CS 433 Computer Networks
Assignment II
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PART-I

A) Implemented the custom topology

```
File  Actions  Edit  View  Help
┌──(kali㉿kali)-[~]
└─$ sudo python Part_I.py
[sudo] password for kali:
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6 r1 r2 r3
*** Adding switches:
s1 s2 s3
*** Adding links:
(h1, s1) (h2, s1) (h3, s2) (h4, s2) (h5, s3) (h6, s3) (r1, r2) (r2, r3) (r3, r1) (s1, r1) (s2, r2) (s3, r3)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 r1 r2 r3
10.0.1.0/24 dev r1-eth0 proto kernel scope link src 10.0.1.1
10.0.2.0/24 via 10.100.1.2 dev r1-eth1
10.0.3.0/24 via 10.100.3.1 dev r1-eth2
10.100.1.0/24 dev r1-eth1 proto kernel scope link src 10.100.1.1
10.100.3.0/24 dev r1-eth2 proto kernel scope link src 10.100.3.2
10.0.1.0/24 via 10.100.1.1 dev r2-eth1
10.0.2.0/24 dev r2-eth0 proto kernel scope link src 10.0.2.1
10.0.3.0/24 via 10.100.2.2 dev r2-eth2
10.100.1.0/24 dev r2-eth1 proto kernel scope link src 10.100.1.2
10.100.2.0/24 dev r2-eth2 proto kernel scope link src 10.100.2.1
10.0.1.0/24 via 10.100.3.2 dev r3-eth2
10.0.2.0/24 via 10.100.2.1 dev r3-eth1
10.0.3.0/24 dev r3-eth0 proto kernel scope link src 10.0.3.1
10.100.2.0/24 dev r3-eth1 proto kernel scope link src 10.100.2.2
10.100.3.0/24 dev r3-eth2 proto kernel scope link src 10.100.3.1
*** Starting controller
c0
*** Starting 3 switches
s1 s2 s3  ...
*** Starting CLI:
mininet> pingall
*** Ping: testing ping reachability
h1 → h2 h3 h4 h5 h6 r1 r2 r3
h2 → h1 h3 h4 h5 h6 r1 r2 r3
h3 → h1 h2 h4 h5 h6 r1 r2 r3
h4 → h1 h2 h3 h5 h6 r1 r2 r3
h5 → h1 h2 h3 h4 h6 r1 r2 r3
h6 → h1 h2 h3 h4 h5 r1 r2 r3
r1 → h1 h2 h3 h4 h5 h6 r2 r3
r2 → h1 h2 h3 h4 h5 h6 r1 r3
r3 → h1 h2 h3 h4 h5 h6 r1 r2
*** Results: 0% dropped (72/72 received)
mininet>
```

B) Wireshark of the packets for the route setup on router1(r1)

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	10.0.1.251	10.0.1.1	ICMP	104	Echo (ping) request id=0x38e0, seq=1/256, ttl=64 (reply in 2)
2	0.000014	10.0.1.1	10.0.1.251	ICMP	104	Echo (ping) reply id=0x38e0, seq=1/256, ttl=64 (request in 1)
3	0.004321	10.0.1.251	10.0.2.1	ICMP	104	Echo (ping) request id=0xd280, seq=1/256, ttl=64 (no response found!)
4	0.004333	10.0.1.251	10.0.2.1	ICMP	104	Echo (ping) request id=0xd280, seq=1/256, ttl=63 (reply in 5)
5	0.004348	10.0.2.1	10.0.1.251	ICMP	104	Echo (ping) reply id=0xd280, seq=1/256, ttl=64 (request in 4)
6	0.004351	10.0.2.1	10.0.1.251	ICMP	104	Echo (ping) reply id=0xd280, seq=1/256, ttl=63
7	0.007040	10.0.1.251	10.0.3.1	ICMP	104	Echo (ping) request id=0x7603, seq=1/256, ttl=64 (no response found!)
8	0.007080	10.0.1.251	10.0.3.1	ICMP	104	Echo (ping) request id=0x7603, seq=1/256, ttl=63 (reply in 9)
9	0.007101	10.0.3.1	10.0.1.251	ICMP	104	Echo (ping) request id=0x7603, seq=1/256, ttl=64 (request in 8)
10	0.007104	10.0.3.1	10.0.1.251	ICMP	104	Echo (ping) reply id=0x7603, seq=1/256, ttl=63
11	0.013270	32:68:72:73:46:57		ARP	48	Who has 10.0.1.1? Tell 10.0.1.252
12	0.013284	42:e8:be:4a:7c:20		ARP	48	10.0.1.1 is at 42:e8:be:4a:7c:20
13	0.013962	10.0.1.252	10.0.2.251	ICMP	104	Echo (ping) request id=0x3bcb, seq=1/256, ttl=64 (no response found!)
14	0.013971	10.0.1.252	10.0.2.251	ICMP	104	Echo (ping) request id=0x3bcb, seq=1/256, ttl=63 (reply in 15)
15	0.014668	10.0.2.251	10.0.1.252	ICMP	104	Echo (ping) reply id=0x3bcb, seq=1/256, ttl=64 (request in 14)
16	0.014673	10.0.2.251	10.0.1.252	ICMP	104	Echo (ping) reply id=0x3bcb, seq=1/256, ttl=62
17	0.016954	10.0.1.252	10.0.2.252	ICMP	104	Echo (ping) request id=0x27e8, seq=1/256, ttl=64 (no response found!)
18	0.016961	10.0.1.252	10.0.2.252	ICMP	104	Echo (ping) request id=0x27e8, seq=1/256, ttl=63 (reply in 19)
19	0.017697	10.0.2.252	10.0.1.252	ICMP	104	Echo (ping) reply id=0x27e8, seq=1/256, ttl=64 (request in 18)
20	0.017701	10.0.2.252	10.0.1.252	ICMP	104	Echo (ping) reply id=0x27e8, seq=1/256, ttl=62
21	0.019723	10.0.1.252	10.0.3.251	ICMP	104	Echo (ping) request id=0x263e, seq=1/256, ttl=64 (no response found!)
22	0.019730	10.0.1.252	10.0.3.251	ICMP	104	Echo (ping) request id=0x263e, seq=1/256, ttl=63 (reply in 23)
23	0.020306	10.0.3.251	10.0.1.252	ICMP	104	Echo (ping) request id=0x263e, seq=1/256, ttl=64 (request in 22)
24	0.020309	10.0.3.251	10.0.1.252	ICMP	104	Echo (ping) reply id=0x263e, seq=1/256, ttl=62
25	0.022197	10.0.1.252	10.0.3.252	ICMP	104	Echo (ping) request id=0xef22, seq=1/256, ttl=64 (no response found!)
26	0.022216	10.0.1.252	10.0.3.252	ICMP	104	Echo (ping) request id=0xef22, seq=1/256, ttl=63 (reply in 27)
27	0.022730	10.0.3.252	10.0.1.252	ICMP	104	Echo (ping) reply id=0xef22, seq=1/256, ttl=63 (request in 26)
28	0.022732	10.0.3.252	10.0.1.252	ICMP	104	Echo (ping) reply id=0xef22, seq=1/256, ttl=62
29	0.025058	10.0.1.252	10.0.1.1	ICMP	104	Echo (ping) request id=0xf497, seq=1/256, ttl=64 (reply in 30)
30	0.025075	10.0.1.1	10.0.1.252	ICMP	104	Echo (ping) reply id=0xf497, seq=1/256, ttl=64 (request in 29)
31	0.028554	10.0.1.252	10.0.2.1	ICMP	104	Echo (ping) request id=0x282a, seq=1/256, ttl=64 (no response found!)
32	0.028564	10.0.1.252	10.0.2.1	ICMP	104	Echo (ping) request id=0x282a, seq=1/256, ttl=63 (reply in 33)
33	0.028577	10.0.2.1	10.0.1.252	ICMP	104	Echo (ping) reply id=0x282a, seq=1/256, ttl=64 (request in 32)
34	0.028579	10.0.2.1	10.0.1.252	ICMP	104	Echo (ping) reply id=0x282a, seq=1/256, ttl=63
35	0.030827	10.0.1.252	10.0.3.1	ICMP	104	Echo (ping) request id=0xed32, seq=1/256, ttl=64 (no response found!)
36	0.030835	10.0.1.252	10.0.3.1	ICMP	104	Echo (ping) request id=0xed32, seq=1/256, ttl=63 (reply in 37)
37	0.030846	10.0.3.1	10.0.1.252	ICMP	104	Echo (ping) request id=0xed32, seq=1/256, ttl=64 (request in 36)
38	0.030848	10.0.3.1	10.0.1.252	ICMP	104	Echo (ping) reply id=0xed32, seq=1/256, ttl=63
39	0.033105	10.0.2.251	10.0.1.251	ICMP	104	Echo (ping) request id=0xeb67, seq=1/256, ttl=63 (no response found!)

No.	Time	Source	Destination	Protocol	Length	Info
40	0.033109	10.0.2.251	10.0.1.251	ICMP	104	Echo (ping) request id=0xeb67, seq=1/256, ttl=62 (reply in 41)
41	0.033526	10.0.1.251	10.0.2.251	ICMP	104	Echo (ping) reply id=0xeb67, seq=1/256, ttl=64 (request in 40)
42	0.033530	10.0.1.251	10.0.2.251	ICMP	104	Echo (ping) reply id=0xeb67, seq=1/256, ttl=63
43	0.035409	10.0.2.251	10.0.1.252	ICMP	104	Echo (ping) request id=0xc57b, seq=1/256, ttl=63 (no response found!)
