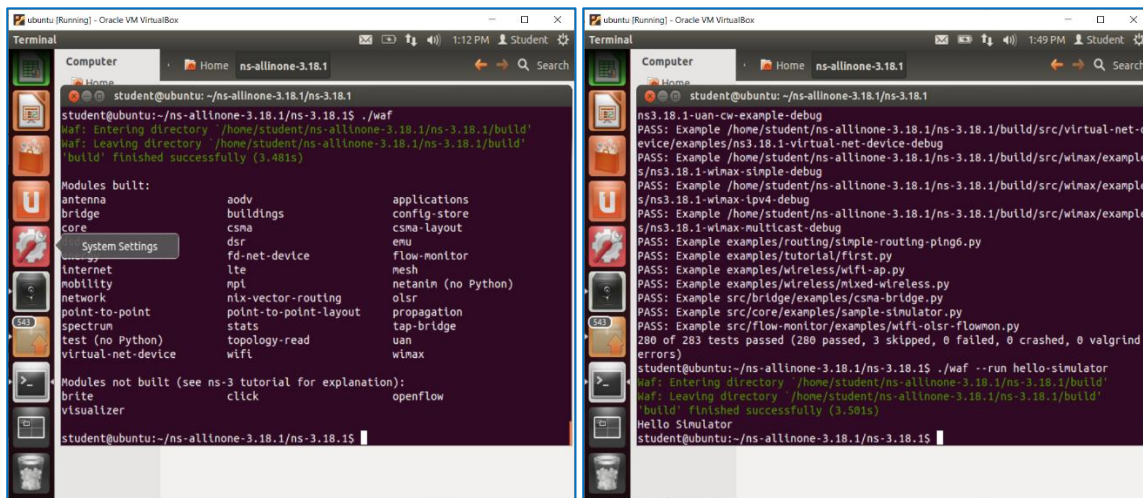
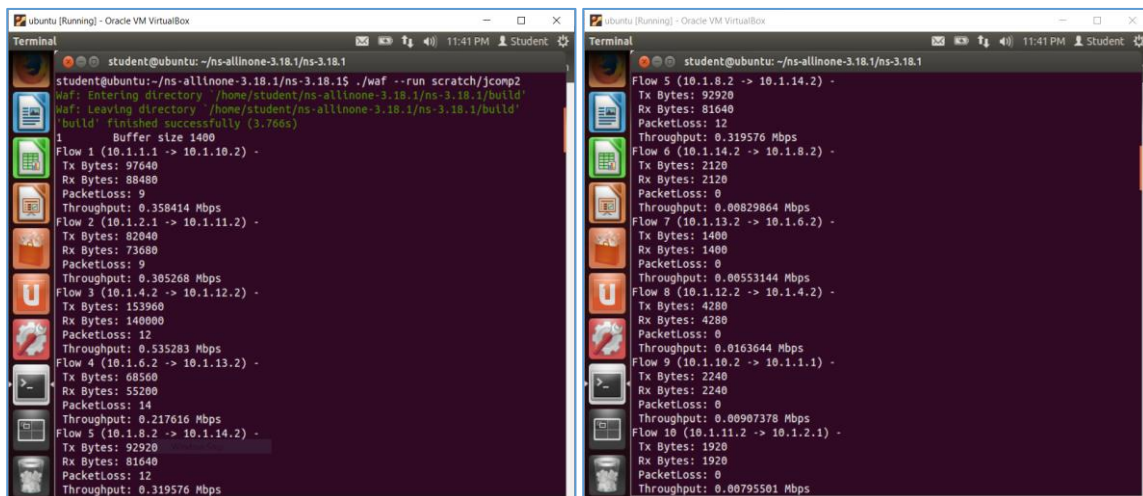


