10.0.0.0        0.0.0.0        255.255.255.0  U     0      0      0  r1-eth1
10.1.0.0        10.100.1.2    255.255.255.0  UG    0      0      0  r1-eth3
10.2.0.0        10.100.0.2    255.255.255.0  UG    0      0      0  r1-eth2
10.100.0.0      0.0.0.0        255.255.255.0  U     0      0      0  r1-eth2
10.100.1.0      0.0.0.0        255.255.255.0  U     0      0      0  r1-eth3
mininet> r2 route
Kernel IP routing table
Destination     Gateway         Genmask        Flags Metric Ref  Use Iface
10.0.0.0        10.100.0.1    255.255.255.0  UG    0      0      0  r2-eth2
10.1.0.0        0.0.0.0        255.255.255.0  U     0      0      0  r2-eth1
10.2.0.0        10.100.2.2    255.255.255.0  UG    0      0      0  r2-eth3
10.100.0.0      0.0.0.0        255.255.255.0  U     0      0      0  r2-eth2
10.100.2.0      0.0.0.0        255.255.255.0  U     0      0      0  r2-eth3
mininet> r3 route
Kernel IP routing table
Destination     Gateway         Genmask        Flags Metric Ref  Use Iface
10.0.0.0        10.100.1.1    255.255.255.0  UG    0      0      0  r3-eth2
10.1.0.0        10.100.2.1    255.255.255.0  UG    0      0      0  r3-eth3
10.2.0.0        0.0.0.0        255.255.255.0  U     0      0      0  r3-eth1