44	0.035412	10.0.2.251	10.0.1.252	ICMP	104	Echo (ping) request id=0xc57b, seq=1/256, ttl=62 (reply in 45)
45	0.035751	10.0.1.252	10.0.2.251	ICMP	104	Echo (ping) reply id=0xc57b, seq=1/256, ttl=64 (request in 44)
46	0.035754	10.0.1.252	10.0.2.251	ICMP	104	Echo (ping) reply id=0xc57b, seq=1/256, ttl=63
47	0.045381	10.0.2.251	10.0.1.1	ICMP	104	Echo (ping) request id=0x525f, seq=1/256, ttl=63 (reply in 48)
48	0.045391	10.0.1.1	10.0.2.251	ICMP	104	Echo (ping) reply id=0x525f, seq=1/256, ttl=64 (request in 47)
49	0.051654	10.0.2.252	10.0.1.251	ICMP	104	Echo (ping) request id=0xd915, seq=1/256, ttl=63 (no response found!)
50	0.051660	10.0.2.252	10.0.1.251	ICMP	104	Echo (ping) request id=0xd915, seq=1/256, ttl=62 (reply in 51)
51	0.051988	10.0.1.251	10.0.2.252	ICMP	104	Echo (ping) reply id=0xd915, seq=1/256, ttl=64 (request in 50)
52	0.051993	10.0.1.251	10.0.2.252	ICMP	104	Echo (ping) reply id=0xd915, seq=1/256, ttl=63
53	0.054714	10.0.2.252	10.0.1.252	ICMP	104	Echo (ping) request id=0xd3e9, seq=1/256, ttl=63 (no response found!)
54	0.054721	10.0.2.252	10.0.1.252	ICMP	104	Echo (ping) request id=0xd3e9, seq=1/256, ttl=62 (reply in 55)
55	0.055523	10.0.1.252	10.0.2.252	ICMP	104	Echo (ping) reply id=0xd3e9, seq=1/256, ttl=64 (request in 54)
56	0.055530	10.0.1.252	10.0.2.252	ICMP	104	Echo (ping) reply id=0xd3e9, seq=1/256, ttl=63
57	0.056696	::	ff02::16	ICMPv6	96	Multicast Listener Report Message v2
58	0.067868	10.0.2.252	10.0.1.1	ICMP	104	Echo (ping) request id=0x2c99, seq=1/256, ttl=63 (reply in 59)
59	0.067879	10.0.1.1	10.0.2.252	ICMP	104	Echo (ping) reply id=0x2c99, seq=1/256, ttl=64 (request in 58)
60	0.068718	::	ff02::16	ICMPv6	96	Multicast Listener Report Message v2
61	0.076799	10.0.3.251	10.0.1.251	ICMP	104	Echo (ping) request id=0x40ff, seq=1/256, ttl=63 (no response found!)
62	0.076806	10.0.3.251	10.0.1.251	ICMP	104	Echo (ping) request id=0x40ff, seq=1/256, ttl=62 (reply in 63)
63	0.077170	10.0.1.251	10.0.3.251	ICMP	104	Echo (ping) reply id=0x40ff, seq=1/256, ttl=64 (request in 62)
64	0.077174	10.0.1.251	10.0.3.251	ICMP	104	Echo (ping) reply id=0x40ff, seq=1/256, ttl=63
65	0.079218	10.0.3.251	10.0.1.252	ICMP	104	Echo (ping) request id=0xf304, seq=1/256, ttl=63 (no response found!)
66	0.079222	10.0.3.251	10.0.1.252	ICMP	104	Echo (ping) request id=0xf304, seq=1/256, ttl=62 (reply in 67)
67	0.079612	10.0.1.252	10.0.3.251	ICMP	104	Echo (ping) reply id=0xf304, seq=1/256, ttl=64 (request in 66)
68	0.079616	10.0.1.252	10.0.3.251	ICMP	104	Echo (ping) reply id=0xf304, seq=1/256, ttl=63
69	0.089550	10.0.3.251	10.0.1.1	ICMP	104	Echo (ping) request id=0xbf9f, seq=1/256, ttl=63 (reply in 70)
70	0.089570	10.0.1.1	10.0.3.251	ICMP	104	Echo (ping) reply id=0xbf9f, seq=1/256, ttl=64 (request in 69)
71	0.098259	10.0.3.252	10.0.1.251	ICMP	104	Echo (ping) request id=0xac8c, seq=1/256, ttl=63 (no response found!)
72	0.098268	10.0.3.252	10.0.1.251	ICMP	104	Echo (ping) request id=0xac8c, seq=1/256, ttl=62 (reply in 73)
73	0.098789	10.0.1.251	10.0.3.252	ICMP	104	Echo (ping) reply id=0xac8c, seq=1/256, ttl=64 (request in 72)
74	0.098794	10.0.1.251	10.0.3.252	ICMP	104	Echo (ping) reply id=0xac8c, seq=1/256, ttl=63
75	0.101384	10.0.3.252	10.0.1.252	ICMP	104	Echo (ping) request id=0x37dd, seq=1/256, ttl=63 (no response found!)
76	0.101388	10.0.3.252	10.0.1.252	ICMP	104	Echo (ping) request id=0x37dd, seq=1/256, ttl=62 (reply in 77)
77	0.102532	10.0.1.252	10.0.3.252	ICMP	104	Echo (ping) reply id=0x37dd, seq=1/256, ttl=64 (request in 76)
78	0.102537	10.0.1.252	10.0.3.252	ICMP	104	Echo (ping) reply id=0x37dd, seq=1/256, ttl=63

No.	Time	Source	Destination	Protocol	Length	Info
79	0.117880	10.0.3.252	10.0.1.1	ICMP	104	Echo (ping) request id=0x3068, seq=1/256, ttl=63 (reply in 80)
80	0.117891	10.0.1.1	10.0.3.252	ICMP	104	Echo (ping) reply id=0x3068, seq=1/256, ttl=64 (request in 79)
81	0.128359	10.0.1.1	10.0.1.251	ICMP	104	Echo (ping) request id=0x013d, seq=1/256, ttl=64 (reply in 82)
82	0.129046	10.0.1.251	10.0.1.1	ICMP	104	Echo (ping) reply id=0x013d, seq=1/256, ttl=64 (request in 81)
83	0.130932	10.0.1.1	10.0.1.252	ICMP	104	Echo (ping) request id=0x9fd6, seq=1/256, ttl=64 (reply in 84)
84	0.131376	10.0.1.252	10.0.1.1	ICMP	104	Echo (ping) reply id=0x9fd6, seq=1/256, ttl=64 (request in 83)
85	0.132697	10.100.1.1	10.0.2.251	ICMP	104	Echo (ping) request id=0xcc67, seq=1/256, ttl=64 (reply in 86)
86	0.133623	10.0.2.251	10.100.1.1	ICMP	104	Echo (ping) reply id=0xcc67, seq=1/256, ttl=63 (request in 85)
87	0.134929	10.100.1.1	10.0.2.252	ICMP	104	Echo (ping) request id=0x1c5b, seq=1/256, ttl=64 (reply in 88)
88	0.135678	10.0.2.252	10.100.1.1	ICMP	104	Echo (ping) reply id=0x1c5b, seq=1/256, ttl=63 (request in 87)
89	0.136832	::	ff02::1:ff73:4657	ICMPv6	92	Neighbor Solicitation for fe80::3068:72ff:fe73:4657
90	0.137147	10.100.3.2	10.0.3.251	ICMP	104	Echo (ping) request id=0x984b, seq=1/256, ttl=64 (reply in 91)
91	0.137578	10.0.3.251	10.100.3.2	ICMP	104	Echo (ping) reply id=0x984b, seq=1/256, ttl=63 (request in 90)
92	0.138837	10.100.3.2	10.0.3.252	ICMP	104	Echo (ping) request id=0x8317, seq=1/256, ttl=64 (reply in 93)
93	0.139243	10.0.3.252	10.100.3.2	ICMP	104	Echo (ping) reply id=0x8317, seq=1/256, ttl=63 (request in 92)
94	0.140676	10.100.1.1	10.0.2.1	ICMP	104	Echo (ping) request id=0xc5e8, seq=1/256, ttl=64 (reply in 95)
95	0.140696	10.0.2.1	10.100.1.1	ICMP	104	Echo (ping) reply id=0xc5e8, seq=1/256, ttl=64 (request in 94)
96	0.143122	10.100.3.2	10.0.3.1	ICMP	104	Echo (ping) request id=0x20ed, seq=1/256, ttl=64 (reply in 97)
97	0.143141	10.0.3.1	10.100.3.2	ICMP	104	Echo (ping) reply id=0x20ed, seq=1/256, ttl=64 (request in 96)
98	0.144676	10.100.1.2	10.0.1.251	ICMP	104	Echo (ping) request id=0xc9d3, seq=1/256, ttl=64 (no response found!)
99	0.144708	10.100.1.2	10.0.1.251	ICMP	104	Echo (ping) request id=0xc9d3, seq=1/256, ttl=63 (reply in 100)
100	0.145591	10.0.1.251	10.100.1.2	ICMP	104	Echo (ping) reply id=0xc9d3, seq=1/256, ttl=64 (request in 99)
101	0.145597	10.0.1.251	10.100.1.2	ICMP	104	Echo (ping) reply id=0xc9d3, seq=1/256, ttl=63
102	0.146812	10.100.1.2	10.0.1.252	ICMP	104	Echo (ping) request id=0xc957, seq=1/256, ttl=64 (no response found!)