Result & Graphs

- In this project, we have successfully employed and analysed TCP Reno for congestion control. It is analysed that unlike TCP Tahoe, one of TCP's earliest variant, TCP Reno is not that aggressive in the reduction of the congestion window and takes precautions on the basis of the light or heavy congestion detected.
- Drop Tail and RED queuing mechanisms are compared and it is found that RED being a relatively random algorithm than Drop Tail which always drops packets at the end, RED performs better. This is because RED can control the average queue length, the congestion situation and hence provides higher throughput and lesser packet loss.
- **Installation of ns3**



- **DropTail mechanism (with 5 different Buffer size)**
- **Buffer Size = 1400**



- Buffer Size = 2800

```

student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
2 Buffer size 2800
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 145840
Rx Bytes: 134720
PacketLoss: 13
Throughput: 0.55783 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 40440
Rx Bytes: 33360
PacketLoss: 7
Throughput: 0.132322 Mbps
Flow 3 (10.1.4.2 -> 10.1.12.2) -
Tx Bytes: 191000
Rx Bytes: 178240
PacketLoss: 14
Throughput: 0.786679 Mbps
Flow 4 (10.1.6.2 -> 10.1.13.2) -
Tx Bytes: 532000
Rx Bytes: 529640
PacketLoss: 2
Throughput: 2.02275 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 67960
Rx Bytes: 57720
PacketLoss: 11
Throughput: 0.229411 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 1520
Rx Bytes: 1520
PacketLoss: 0
Throughput: 0

student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 67960
Rx Bytes: 57720
PacketLoss: 11
Throughput: 0.229411 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 1520
Rx Bytes: 1520
PacketLoss: 0
Throughput: 0.00605403 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 14520
Rx Bytes: 14520
PacketLoss: 0
Throughput: 0.0554535 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 4640
Rx Bytes: 4640
PacketLoss: 0
Throughput: 0.0184499 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 3840
Rx Bytes: 3840
PacketLoss: 0
Throughput: 0.0159001 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 920
Rx Bytes: 920
PacketLoss: 0
Throughput: 0.00364922 Mbps

```

- Buffer Size = 4200

```

student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
3 Buffer size 4200
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 542200
Rx Bytes: 528000
PacketLoss: 15
Throughput: 2.01762 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 464040
Rx Bytes: 449200
PacketLoss: 13
Throughput: 1.71385 Mbps
Flow 3 (10.1.4.2 -> 10.1.12.2) -
Tx Bytes: 316080
Rx Bytes: 306040
PacketLoss: 10
Throughput: 1.2991 Mbps
Flow 4 (10.1.6.2 -> 10.1.13.2) -
Tx Bytes: 338800
Rx Bytes: 326640
PacketLoss: 14
Throughput: 1.27518 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 377320
Rx Bytes: 363680
PacketLoss: 16
Throughput: 1.48725 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 9280
Rx Bytes: 9280
PacketLoss: 0
Throughput: 0

student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 377320
Rx Bytes: 363680
PacketLoss: 16
Throughput: 1.48725 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 9280
Rx Bytes: 9280
PacketLoss: 0
Throughput: 0.03795 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 7760
Rx Bytes: 7760
PacketLoss: 0
Throughput: 0.0303908 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 7840
Rx Bytes: 7840
PacketLoss: 0
Throughput: 0.0332797 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 14600
Rx Bytes: 14600
PacketLoss: 0
Throughput: 0.0557796 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 10120
Rx Bytes: 10120
PacketLoss: 0
Throughput: 0.0387128 Mbps

