THE SURPRISING IMPACT OF 1% PACKET LOSS

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RESEARCHED BUT NOT QUANTIFIED PROBLEM

- Intricacies of TCP are well researched
- Packet loss has negative effect on flows
- Not something that we quantify often
- Network engineers tend to look past “small” levels of packet loss (say 1 or 2%)

VARIOUS METHODS TCP USES TO HANDLE PACKET LOSS

- Duplicate ACKs
- Timeouts
- Explicit Congestion Notifications (ECN)
- Selective Acknowledgements (SACK)
- Congestion Avoidance Algorithms

CUBIC: THE DEFAULT CONGESTION AVOIDANCE ALGORITHM

- Older congestion algorithms such as Reno and Tahoe slow at utilising available bandwidth
- Default congestion avoidance algorithm on all major operating systems

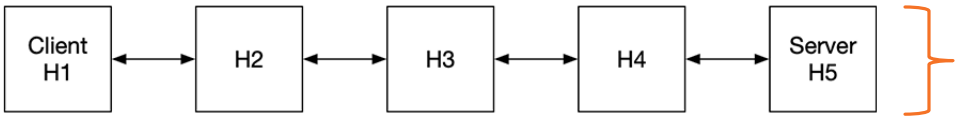
CUBIC: HOW IT WORKS?

- Congestion Window Adjustment
- Window Scaling
- TCP Timestamps
- Congestion Avoidance
- Packet Loss Reaction

TEST METHODOLOGY

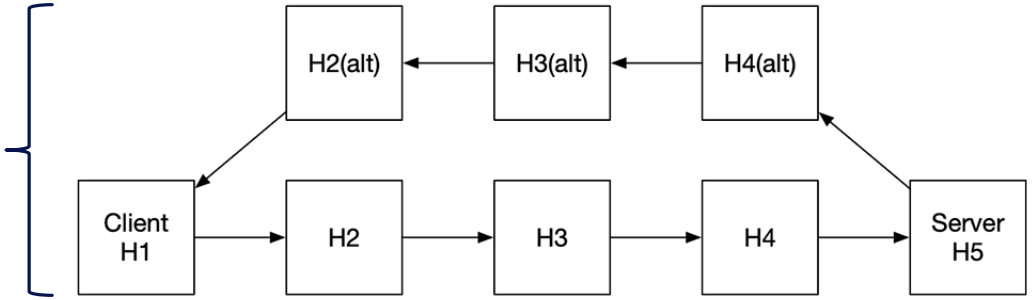
- Five Linux (Ubuntu 22.04) hosts configured to forward packets
- 1Gbps connectivity between devices
- Static routing
- Sub interfaces configured on hosts, required VLAN configuration on switch
- Measuring throughput using iperf3

SYMMETRIC AND ASYMMETRIC NETWORK PATHS



SYMMETRIC NETWORK

ASYMMETRIC NETWORK



ESTABLISHING A BASELINE (NO PACKET LOSS)

	Baseline (symmetric)
Mean	804.673506
STD	13.0217464
Min.	710
25%	799.99
50%	809.93
75%	810.046
Max.	830.419