103	0.146819	10.100.1.2	10.0.1.252	ICMP	104	Echo (ping) request id=0xc957, seq=1/256, ttl=63 (reply in 104)
104	0.147483	10.0.1.252	10.100.1.2	ICMP	104	Echo (ping) reply id=0xc957, seq=1/256, ttl=64 (request in 103)
105	0.147487	10.0.1.252	10.100.1.2	ICMP	104	Echo (ping) reply id=0xc957, seq=1/256, ttl=63
106	0.161054	10.100.1.2	10.0.1.1	ICMP	104	Echo (ping) request id=0xafd5, seq=1/256, ttl=64 (reply in 107)
107	0.161073	10.0.1.1	10.100.1.2	ICMP	104	Echo (ping) reply id=0xafd5, seq=1/256, ttl=64 (request in 106)
108	0.163874	10.100.3.1	10.0.1.251	ICMP	104	Echo (ping) request id=0xf734, seq=1/256, ttl=64 (no response found!)
109	0.163883	10.100.3.1	10.0.1.251	ICMP	104	Echo (ping) request id=0xf734, seq=1/256, ttl=63 (reply in 110)
110	0.164709	10.0.1.251	10.100.3.1	ICMP	104	Echo (ping) reply id=0xf734, seq=1/256, ttl=64 (request in 109)
111	0.164716	10.0.1.251	10.100.3.1	ICMP	104	Echo (ping) reply id=0xf734, seq=1/256, ttl=63
112	0.166241	10.100.3.1	10.0.1.252	ICMP	104	Echo (ping) request id=0x596f, seq=1/256, ttl=64 (no response found!)
113	0.166252	10.100.3.1	10.0.1.252	ICMP	104	Echo (ping) request id=0x596f, seq=1/256, ttl=63 (reply in 114)
114	0.167165	10.0.1.252	10.100.3.1	ICMP	104	Echo (ping) reply id=0x596f, seq=1/256, ttl=64 (request in 113)
115	0.167169	10.0.1.252	10.100.3.1	ICMP	104	Echo (ping) reply id=0x596f, seq=1/256, ttl=63
116	0.168813	::	ff02::16	ICMPv6	96	Multicast Listener Report Message v2
117	0.179113	10.100.3.1	10.0.1.1	ICMP	104	Echo (ping) request id=0x06a9, seq=1/256, ttl=64 (reply in 118)

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117 0.179113       10.100.3.1          10.0.1.1           ICMP     104 Echo (ping) request  id=0x06a9, seq=1/256, ttl=64 (reply in 118)
118 0.179125       10.0.1.1            10.100.3.1         ICMP     104 Echo (ping) reply    id=0x06a9, seq=1/256, ttl=64 (request in 117)
119 0.361450       ::                  ff02::16           ICMPv6    96 Multicast Listener Report Message v2
120 0.457839       ::                  ff02::1:ff06:d175  ICMPv6    92 Neighbor Solicitation for fe80::6449:45ff:fe06:d175
121 0.520703       ::                  ff02::1:ff4a:7c20  ICMPv6    92 Neighbor Solicitation for fe80::40e8:beff:fe4a:7c20
122 0.520742       ::                  ff02::1:ffc5:d95f  ICMPv6    92 Neighbor Solicitation for fe80::7c74:15ff:fec5:d95f
123 0.520755       ::                  ff02::1:ffbe:47af  ICMPv6    92 Neighbor Solicitation for fe80::9c66:30ff:febe:47af
124 0.648779       ::                  ff02::16           ICMPv6    96 Multicast Listener Report Message v2
125 0.760693       ::                  ff02::16           ICMPv6    96 Multicast Listener Report Message v2
126 0.760708       ::                  ff02::16           ICMPv6    96 Multicast Listener Report Message v2
127 0.840994       ::                  ff02::16           ICMPv6    96 Multicast Listener Report Message v2
128 0.873302       fe80::94bc:61ff:fe8… ff02::16          ICMPv6    96 Multicast Listener Report Message v2
129 0.873313       fe80::94bc:61ff:fe8… ff02::2           ICMPv6    76 Router Solicitation from 96:bc:61:86:13:b4
130 0.969756       fe80::c466:ddff:fe8… ff02::16          ICMPv6    96 Multicast Listener Report Message v2
131 0.969774       fe80::c466:ddff:fe8… ff02::2           ICMPv6    76 Router Solicitation from c6:66:dd:8c:30:cb
132 1.000753       fe80::509a:e1ff:fee… ff02::16          ICMPv6    96 Multicast Listener Report Message v2
133 1.000766       fe80::509a:e1ff:fee… ff02::2           ICMPv6    76 Router Solicitation from 52:9a:e1:e5:e4:38
134 1.161412       fe80::3068:72ff:fe7… ff02::16          ICMPv6    96 Multicast Listener Report Message v2
135 1.161503       fe80::3068:72ff:fe7… ff02::2           ICMPv6    76 Router Solicitation from 32:68:72:73:46:57
136 1.288931       ::                  ff02::16           ICMPv6    96 Multicast Listener Report Message v2
137 1.321969       ::                  ff02::16           ICMPv6    96 Multicast Listener Report Message v2
138 1.352716       fe80::94bc:61ff:fe8… ff02::16          ICMPv6    96 Multicast Listener Report Message v2
139 1.481396       fe80::6449:45ff:fe0… ff02::16          ICMPv6    96 Multicast Listener Report Message v2
140 1.481421       fe80::6449:45ff:fe0… ff02::2           ICMPv6    76 Router Solicitation from 66:49:45:06:d1:75
```

C) Latency difference through the old route

```
h1 h2 h3 h4 h5 h6 r1 r2 r3
*** Adding switches:
s1 s2 s3
*** Adding links:
(h1, s1) (h2, s1) (h3, s2) (h4, s2) (h5, s3) (h6, s3) (r1, r2) (r2, r3) (r3, r1) (s1, r1) (s2, r2) (s3, r3)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 r1 r2 r3
10.0.1.0/24 dev r1-eth0 proto kernel scope link src 10.0.1.1
10.0.2.0/24 via 10.100.1.2 dev r1-eth1
10.0.3.0/24 via 10.100.3.1 dev r1-eth2
10.100.1.0/24 dev r1-eth1 proto kernel scope link src 10.100.1.1
10.100.3.0/24 dev r1-eth2 proto kernel scope link src 10.100.3.2
10.0.1.0/24 via 10.100.1.1 dev r2-eth1
10.0.2.0/24 dev r2-eth0 proto kernel scope link src 10.0.2.1
10.0.3.0/24 via 10.100.2.2 dev r2-eth2
10.100.1.0/24 dev r2-eth1 proto kernel scope link src 10.100.1.2
10.100.2.0/24 dev r2-eth2 proto kernel scope link src 10.100.2.1
10.0.1.0/24 via 10.100.3.2 dev r3-eth2
10.0.2.0/24 via 10.100.2.1 dev r3-eth1
10.0.3.0/24 dev r3-eth0 proto kernel scope link src 10.0.3.1
10.100.2.0/24 dev r3-eth1 proto kernel scope link src 10.100.2.2
10.100.3.0/24 dev r3-eth2 proto kernel scope link src 10.100.3.1
*** Starting controller
c0
*** Starting 3 switches
s1 s2 s3 ...
*** Starting CLI:
mininet> h1 ping h6
PING 10.0.3.252 (10.0.3.252) 56(84) bytes of data.