```

- Buffer Size = 5600

```

student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
4 Buffer size 5600
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 437480
Rx Bytes: 422800
PacketLoss: 15
Throughput: 1.61443 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 472440
Rx Bytes: 456320
PacketLoss: 13
Throughput: 1.74097 Mbps
Flow 3 (10.1.4.2 -> 10.1.12.2) -
Tx Bytes: 482280
Rx Bytes: 470880
PacketLoss: 14
Throughput: 1.79727 Mbps
Flow 4 (10.1.6.2 -> 10.1.13.2) -
Tx Bytes: 385400
Rx Bytes: 372040
PacketLoss: 14
Throughput: 1.5182 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 408680
Rx Bytes: 388200
PacketLoss: 22
Throughput: 1.51026 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 9440
Rx Bytes: 9440
PacketLoss: 0
Throughput: 0

student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 408680
Rx Bytes: 388200
PacketLoss: 22
Throughput: 1.51026 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 9440
Rx Bytes: 9440
PacketLoss: 0
Throughput: 0.0367256 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 8480
Rx Bytes: 8480
PacketLoss: 0
Throughput: 0.0346048 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 12040
Rx Bytes: 12040
PacketLoss: 0
Throughput: 0.0461277 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 9760
Rx Bytes: 9760
PacketLoss: 0
Throughput: 0.0372988 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 10040
Rx Bytes: 10040
PacketLoss: 0
Throughput: 0.0382486 Mbps

```

- Buffer Size = 7000

```

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
5 Buffer size 1400
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 485720
Rx Bytes: 478640
PacketLoss: 10
Throughput: 1.82963 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 451400
Rx Bytes: 443360
PacketLoss: 10
Throughput: 1.69187 Mbps
Flow 3 (10.1.4.2 -> 10.1.12.2) -
Tx Bytes: 481160
Rx Bytes: 407360
PacketLoss: 12
Throughput: 1.78812 Mbps
Flow 4 (10.1.6.2 -> 10.1.13.2) -
Tx Bytes: 536400
Rx Bytes: 523800
PacketLoss: 13
Throughput: 2.00045 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 308160
Rx Bytes: 291080
PacketLoss: 17
Throughput: 1.14973 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 6640
Rx Bytes: 6640
PacketLoss: 0

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
Tx Bytes: 308160
Rx Bytes: 291080
PacketLoss: 17
Throughput: 1.14973 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 6640
Rx Bytes: 6640
PacketLoss: 0
Throughput: 0.0262272 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 12520
Rx Bytes: 12520
PacketLoss: 0
Throughput: 0.0478153 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 11440
Rx Bytes: 11440
PacketLoss: 0
Throughput: 0.0437695 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 13760
Rx Bytes: 13760
PacketLoss: 0
Throughput: 0.0525983 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 11280
Rx Bytes: 11280
PacketLoss: 0
Throughput: 0.0431837 Mbps
student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1

```

- RED mechanism (with 5 different Buffer size)
- Buffer Size = 1400

```

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1$ ./waf --run scratch/jcomp2
waf: Entering directory '/home/student/ns-allinone-3.18.1/ns-3.18.1/build'
[ 773/2152] cxx: scratch/jcomp2.cc -> build/scratch/jcomp2.cc.2.o
[2122/2152] cxxprogram: build/scratch/jcomp2.cc.2.o -> build/scratch/jcomp2
waf: Leaving directory '/home/student/ns-allinone-3.18.1/ns-3.18.1/build'
'build' finished successfully (7.667s)
1 Buffer size 1400
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 529880
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95657 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 529200
Rx Bytes: 511000
PacketLoss: 1
Throughput: 1.95182 Mbps
Flow 3 (10.1.4.2 -> 10.1.12.2) -
Tx Bytes: 529880
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95808 Mbps
Flow 4 (10.1.6.2 -> 10.1.13.2) -
Tx Bytes: 459160
Rx Bytes: 440320
PacketLoss: 7
Throughput: 1.67985 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 530280
Rx Bytes: 513120

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 530280
Rx Bytes: 513120
PacketLoss: 2
Throughput: 1.95841 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 13840
Rx Bytes: 13840
PacketLoss: 0
Throughput: 0.052832 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 11480
Rx Bytes: 11480
PacketLoss: 0
Throughput: 0.0439352 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530698 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530289 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 13560
Rx Bytes: 13560
PacketLoss: 0
Throughput: 0.0518039 Mbps

