CS 433 ASSIGNMENT 2

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GitHub repository link: https://github.com/eelfire/cn-mininet

Part 1

a.

```
⚡ sudo ./custom_network.py
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6 ra rb rc
*** Adding switches:
s1 s2 s3
*** Adding links:
(h1, s1) (h2, s1) (h3, s2) (h4, s2) (h5, s3) (h6, s3) (ra, rb) (rb, rc) (rc, ra) (s1, ra) (s2, rb) (s3, rc)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 ra rb rc
*** Starting controller
c0
*** Starting 3 switches
s1 s2 s3 ...
*** Waiting for switches to connect
s1 s2 s3
--- Routes on Ra: ---
10.1.0.0/24     dev  ra-ethsa     proto  kernel    scope  link  src  10.1.0.1
10.2.0.0/24     via  10.100.12.2  dev    ra-ethrb
10.3.0.0/24     via  10.100.31.3  dev    ra-ethrc
10.100.12.0/24  dev  ra-ethrb     proto  kernel    scope  link  src  10.100.12.1
10.100.31.0/24  dev  ra-ethrc     proto  kernel    scope  link  src  10.100.31.1
--- Routes on Rb: ---
10.1.0.0/24     via  10.100.12.1  dev    rb-ethra
10.2.0.0/24     dev  rb-ethsb     proto  kernel    scope  link  src  10.2.0.1
10.3.0.0/24     via  10.100.23.3  dev    rb-ethrc
10.100.12.0/24  dev  rb-ethra     proto  kernel    scope  link  src  10.100.12.2
10.100.23.0/24  dev  rb-ethrc     proto  kernel    scope  link  src  10.100.23.2
--- Routes on Rc: ---
10.1.0.0/24     via  10.100.31.1  dev    rc-ethra
10.2.0.0/24     via  10.100.23.2  dev    rc-ethrb
10.3.0.0/24     dev  rc-ethsc     proto  kernel    scope  link  src  10.3.0.1
10.100.23.0/24  dev  rc-ethrb     proto  kernel    scope  link  src  10.100.23.3
10.100.31.0/24  dev  rc-ethra     proto  kernel    scope  link  src  10.100.31.3
```

Fig 1: Custom Topology Setup in Mininet

```
--- --- ---
--- Starting tcpdump on Ra, Rb, Rc ---
--- Running pingAll() ---
*** Ping: testing ping reachability
h1 -> h2 h3 h4 h5 h6 ra rb rc
h2 -> h1 h3 h4 h5 h6 ra rb rc
h3 -> h1 h2 h4 h5 h6 ra rb rc
h4 -> h1 h2 h3 h5 h6 ra rb rc
h5 -> h1 h2 h3 h4 h6 ra rb rc
h6 -> h1 h2 h3 h4 h5 ra rb rc
ra -> h1 h2 h3 h4 h5 h6 rb rc
rb -> h1 h2 h3 h4 h5 h6 ra rc
rc -> h1 h2 h3 h4 h5 h6 ra rb
*** Results: 0% dropped (72/72 received)
*** Stopping 1 controllers
c0
*** Stopping 12 links
............
*** Stopping 3 switches
s1 s2 s3
*** Stopping 9 hosts
h1 h2 h3 h4 h5 h6 ra rb rc
*** Done
```

Fig 2: Testing *pingall* Functionality For Each Node

b. Packets for each of the routers is captured using the `tcpdump` command and written to files: **ra_capture.pcap, rb_capture.pcap. rc_capture.pcap**.

ra_capture.pcap

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No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	fe80::c05b:4bff:fe3…	ff02::2	ICMPv6	76	Router Solicitation from c2:5b:4b:37:aa:84
2	0.000023	fe80::b8cf:bfff:feb…	ff02::2	ICMPv6	76	Router Solicitation from ba:cf:bf:b2:73:fe
3	0.255649	fe80::801c:6cff:fe9…	ff02::2	ICMPv6	76	Router Solicitation from 82:1c:6c:90:7c:e2
4	0.255688	fe80::884:23ff:fea3…	ff02::2	ICMPv6	76	Router Solicitation from 0a:84:23:a3:ae:9e
5	0.255770	fe80::24e3:49ff:fe2…	ff02::2	ICMPv6	76	Router Solicitation from 26:e3:49:25:e4:70
6	0.766987	fe80::8fa:dfff:fe29…	ff02::2	ICMPv6	76	Router Solicitation from 0a:fa:df:29:ab:9c
7	0.946117	ba:cf:bf:b2:73:fe		ARP	48	Who has 10.1.0.20? Tell 10.1.0.10
8	0.954351	ba:cf:bf:b2:73:fe		ARP	48	Who has 10.1.0.1? Tell 10.1.0.10
9	0.954391	d6:81:92:be:ea:f8		ARP	48	10.1.0.1 is at d6:81:92:be:ea:f8
10	0.955223	10.1.0.10	10.2.0.10	ICMP	104	Echo (ping) request id=0x4861, seq=1/256, ttl=64 (no response found!)
11	0.955255	82:1c:6c:90:7c:e2		ARP	48	Who has 10.100.12.2? Tell 10.100.12.1
12	0.955281	0a:fa:df:29:ab:9c		ARP	48	10.100.12.2 is at 0a:fa:df:29:ab:9c
13	0.955283	10.1.0.10	10.2.0.10	ICMP	104	Echo (ping) request id=0x4861, seq=1/256, ttl=63 (reply in 14)
14	0.957569	10.2.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x4861, seq=1/256, ttl=63 (request in 13)
15	0.957580	10.2.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x4861, seq=1/256, ttl=62
16	0.964178	10.1.0.10	10.2.0.20	ICMP	104	Echo (ping) request id=0x290f, seq=1/256, ttl=64 (no response found!)
17	0.964199	10.1.0.10	10.2.0.20	ICMP	104	Echo (ping) request id=0x290f, seq=1/256, ttl=63 (reply in 18)
18	0.966650	10.2.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0x290f, seq=1/256, ttl=63 (request in 17)
19	0.966655	10.2.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0x290f, seq=1/256, ttl=62
20	0.972462	10.1.0.10	10.3.0.10	ICMP	104	Echo (ping) request id=0x476b, seq=1/256, ttl=64 (no response found!)
21	0.972489	0a:84:23:a3:ae:9e		ARP	48	Who has 10.100.31.3? Tell 10.100.31.1
22	0.972505	26:e3:49:25:e4:70		ARP	48	10.100.31.3 is at 26:e3:49:25:e4:70
23	0.972507	10.1.0.10	10.3.0.10	ICMP	104	Echo (ping) request id=0x476b, seq=1/256, ttl=63 (reply in 24)
24	0.975129	10.3.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x476b, seq=1/256, ttl=63 (request in 23)
25	0.975133	10.3.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x476b, seq=1/256, ttl=62
26	0.979771	10.1.0.10	10.3.0.20	ICMP	104	Echo (ping) request id=0xdd19, seq=1/256, ttl=64 (no response found!)
27	0.979781	10.1.0.10	10.3.0.20	ICMP	104	Echo (ping) request id=0xdd19, seq=1/256, ttl=63 (reply in 28)
28	0.981358	10.3.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0xdd19, seq=1/256, ttl=63 (request in 27)
29	0.981361	10.3.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0xdd19, seq=1/256, ttl=62
30	0.985141	10.1.0.10	10.1.0.1	ICMP	104	Echo (ping) request id=0x3b37, seq=1/256, ttl=64 (reply in 31)
31	0.985158	10.1.0.1	10.1.0.10	ICMP	104	Echo (ping) reply id=0x3b37, seq=1/256, ttl=64 (request in 30)
32	0.989207	10.1.0.10	10.2.0.1	ICMP	104	Echo (ping) request id=0x9f89, seq=1/256, ttl=64 (no response found!)
33	0.989219	10.1.0.10	10.2.0.1	ICMP	104	Echo (ping) request id=0x9f89, seq=1/256, ttl=63 (reply in 34)
34	0.989270	10.2.0.1	10.1.0.10	ICMP	104	Echo (ping) reply id=0x9f89, seq=1/256, ttl=64 (request in 33)
35	0.989274	10.2.0.1	10.1.0.10	ICMP	104	Echo (ping) reply id=0x9f89, seq=1/256, ttl=63
36	0.992898	10.1.0.10	10.3.0.1	ICMP	104	Echo (ping) request id=0xef56, seq=1/256, ttl=64 (no response found!)

rb_capture.pcap

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No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	fe80::801c:6cff:fe9…	ff02::2	ICMPv6	76	Router Solicitation from 82:1c:6c:90:7c:e2
2	0.000071	fe80::34ea:93ff:fe7…	ff02::2	ICMPv6	76	Router Solicitation from 36:ea:93:78:41:ae
3	0.001103	fe80::e4b9:d5ff:fe7…	ff02::2	ICMPv6	76	Router Solicitation from e6:b9:d5:7f:3e:5a
4	0.260736	fe80::3cc9:dcff:fe6…	ff02::2	ICMPv6	76	Router Solicitation from 3e:c9:dc:6a:1a:d2
5	0.511200	fe80::8fa:dfff:fe29…	ff02::2	ICMPv6	76	Router Solicitation from 0a:fa:df:29:ab:9c
6	0.699515	82:1c:6c:90:7c:e2		ARP	48	Who has 10.100.12.2? Tell 10.100.12.1
7	0.699535	0a:fa:df:29:ab:9c		ARP	48	10.100.12.2 is at 0a:fa:df:29:ab:9c
8	0.699541	10.1.0.10	10.2.0.10	ICMP	104	Echo (ping) request id=0x4861, seq=1/256, ttl=63 (no response found!)
9	0.699561	fe:c1:fc:b2:6c:12		ARP	48	Who has 10.2.0.10? Tell 10.2.0.1
10	0.700381	e6:b9:d5:7f:3e:5a		ARP	48	10.2.0.10 is at e6:b9:d5:7f:3e:5a
11	0.700385	10.1.0.10	10.2.0.10	ICMP	104	Echo (ping) request id=0x4861, seq=1/256, ttl=62 (reply in 12)
12	0.701809	10.2.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x4861, seq=1/256, ttl=64 (request in 11)
13	0.701825	10.2.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x4861, seq=1/256, ttl=63
14	0.708457	10.1.0.10	10.2.0.20	ICMP	104	Echo (ping) request id=0x290f, seq=1/256, ttl=63 (no response found!)
15	0.708473	fe:c1:fc:b2:6c:12		ARP	48	Who has 10.2.0.20? Tell 10.2.0.1
16	0.709796	3e:c9:dc:6a:1a:d2		ARP	48	10.2.0.20 is at 3e:c9:dc:6a:1a:d2
17	0.709801	10.1.0.10	10.2.0.20	ICMP	104	Echo (ping) request id=0x290f, seq=1/256, ttl=62 (reply in 18)
18	0.710897	10.2.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0x290f, seq=1/256, ttl=64 (request in 17)
19	0.710906	10.2.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0x290f, seq=1/256, ttl=63
20	0.733476	10.1.0.10	10.2.0.1	ICMP	104	Echo (ping) request id=0x9f89, seq=1/256, ttl=63 (reply in 21)
21	0.733526	10.2.0.1	10.1.0.10	ICMP	104	Echo (ping) reply id=0x9f89, seq=1/256, ttl=64 (request in 20)
22	0.743704	10.1.0.20	10.2.0.10	ICMP	104	Echo (ping) request id=0x4695, seq=1/256, ttl=63 (no response found!)
23	0.743708	10.1.0.20	10.2.0.10	ICMP	104	Echo (ping) request id=0x4695, seq=1/256, ttl=62 (reply in 24)
24	0.744376	10.2.0.10	10.1.0.20	ICMP	104	Echo (ping) reply id=0x4695, seq=1/256, ttl=64 (request in 23)
25	0.744379	10.2.0.10	10.1.0.20	ICMP	104	Echo (ping) reply id=0x4695, seq=1/256, ttl=63
26	0.747072	10.1.0.20	10.2.0.20	ICMP	104	Echo (ping) request id=0x70ed, seq=1/256, ttl=63 (no response found!)
27	0.747075	10.1.0.20	10.2.0.20	ICMP	104	Echo (ping) request id=0x70ed, seq=1/256, ttl=62 (reply in 28)
28	0.747595	10.2.0.20	10.1.0.20	ICMP	104	Echo (ping) reply id=0x70ed, seq=1/256, ttl=64 (request in 27)
29	0.747599	10.2.0.20	10.1.0.20	ICMP	104	Echo (ping) reply id=0x70ed, seq=1/256, ttl=63
30	0.760230	10.1.0.20	10.2.0.1	ICMP	104	Echo (ping) request id=0x8590, seq=1/256, ttl=63 (reply in 31)
31	0.760237	10.2.0.1	10.1.0.20	ICMP	104	Echo (ping) reply id=0x8590, seq=1/256, ttl=64 (request in 30)
32	0.765065	10.2.0.10	10.1.0.10	ICMP	104	Echo (ping) request id=0xab49, seq=1/256, ttl=64 (no response found!)
33	0.765075	10.2.0.10	10.1.0.10	ICMP	104	Echo (ping) request id=0xab49, seq=1/256, ttl=63 (reply in 34)
34	0.765523	10.1.0.10	10.2.0.10	ICMP	104	Echo (ping) reply id=0xab49, seq=1/256, ttl=63 (request in 33)
35	0.765525	10.1.0.10	10.2.0.10	ICMP	104	Echo (ping) reply id=0xab49, seq=1/256, ttl=62
36	0.768294	10.2.0.10	10.1.0.20	ICMP	104	Echo (ping) request id=0x9870, seq=1/256, ttl=64 (no response found!)