64 bytes from 10.0.3.252: icmp_seq=1 ttl=62 time=3.68 ms
64 bytes from 10.0.3.252: icmp_seq=2 ttl=62 time=0.282 ms
64 bytes from 10.0.3.252: icmp_seq=3 ttl=62 time=0.073 ms
64 bytes from 10.0.3.252: icmp_seq=4 ttl=62 time=0.087 ms
64 bytes from 10.0.3.252: icmp_seq=5 ttl=62 time=0.082 ms
64 bytes from 10.0.3.252: icmp_seq=6 ttl=62 time=0.072 ms
64 bytes from 10.0.3.252: icmp_seq=7 ttl=62 time=0.075 ms
64 bytes from 10.0.3.252: icmp_seq=8 ttl=62 time=0.079 ms
64 bytes from 10.0.3.252: icmp_seq=9 ttl=62 time=0.075 ms
64 bytes from 10.0.3.252: icmp_seq=10 ttl=62 time=0.076 ms
64 bytes from 10.0.3.252: icmp_seq=11 ttl=62 time=0.067 ms
64 bytes from 10.0.3.252: icmp_seq=12 ttl=62 time=0.076 ms
64 bytes from 10.0.3.252: icmp_seq=13 ttl=62 time=0.069 ms
64 bytes from 10.0.3.252: icmp_seq=14 ttl=62 time=0.073 ms
64 bytes from 10.0.3.252: icmp_seq=15 ttl=62 time=0.077 ms
64 bytes from 10.0.3.252: icmp_seq=16 ttl=62 time=0.075 ms
64 bytes from 10.0.3.252: icmp_seq=17 ttl=62 time=0.076 ms
64 bytes from 10.0.3.252: icmp_seq=18 ttl=62 time=0.084 ms
^C
--- 10.0.3.252 ping statistics ---
18 packets transmitted, 18 received, 0% packet loss, time 17399ms
rtt min/avg/max/mdev = 0.067/0.287/3.679/0.823 ms
mininet>
```

Latency difference through the new route

```
*** Adding hosts:
h1 h2 h3 h4 h5 h6 r1 r2 r3
*** Adding switches:
s1 s2 s3
*** Adding links:
(h1, s1) (h2, s1) (h3, s2) (h4, s2) (h5, s3) (h6, s3) (r1, r2) (r2, r3) (r3, r1) (s1, r1) (s2, r2) (s3, r3)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 r1 r2 r3
10.0.1.0/24 dev r1-eth0 proto kernel scope link src 10.0.1.1
10.0.2.0/24 via 10.100.1.2 dev r1-eth1
10.0.3.0/24 via 10.100.1.2 dev r1-eth1
10.100.1.0/24 dev r1-eth1 proto kernel scope link src 10.100.1.1
10.100.3.0/24 dev r1-eth2 proto kernel scope link src 10.100.3.2
10.0.1.0/24 via 10.100.1.1 dev r2-eth1
10.0.2.0/24 dev r2-eth0 proto kernel scope link src 10.0.2.1
10.0.3.0/24 via 10.100.2.2 dev r2-eth2
10.100.1.0/24 dev r2-eth1 proto kernel scope link src 10.100.1.2
10.100.2.0/24 dev r2-eth2 proto kernel scope link src 10.100.2.1
10.0.1.0/24 via 10.100.3.2 dev r3-eth2
10.0.2.0/24 via 10.100.2.1 dev r3-eth1
10.0.3.0/24 dev r3-eth0 proto kernel scope link src 10.0.3.1
10.100.2.0/24 dev r3-eth1 proto kernel scope link src 10.100.2.2
10.100.3.0/24 dev r3-eth2 proto kernel scope link src 10.100.3.1
*** Starting controller
c0
*** Starting 3 switches
s1 s2 s3 ...
*** Starting CLI:
mininet> h1 ping h6
PING 10.0.3.252 (10.0.3.252) 56(84) bytes of data.
64 bytes from 10.0.3.252: icmp_seq=1 ttl=62 time=4.49 ms
64 bytes from 10.0.3.252: icmp_seq=2 ttl=62 time=0.600 ms
64 bytes from 10.0.3.252: icmp_seq=3 ttl=62 time=0.082 ms
64 bytes from 10.0.3.252: icmp_seq=4 ttl=62 time=0.097 ms
64 bytes from 10.0.3.252: icmp_seq=5 ttl=62 time=0.082 ms
64 bytes from 10.0.3.252: icmp_seq=6 ttl=62 time=0.077 ms
64 bytes from 10.0.3.252: icmp_seq=7 ttl=62 time=0.077 ms
64 bytes from 10.0.3.252: icmp_seq=8 ttl=62 time=0.084 ms
64 bytes from 10.0.3.252: icmp_seq=9 ttl=62 time=0.086 ms
64 bytes from 10.0.3.252: icmp_seq=10 ttl=62 time=0.122 ms
64 bytes from 10.0.3.252: icmp_seq=11 ttl=62 time=0.085 ms
64 bytes from 10.0.3.252: icmp_seq=12 ttl=62 time=0.089 ms
64 bytes from 10.0.3.252: icmp_seq=13 ttl=62 time=0.088 ms
64 bytes from 10.0.3.252: icmp_seq=14 ttl=62 time=0.096 ms
64 bytes from 10.0.3.252: icmp_seq=15 ttl=62 time=0.090 ms
64 bytes from 10.0.3.252: icmp_seq=16 ttl=62 time=0.092 ms
64 bytes from 10.0.3.252: icmp_seq=17 ttl=62 time=0.086 ms
^C
--- 10.0.3.252 ping statistics ---
17 packets transmitted, 17 received, 0% packet loss, time 16349ms
rtt min/avg/max/mdev = 0.077/0.378/4.494/1.036 ms
mininet>
```

D) Routing tables for all three routers

```
10.0.1.0/24 dev r1-eth0 proto kernel scope link src 10.0.1.1
10.0.2.0/24 via 10.100.1.2 dev r1-eth1
10.0.3.0/24 via 10.100.3.1 dev r1-eth2
10.100.1.0/24 dev r1-eth1 proto kernel scope link src 10.100.1.1
10.100.3.0/24 dev r1-eth2 proto kernel scope link src 10.100.3.2
10.0.1.0/24 via 10.100.1.1 dev r2-eth1
10.0.2.0/24 dev r2-eth0 proto kernel scope link src 10.0.2.1
10.0.3.0/24 via 10.100.2.2 dev r2-eth2
10.100.1.0/24 dev r2-eth1 proto kernel scope link src 10.100.1.2
10.100.2.0/24 dev r2-eth2 proto kernel scope link src 10.100.2.1
10.0.1.0/24 via 10.100.3.2 dev r3-eth2
10.0.2.0/24 via 10.100.2.1 dev r3-eth1
10.0.3.0/24 dev r3-eth0 proto kernel scope link src 10.0.3.1
10.100.2.0/24 dev r3-eth1 proto kernel scope link src 10.100.2.2
10.100.3.0/24 dev r3-eth2 proto kernel scope link src 10.100.3.1
```

PART-II

## A)Implementation of the mininet topology and TCP client-server program:

The Part_II.py file is uploaded in the given link which can run with required configuration, congestion control scheme and link loss parameters.

For example the command can be
"sudo python Part_II.py --config=b --congestion-control=Reno --link_loss=1.0"

B)Run the client on H1 and the server on H4:

Reno:

Throughput for 10.0.0.1:47474 → 10.0.0.4:5001 (MA)

h4.pcap
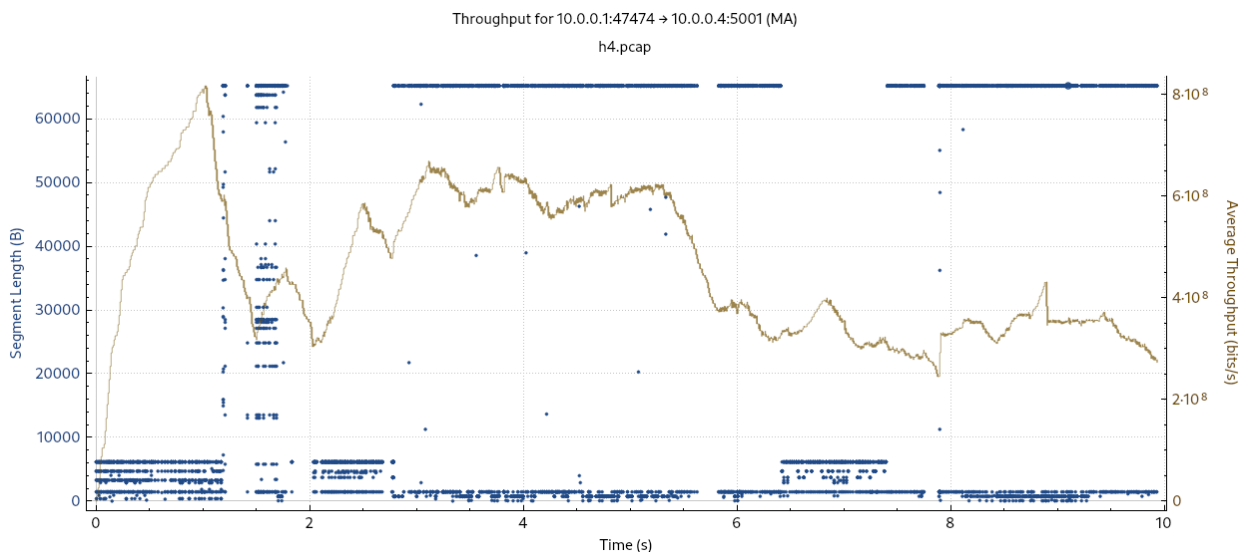
 Reno's congestion control involves a conservative approach with frequent reductions, leading to periodic dips in throughput. It reacts to packet loss as a sign of congestion and backs off, causing fluctuations in the throughput.

Cubic:

Throughput for 10.0.0.1:47628 → 10.0.0.4:5001 (MA)

h4-b-C.pcap
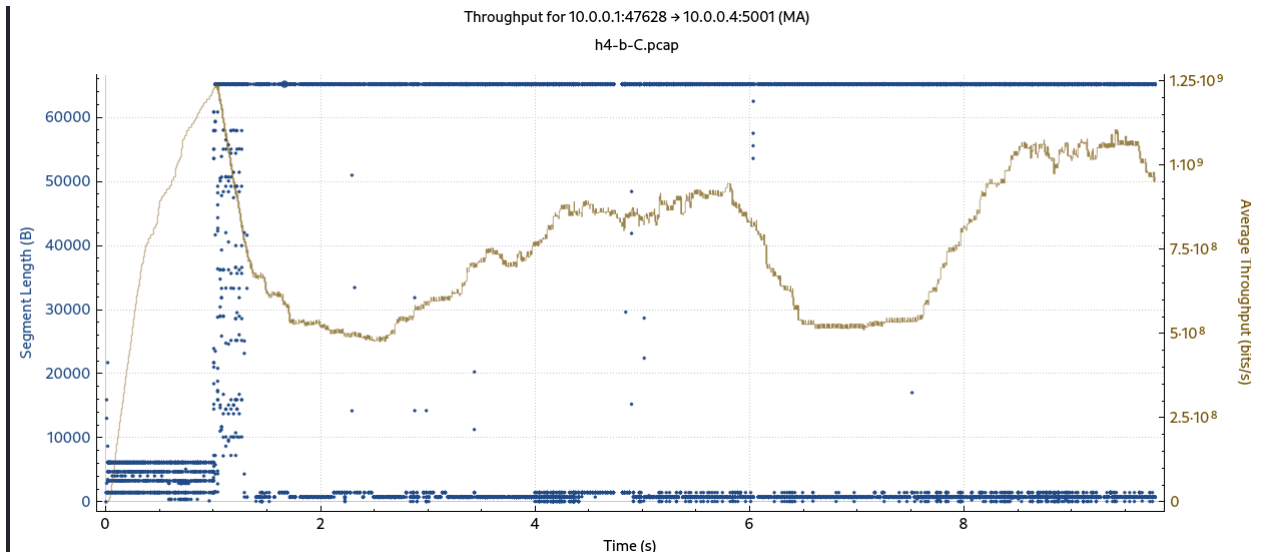
Cubic is known for its aggressive behavior, achieving higher throughput quickly. It adapts well to network conditions, reaching and maintaining a high throughput without excessive fluctuations.