10.100.1.0      0.0.0.0        255.255.255.0  U     0      0      0  r3-eth2
10.100.2.0      0.0.0.0        255.255.255.0  U     0      0      0  r3-eth3
mininet>
```

PART 2

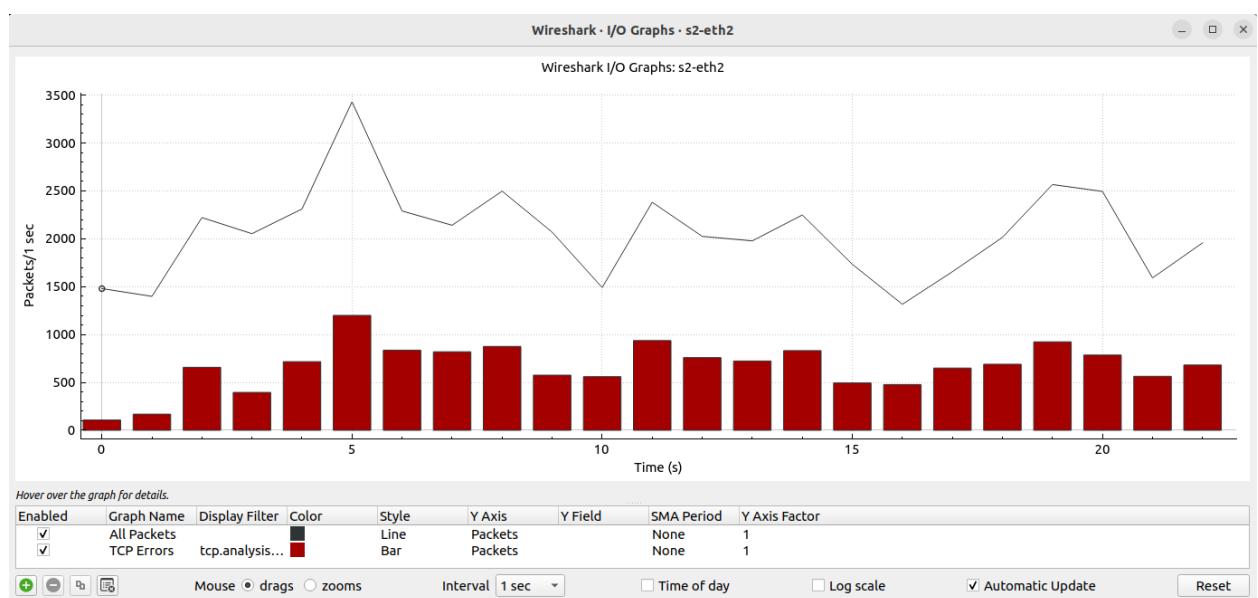
B. H1 (IP 10.0.0.1) is client and H4 is server (IP 10.0.0.4)

I. Loss = 0 Congestion scheme = Vegas

Throughput

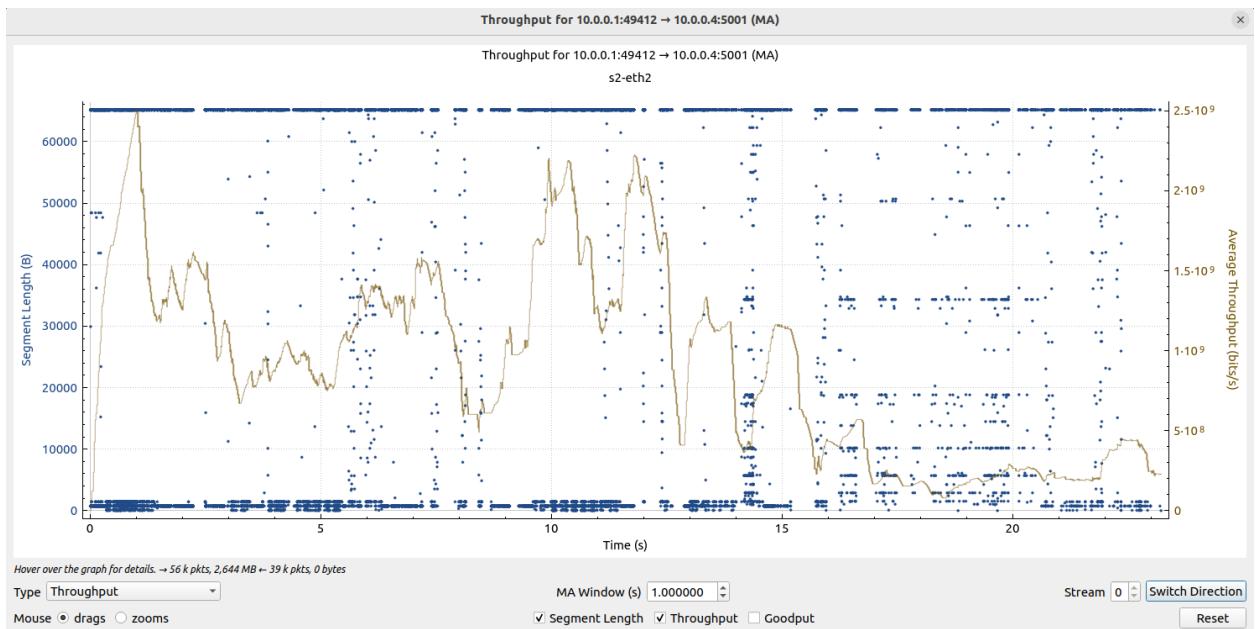


I/O Graph

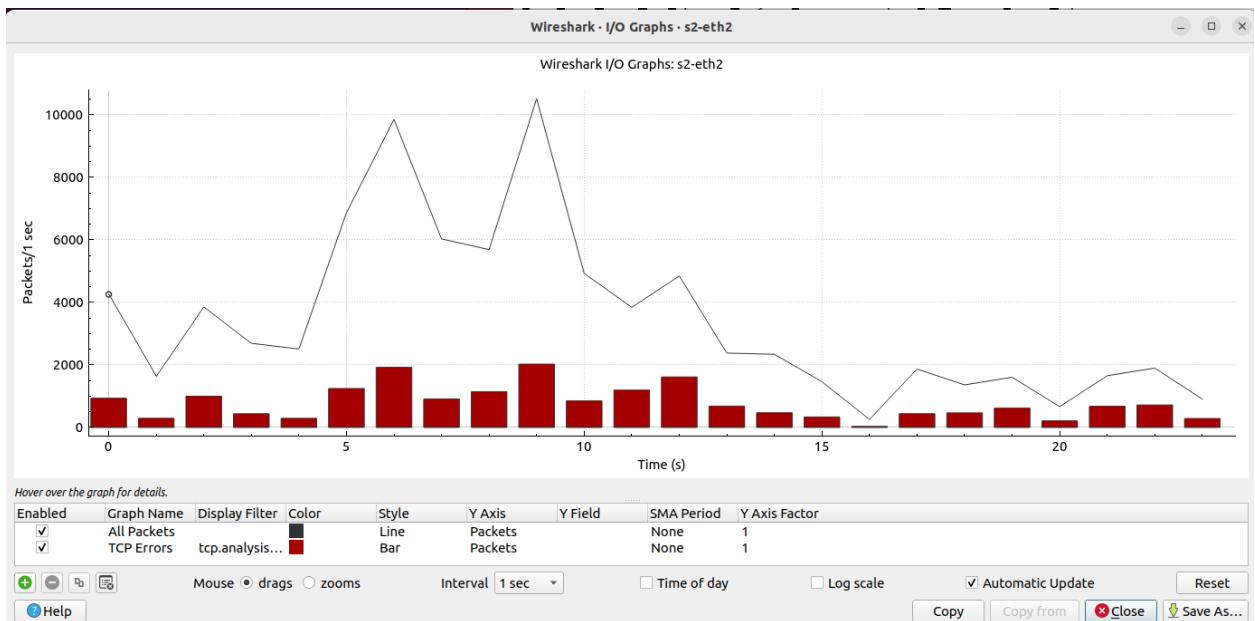


II. Loss = 0 Congestion scheme = Reno

Throughput

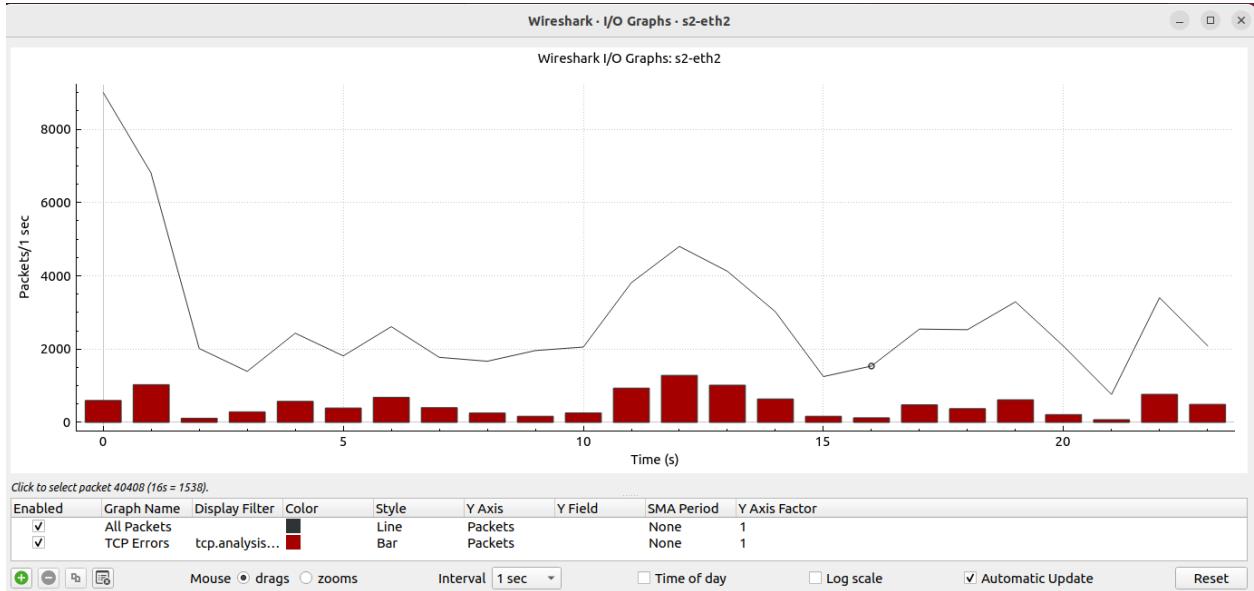


I/O graph

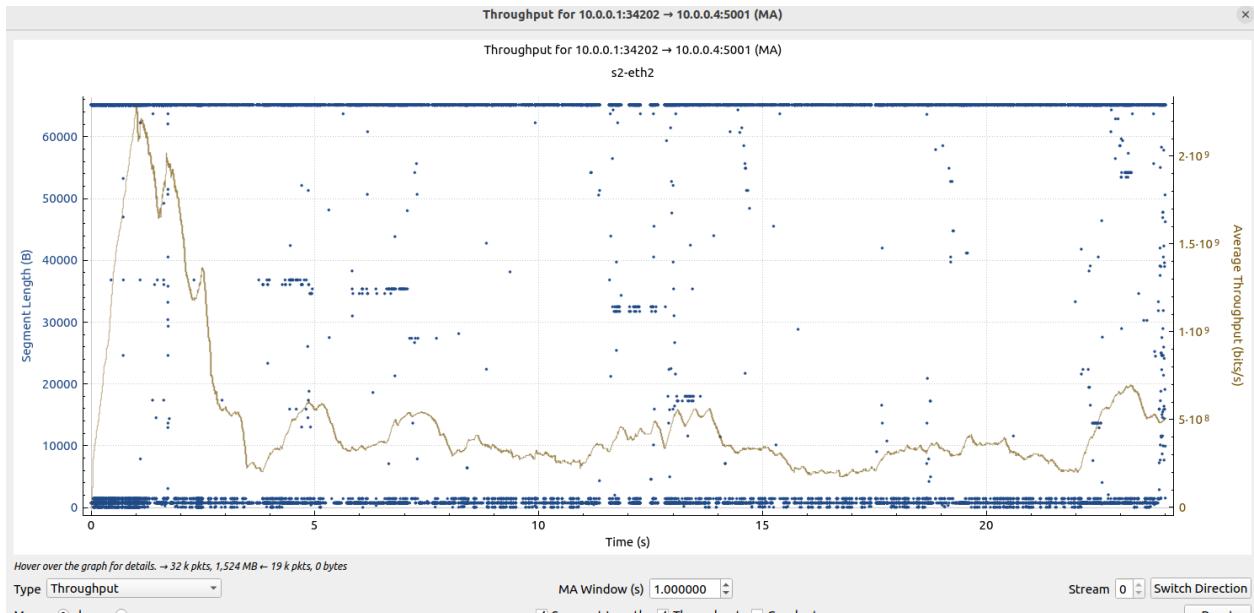


III. Loss =0 congestion scheme = cubic

I/O Graph

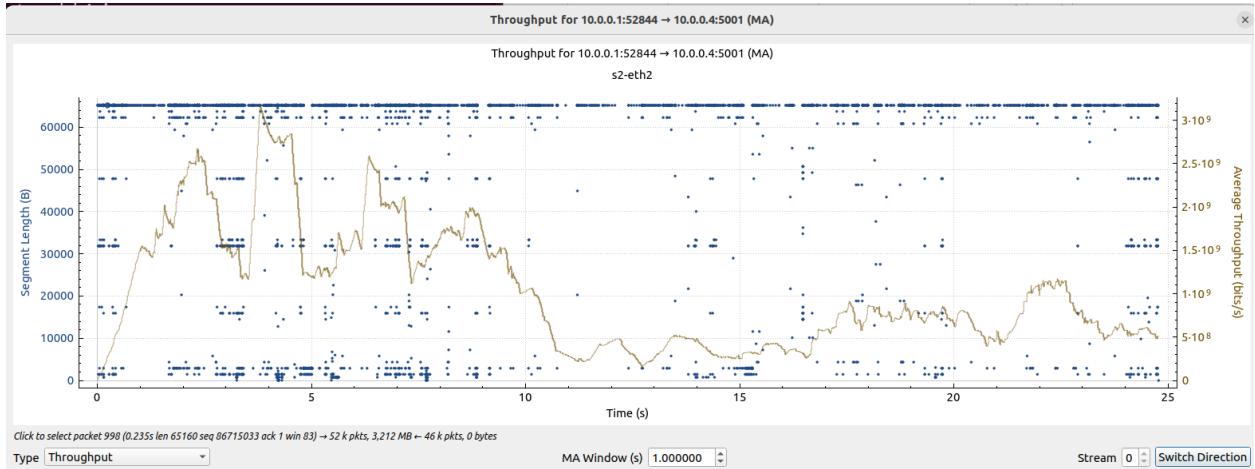