```

- Buffer Size = 2800

```

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
2 Buffer size 2800
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 529880
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95657 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 529200
Rx Bytes: 511000
PacketLoss: 1
Throughput: 1.95182 Mbps
Flow 3 (10.1.4.2 -> 10.1.12.2) -
Tx Bytes: 529880
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95808 Mbps
Flow 4 (10.1.6.2 -> 10.1.13.2) -
Tx Bytes: 459160
Rx Bytes: 440320
PacketLoss: 7
Throughput: 1.67985 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 530280
Rx Bytes: 513120
PacketLoss: 2
Throughput: 1.95841 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 13840
Rx Bytes: 13840
PacketLoss: 0

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 530280
Rx Bytes: 513120
PacketLoss: 2
Throughput: 1.95841 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 13840
Rx Bytes: 13840
PacketLoss: 0
Throughput: 0.052832 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 11480
Rx Bytes: 11480
PacketLoss: 0
Throughput: 0.0439352 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530698 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530289 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 13560
Rx Bytes: 13560
PacketLoss: 0
Throughput: 0.0518039 Mbps

```


-
- The image displays two terminal windows from an Ubuntu VM, showing the output of a network simulation using ns-3.18.1. The left terminal window shows the first six flows, and the right terminal window shows flows five through ten. Each flow entry provides detailed statistics including the flow identifier, source and destination IP addresses, transmitted and received bytes, packet loss percentage, and throughput in Mbps.
- | Flow ID | Source IP | Destination IP | Tx Bytes | Rx Bytes | Packet Loss | Throughput (Mbps) |
|---------|-----------|----------------|----------|----------|-------------|-------------------|
| Flow 1 | 10.1.1.1 | 10.1.10.2 | 529880 | 512120 | 0 | 1.95657 |
| Flow 2 | 10.1.2.1 | 10.1.11.2 | 529200 | 511000 | 1 | 1.95182 |
| Flow 3 | 10.1.4.2 | 10.1.12.2 | 529880 | 512120 | 0 | 1.95808 |
| Flow 4 | 10.1.6.2 | 10.1.13.2 | 459160 | 440320 | 7 | 1.67985 |
| Flow 5 | 10.1.8.2 | 10.1.14.2 | 530280 | 513120 | 2 | 1.95841 |
| Flow 6 | 10.1.14.2 | 10.1.8.2 | 13840 | 13840 | 0 | 0.052832 |
| Flow 7 | 10.1.13.2 | 10.1.6.2 | 11480 | 11480 | 0 | 0.0439352 |
| Flow 8 | 10.1.12.2 | 10.1.4.2 | 13880 | 13880 | 0 | 0.0530698 |
| Flow 9 | 10.1.10.2 | 10.1.1.1 | 13880 | 13880 | 0 | 0.0530289 |
| Flow 10 | 10.1.11.2 | 10.1.2.1 | 13560 | 13560 | 0 | 0.0518039 |

-
- The image displays two terminal windows from an Ubuntu VM, showing network traffic statistics for various flows. The left window shows statistics for flows 1 through 6, and the right window shows statistics for flows 5 through 10. Each flow entry includes the flow ID, source and destination IP addresses, Tx and Rx bytes, packet loss percentage, and throughput in Mbps.
- Left Terminal Window:**
- ```

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
4 Buffer size 5600
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 529080
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95657 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 529200
Rx Bytes: 511000
PacketLoss: 1
Throughput: 1.95182 Mbps
Flow 3 (10.1.4.2 -> 10.1.12.2) -
Tx Bytes: 529080
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95182 Mbps
Flow 4 (10.1.10.2 -> 10.1.13.2) -
Tx Bytes: 459160
Rx Bytes: 440320
PacketLoss: 7
Throughput: 1.67985 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 530280
Rx Bytes: 513120
PacketLoss: 2
Throughput: 1.95841 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 13840
Rx Bytes: 13840
PacketLoss: 0