Vegas:

Throughput for 10.0.0.1:42244 → 10.0.0.4:5001 (MA)

h4-b-V.pcap
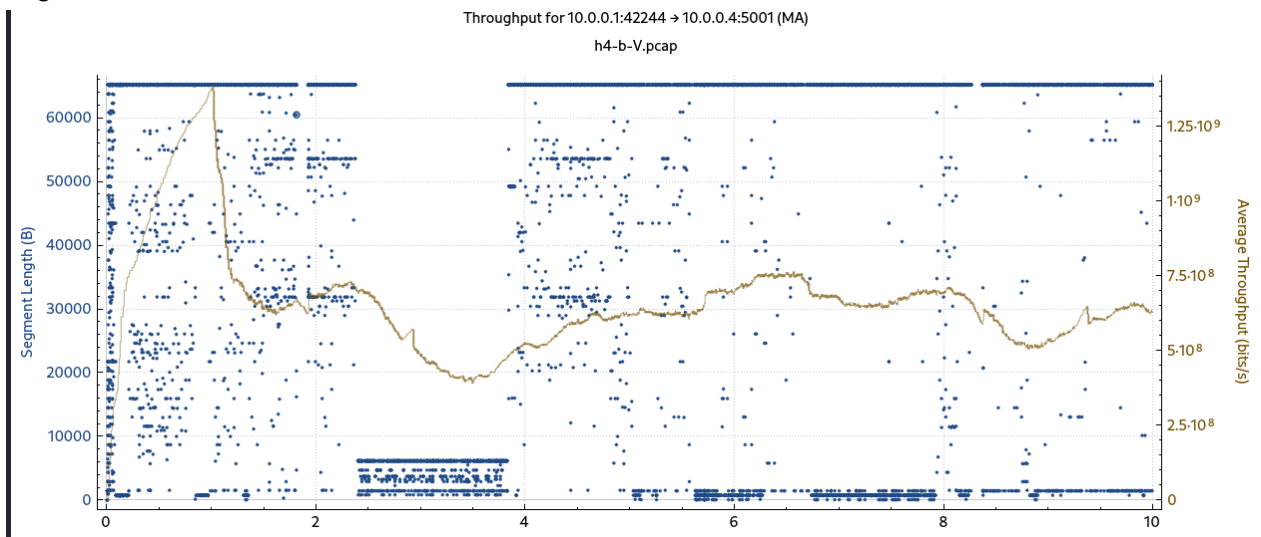
Vegas focuses on minimizing packet loss and, as a result, exhibits a smoother throughput curve. It tends to be more responsive to network changes, adjusting the sending rate without drastic reductions.

BBR:

Throughput for 10.0.0.1:41468 → 10.0.0.4:5001 (MA)

h4-b-bbr.pcap
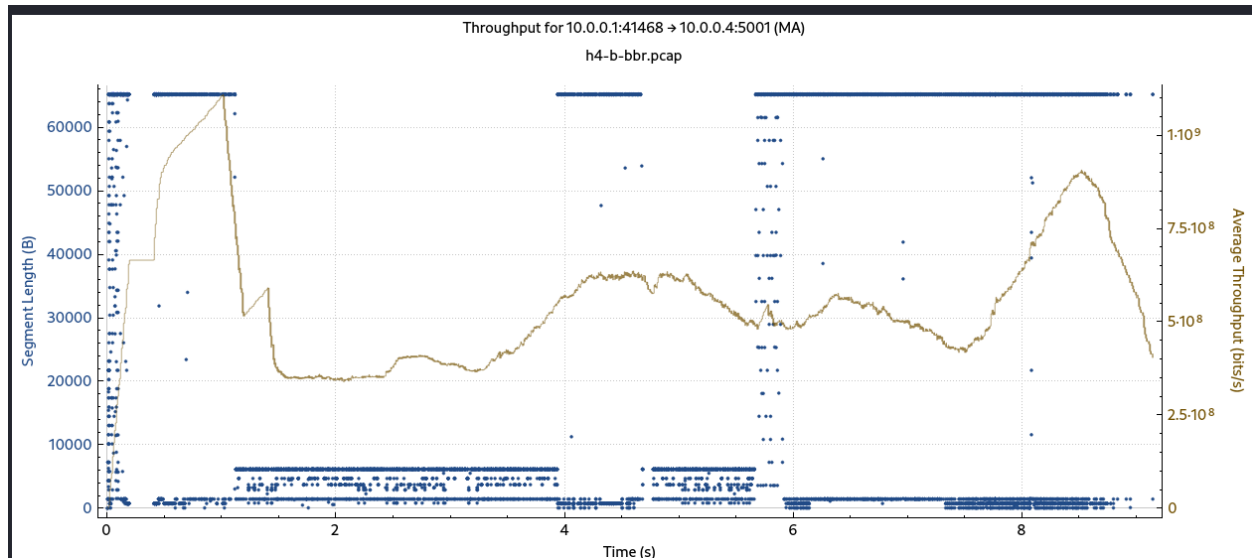
BBR's advanced congestion control algorithms contribute to its remarkable performance. It quickly reaches a high throughput and efficiently utilizes available bandwidth, making it a strong performer.

C)Run the client on H1, H2, H3 simultaneously and the server on H4:

Reno:

Throughput for 10.0.0.2:38158 → 10.0.0.4:5001 (MA)

h4-c-r.pcap
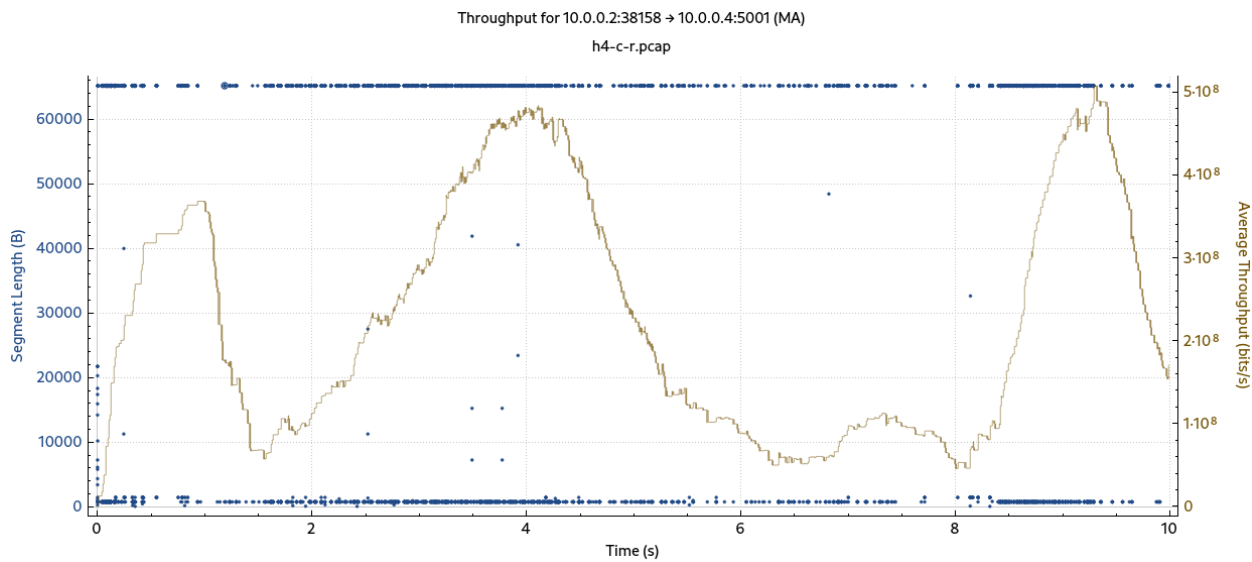
Reno's conservative approach, while reactive to congestion, led to more noticeable fluctuations in the presence of multiple clients. The competition for bandwidth triggered frequent adjustments, impacting overall throughput.