rc_capture.pcap

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No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	fe80::24e3:49ff:fe2…	ff02::2	ICMPv6	76	Router Solicitation from 26:e3:49:25:e4:70
2	0.000020	fe80::50e7:c7ff:fe8…	ff02::2	ICMPv6	76	Router Solicitation from 52:e7:c7:8e:c9:b6
3	0.000046	fe80::34ea:93ff:fe7…	ff02::2	ICMPv6	76	Router Solicitation from 36:ea:93:78:41:ae
4	0.000102	fe80::884:23ff:fea3…	ff02::2	ICMPv6	76	Router Solicitation from 0a:84:23:a3:ae:9e
5	0.001078	fe80::a828:d3ff:fe2…	ff02::2	ICMPv6	76	Router Solicitation from aa:28:d3:29:33:dc
6	0.259610	fe80::244a:20ff:fed…	ff02::2	ICMPv6	76	Router Solicitation from 26:4a:20:d2:bf:70
7	0.716814	0a:84:23:a3:ae:9e		ARP	48	Who has 10.100.31.3? Tell 10.100.31.1
8	0.716827	26:e3:49:25:e4:70		ARP	48	10.100.31.3 is at 26:e3:49:25:e4:70
9	0.716830	10.1.0.10	10.3.0.10	ICMP	104	Echo (ping) request id=0x476b, seq=1/256, ttl=63 (no response found!)
10	0.716838	52:e7:c7:8e:c9:b6		ARP	48	Who has 10.3.0.10? Tell 10.3.0.1
11	0.718262	aa:28:d3:29:33:dc		ARP	48	10.3.0.10 is at aa:28:d3:29:33:dc
12	0.718267	10.1.0.10	10.3.0.10	ICMP	104	Echo (ping) request id=0x476b, seq=1/256, ttl=62 (reply in 13)
13	0.719412	10.3.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x476b, seq=1/256, ttl=64 (request in 12)
14	0.719450	10.3.0.10	10.1.0.10	ICMP	104	Echo (ping) reply id=0x476b, seq=1/256, ttl=63
15	0.724105	10.1.0.10	10.3.0.20	ICMP	104	Echo (ping) request id=0xdd19, seq=1/256, ttl=63 (no response found!)
16	0.724114	52:e7:c7:8e:c9:b6		ARP	48	Who has 10.3.0.20? Tell 10.3.0.1
17	0.724912	d2:0d:0b:57:7c:81		ARP	48	10.3.0.20 is at d2:0d:0b:57:7c:81
18	0.724917	10.1.0.10	10.3.0.20	ICMP	104	Echo (ping) request id=0xdd19, seq=1/256, ttl=62 (reply in 19)
19	0.725675	10.3.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0xdd19, seq=1/256, ttl=64 (request in 18)
20	0.725680	10.3.0.20	10.1.0.10	ICMP	104	Echo (ping) reply id=0xdd19, seq=1/256, ttl=63
21	0.737230	10.1.0.10	10.3.0.1	ICMP	104	Echo (ping) request id=0xef56, seq=1/256, ttl=63 (reply in 22)
22	0.737242	10.3.0.1	10.1.0.10	ICMP	104	Echo (ping) reply id=0xef56, seq=1/256, ttl=64 (request in 21)
23	0.751093	10.1.0.20	10.3.0.10	ICMP	104	Echo (ping) request id=0x2461, seq=1/256, ttl=63 (no response found!)
24	0.751100	10.1.0.20	10.3.0.10	ICMP	104	Echo (ping) request id=0x2461, seq=1/256, ttl=62 (reply in 25)
25	0.751603	10.3.0.10	10.1.0.20	ICMP	104	Echo (ping) reply id=0x2461, seq=1/256, ttl=64 (request in 24)
26	0.751608	10.3.0.10	10.1.0.20	ICMP	104	Echo (ping) reply id=0x2461, seq=1/256, ttl=63
27	0.755278	10.1.0.20	10.3.0.20	ICMP	104	Echo (ping) request id=0x542d, seq=1/256, ttl=63 (no response found!)
28	0.755283	10.1.0.20	10.3.0.20	ICMP	104	Echo (ping) request id=0x542d, seq=1/256, ttl=62 (reply in 29)
29	0.755771	10.3.0.20	10.1.0.20	ICMP	104	Echo (ping) reply id=0x542d, seq=1/256, ttl=64 (request in 28)
30	0.755773	10.3.0.20	10.1.0.20	ICMP	104	Echo (ping) reply id=0x542d, seq=1/256, ttl=63
31	0.762240	10.1.0.20	10.3.0.1	ICMP	104	Echo (ping) request id=0x8f55, seq=1/256, ttl=63 (reply in 32)
32	0.762248	10.3.0.1	10.1.0.20	ICMP	104	Echo (ping) reply id=0x8f55, seq=1/256, ttl=64 (request in 31)
33	0.772915	22:03:e6:f5:e4:b2		ARP	48	Who has 10.100.23.3? Tell 10.100.23.2
34	0.772920	36:ea:93:78:41:ae		ARP	48	10.100.23.3 is at 36:ea:93:78:41:ae
35	0.772921	10.2.0.10	10.3.0.10	ICMP	104	Echo (ping) request id=0x3cbd, seq=1/256, ttl=63 (no response found!)
36	0.772924	10.2.0.10	10.3.0.10	ICMP	104	Echo (ping) request id=0x3cbd, seq=1/256, ttl=62 (reply in 37)

Fig 3: Packet Capture Results for Routers After Initial Setup And *pingall* Test

c.

```
*** h1 -> ra -> rc -> h6
*** ping h1 -> h6 for 10 counts
PING 10.3.0.20 (10.3.0.20) 56(84) bytes of data.
64 bytes from 10.3.0.20: icmp_seq=1 ttl=62 time=0.807 ms
64 bytes from 10.3.0.20: icmp_seq=2 ttl=62 time=0.236 ms
64 bytes from 10.3.0.20: icmp_seq=3 ttl=62 time=0.219 ms
64 bytes from 10.3.0.20: icmp_seq=4 ttl=62 time=0.260 ms
64 bytes from 10.3.0.20: icmp_seq=5 ttl=62 time=0.211 ms
64 bytes from 10.3.0.20: icmp_seq=6 ttl=62 time=0.312 ms
64 bytes from 10.3.0.20: icmp_seq=7 ttl=62 time=0.330 ms
64 bytes from 10.3.0.20: icmp_seq=8 ttl=62 time=0.217 ms
64 bytes from 10.3.0.20: icmp_seq=9 ttl=62 time=0.293 ms
64 bytes from 10.3.0.20: icmp_seq=10 ttl=62 time=0.240 ms

--- 10.3.0.20 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9203ms
rtt min/avg/max/mdev = 0.211/0.312/0.807/0.169 ms
--- --- ---

*** traceroute h1 -> h6
traceroute to 10.3.0.20 (10.3.0.20), 30 hops max, 60 byte packets
 1  10.1.0.1 (10.1.0.1)  5.380 ms  5.315 ms  5.323 ms
 2  10.100.31.3 (10.100.31.3)  5.378 ms  5.387 ms  5.397 ms
 3  10.3.0.20 (10.3.0.20)  8.024 ms  8.037 ms  8.044 ms
--- --- ---

*** iperf h1 -> h6 for 10 seconds
------------------------------------------------------------
Client connecting to 10.3.0.20, TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[  1] local 10.1.0.10 port 34422 connected with 10.3.0.20 port 5001 (icwnd/mss/irtt=14/1448/4511)
[ ID] Interval       Transfer     Bandwidth
[  1] 0.0000-10.0129 sec  89.8 GBytes  77.0 Gbits/sec
--- --- ---
```

Fig 4: Ping, Traceroute & iPerf Statistics for Initial Routing Configuration (Short Path)

```
*** h1 -> ra -> rb -> rc -> h6
*** ping h1 -> h6 for 10 counts
PING 10.3.0.20 (10.3.0.20) 56(84) bytes of data.
64 bytes from 10.3.0.20: icmp_seq=1 ttl=61 time=2.09 ms
64 bytes from 10.3.0.20: icmp_seq=2 ttl=61 time=0.517 ms
64 bytes from 10.3.0.20: icmp_seq=3 ttl=61 time=0.163 ms
64 bytes from 10.3.0.20: icmp_seq=4 ttl=61 time=0.139 ms
64 bytes from 10.3.0.20: icmp_seq=5 ttl=61 time=0.255 ms
64 bytes from 10.3.0.20: icmp_seq=6 ttl=61 time=0.331 ms
64 bytes from 10.3.0.20: icmp_seq=7 ttl=61 time=0.296 ms
64 bytes from 10.3.0.20: icmp_seq=8 ttl=61 time=0.299 ms
64 bytes from 10.3.0.20: icmp_seq=9 ttl=61 time=0.210 ms
64 bytes from 10.3.0.20: icmp_seq=10 ttl=61 time=0.356 ms

--- 10.3.0.20 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9186ms
rtt min/avg/max/mdev = 0.139/0.466/2.094/0.552 ms
--- --- ---

*** traceroute h1 -> h6
traceroute to 10.3.0.20 (10.3.0.20), 30 hops max, 60 byte packets
 1  10.1.0.1 (10.1.0.1)  5.565 ms  4.929 ms  4.894 ms
 2  10.100.12.2 (10.100.12.2)  4.869 ms  4.769 ms  4.777 ms
 3  10.100.23.3 (10.100.23.3)  4.749 ms  4.685 ms  4.619 ms
 4  10.3.0.20 (10.3.0.20)  6.519 ms  6.492 ms *
--- --- ---

*** iperf h1 -> h6 for 10 seconds
------------------------------------------------------------
Client connecting to 10.3.0.20, TCP port 5001
TCP window size:  187 KByte (default)
------------------------------------------------------------
[  1] local 10.1.0.10 port 55230 connected with 10.3.0.20 port 5001 (icwnd/mss/irtt=14/1448/4230)
[ ID] Interval       Transfer     Bandwidth
[  1] 0.0000-10.0092 sec  79.8 GBytes  68.5 Gbits/sec
```

Fig 5: Ping, Traceroute & iPerf Statistics for New Routing Configuration (Long Path)

d. Routing tables for each of the routers Ra, Rb, Rc can be read from their respective dumps: **ra_routes.txt, rb_routes.txt, rc_routes.txt** created on running the python script.