Throughput

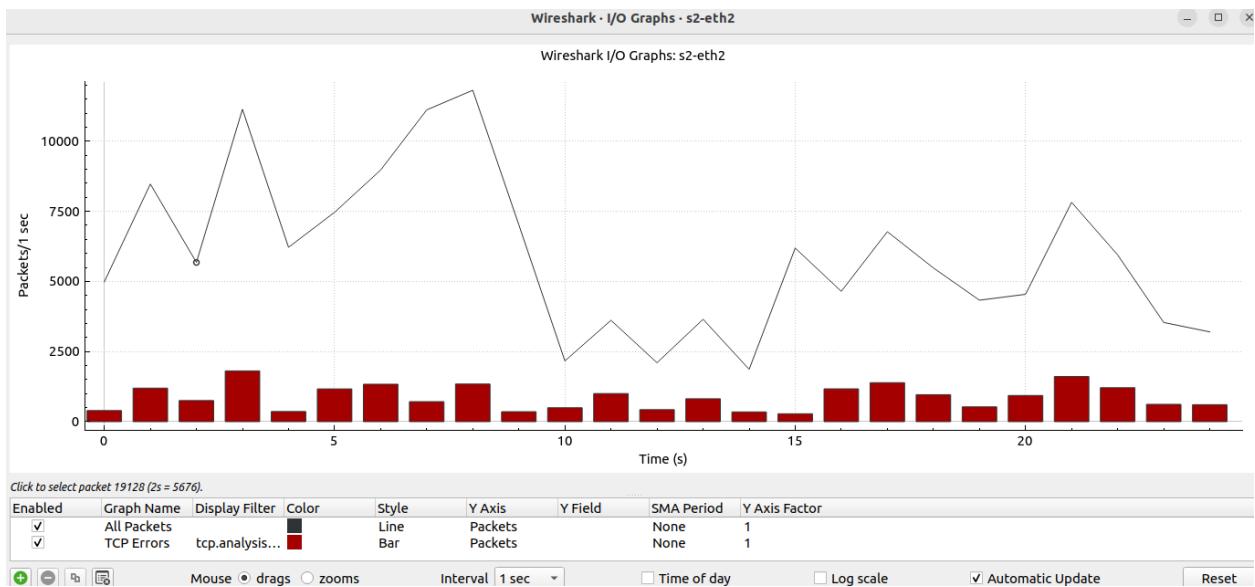


IV. Loss =0 congestion scheme = bbr

Throughput

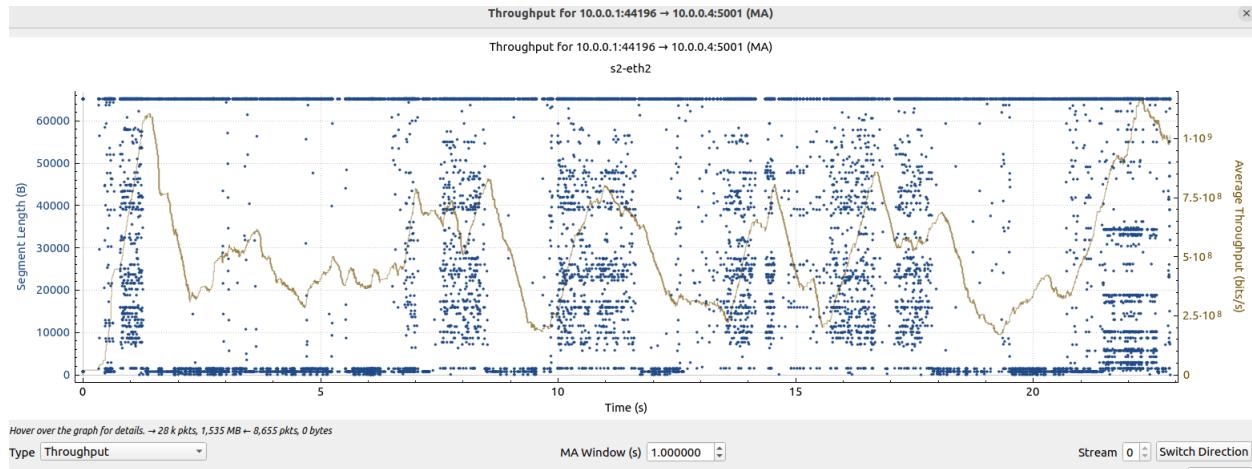


I/O Graph

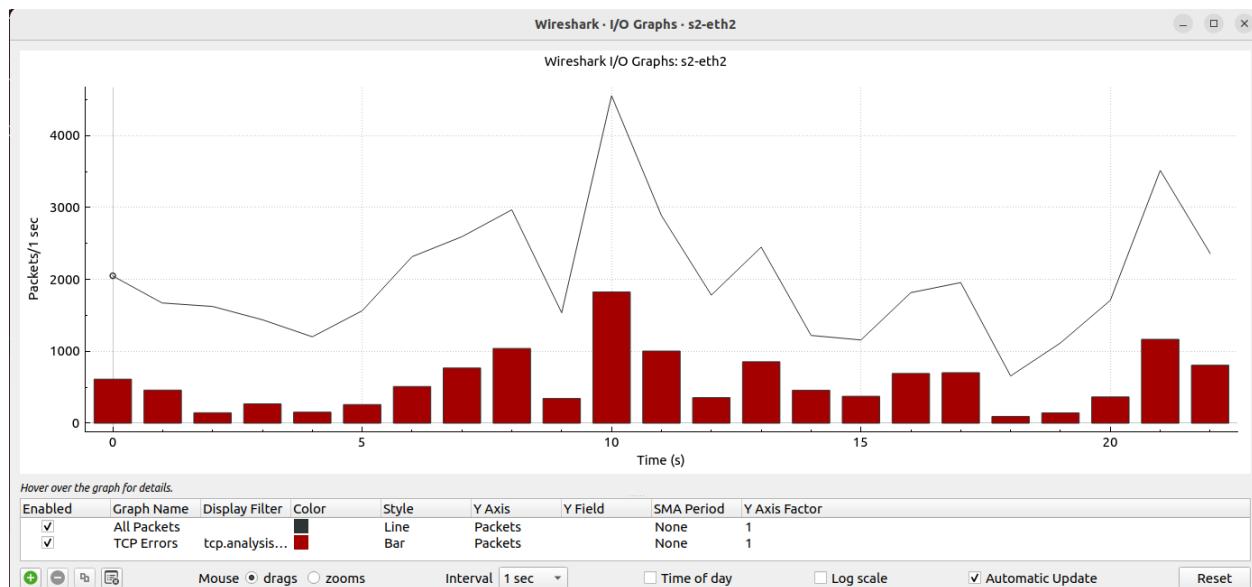


I. Loss =1 congestion scheme =vegas

Throughput

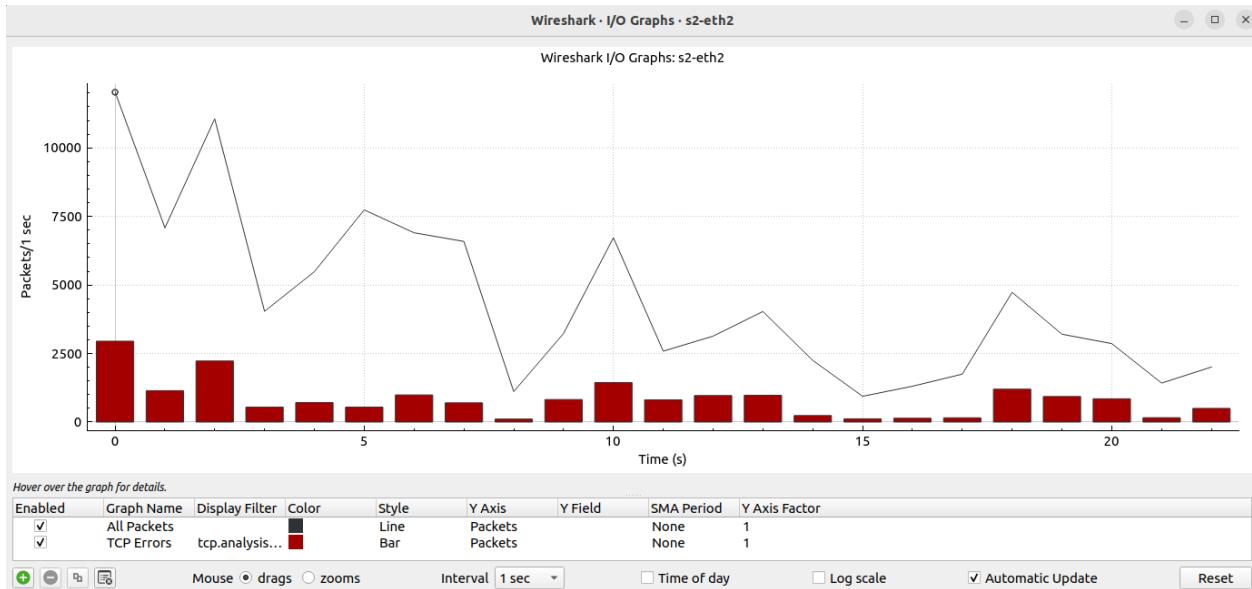


I/O Graph

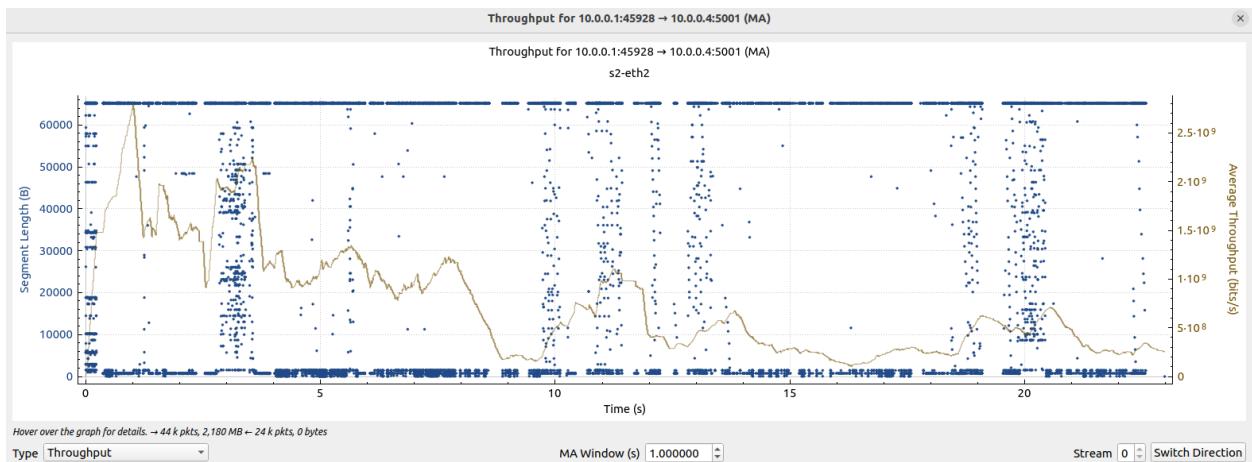


II. Loss =1 congestion scheme = Reno

I/O Graph

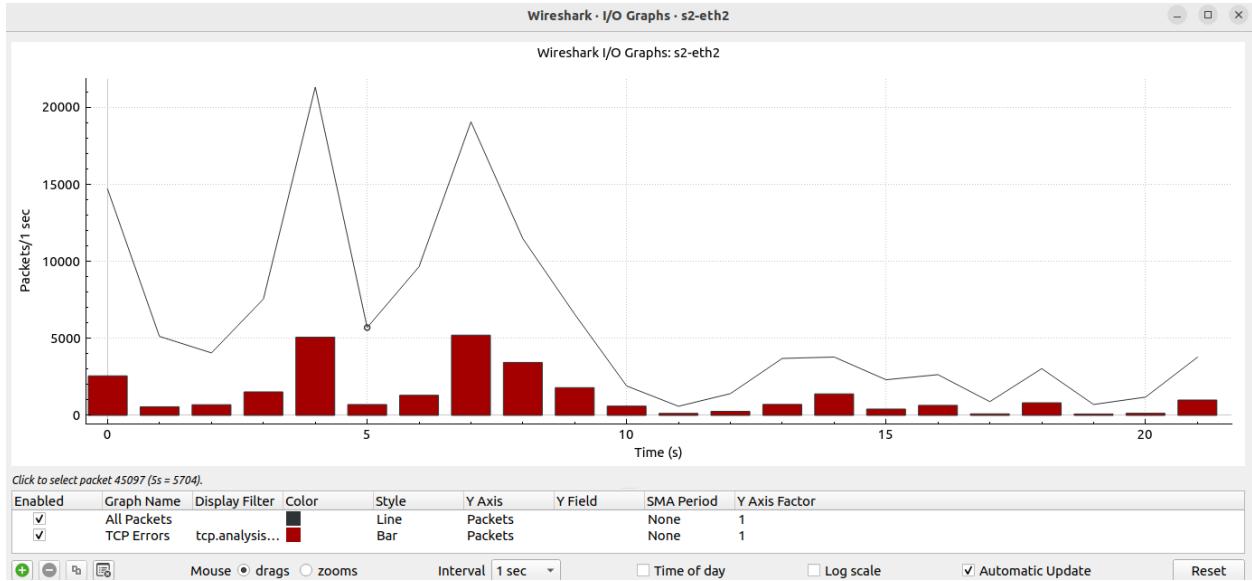


Throughput

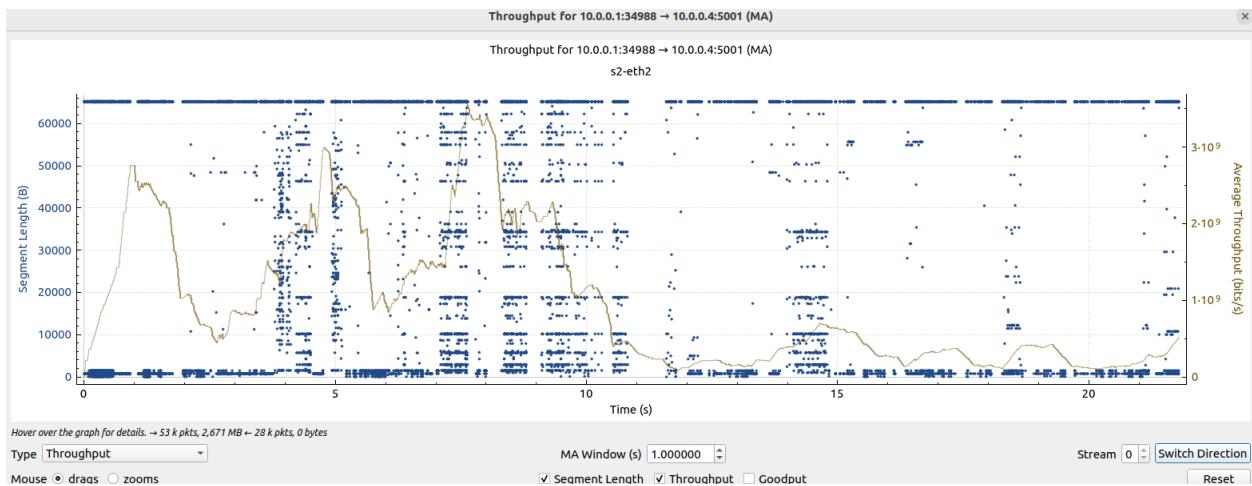


III. Loss =1 congestion scheme =cubic

I/O Graph

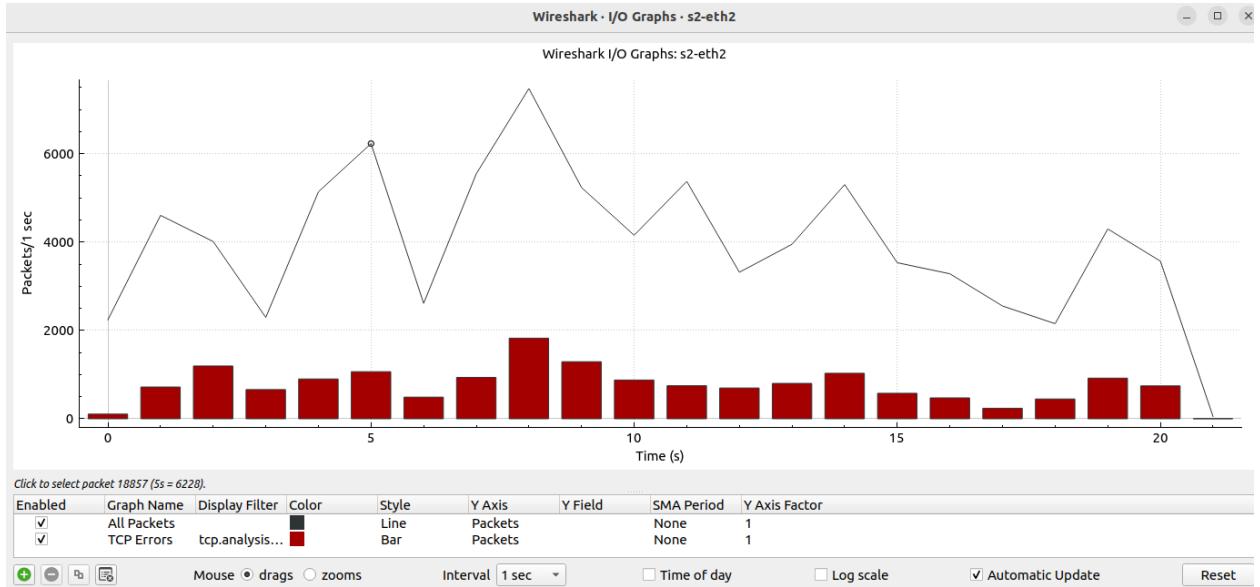


Throughput

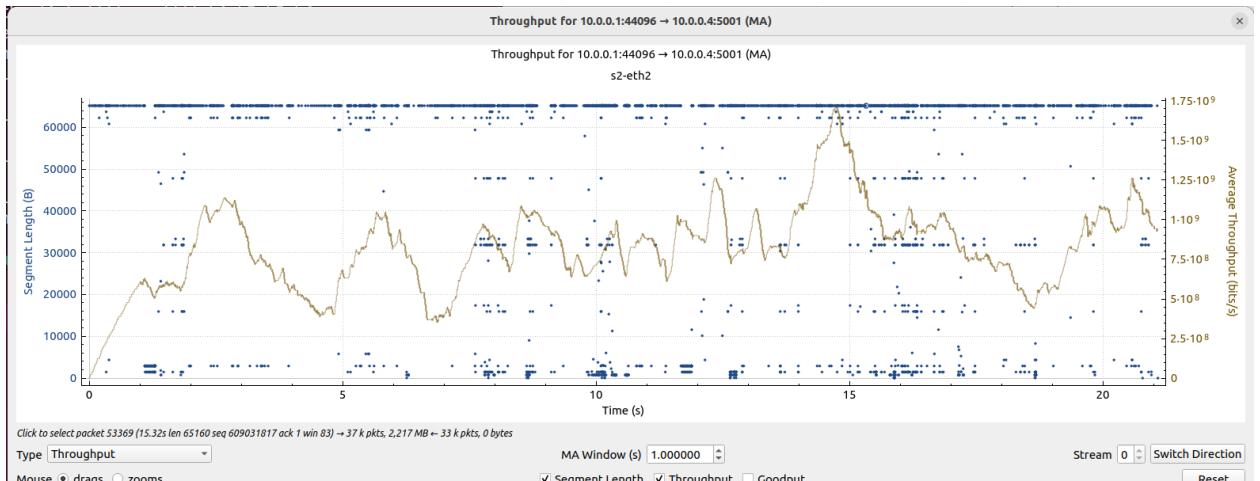