Cubic:

Throughput for 10.0.0.3:47978 → 10.0.0.4:5001 (MA)

h4-c-C.pcap
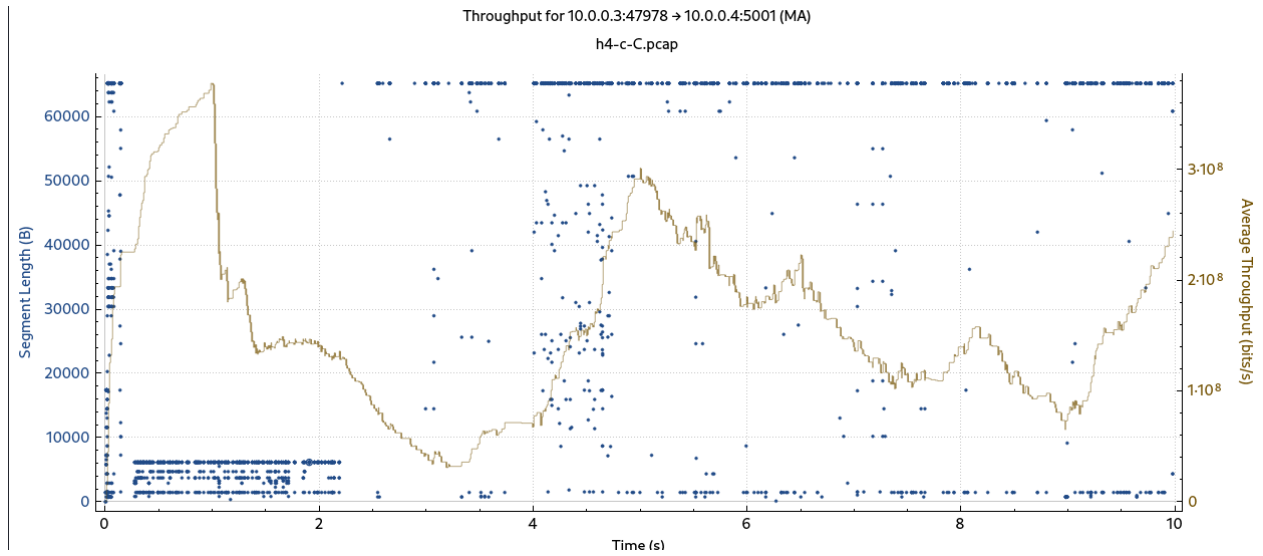
 Cubic's aggressive nature contributed to its ability to handle multiple clients efficiently. While some fluctuations were observed, Cubic maintained a high throughput for all clients.

Vegas:

Throughput for 10.0.0.2:38826 → 10.0.0.4:5001 (MA)

h4-c-v.pcap
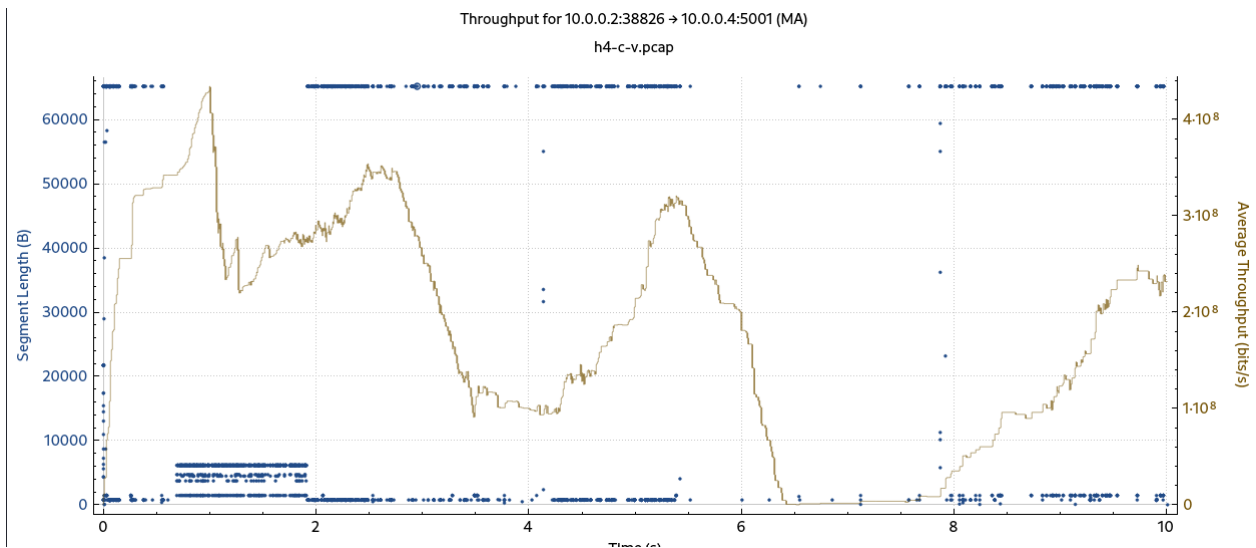
 Vegas, with its focus on minimizing packet loss, demonstrated a more stable throughput distribution among clients. Its responsiveness to network changes resulted in gradual adjustments, avoiding drastic fluctuations.

BBR:

Throughput for 10.0.0.2:46472 → 10.0.0.4:5001 (MA)
h4-c-bbr.pcap
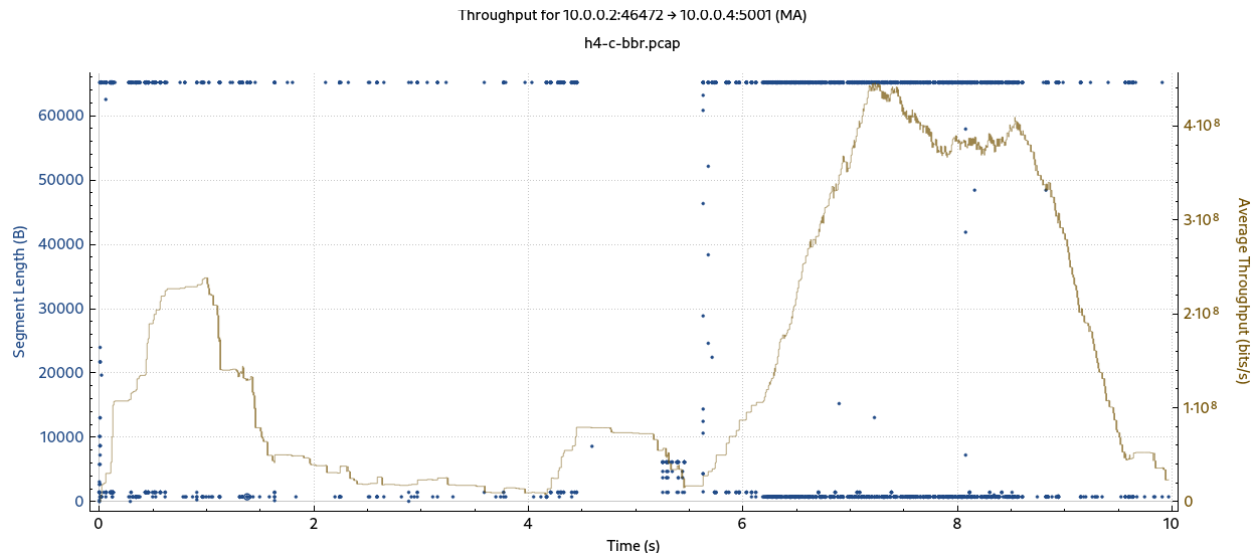
BBR's advanced congestion control mechanisms proved effective in the multi-client scenario. It efficiently managed contention, providing a high and stable throughput for all clients.

## D)Configure the link loss parameter of the middle link (s1 - s2) to 1% and 3%

For 1% Link Loss:
Reno:

Throughput for 10.0.0.1:42466 → 10.0.0.4:5001 (MA)
h4-d1-r.pcap
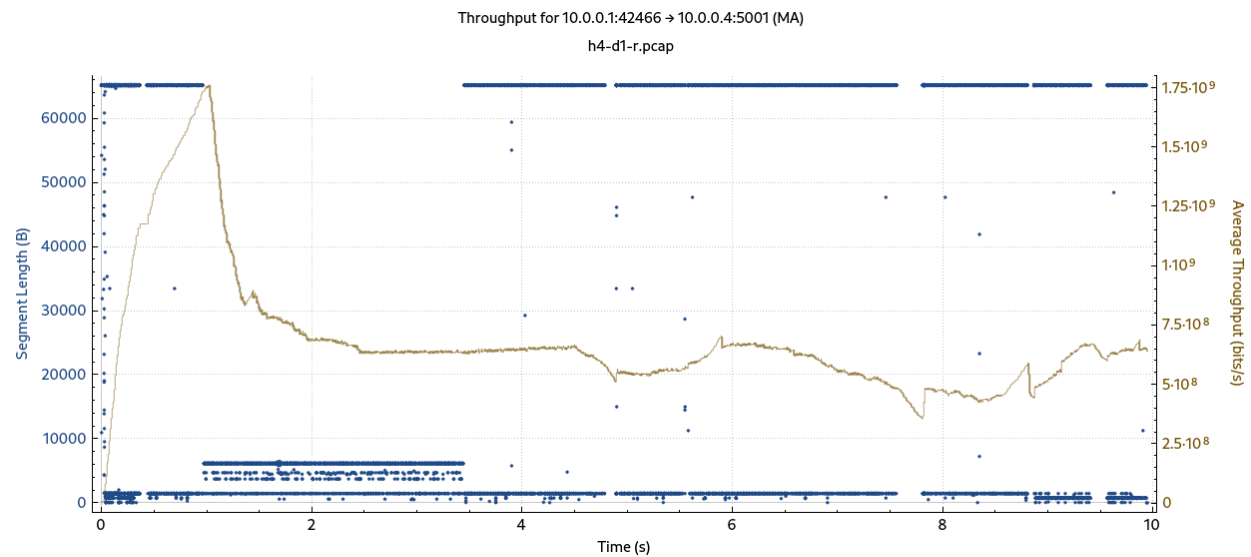
The introduction of 1% link loss resulted in a noticeable reduction in throughput. Reno's reactive nature to packet loss led to frequent adjustments, impacting overall performance. Reactive to packet loss, experienced more significant reductions, reflecting their challenges in adapting to minor disturbances.