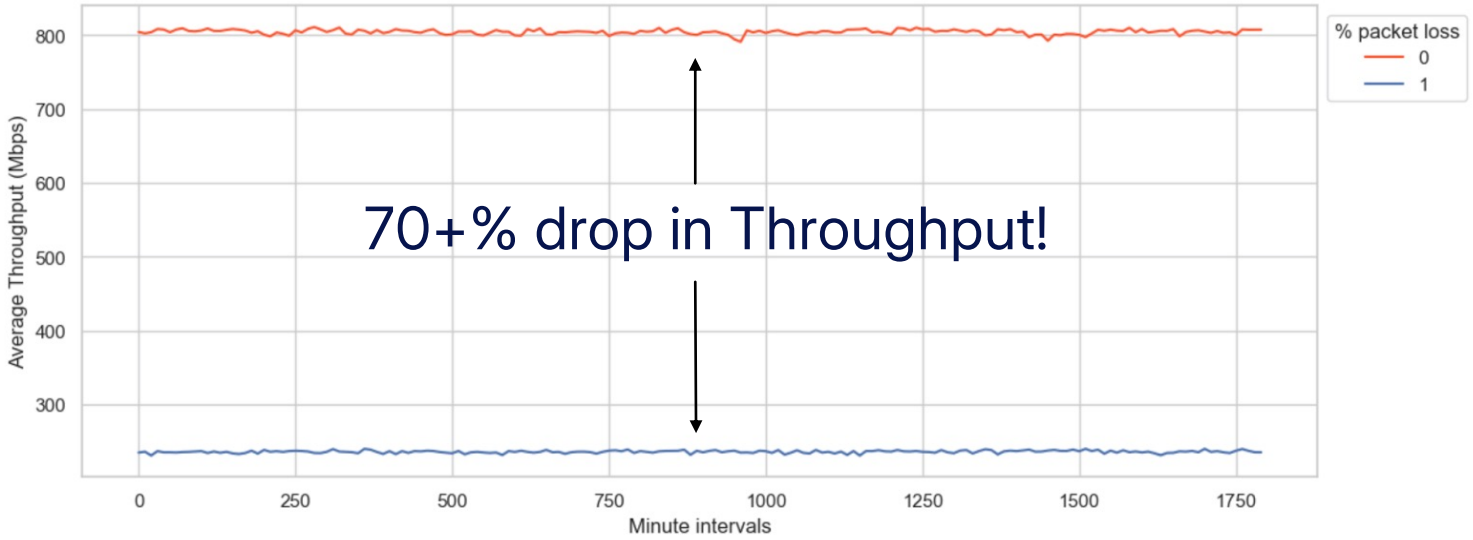
	Baseline (asymmetric)
Mean	864.139471
STD	14.647341
Min.	720.067
25%	859.973
50%	869.965
75%	870.3815
Max.	900.002

- **804.6 Mbps** and **865.13 Mbps** of Throughput for symmetric and asymmetric network, respectfully

INTRODUCING PACKET LOSS

- tc ("traffic control") utility
- tc has capabilities such as shaping, scheduling, policing, and dropping
- Enhancement called netem ("network emulation") that allows adding delay, packet loss, duplication, and other characteristics to packets outgoing from a specific network interface

THE CURIOUS CASE OF 1% PACKET LOSS



- 804.6 Mbps baseline, 235.5 Mbps at 1% loss in symmetric topology
- 864.13 Mbps baseline, 222.4 Mbps at 1% loss in asymmetric topology

THE CURIOUS CASE OF 1% PACKET LOSS

	1% (symmetric)
Mean	235.513105
STD	13.5692798
Min.	93.967
25%	229.667
50%	236.635
75%	243.596
Max.	281.886

	1% (asymmetric)
Mean	222.493196
STD	13.7883065
Min.	51.21
25%	214.788
50%	222.729
75%	230.675
Max.	280.877

1% of packet loss caused a **70.7%** decrease in throughput in symmetric network topology, while in asymmetric topology it resulted in **74.2%** decrease in throughput!