IV. Loss =1 congestion scheme =bbr

I/O Graph

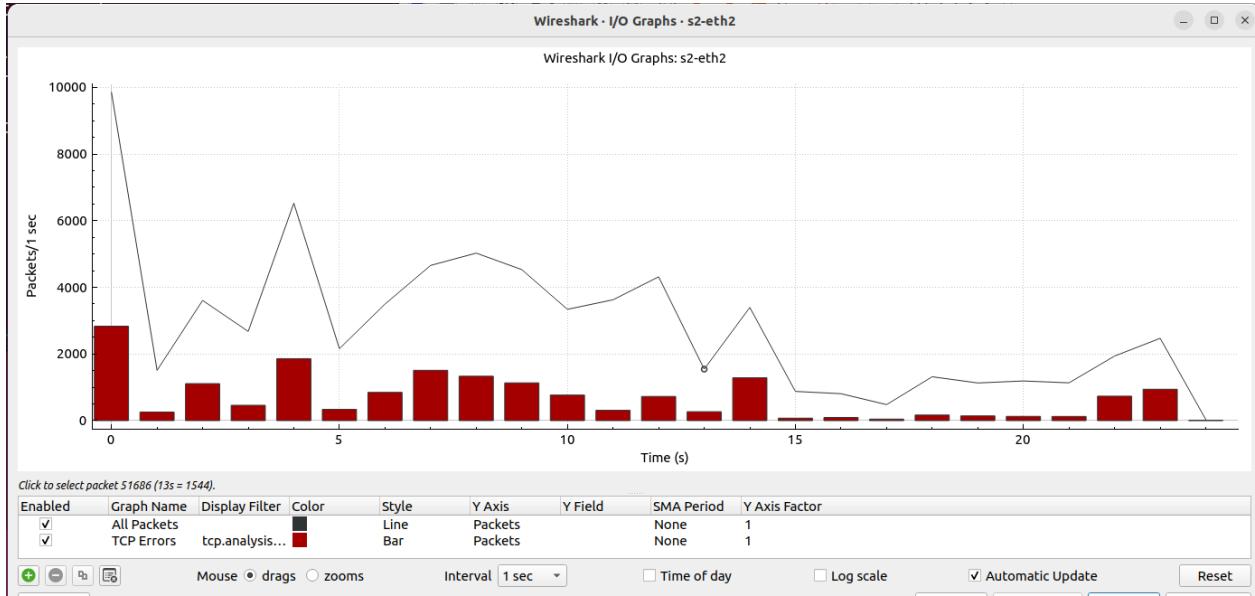


Throughput

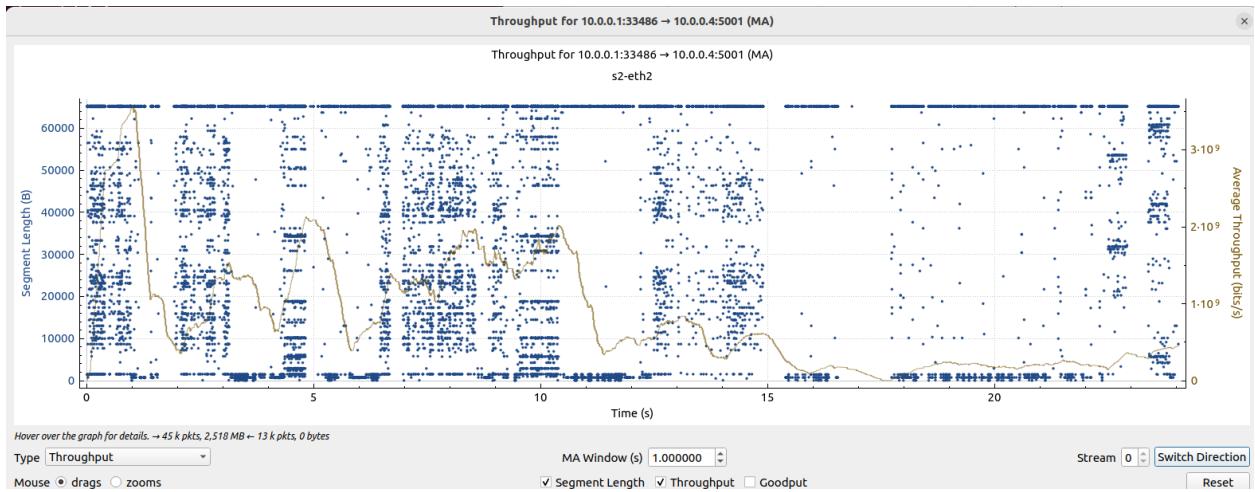


I. Loss =3 congestion scheme= vegas

I/O Graph

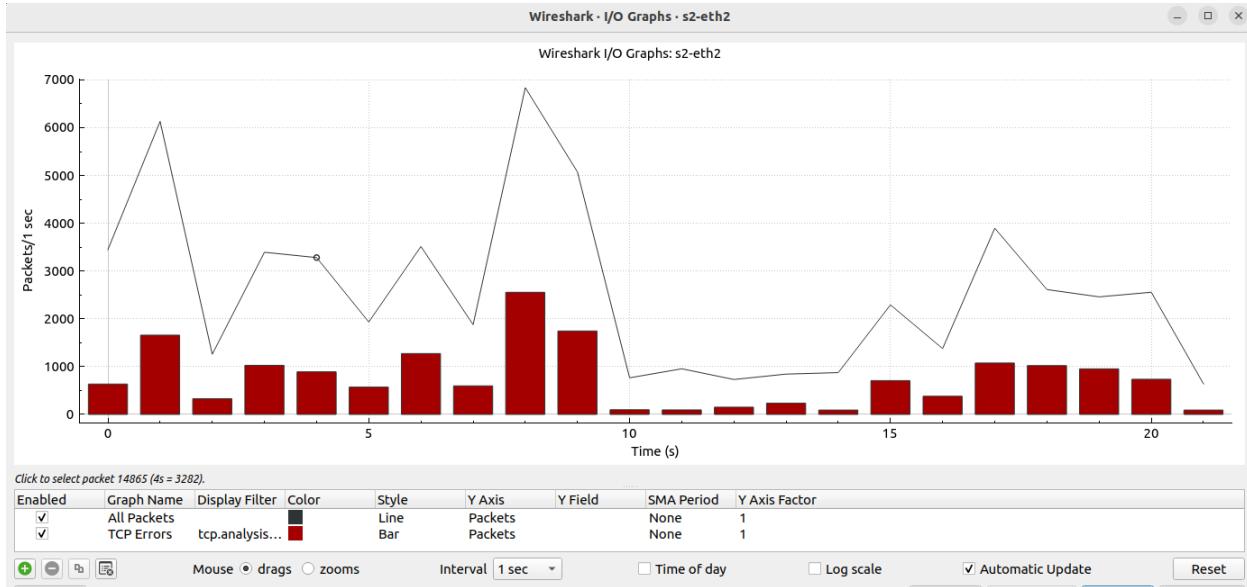


Throughput

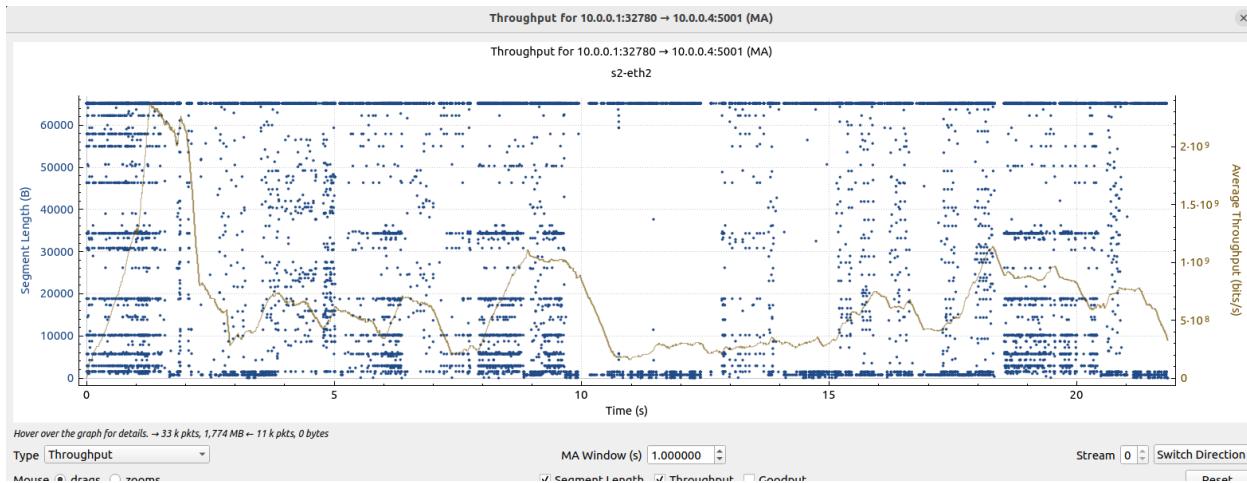


II. Loss=3 congestion scheme= reno

I/O Graph

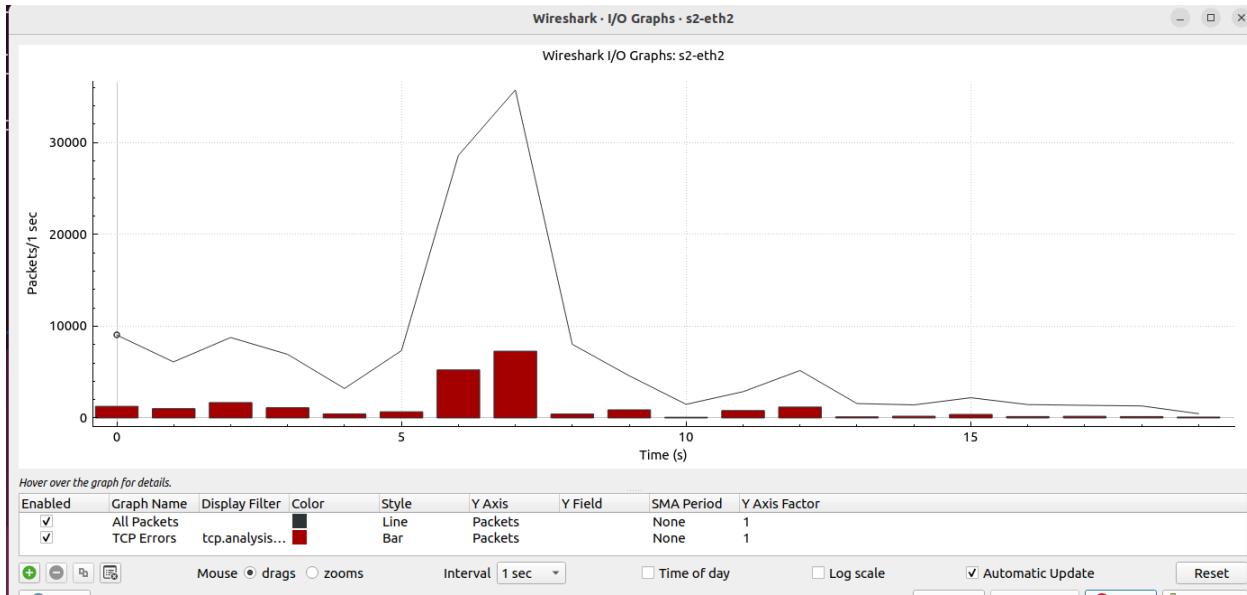


Throughput

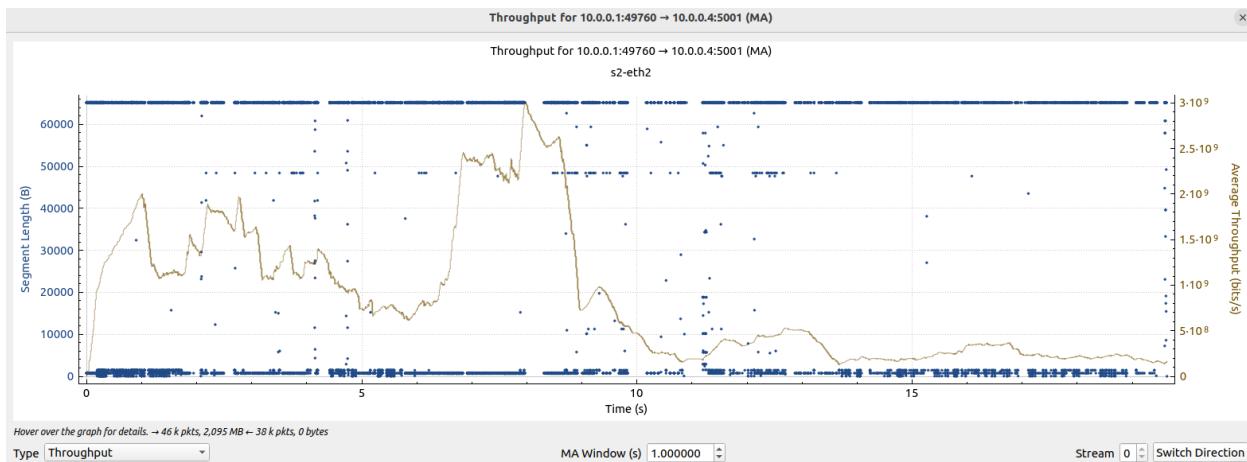


III. Loss =3 congestion scheme = cubic

I/O Graph

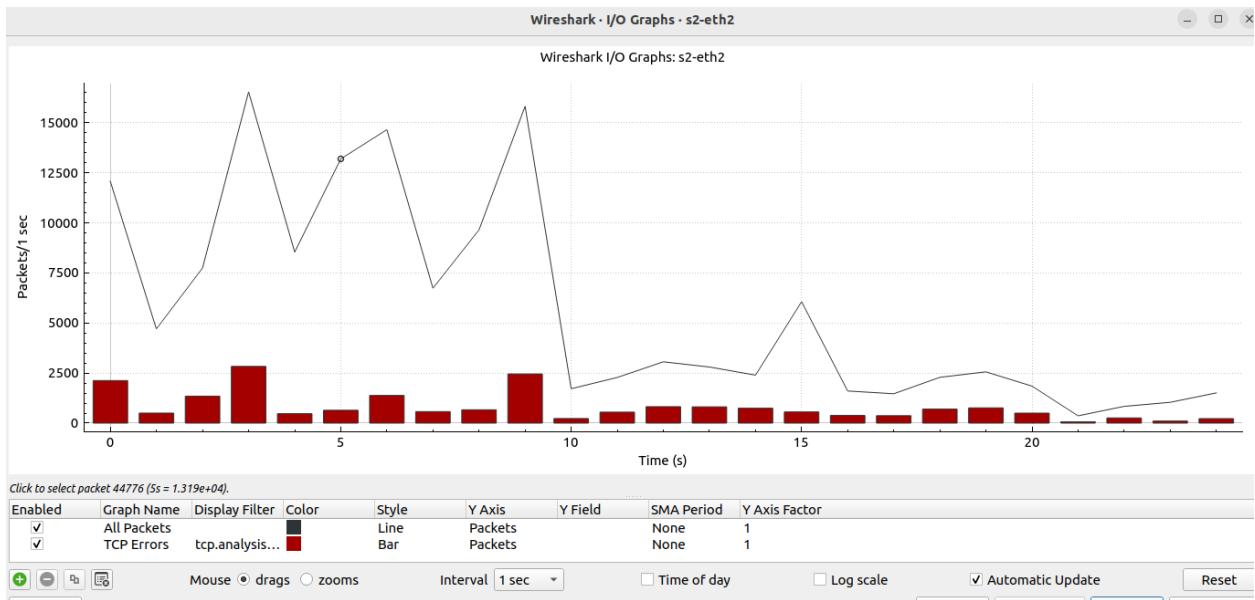


Throughput

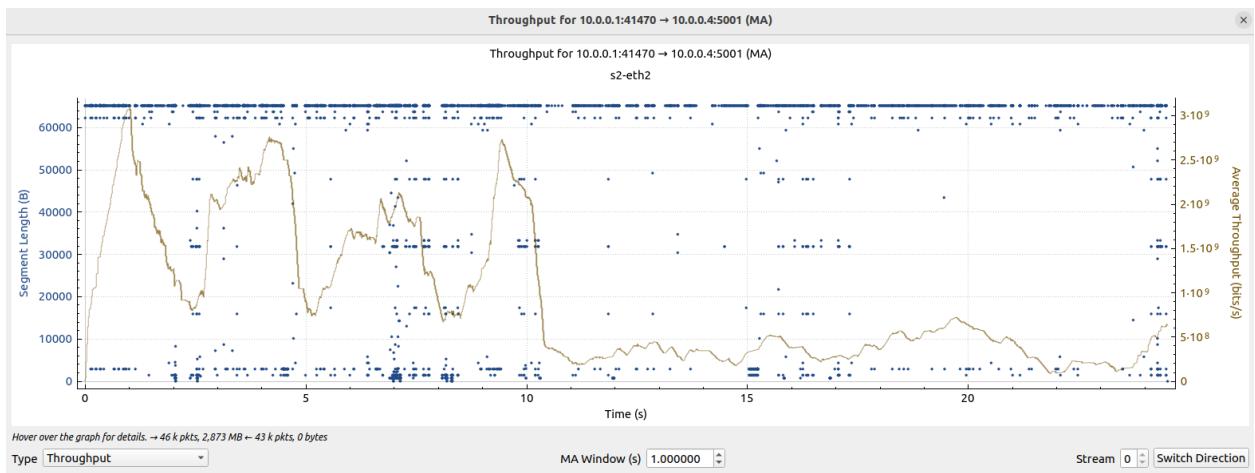


IV. Loss =3 congestion scheme = bbr