Cubic:

Throughput for 10.0.0.1:38226 → 10.0.0.4:5001 (MA)
h4–d1–C.pcap
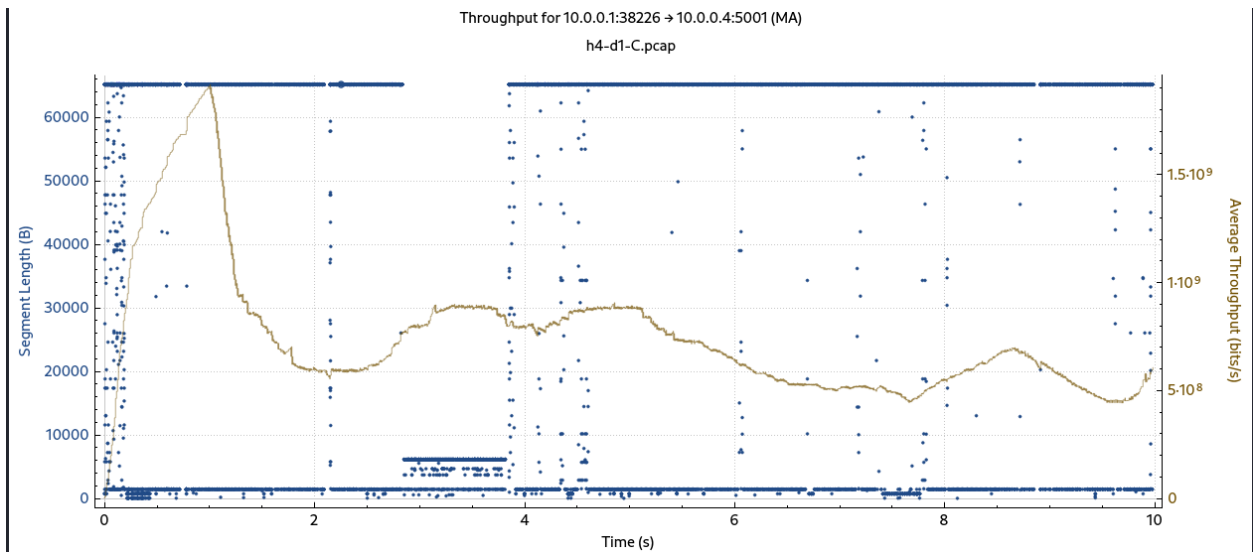
Similar to Reno, Cubic experienced a decrease in throughput with 1% link loss. Its aggressive approach contributed to quick ramp-up but also led to more significant fluctuations in the face of network challenges. Reactive to packet loss, experienced more significant reductions, reflecting their challenges in adapting to minor disturbances.

Vegas:

Throughput for 10.0.0.1:50858 → 10.0.0.4:5001 (MA)
h4–d1–v.pcap
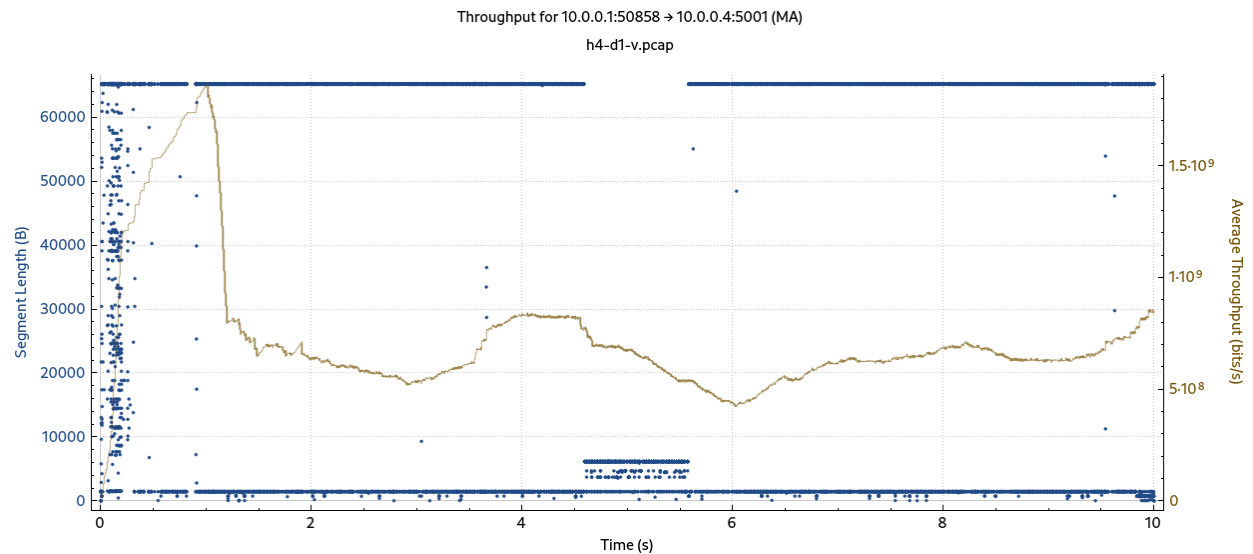
Vegas demonstrated resilience to the increased link loss, with smaller reductions in throughput compared to Reno and Cubic. Vegas's focus on minimizing packet loss allowed it to adapt more effectively. Showed resilience with smaller reductions, emphasizing its focus on minimizing packet loss.
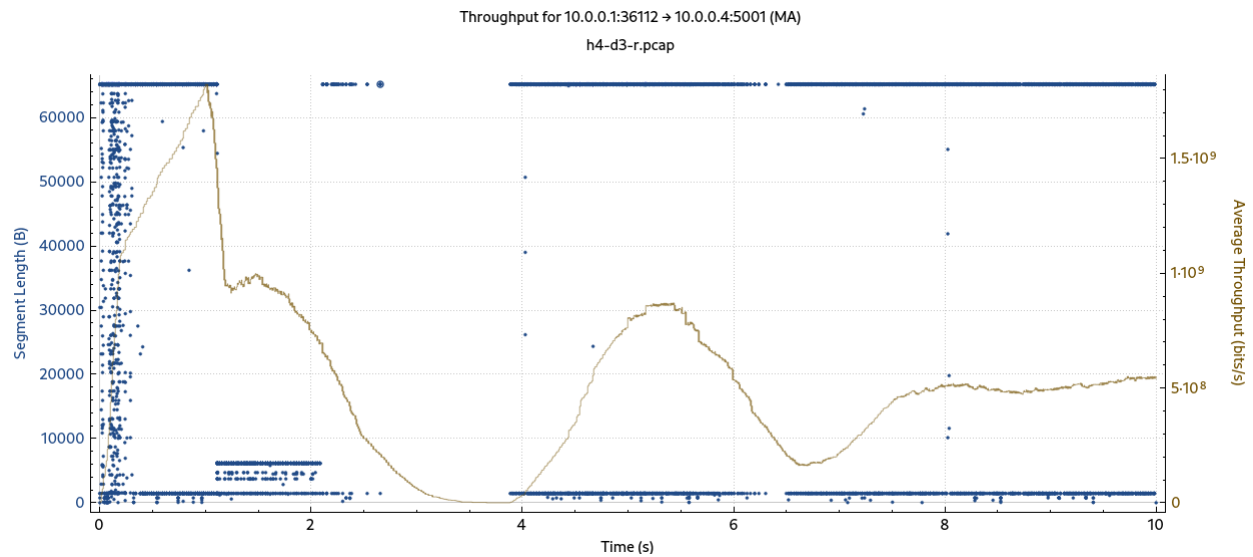
BBR:

Throughput for 10.0.0.1:35236 → 10.0.0.4:5001 (MA)

h4-d1-bbr.pcap
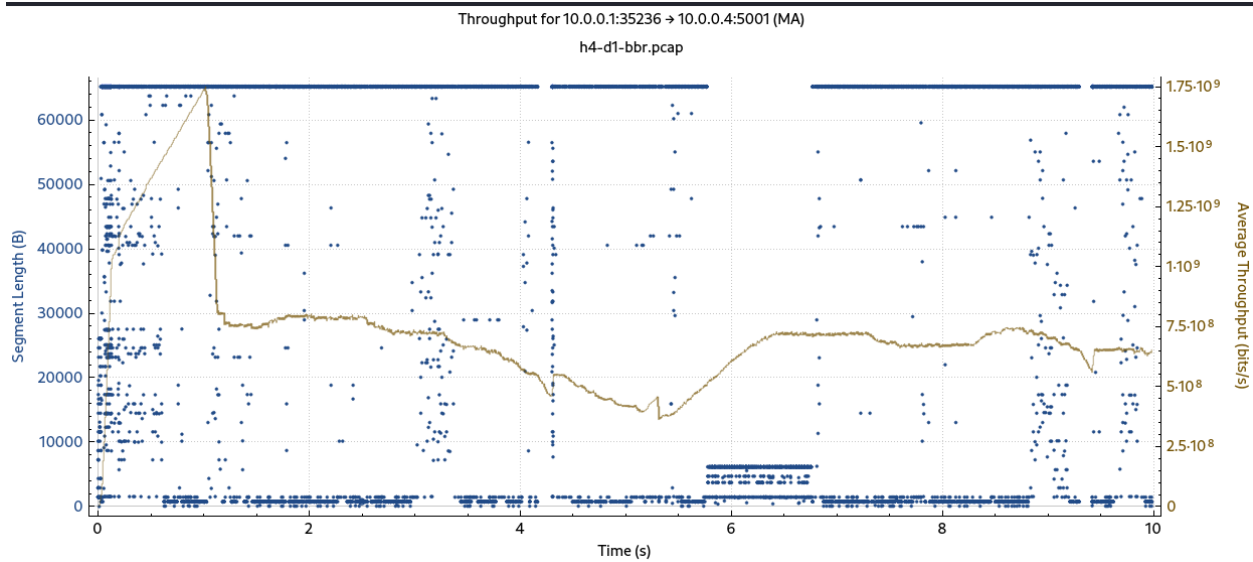
BBR showcased remarkable adaptability, maintaining a higher and more stable throughput even with the introduction of 1% link loss.