Initial Routing Configuration (Short Path)

ra_routes.txt

```
10.1.0.0/24     dev  ra-ethsa     proto  kernel    scope  link  src  10.1.0.1
10.2.0.0/24     via  10.100.12.2  dev    ra-ethrb
10.3.0.0/24     via  10.100.31.3  dev    ra-ethrc
10.100.12.0/24  dev  ra-ethrb     proto  kernel    scope  link  src  10.100.12.1
10.100.31.0/24  dev  ra-ethrc     proto  kernel    scope  link  src  10.100.31.1
```

Fig 6: Routing Table for Ra

rb_routes.txt

```
10.1.0.0/24     via  10.100.12.1  dev    rb-ethra
10.2.0.0/24     dev  rb-ethsb     proto  kernel    scope  link  src  10.2.0.1
10.3.0.0/24     via  10.100.23.3  dev    rb-ethrc
10.100.12.0/24  dev  rb-ethra     proto  kernel    scope  link  src  10.100.12.2
10.100.23.0/24  dev  rb-ethrc     proto  kernel    scope  link  src  10.100.23.2
```

Fig 7: Routing Table for Rb

rc_routes.txt

```
10.1.0.0/24     via  10.100.31.1  dev    rc-ethra
10.2.0.0/24     via  10.100.23.2  dev    rc-ethrb
10.3.0.0/24     dev  rc-ethsc     proto  kernel    scope  link  src  10.3.0.1
10.100.23.0/24  dev  rc-ethrb     proto  kernel    scope  link  src  10.100.23.3
10.100.31.0/24  dev  rc-ethra     proto  kernel    scope  link  src  10.100.31.3
```

Fig 8: Routing Table for Rc

New Routing Configuration (Long Path)

ra_routes.txt

```
10.1.0.0/24     dev  ra-ethsa     proto  kernel   scope  link  src  10.1.0.1
10.2.0.0/24     via  10.100.12.2  dev    ra-ethb
10.3.0.0/24     via  10.100.12.2  dev    ra-ethb
10.100.12.0/24  dev  ra-ethb      proto  kernel   scope  link  src  10.100.12.1
10.100.31.0/24  dev  ra-ethc      proto  kernel   scope  link  src  10.100.31.1
```

Fig 9: Routing Table for Ra

ra_routes.txt

```
10.1.0.0/24     dev  ra-ethsa     proto  kernel   scope  link  src  10.1.0.1
10.2.0.0/24     via  10.100.12.2  dev    ra-ethb
10.3.0.0/24     via  10.100.12.2  dev    ra-ethb
10.100.12.0/24  dev  ra-ethb      proto  kernel   scope  link  src  10.100.12.1
10.100.31.0/24  dev  ra-ethc      proto  kernel   scope  link  src  10.100.31.1
```

Fig 10: Routing Table for Rb

rc_routes.txt

```
10.1.0.0/24     via  10.100.23.2  dev    rc-ethb
10.2.0.0/24     via  10.100.23.2  dev    rc-ethb
10.3.0.0/24     dev  rc-ethsc     proto  kernel   scope  link  src  10.3.0.1
10.100.23.0/24  dev  rc-ethb      proto  kernel   scope  link  src  10.100.23.3
10.100.31.0/24  dev  rc-etha      proto  kernel   scope  link  src  10.100.31.3
```

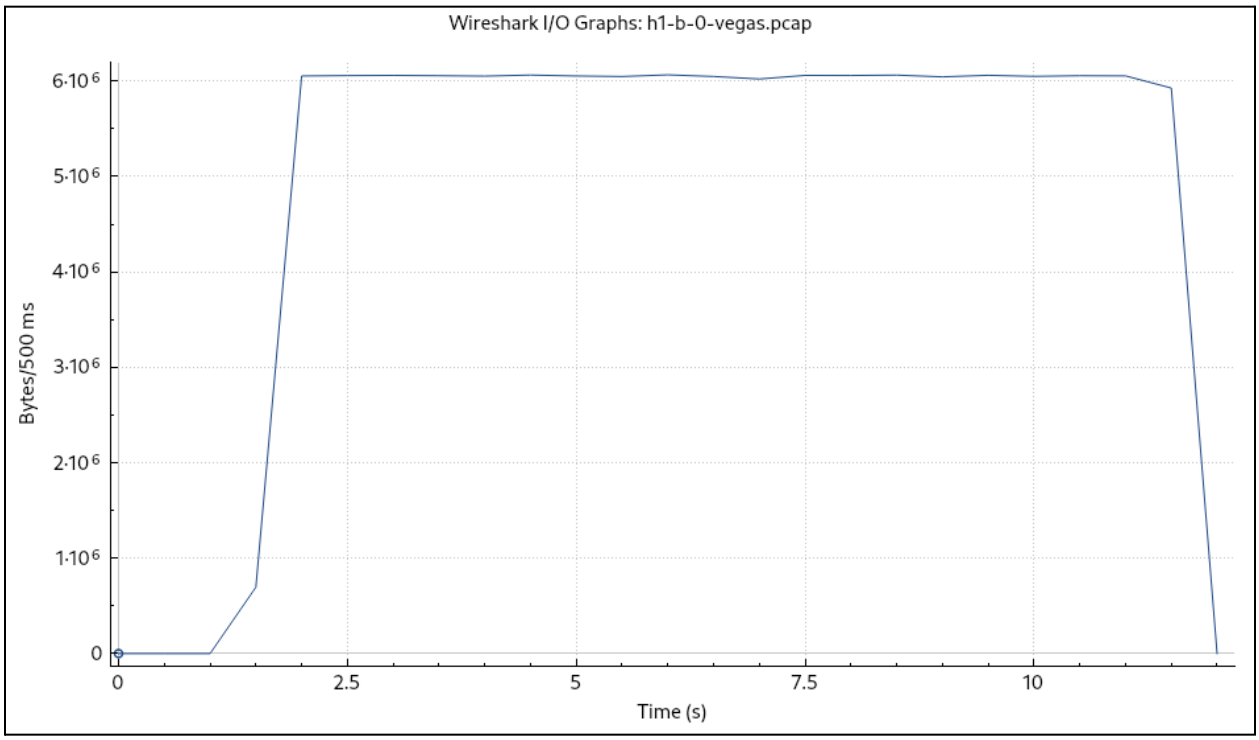
Fig 11: Routing Table for Rc

Part 2

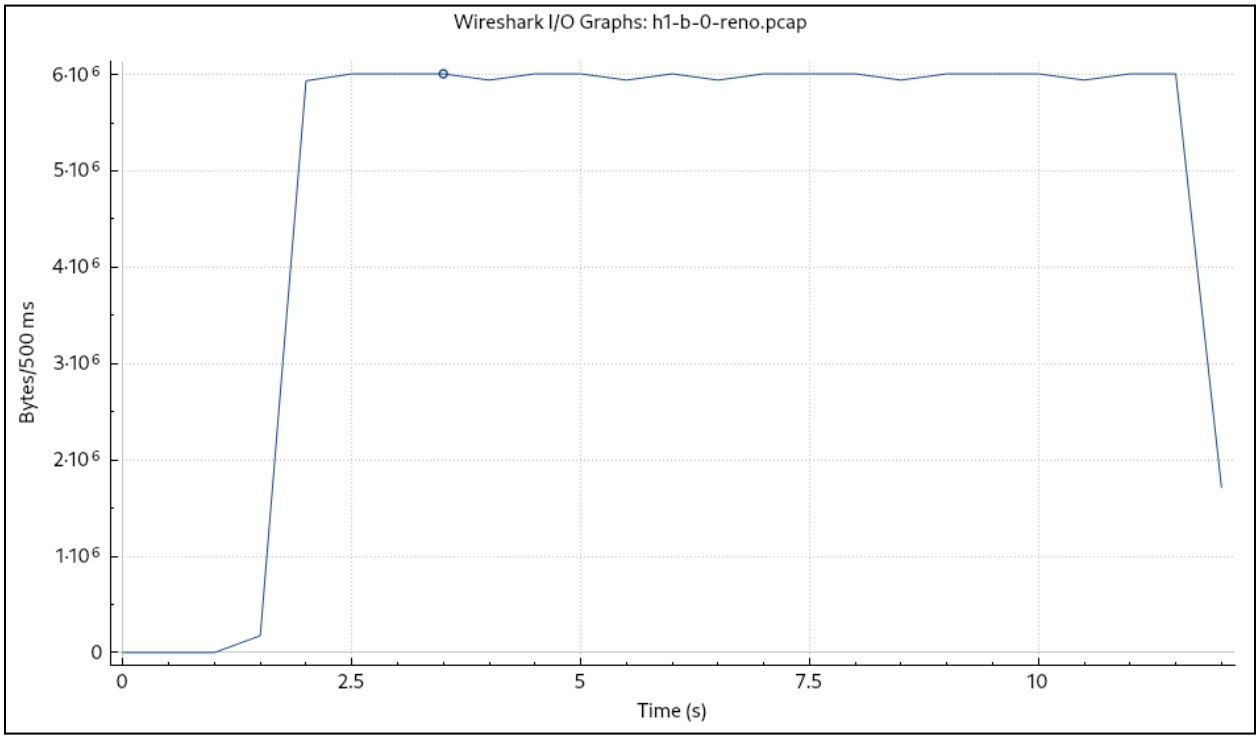
a. File: mininet-tcp.py
Example Usage: `sudo python3 mininet-tcp.py --config b --link-loss 3 --congestion vegas`

b. Running iperf server on H4 and iperf client on H1. Following are the graphs of different congestion control scheme.