I/O Graph



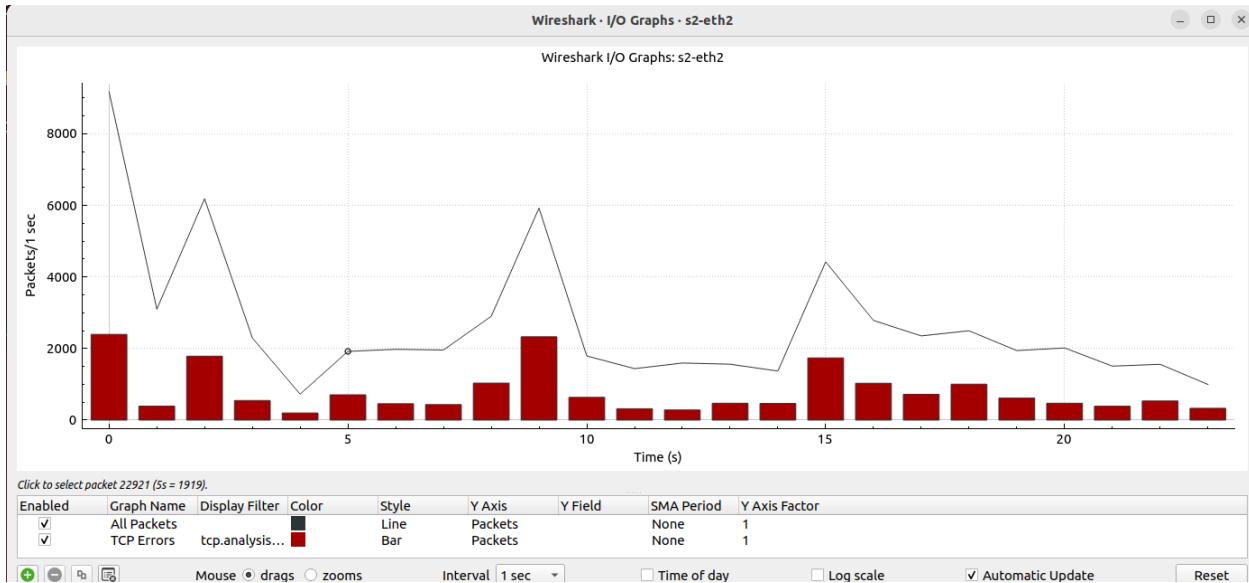
Throughput



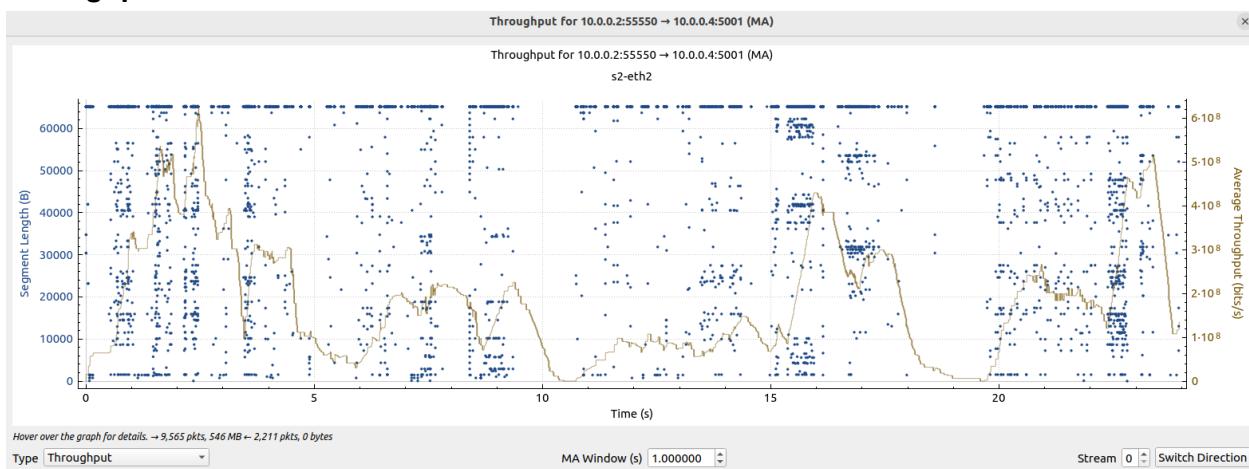
C. H1 (10.0.0.1), H2 (10.0.0.2), H3 (10.0.0.3) are clients and H4 (10.0.0.4) is server

I. Loss =0 and congestion scheme = vegas

I/O Graph

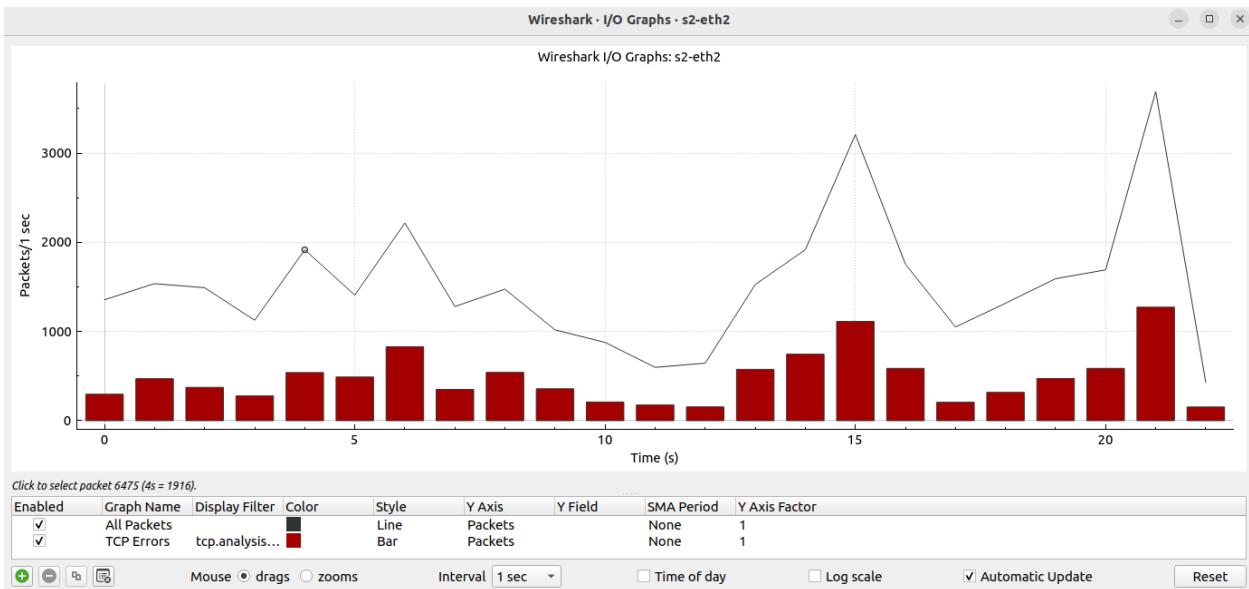


Throughput

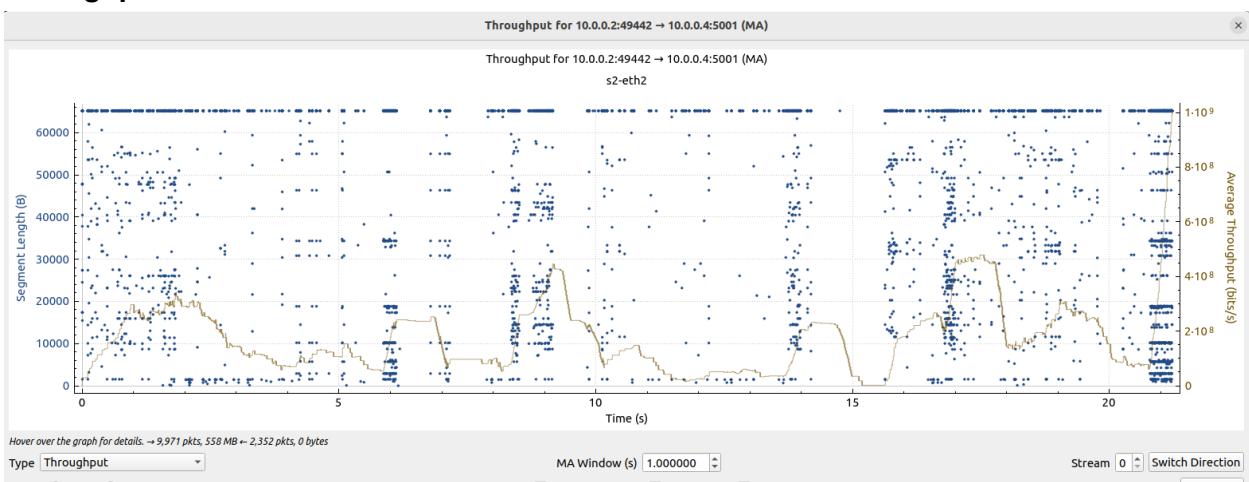


II. Loss =0 and congestion scheme = reno

I/O Graph

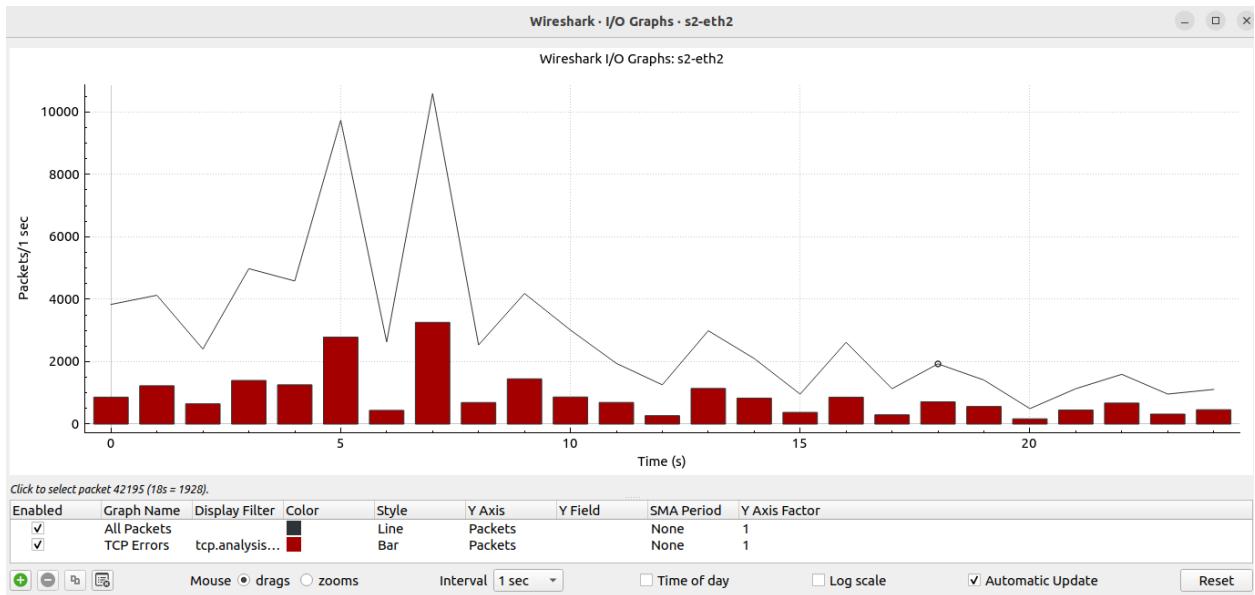


Throughput

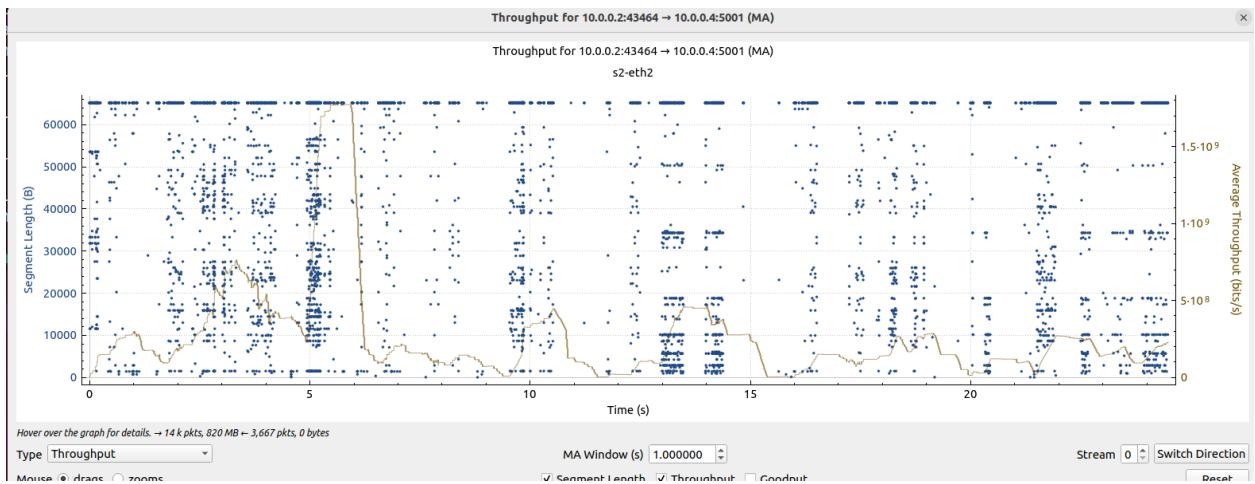


III. Loss = 0 and congestion scheme = cubic

I/O Graph

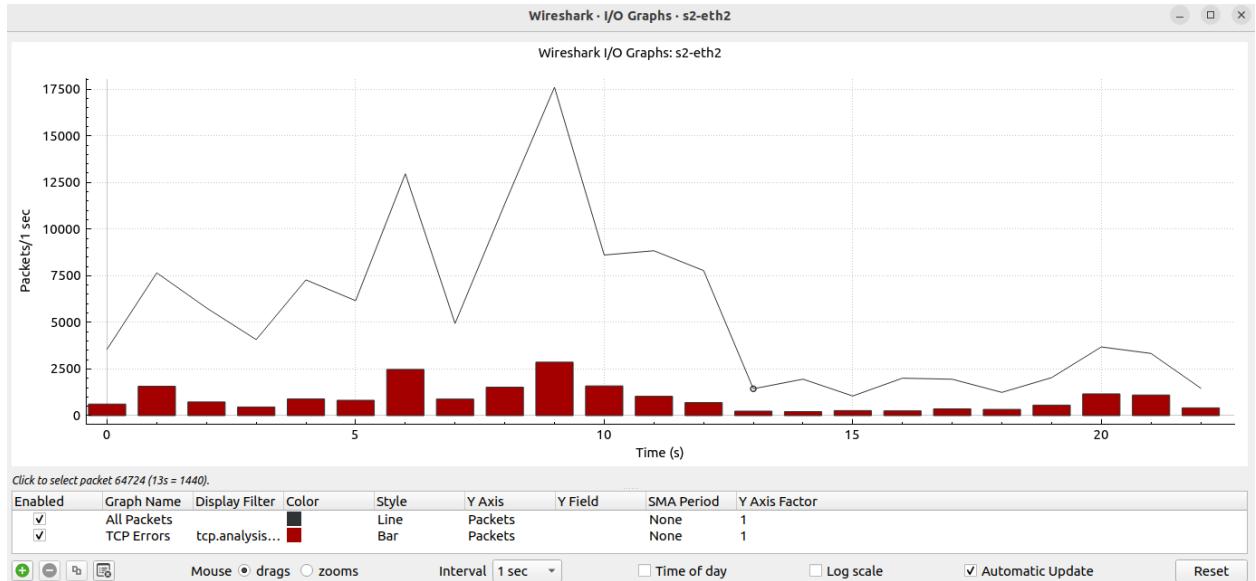