OVERALL RESULTS

SYMMETRIC NETWORK

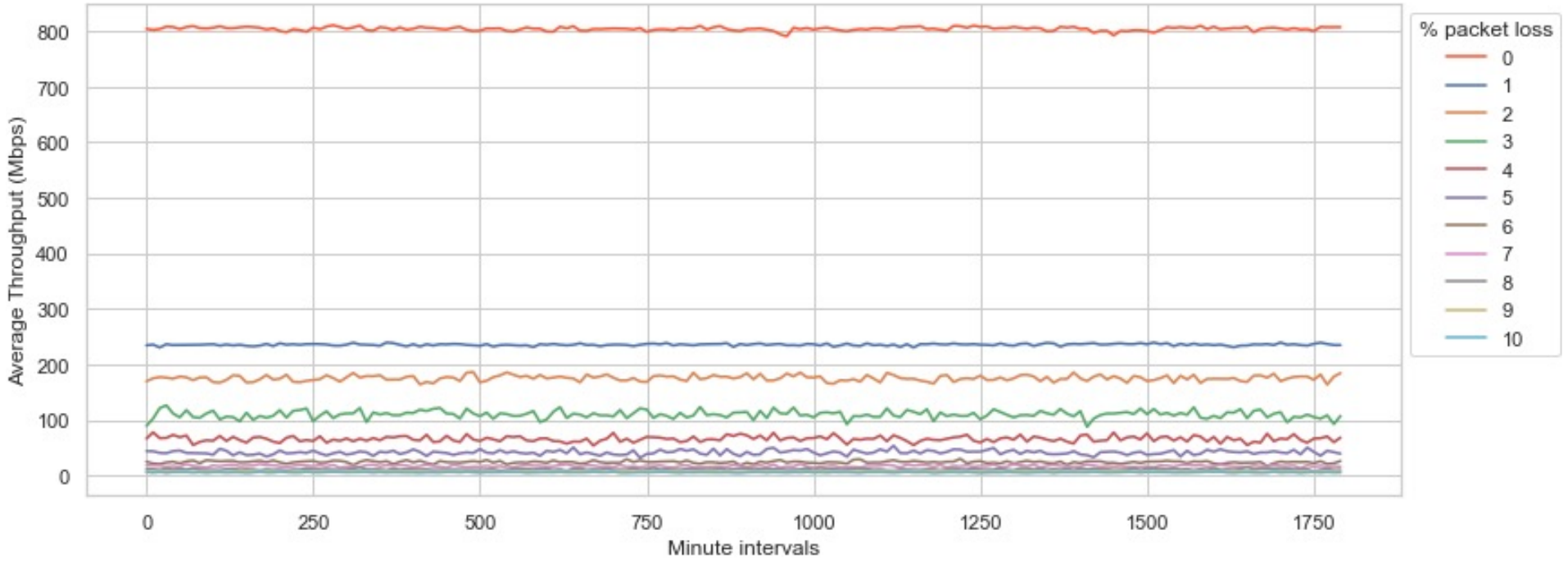
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Mean	235.51	175.19	109.76	65.68	41.37	23.95	16.75	11	7.52	5.29
STD	13.57	37.48	46.68	36.09	25.48	17.31	12.16	8.4	5.97	4.33
Min.	93.97	11.93	0	0	0	0	0	0	0	0
25%	229.67	158.09	74.56	37.77	21.38	9.94	6.96	4.97	2.98	1.99
50%	236.64	190.91	111.86	61.67	37.77	19.89	13.92	8.95	5.97	3.98
75%	243.6	199.86	150.14	89.53	57.18	33.81	23.37	15.41	9.95	6.96
Max.	281.89	223.72	201.33	175.49	149.62	119.3	87.5	68.59	46.76	37.78

ASYMMETRIC NETWORK

	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Mean	222.49	168.03	106.43	63.57	36.59	24.99	15.52	10.82	36.59	15.52
STD	13.79	34.91	44.62	34.81	24.44	16.93	11.58	8.26	24.44	11.58
Min.	51.21	5.97	0	0	0	0	0	0	0	0
25%	214.79	151.14	72.57	35.8	16.9	11.93	5.97	4.97	16.9	5.97
50%	222.73	182.45	108.35	59.66	31.84	21.87	11.94	8.95	31.84	11.94
75%	230.68	191.89	144.67	87	51.7	34.79	21.87	14.92	51.7	21.87
Max.	280.88	212.79	188.91	163.07	148.64	118.81	82.03	63.64	148.64	82.03