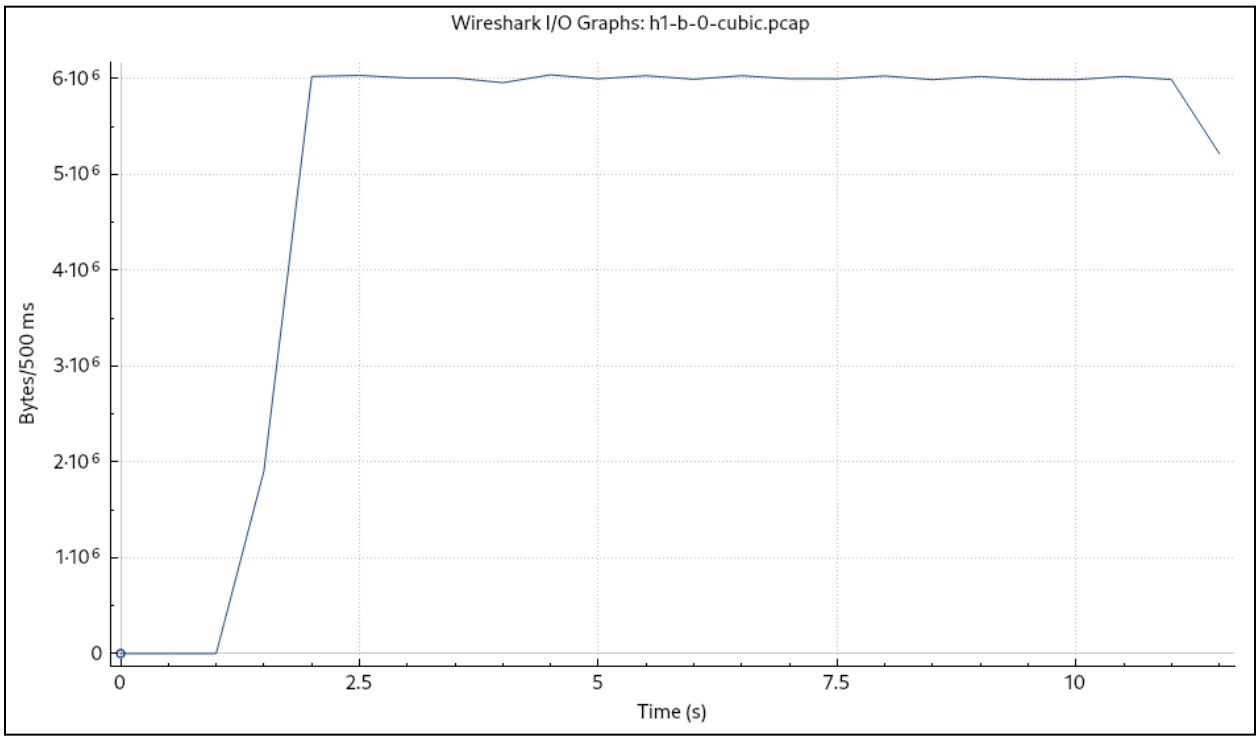
I. Vegas



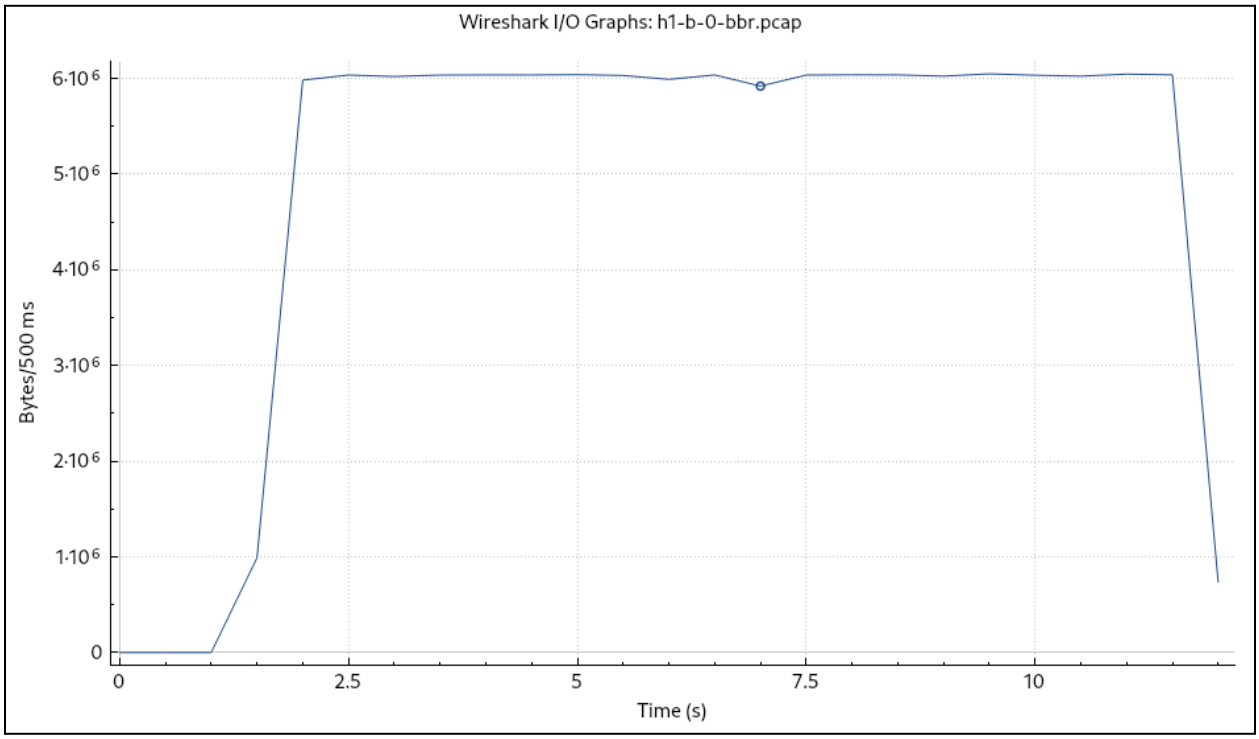
II. Reno



III. Cubic



IV. BBR



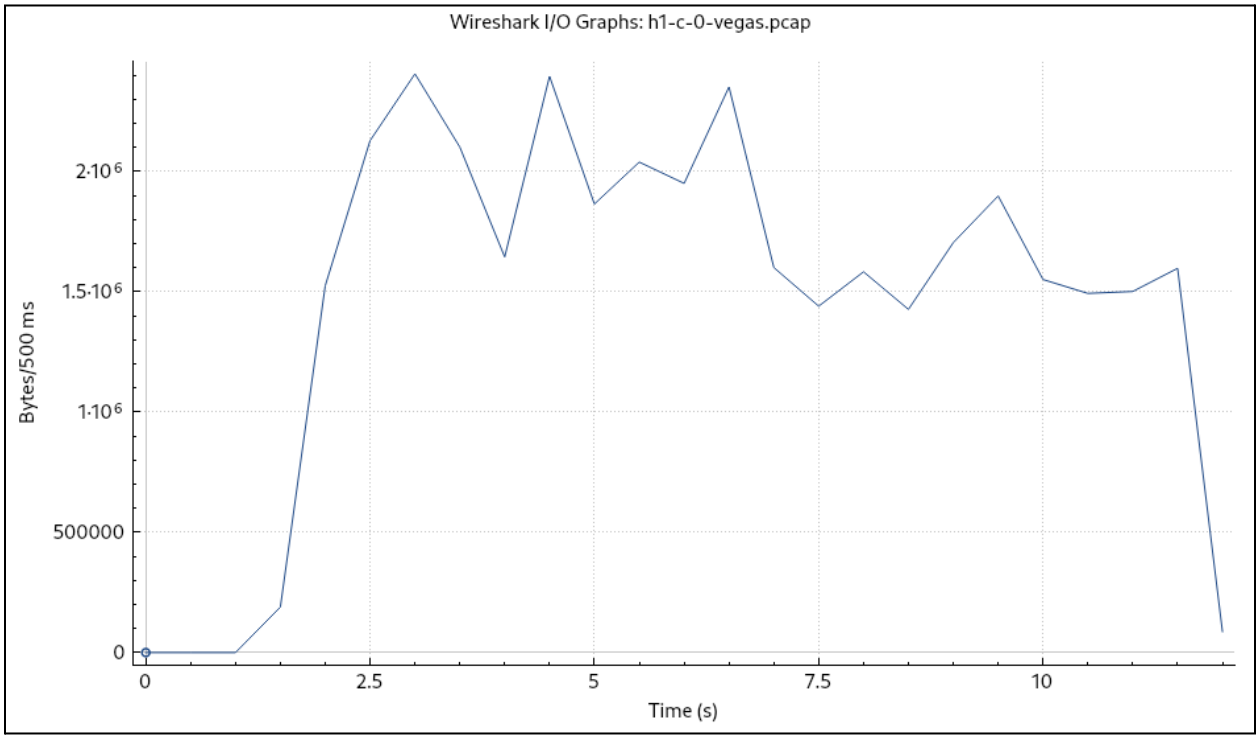
Observation:

There is no congestion in the link as the link loss is 0, and only one client is connected to the server. Thus, the Throughput v/s Time graphs for the given congestion control schemes are stable.

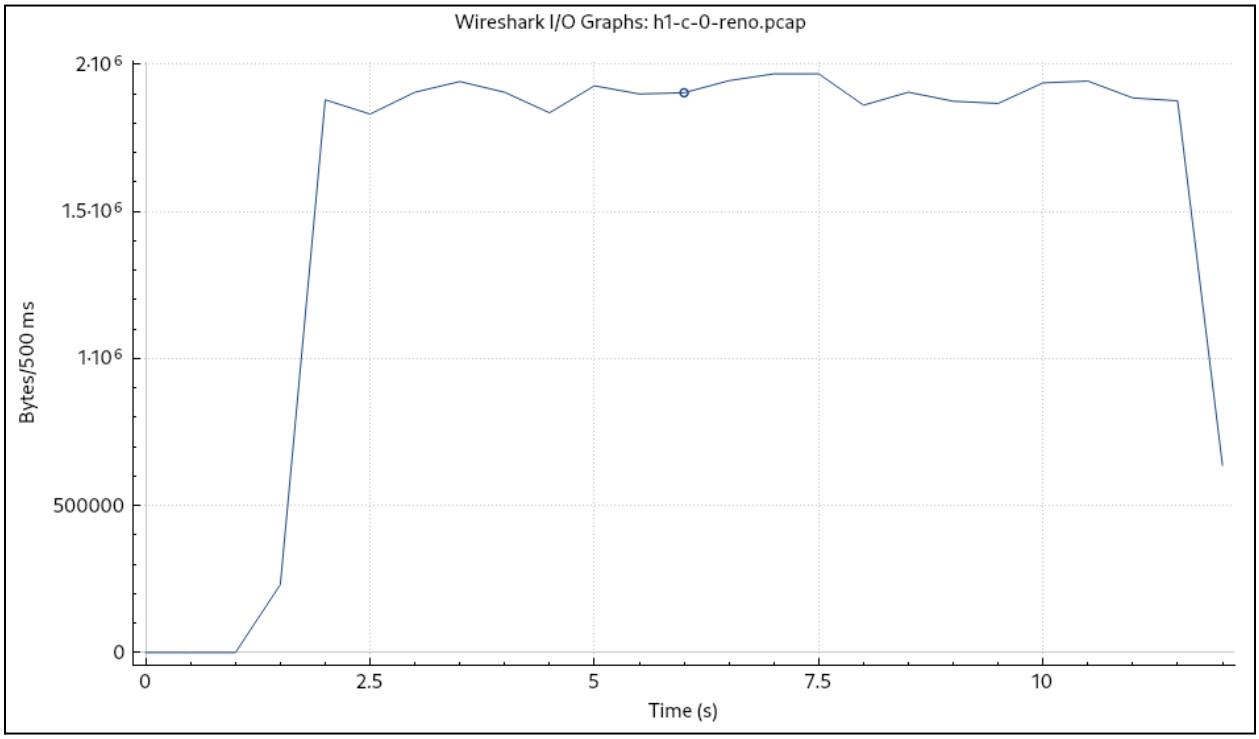
c. Running iperf server on H4 and iperf client on H1, H2 and H3. Following are the graphs of different congestion control scheme.