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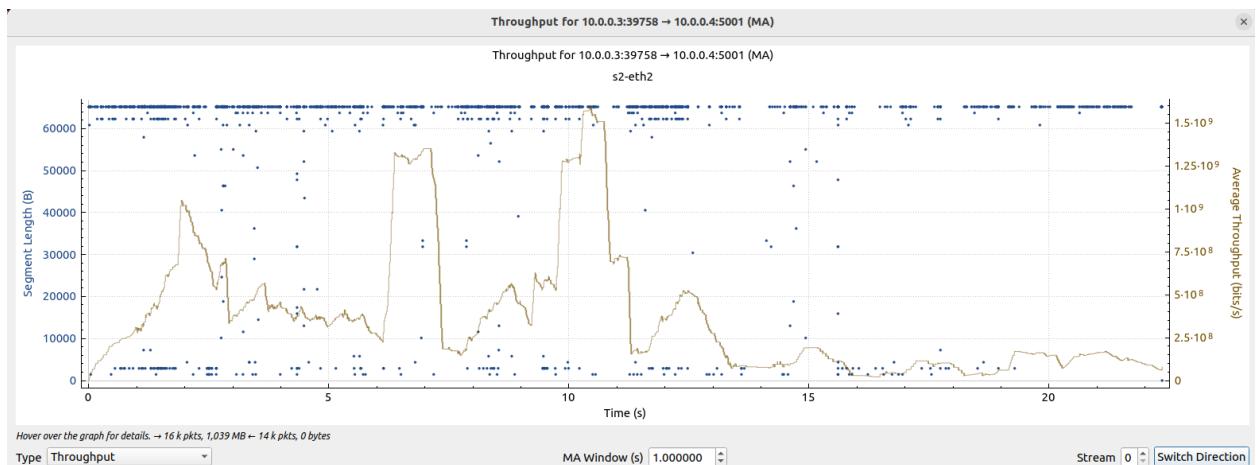


IV. Loss =0 and congestion scheme = bbr

I/O Graph

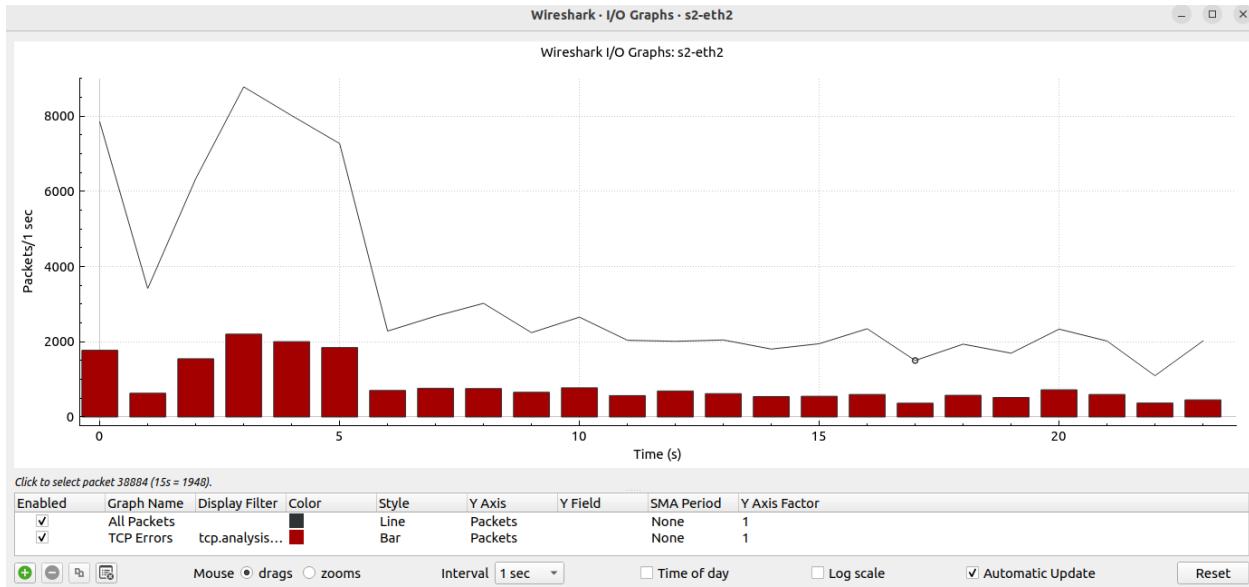


Throughput

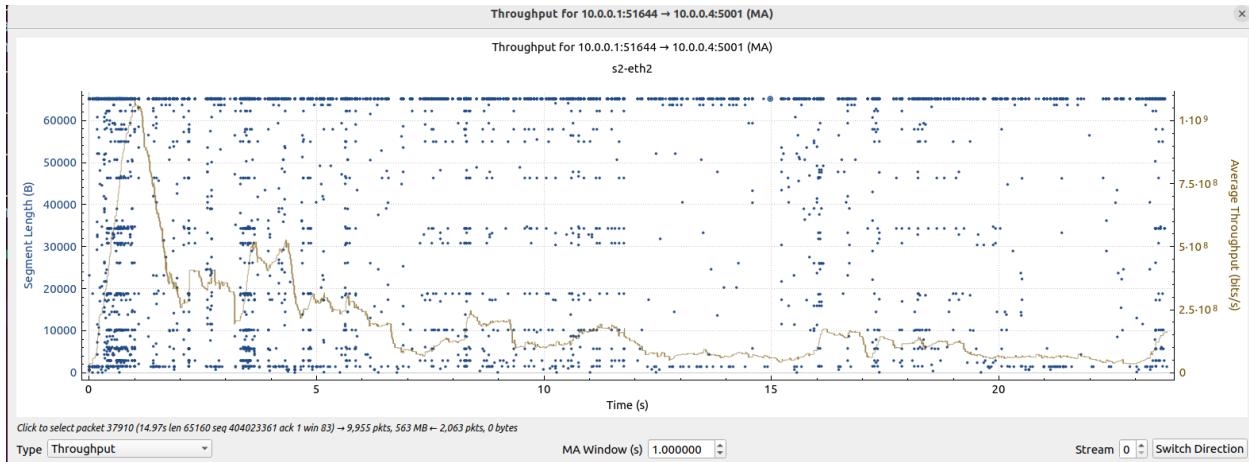


I. Loss = 1 congestion scheme = vegas

I/O Graph

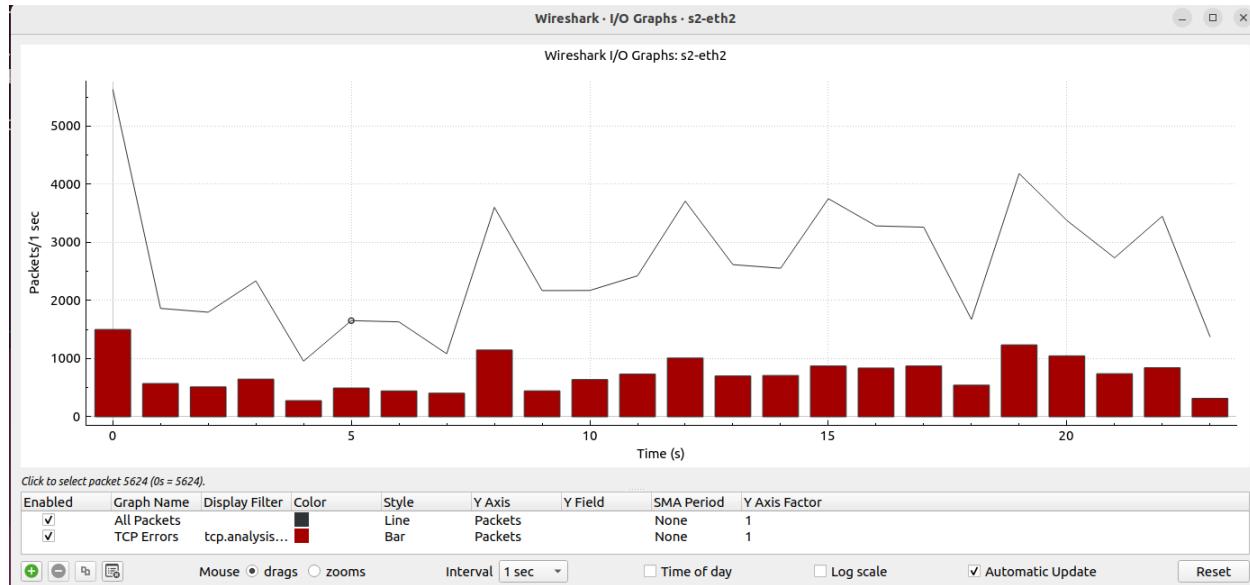


Throughput

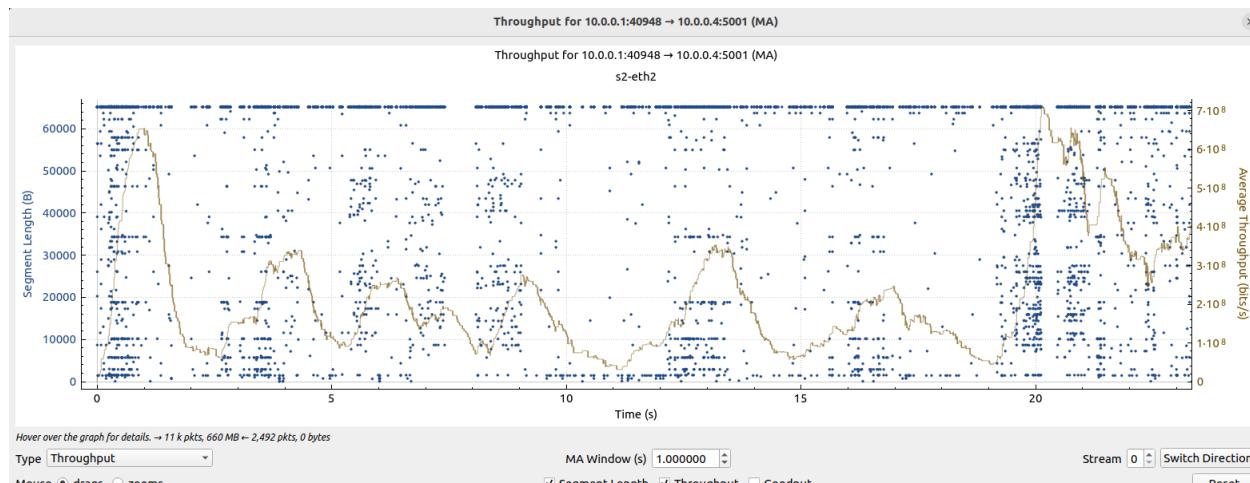


II. Loss =1 congestion scheme=reno

I/O Graph

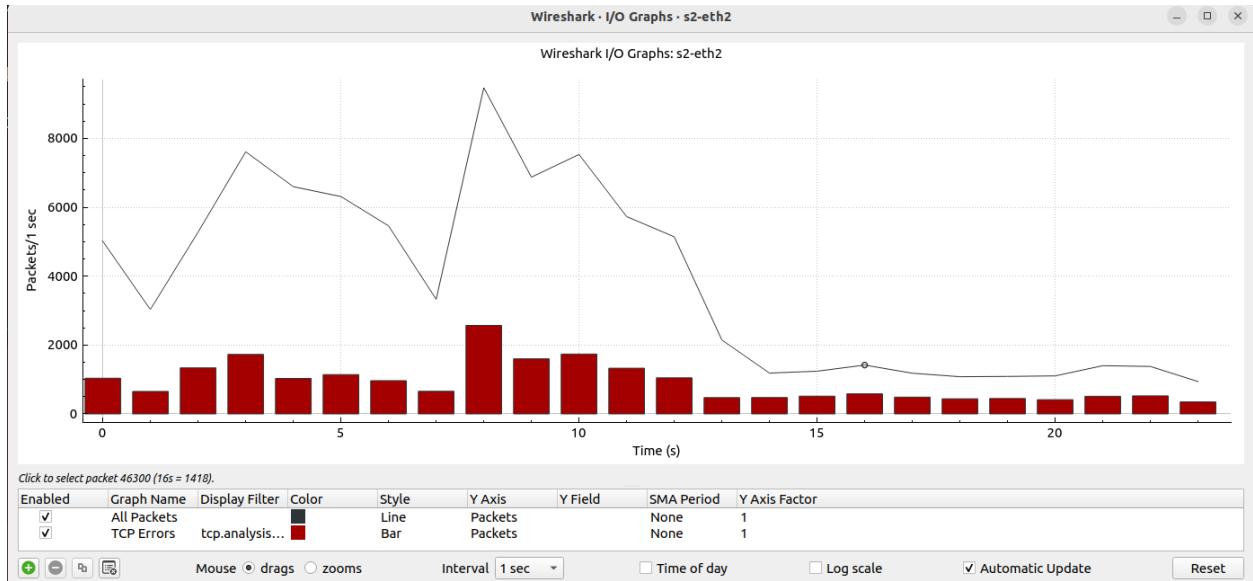


Throughput

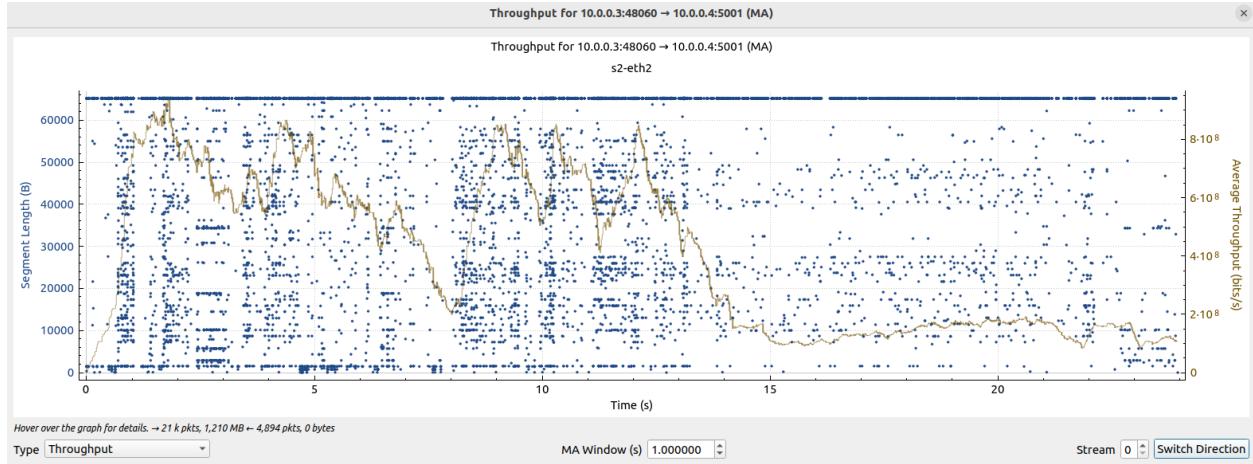


III. Loss =1 congestion scheme=cubic

I/O Graph

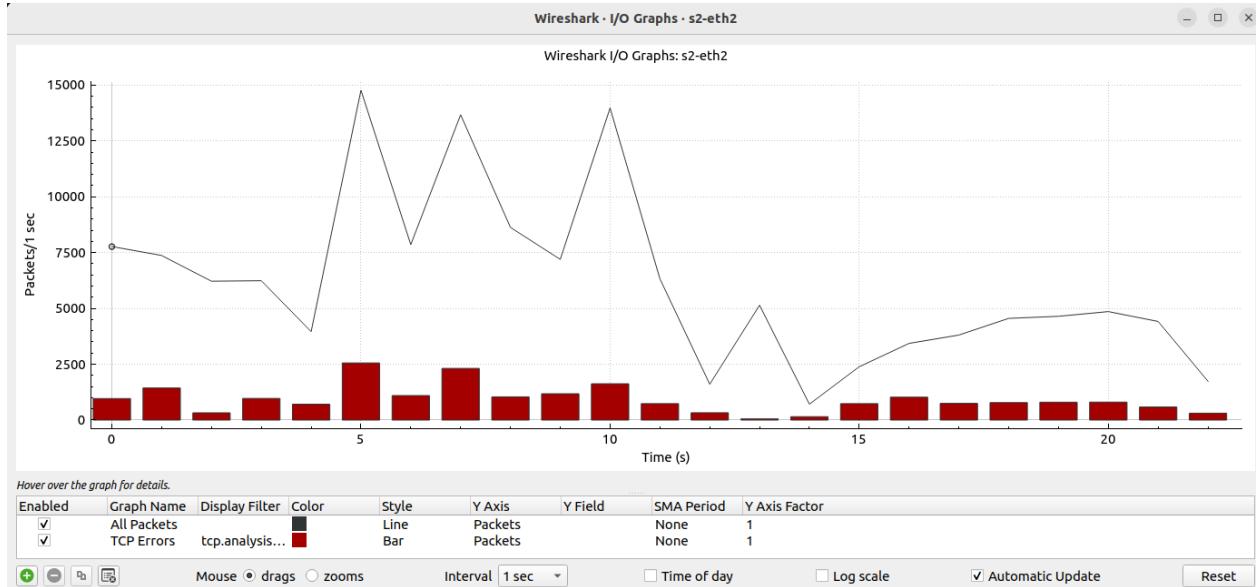


Throughput