```
- Right Terminal Window:**
- ```

student@ubuntu:~/ns-allinone-3.18.1/ns-3.18.1
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 530280
Rx Bytes: 513120
PacketLoss: 2
Throughput: 1.95841 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 13840
Rx Bytes: 13840
PacketLoss: 0
Throughput: 0.052832 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 11480
Rx Bytes: 11480
PacketLoss: 0
Throughput: 0.0439352 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530698 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530289 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 13560
Rx Bytes: 13560
PacketLoss: 0
Throughput: 0.0518039 Mbps

```

- The image displays two terminal windows from an Ubuntu VM, showing the output of a network analysis tool. The left terminal shows a summary of flows, and the right terminal shows a detailed breakdown of individual flows.

Left Terminal Output:

```

student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
$
Flow 1 (10.1.1.1 -> 10.1.10.2) -
Tx Bytes: 529880
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95657 Mbps
Flow 2 (10.1.2.1 -> 10.1.11.2) -
Tx Bytes: 529200
Rx Bytes: 511000
PacketLoss: 1
Throughput: 1.95182 Mbps
Flow 3 (10.1.1.4.2 -> 10.1.11.2) -
Tx Bytes: 529880
Rx Bytes: 512120
PacketLoss: 0
Throughput: 1.95808 Mbps
Flow 4 (10.1.1.4.2 -> 10.1.13.2) -
Tx Bytes: 459160
Throughput: 1.67985 Mbps
Flow 5 (10.1.8.2 -> 10.1.14.2) -
Tx Bytes: 530280
Rx Bytes: 513120
PacketLoss: 2
Throughput: 1.95841 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 13840
Rx Bytes: 13840
PacketLoss: 0