Host 1

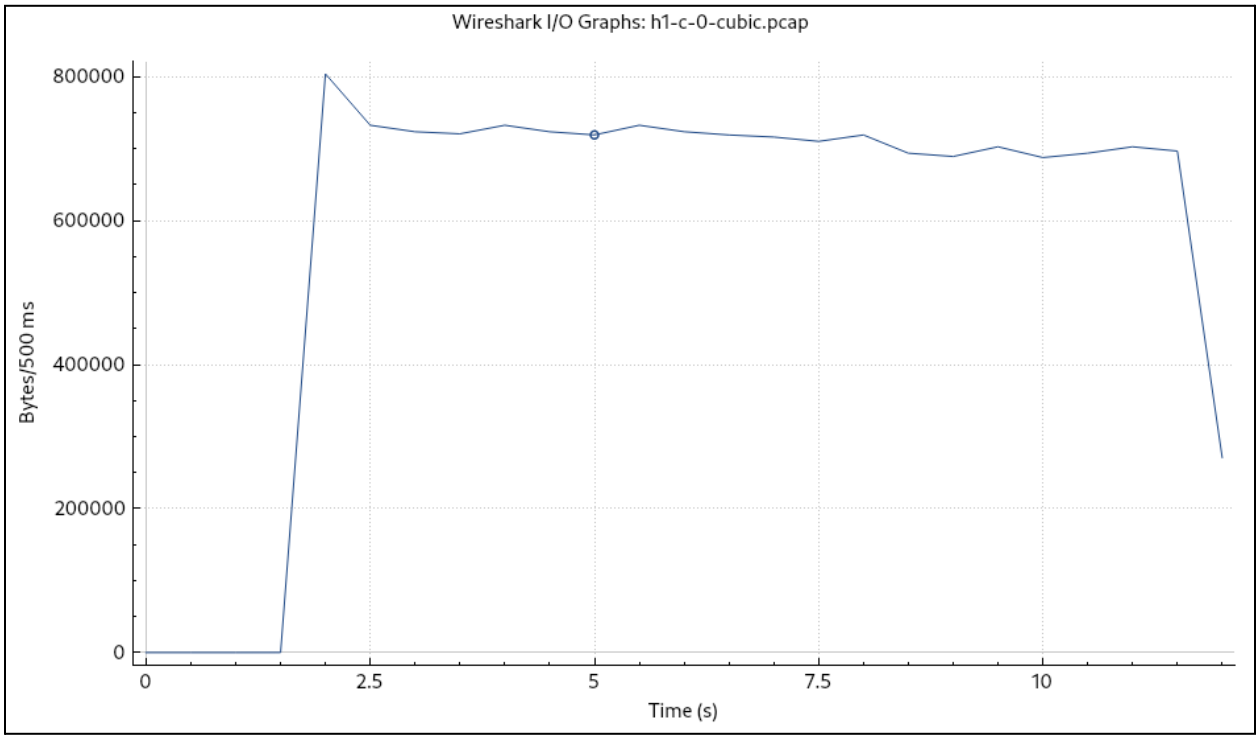
I. Vegas



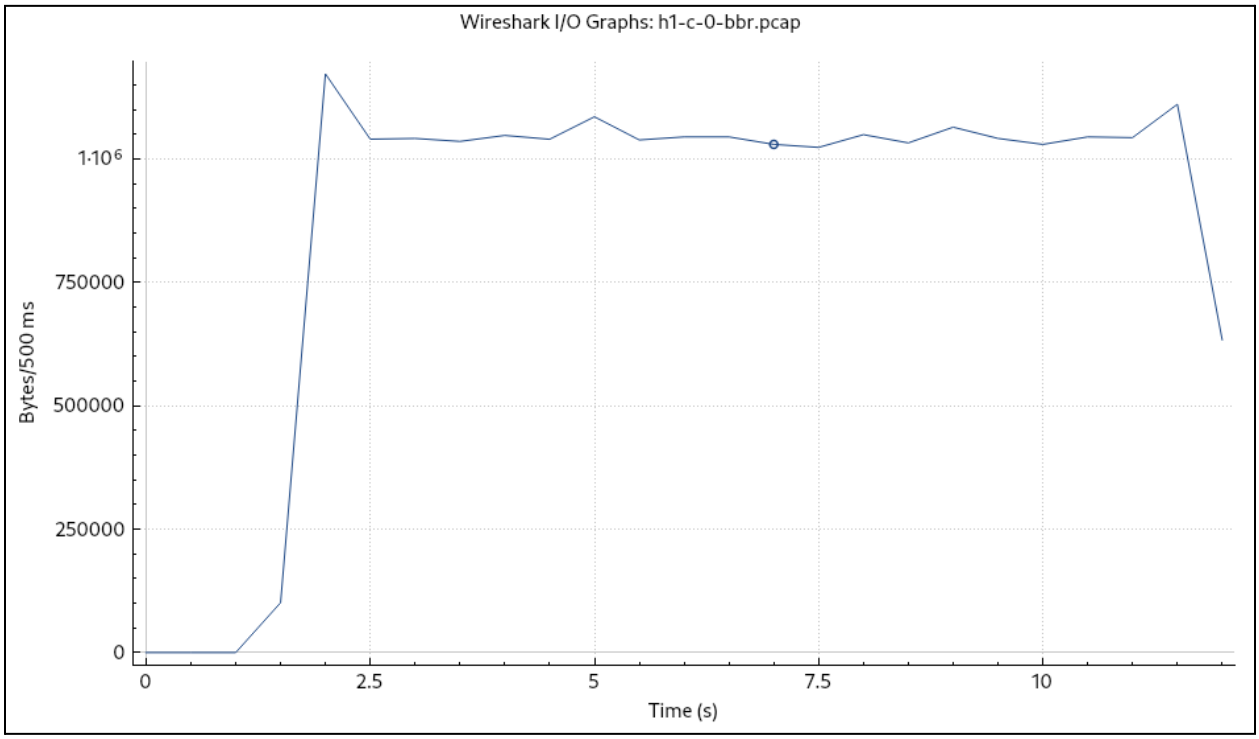
II. Reno



III. Cubic



IV. BBR



Reasoning:

In the presence of multiple clients, there is heightened competition for available bandwidth. Among the congestion control schemes, Vegas exhibits the highest level of

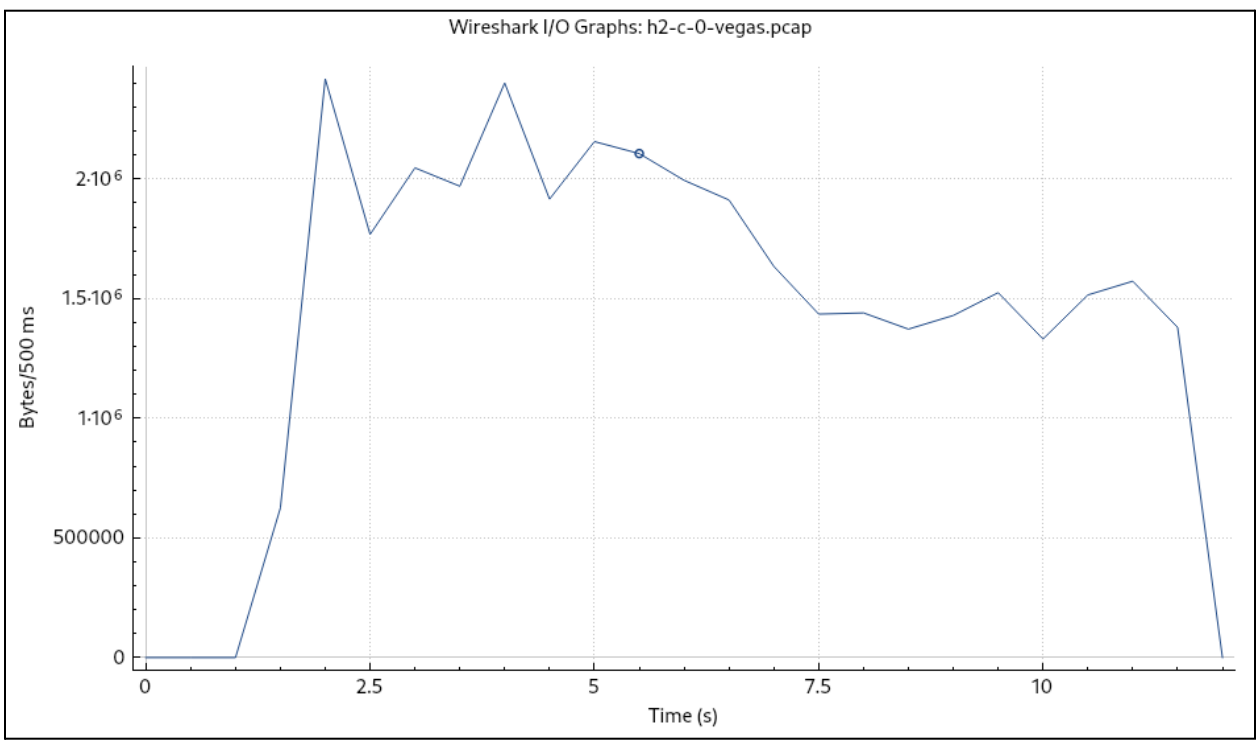
instability, while BBR demonstrates the most stability, owing to the inherent algorithms of these congestion control mechanisms. Reno falls on the spectrum with a moderate level of instability, and Cubic experiences a decline in throughput under these conditions.

Algorithmic Explanation:

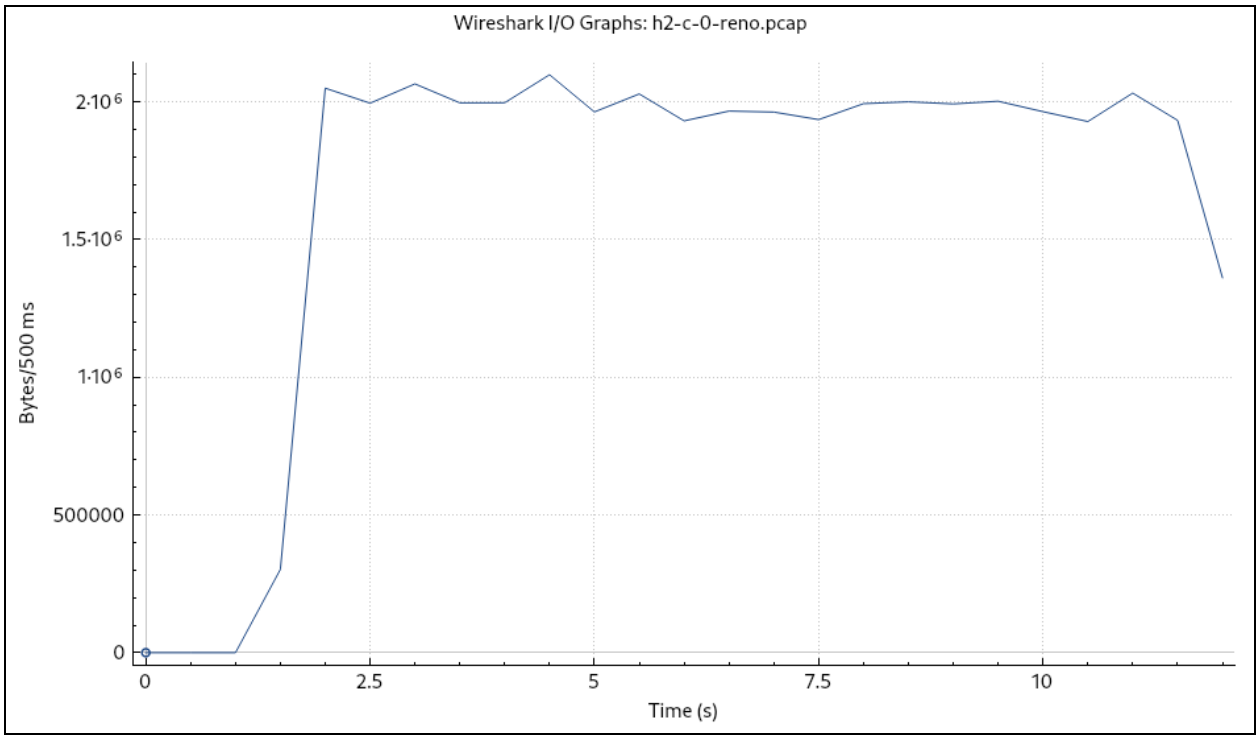
- Vegas:
    - Vegas tends to be more unstable in scenarios with increased competition for bandwidth, as it relies on detecting changes in round-trip time (RTT) and packet loss to adjust its congestion window.
- BBR:
    - BBR is known for its stability in varying network conditions. It achieves this through efficient bandwidth and round-trip time estimation, optimizing throughput.
- Reno:
    - Reno responds to packet loss, triggering a halving of the congestion window. In scenarios with multiple clients, this loss-triggered behavior can contribute to a moderate level of instability.
- Cubic:
    - Cubic may observe a decrease in throughput in scenarios with increased competition, as it adapts to varying network conditions. However, it generally maintains a smoother increase in throughput compared to some other algorithms.