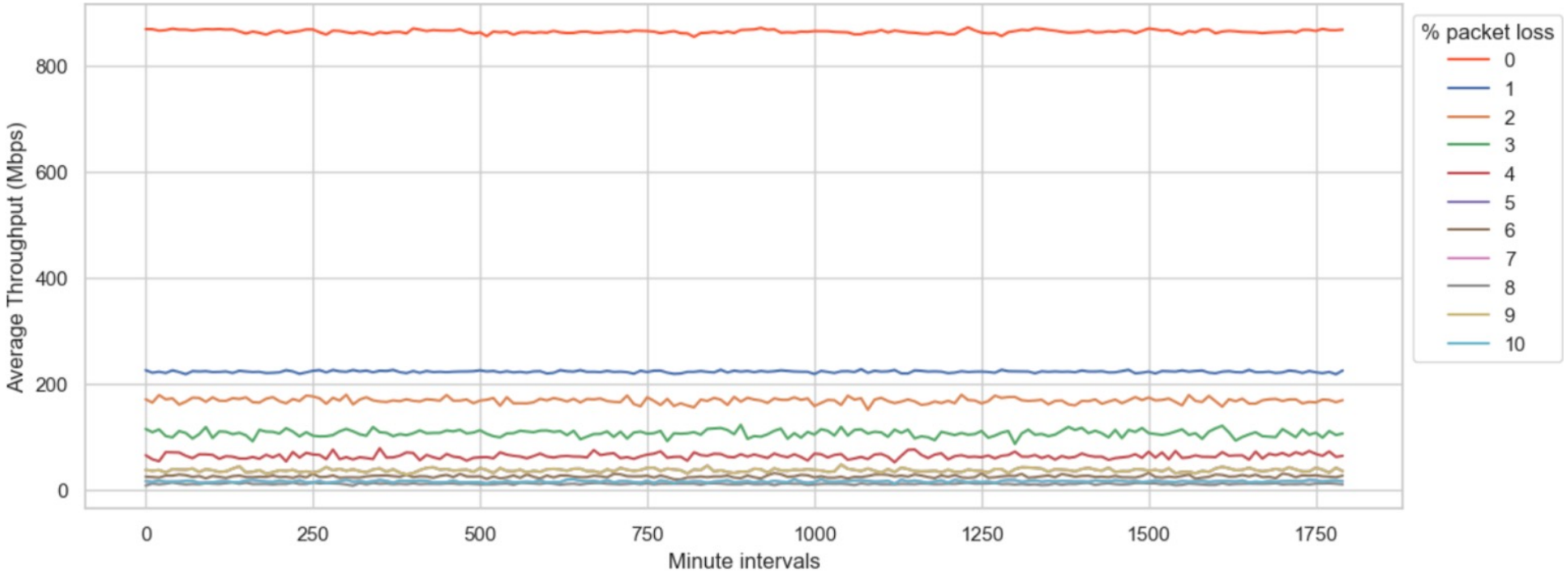
OVERALL RESULTS VISUALISED

SYMMETRIC NETWORK



OVERALL RESULTS VISUALISED

ASYMMETRIC NETWORK



BBR: THE FUTURE OF CONGESTION AVOIDANCE?

- BBR stands for Bottleneck Bandwidth and Round-Trip Time
- It is a congestion control algorithm developed by Google
- Designed to optimize network utilization and throughput by continuously probing for the available bandwidth and adjusting sending rate accordingly

BBR: HOW IT WORKS?

- Bandwidth estimation
- Round-Trip Time (RTT) Estimation
- Bottleneck Detection
- Congestion Window Management
- Low Latency Operation

KEY DIFFERENCES BETWEEN CUBIC AND BBR

- Congestion Window Adjustment
- Bandwidth Estimation
- Latency Optimization
- Implementation

ENABLING BBR

```
cat /proc/sys/net/ipv4/tcp_congestion_control
cubic
```

Verify

```
echo "net.core.default_qdisc=fq" >> /etc/sysctl.conf
echo "net.ipv4.tcp_congestion_control=bbr" >> /etc/sysctl.conf
sysctl -p
```

Enable

```
cat /proc/sys/net/ipv4/tcp_congestion_control
bbr
```

Verify

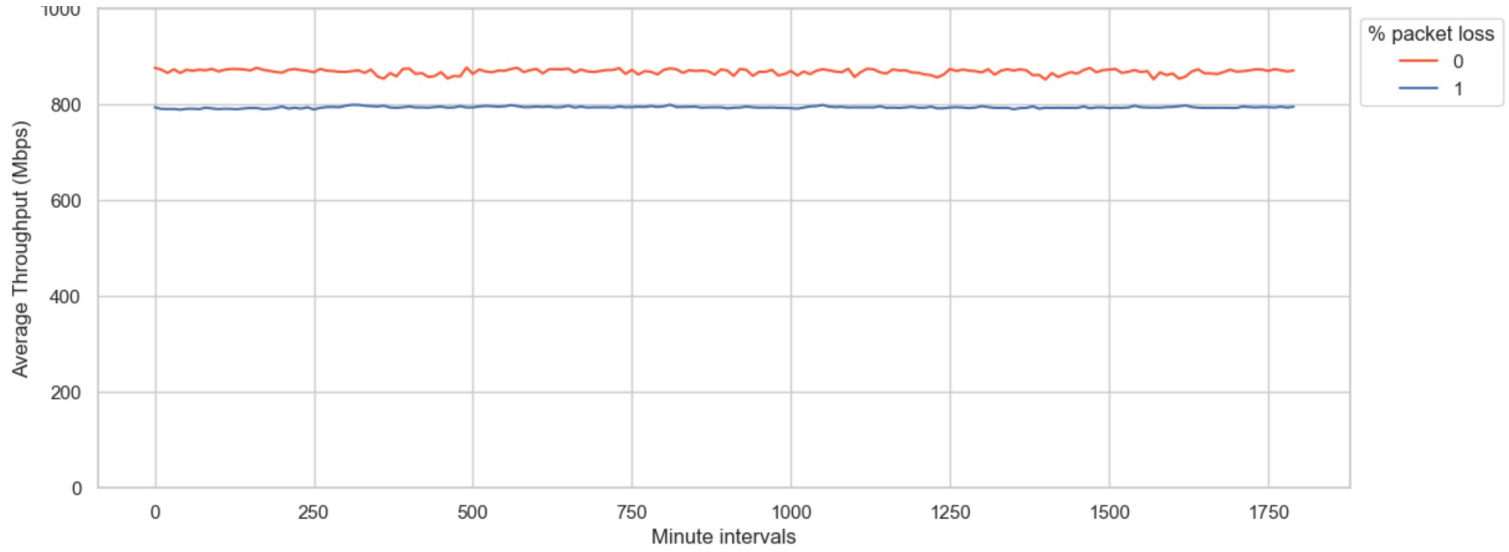
ESTABLISHING A BASELINE WITH BBR (NO PACKET LOSS)