For 3% Link Loss:

Reno:

Throughput for 10.0.0.1:36112 → 10.0.0.4:5001 (MA)

h4-d3-r.pcap

With 3% link loss, Reno struggled further, experiencing a more pronounced reduction in throughput. Its reactive adjustments to congestion led to a less stable performance. Struggled with recovery, leading to more pronounced reductions and fluctuations.

Cubic:

Throughput for 10.0.0.1:40432 → 10.0.0.4:5001 (MA)

h4–d3–C.pcap
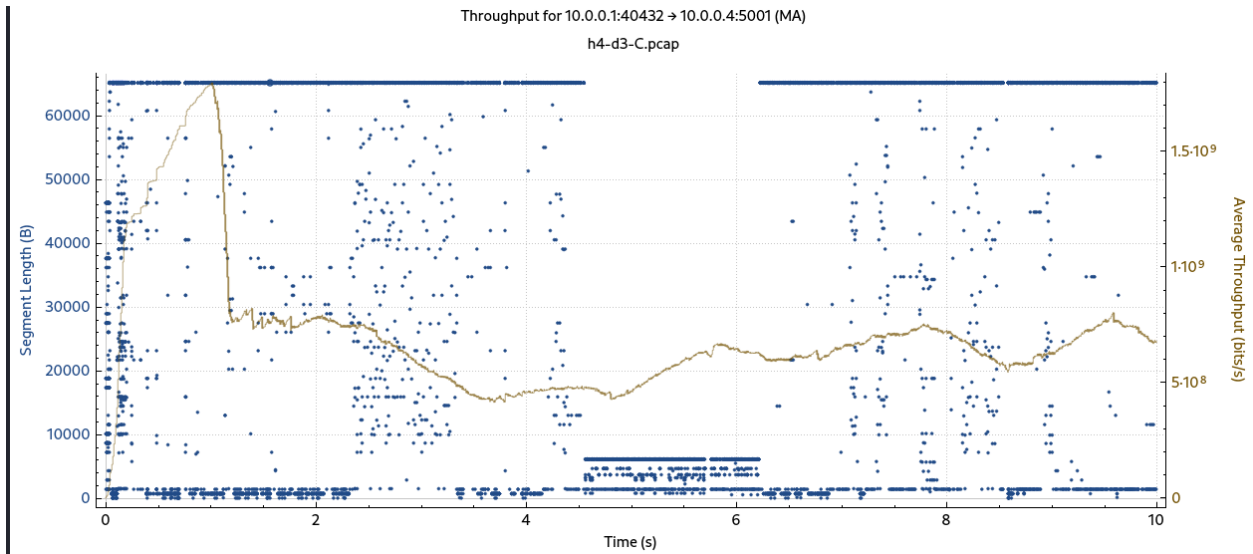
Cubic exhibited increased fluctuations and a significant drop in throughput with 3% link loss. The aggressive nature of Cubic resulted in challenges in recovering from the network disturbances. Struggled with recovery, leading to more pronounced reductions and fluctuations.

Vegas:

Throughput for 10.0.0.1:59070 → 10.0.0.4:5001 (MA)

h4–d3–V.pcap
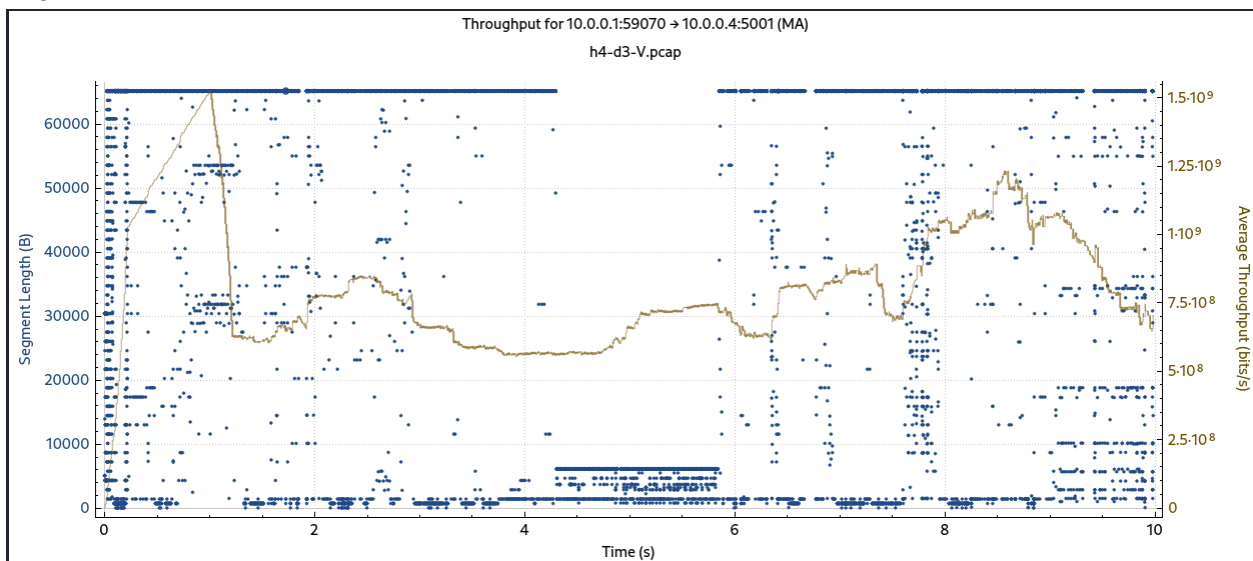
Vegas continued to demonstrate resilience, with a relatively stable throughput distribution even under 3% link loss. Its adaptive congestion control allowed for effective handling of network challenges.

BBR:

Throughput for 10.0.0.1:42930 → 10.0.0.4:5001 (MA)

h4-d3-bbr.pcap
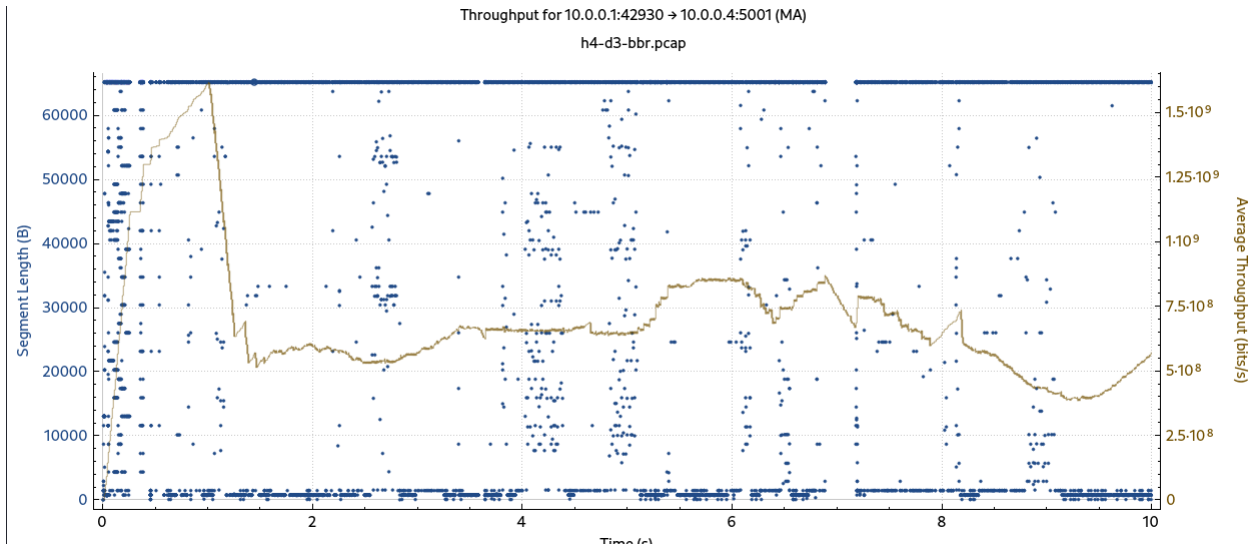
it maintained its superior performance, minimizing the impact of 3% link loss on overall throughput. BBR's advanced congestion control mechanisms proved effective in challenging network conditions. Maintained superior performance, minimizing the impact of increased link loss on overall throughput.