Host 2

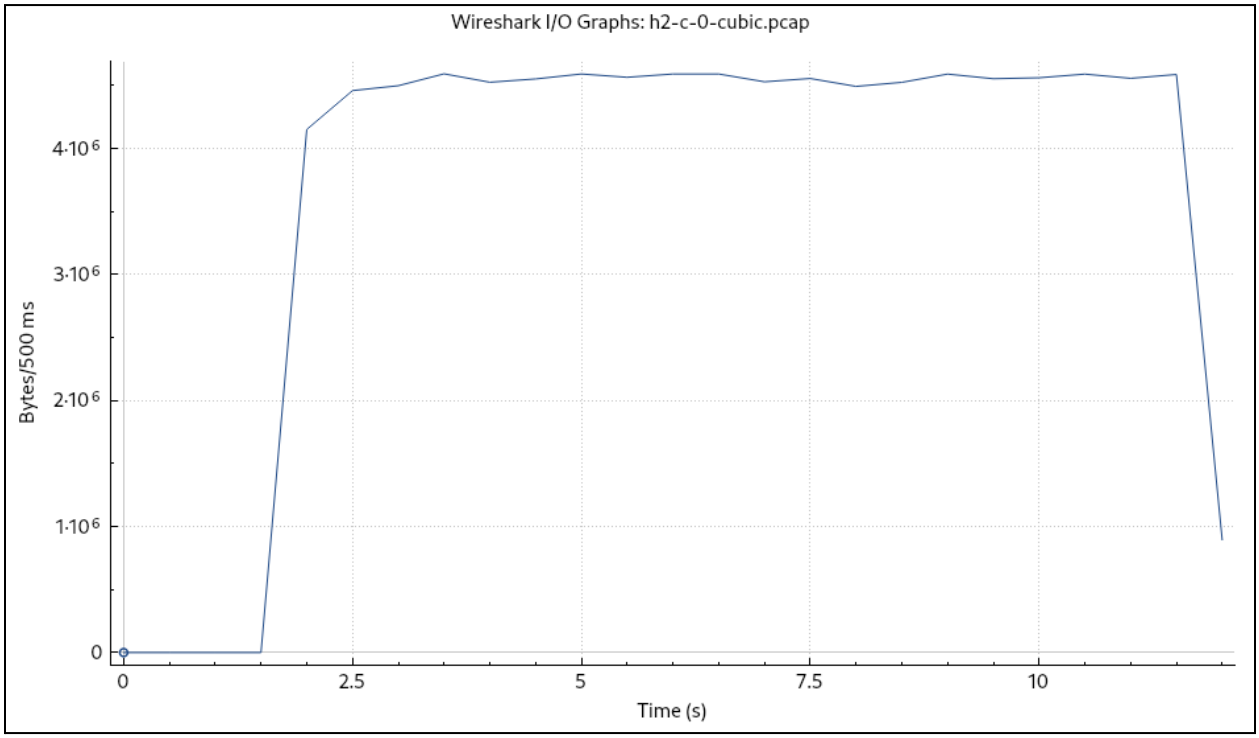
I. Vegas



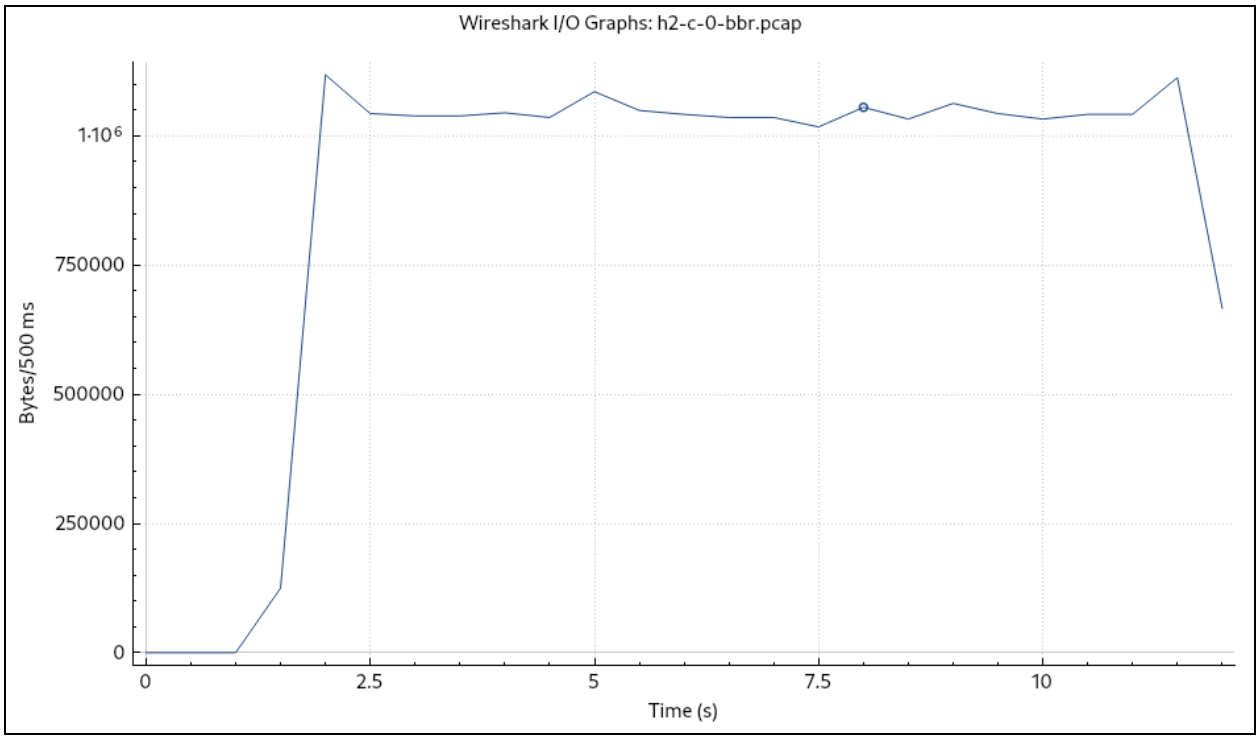
II. Reno



III. Cubic



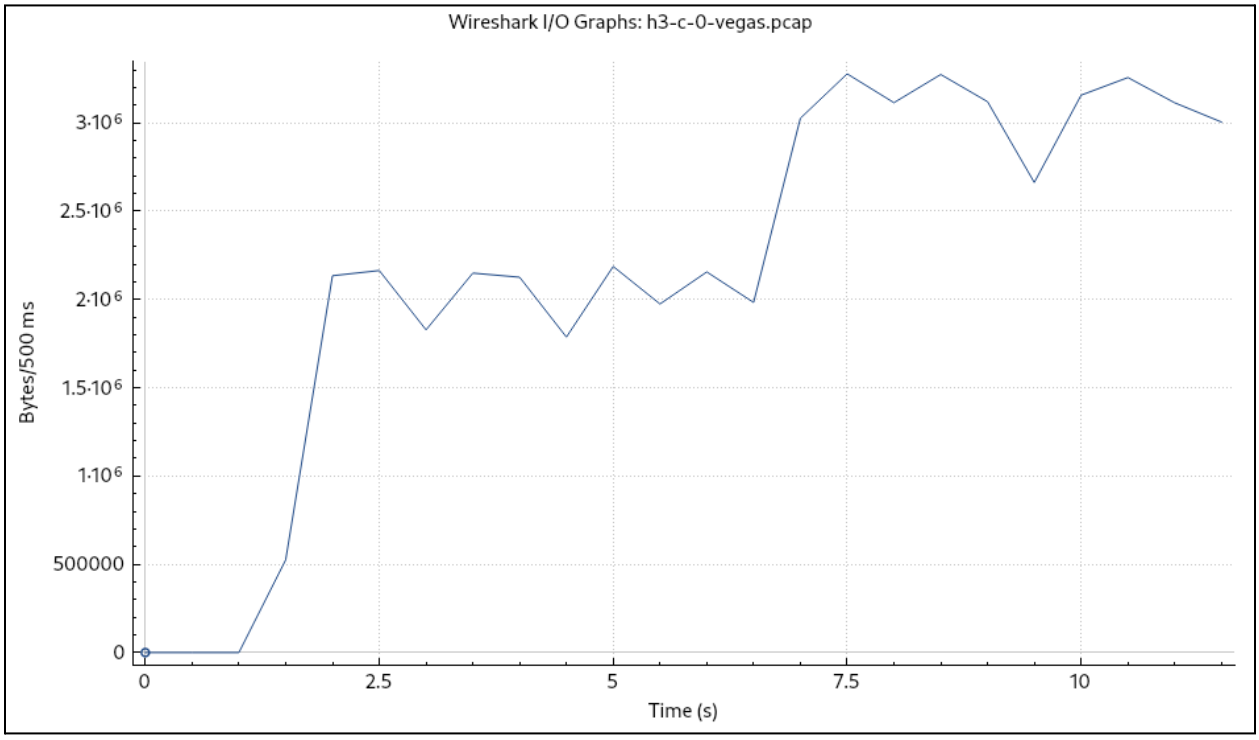
IV. BBR



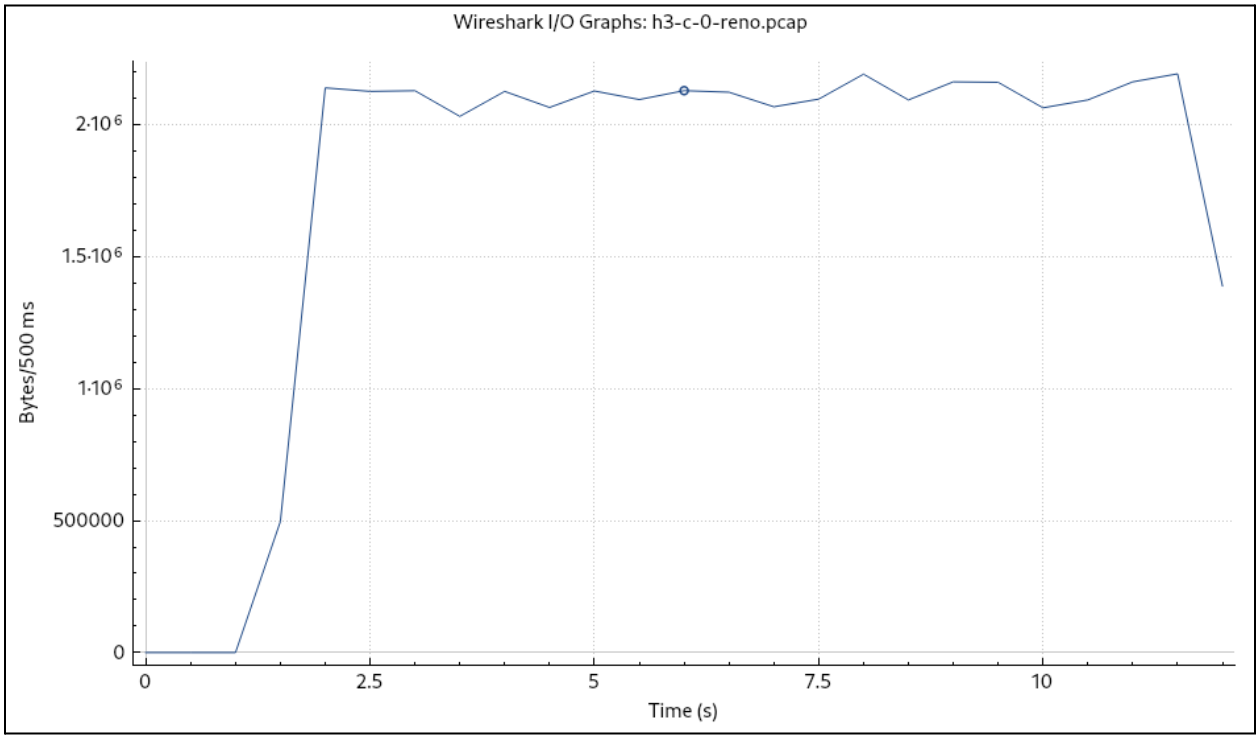
Reasoning:
Similar to that of Host 1.