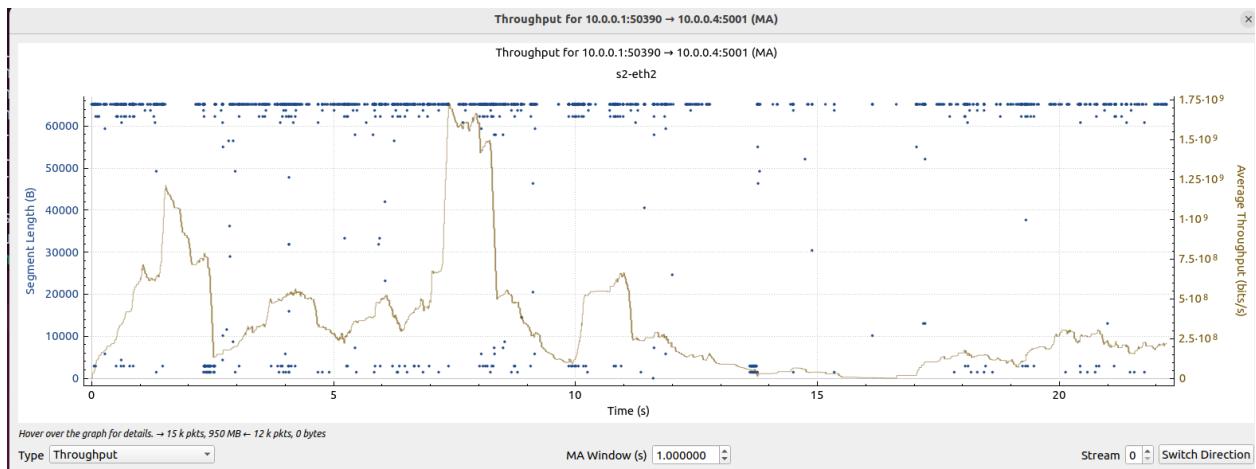


IV. Loss =1 congestion scheme=bbr

I/O Graph

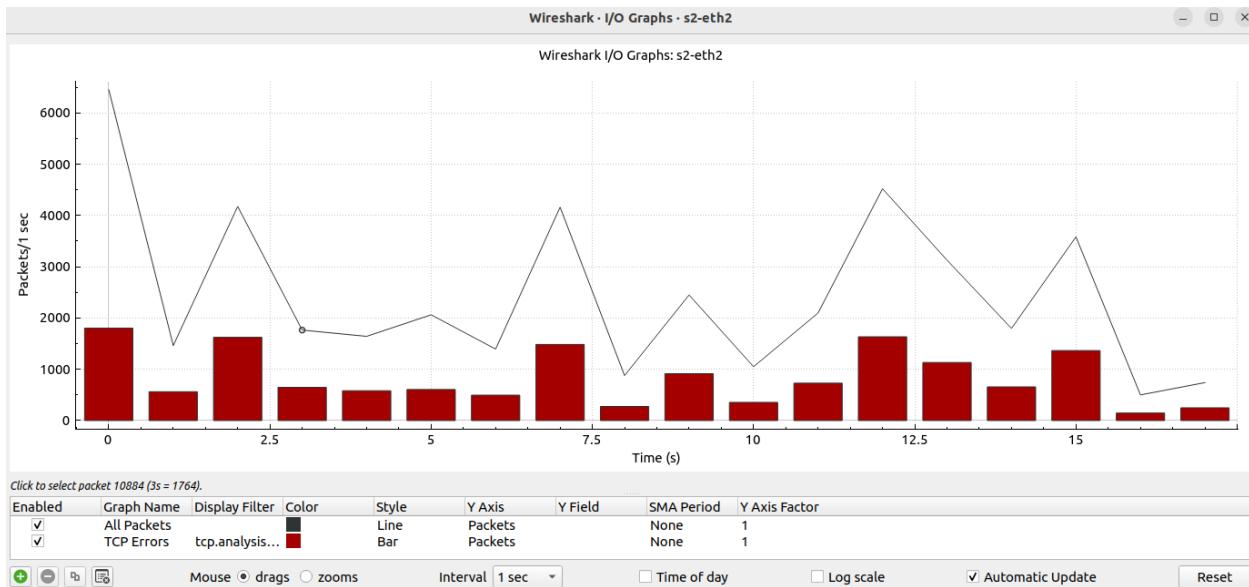


Throughput

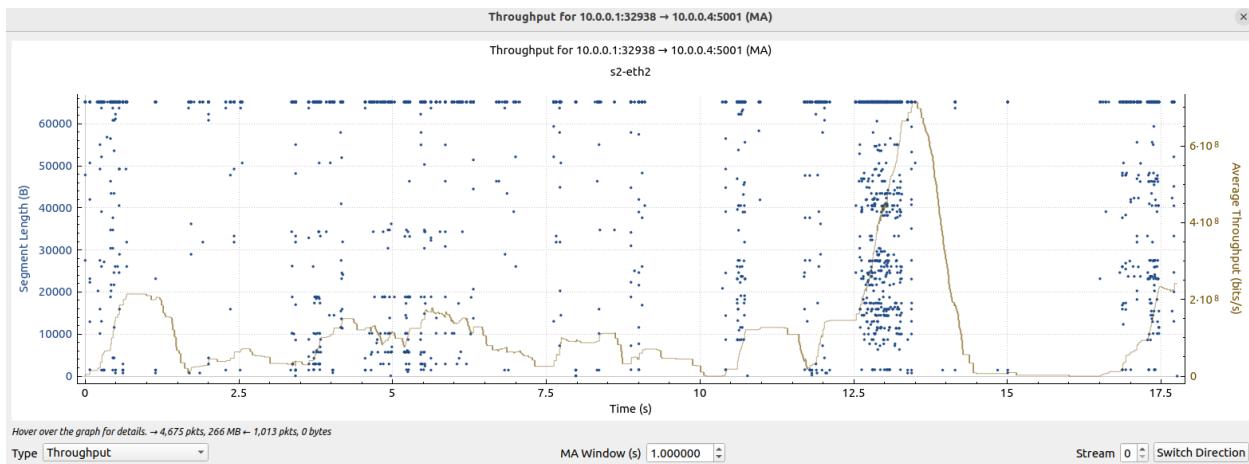


I. Loss =3 congestion scheme=vegas

I/O Graph

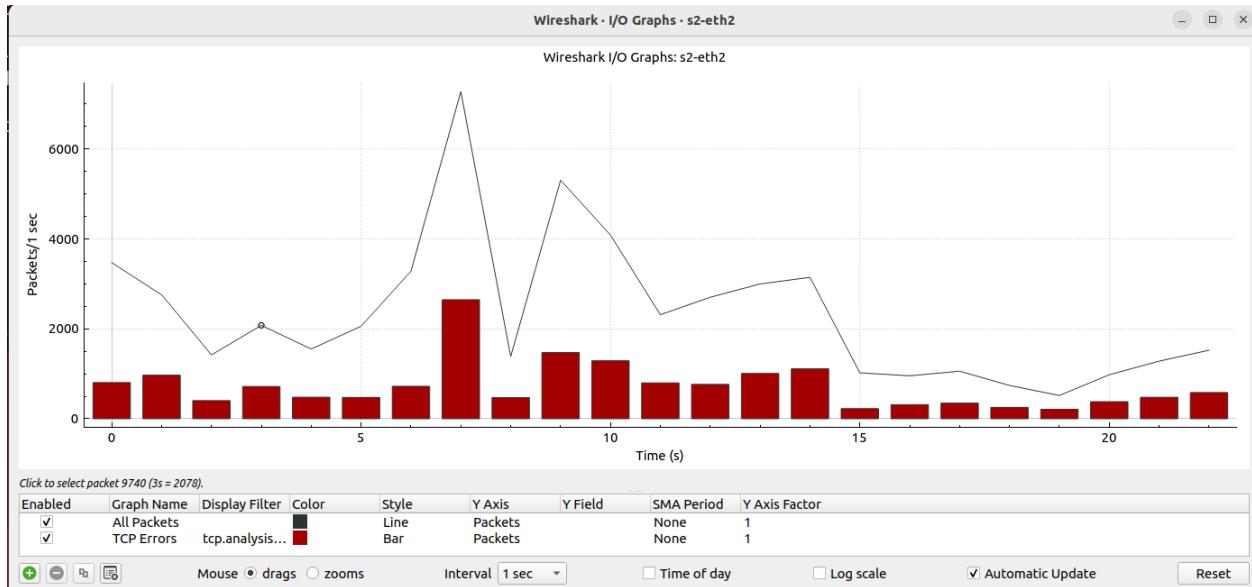


Throughput

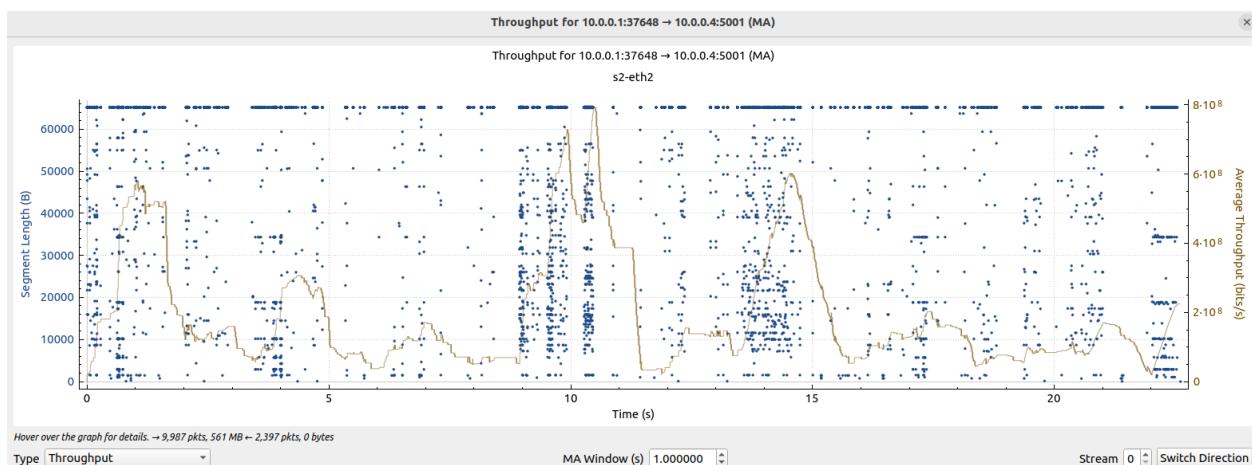


II. Loss =3 congestion scheme=reno

I/O Graph

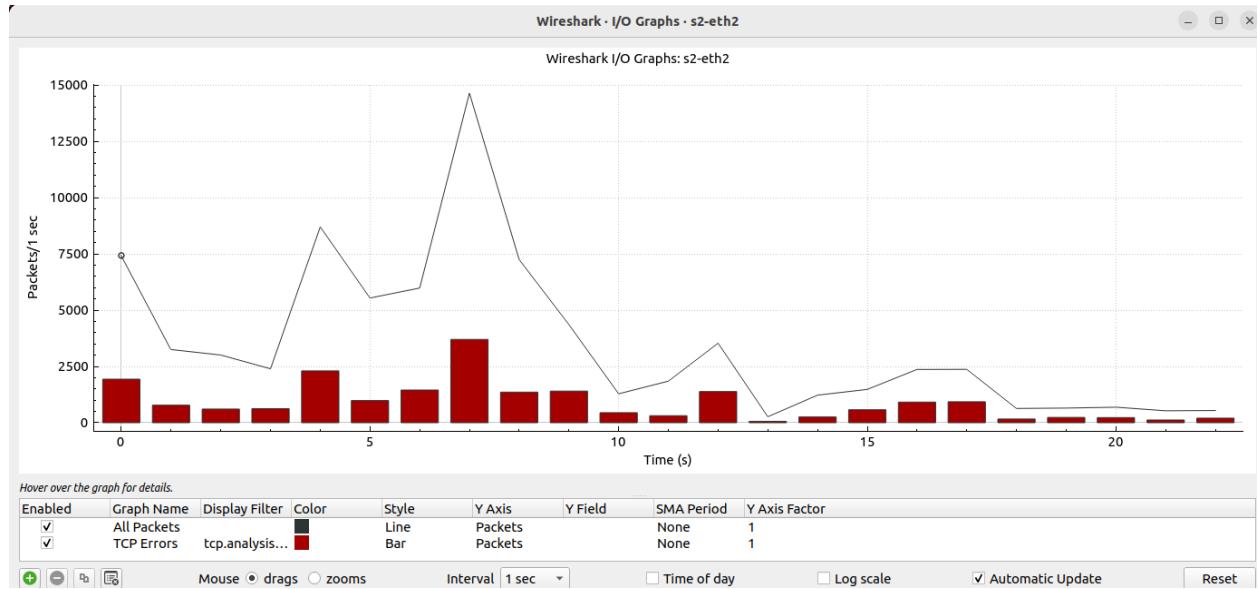


Throughput

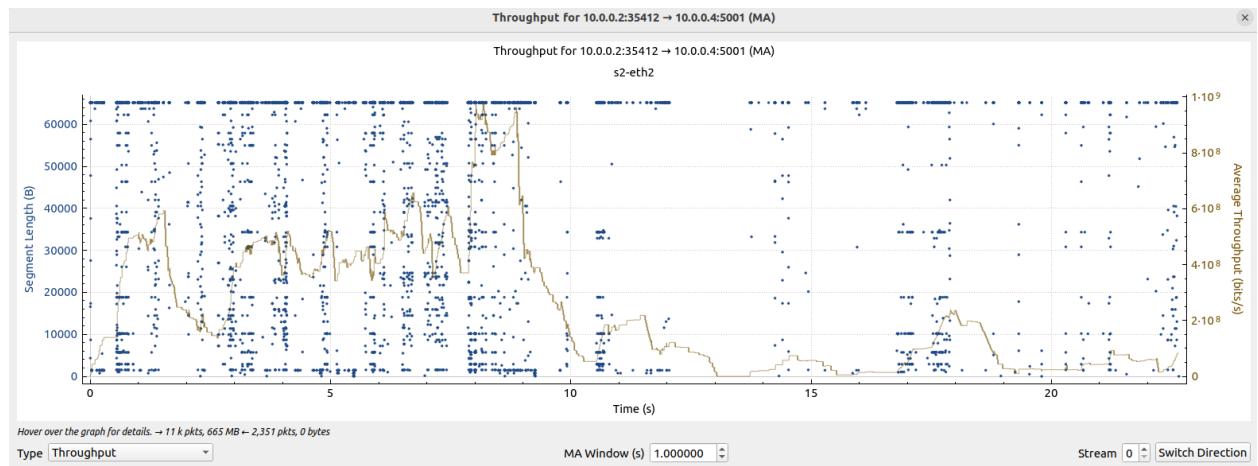


III. Loss =3 congestion scheme=cubic

I/O Graph

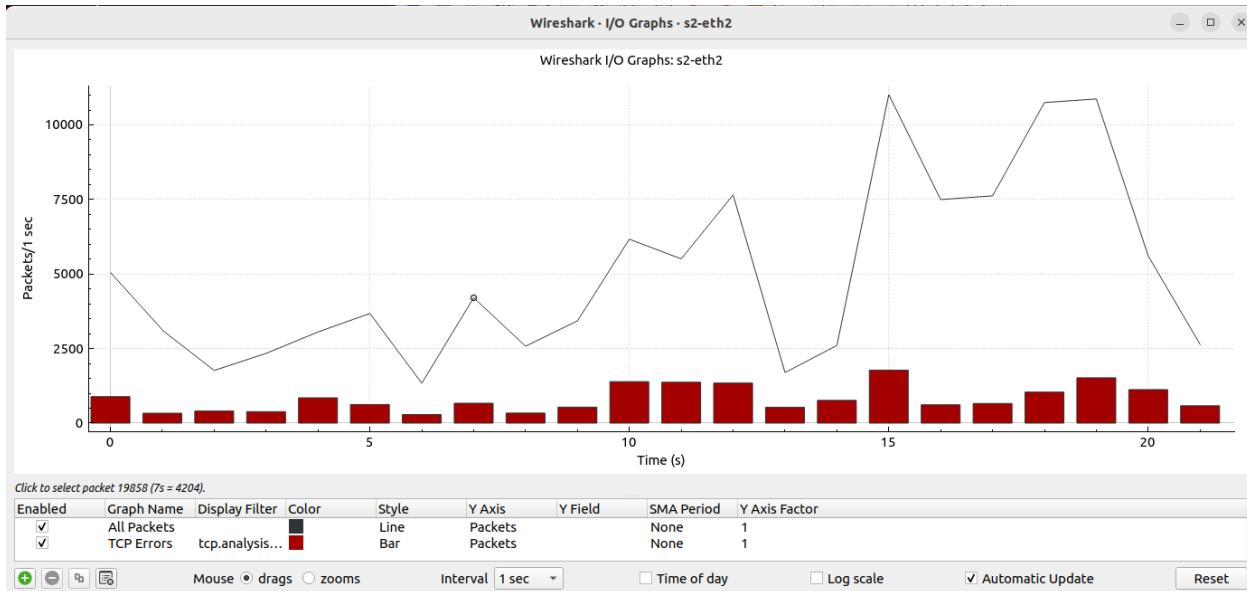


Throughput



IV. Loss= 3 congestion scheme= bbr

I/O Graph



Throughput