	Baseline (symmetric)
Mean	868.50
STD	49.36
Min.	679.99
25%	860.15
50%	889.99
75%	890
Max.	900.31

	Baseline (asymmetric)
Mean	827.20
STD	46.06
Min.	639.99
25%	839.92
50%	840
75%	849.99
Max.	860.26

- **868.5 Mbps** and **827.20 Mbps** of Throughput for symmetric and asymmetric network, respectfully

MEASURING IMPACT OF 1% PACKET LOSS WHILE USING BBR



On average, **1%** of packet loss caused **8.5%** decrease in throughput while using BBR, stark difference to **70.7%** decrease using CUBIC!

MEASURING IMPACT OF 1% PACKET LOSS WHILE USING BBR

	1% (symmetric)
Mean	794.06
STD	44.08
Min.	489.99
25%	800.33
50%	809.99
75%	810.01
Max.	830.08

- **8.5%** throughput decrease using BBR
- **70.7%** throughput decrease using CUBIC

MEASURING IMPACT OF 1% PACKET LOSS WHILE USING BBR

	1% (asymmetric)
Mean	763.42
STD	44.28
Min.	519.96
25%	760
50%	779.99
75%	789.98
Max.	810.41

- **7.7%** throughput decrease using BBR
- **74.2%** throughput decrease using CUBIC

OVERALL RESULTS WITH BBR

SYMMETRIC NETWORK

	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Mean	794.06	791.65	768.94	775.34	773.7	787.71	784.07	644.04	761.61	751.89
STD	44.08	44.58	47.55	50.11	56.29	61.42	64.99	268.31	76.86	77.96
Min	490	370	140	280.05	209.86	0	130	0	0	0
25%	800.34	799.99	779.99	780.27	788.9	800	799.99	750.01	780	770
50%	810	809.93	780.02	790	790	800.92	800	769.99	780.03	770.8
75%	810.01	810	790	790.2	790.25	810	810	770.02	790	780
Max	830.09	830.76	810.53	831.33	820.09	831.26	830.07	800.09	810.07	800.2

ASYMMETRIC NETWORK

	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Mean	763.42	822.11	795.6	812.53	792.47	793.79	750.63	749.33	760.8	751.64
STD	44.28	46.83	48.91	53.64	57.29	62.64	63.99	68.44	73.83	81.68
Min	519.96	500	270	249.83	160	39.98	0	0	0	0
25%	760.01	830	800.02	820.01	800.33	809.6	760.01	760	779.98	770
50%	780	839.99	810	830	810	810	770	770	780.01	779.77
75%	789.99	840.01	819.98	830.07	811.09	819.98	770.05	770.03	790	780.01
Max	810.42	860.04	840.08	850.17	840	840	820	810.09	810.14	800.07

CONCLUSION

- Even the smallest amount of packet loss has extremely negative consequences on throughput
- CUBIC is, still, default congestion avoidance algorithm
- Packet loss outcomes significantly differ based on congestion avoidance algorithm used
- BBR shows significantly better results at any packet loss %
- Production readiness