Host 3

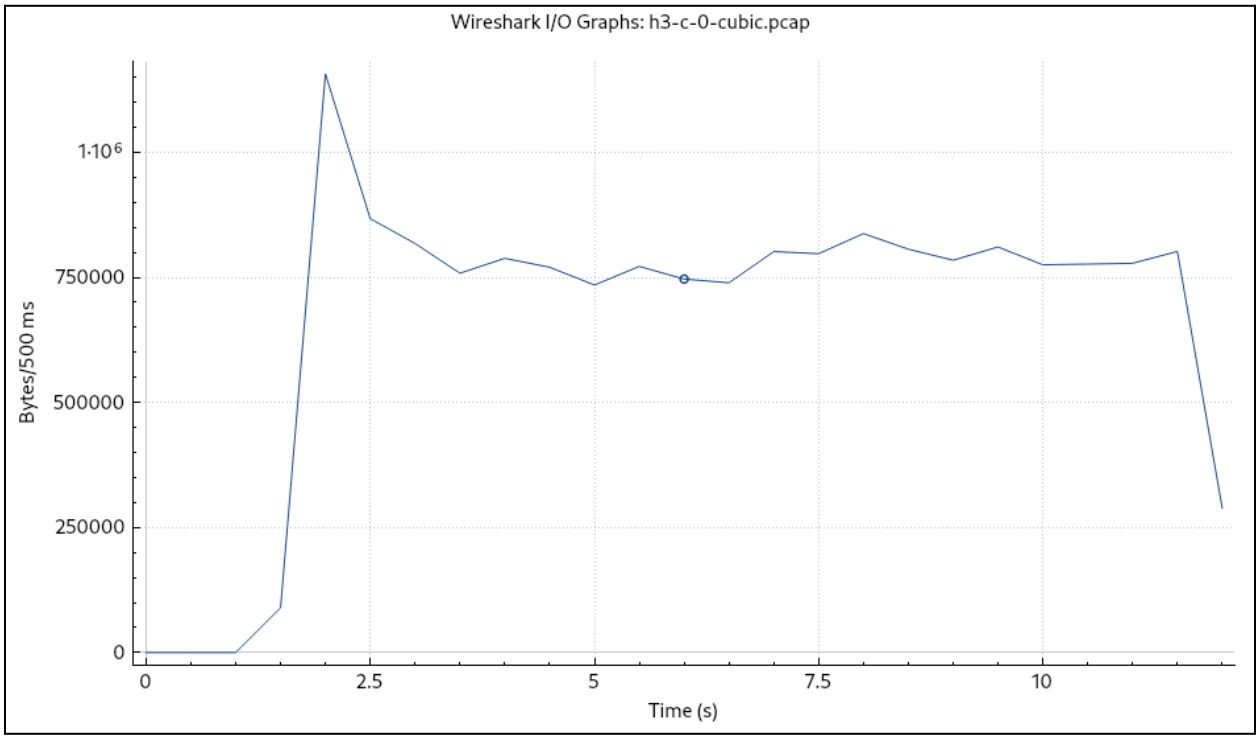
I. Vegas



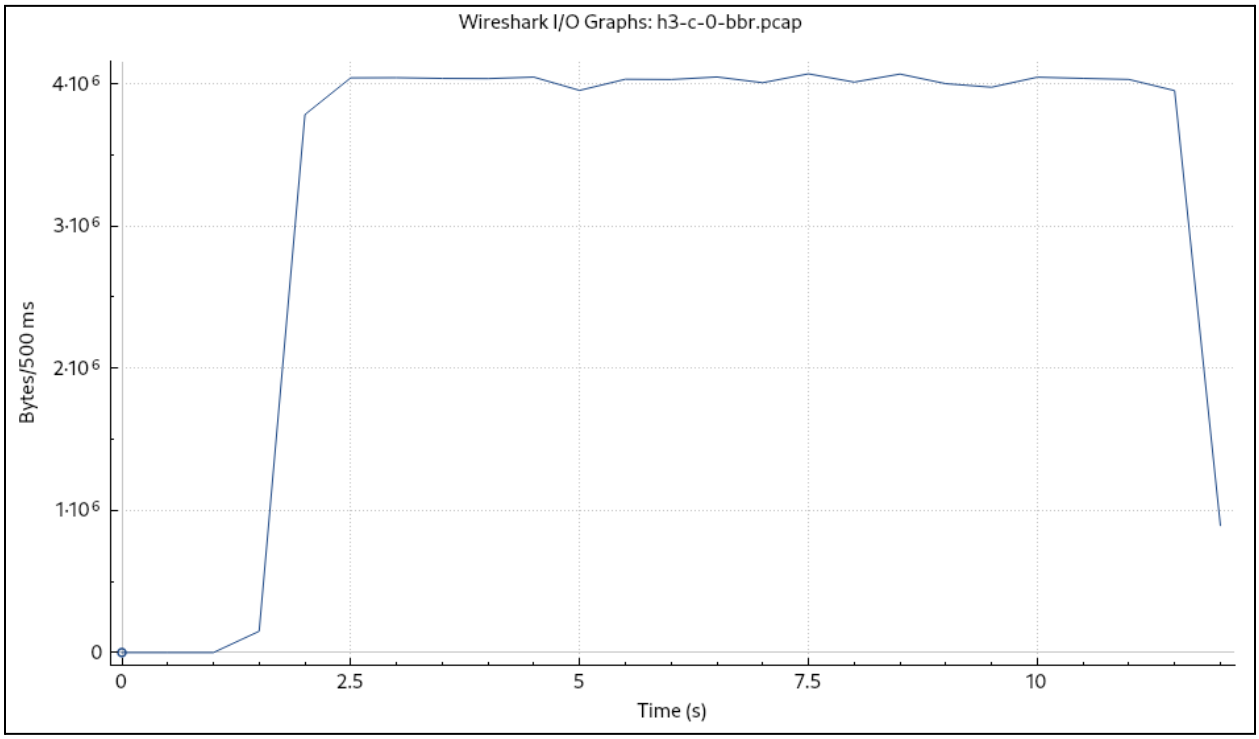
II. Reno



III. Cubic



IV. BBR



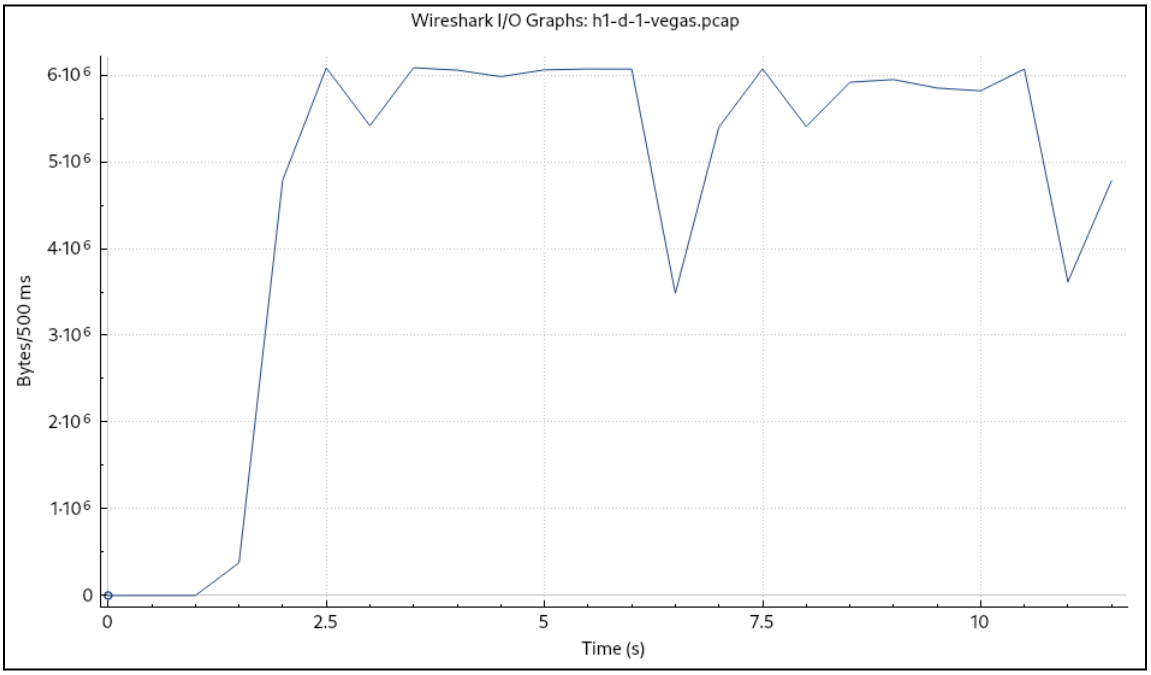
Reasoning:

H3 is not connected to H4 via the link loss path yet it has to face the same congestion consequences as of H1 and H2.

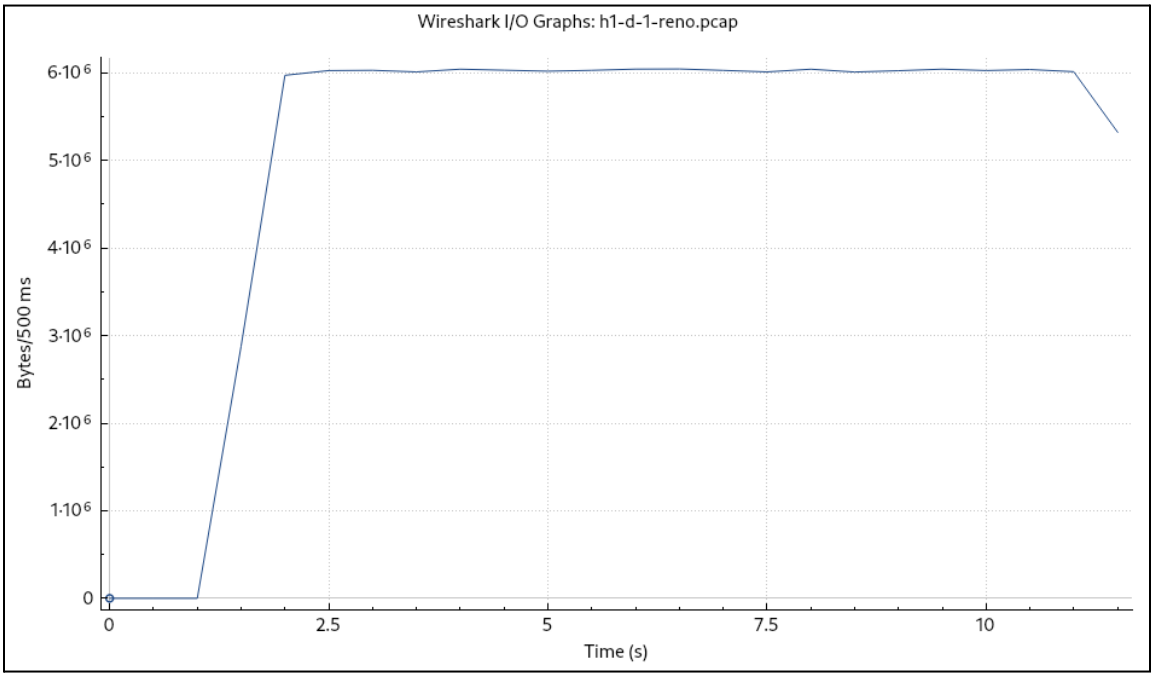
d. Running iperf server on H4 and iperf client on H1. Following are the graphs of different congestion control scheme. The link loss parameter of the middle link (s1 - s2) is set to 1% and 3%.

Loss: 1%

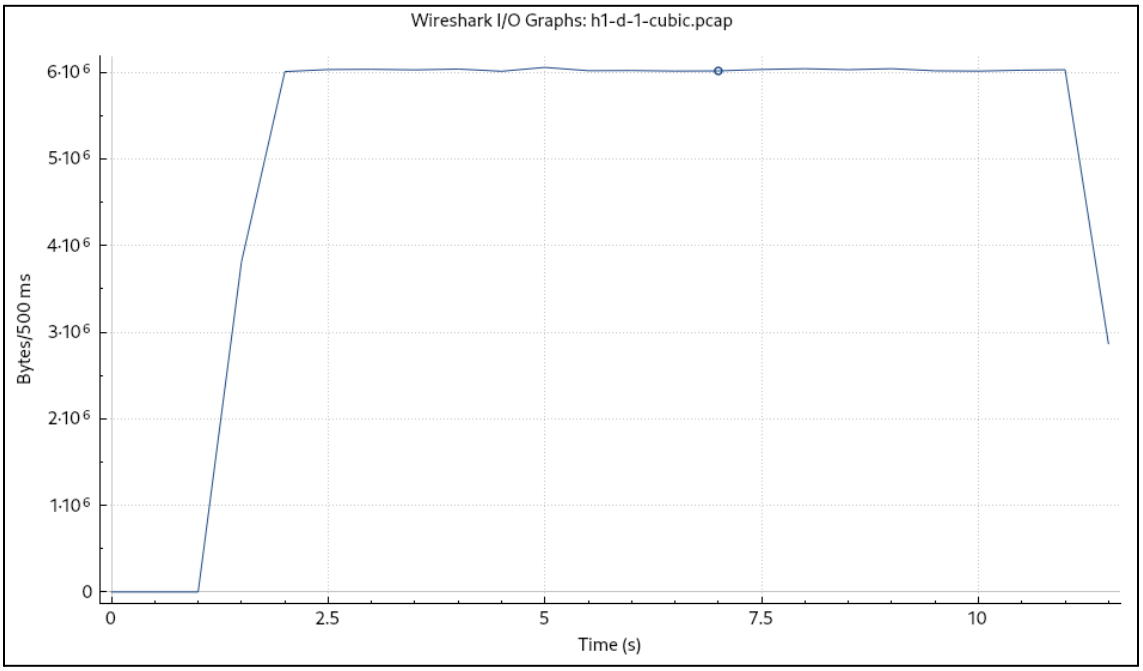
I. Vegas



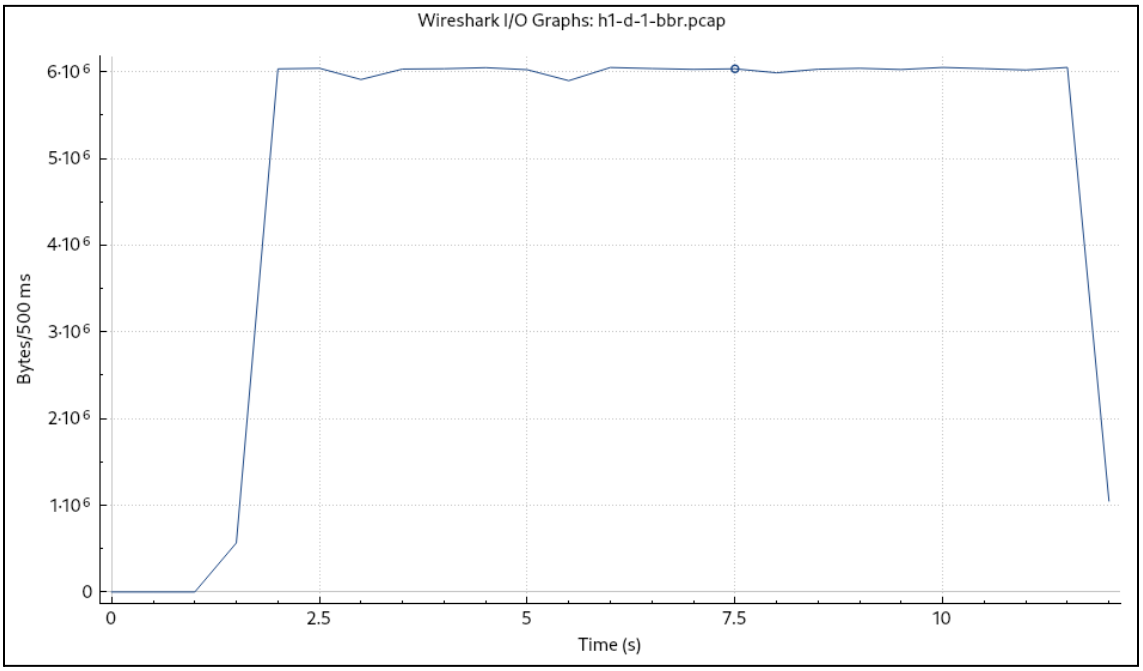
II. Reno



III. Cubic



IV. BBR

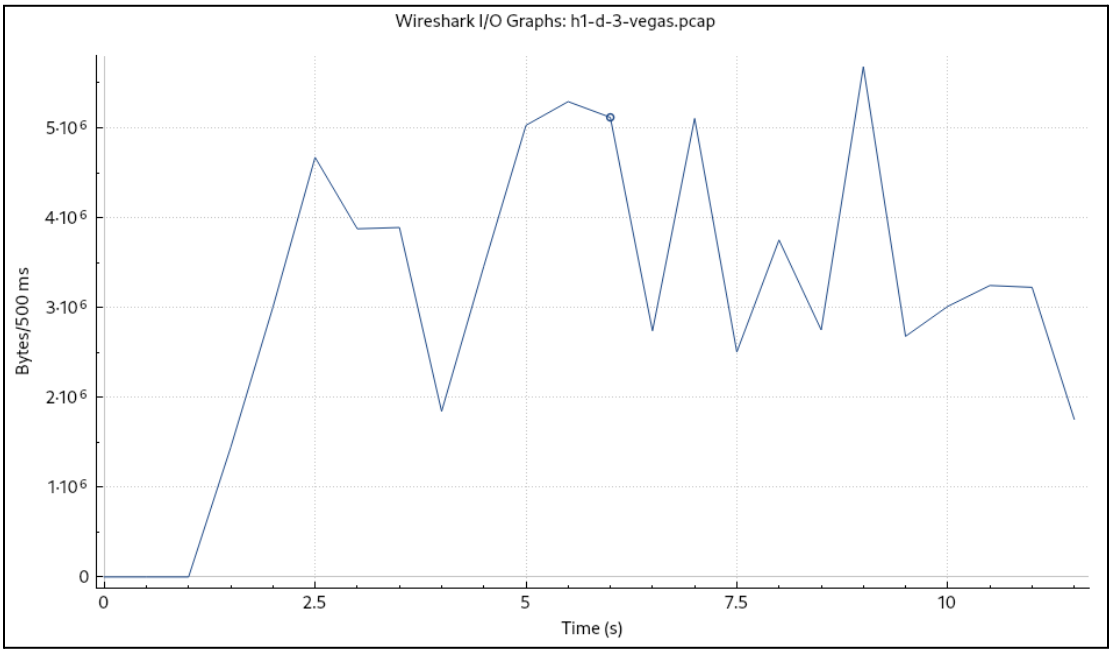


Reasoning:

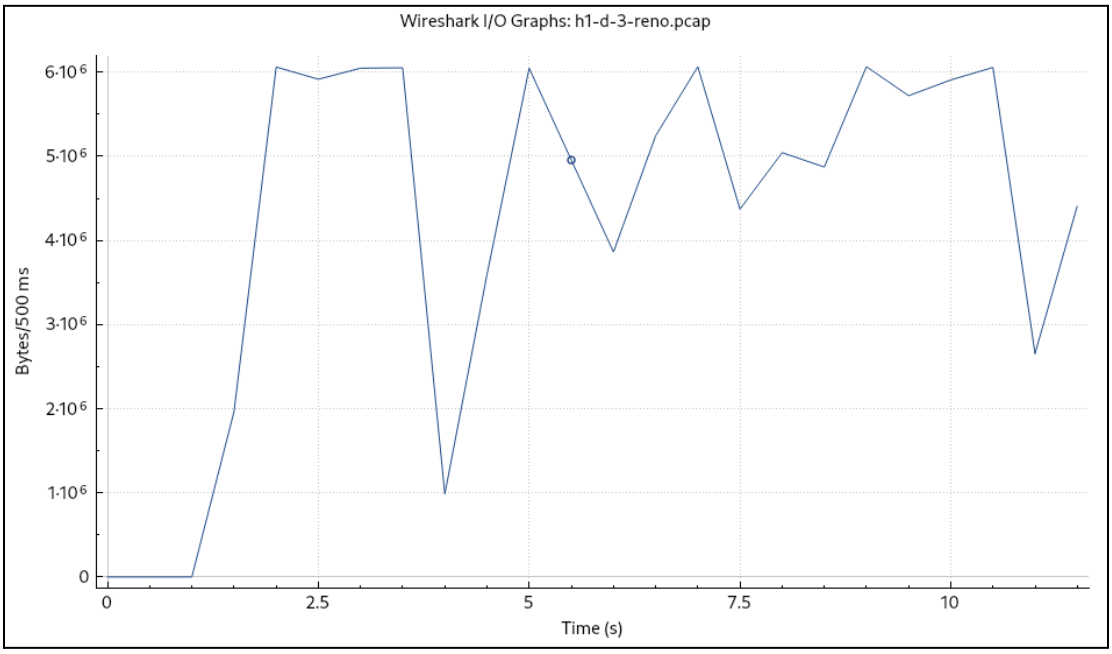
With the presence of minor link loss, and a poorly optimized congestion control scheme, Vegas experiences the most unstable throughput v/s time. The Reno, Cubic and BBR can handle congestion due to link loss better than Vegas as they are somewhat optimized.

Loss 3%

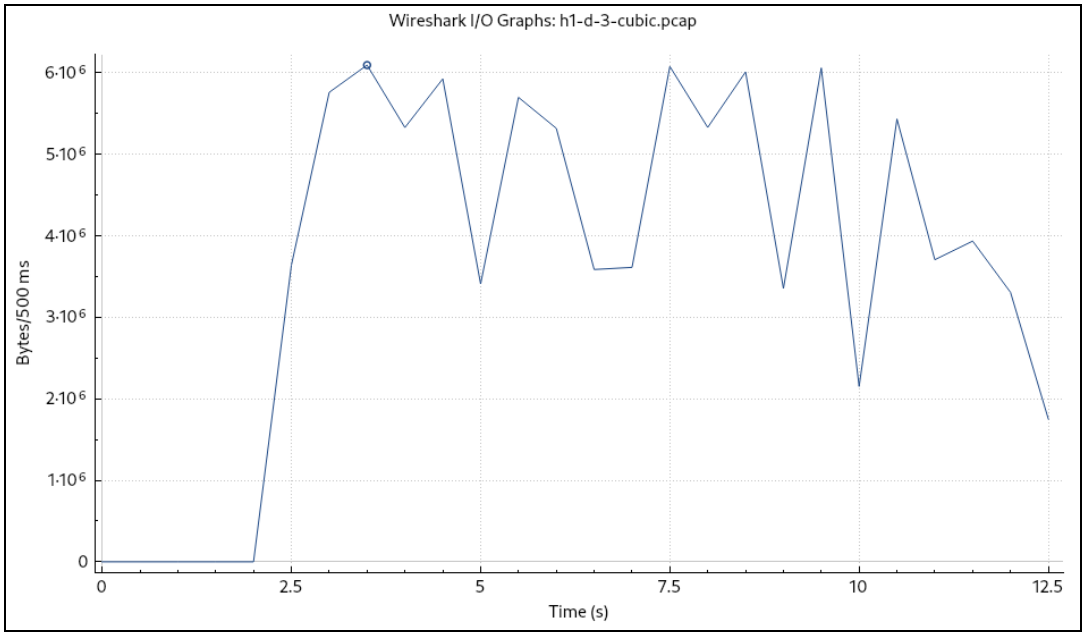
I. Vegas



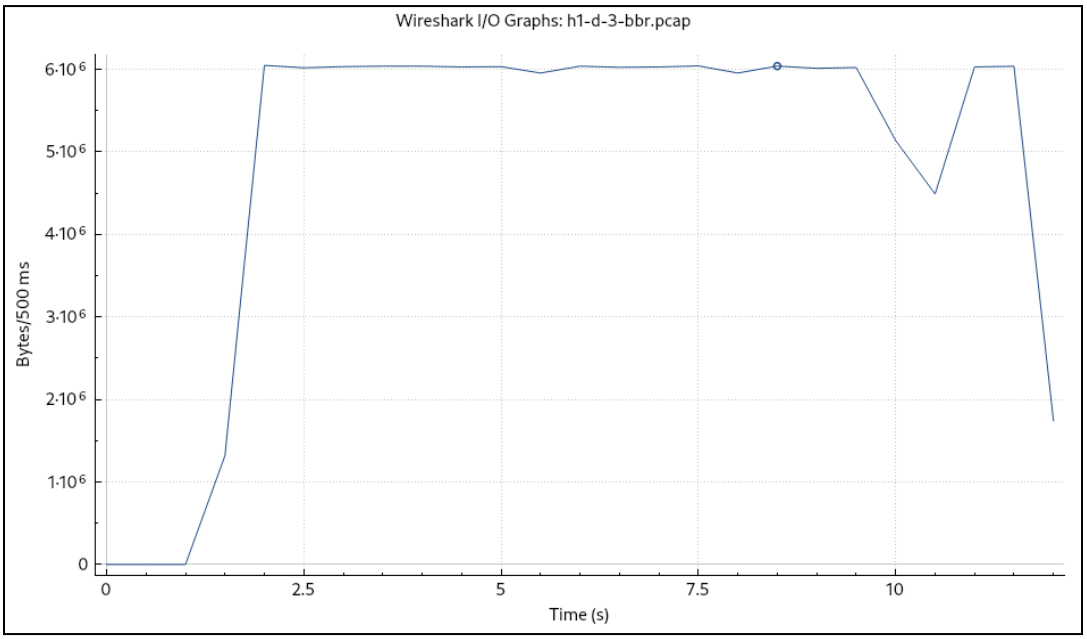
II. Reno



III. Cubic



IV. BBR



Reasoning:

With even more link loss, the effect of congestion is noticeable in all congestion control scheme. But the most well defined algorithm, BBR handles link loss the best. The rest of the three reach their limitation and experience large changes in RTT and throughput resulting in unstable throughput vs time graph.