```

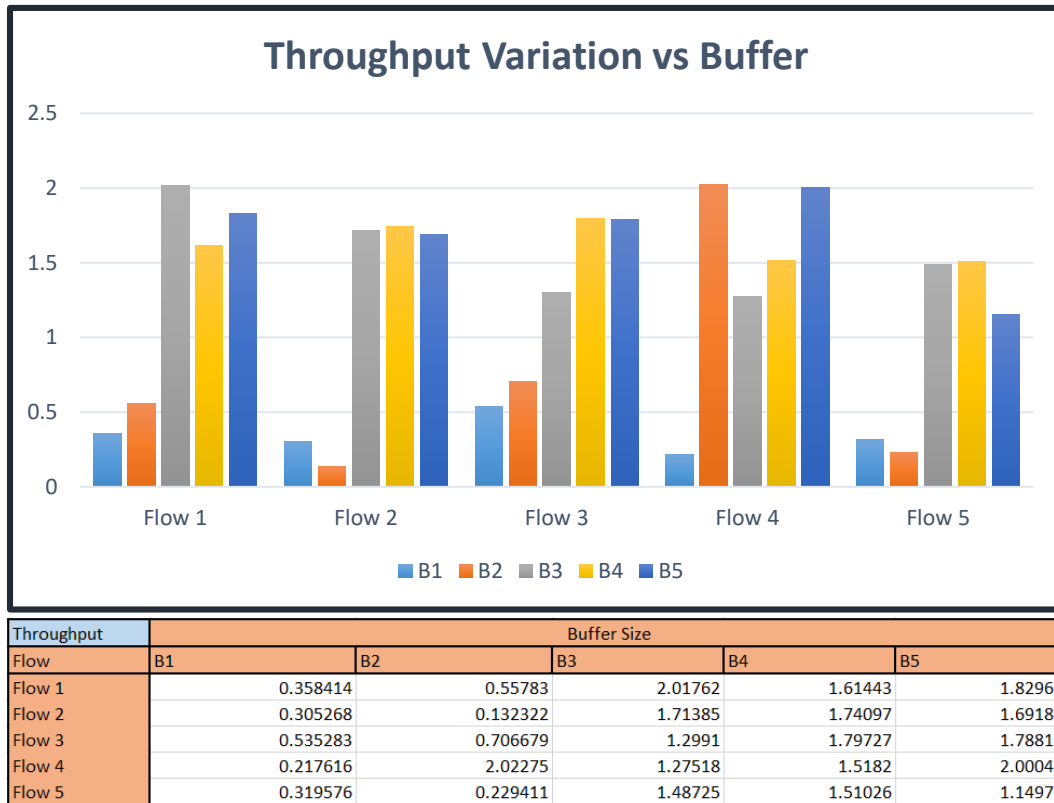
Right Terminal Output:

```

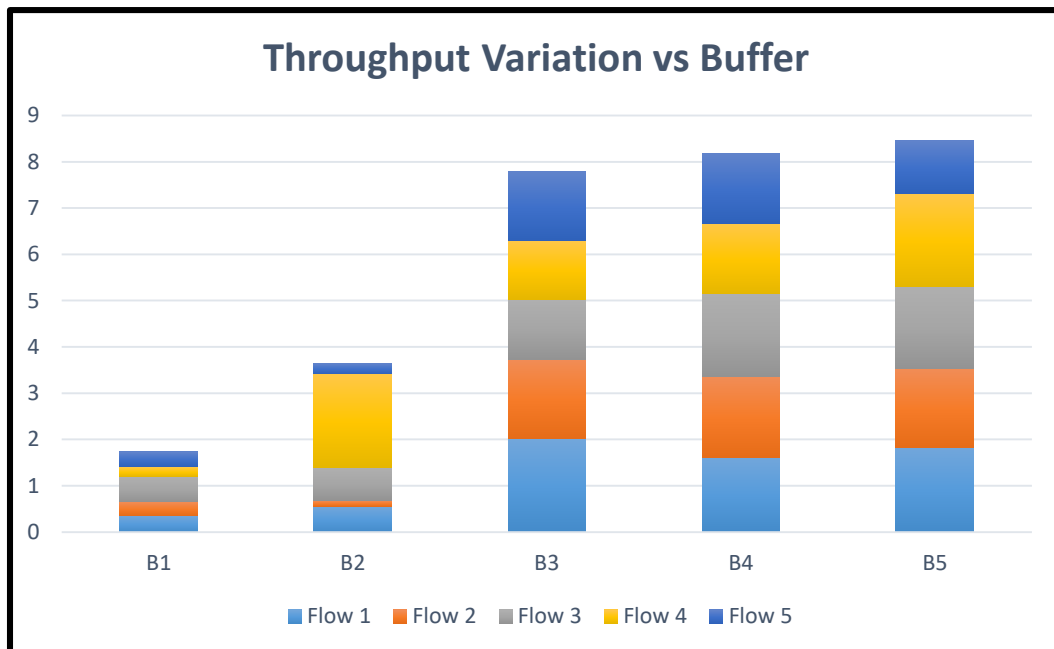
student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1
Tx Bytes: 530280
Rx Bytes: 513120
PacketLoss: 2
Throughput: 1.95841 Mbps
Flow 6 (10.1.14.2 -> 10.1.8.2) -
Tx Bytes: 13840
Rx Bytes: 13840
PacketLoss: 0
Throughput: 0.052832 Mbps
Flow 7 (10.1.13.2 -> 10.1.6.2) -
Tx Bytes: 11480
Rx Bytes: 11480
PacketLoss: 0
Throughput: 0.0439352 Mbps
Flow 8 (10.1.12.2 -> 10.1.4.2) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530698 Mbps
Flow 9 (10.1.10.2 -> 10.1.1.1) -
Tx Bytes: 13880
Rx Bytes: 13880
PacketLoss: 0
Throughput: 0.0530289 Mbps
Flow 10 (10.1.11.2 -> 10.1.2.1) -
Tx Bytes: 13560
Rx Bytes: 13560
PacketLoss: 0
Throughput: 0.0518039 Mbps
student@ubuntu: ~/ns-allinone-3.18.1/ns-3.18.1

```

- **Flow-wise Throughput vs Buffer Size for Drop Tail**



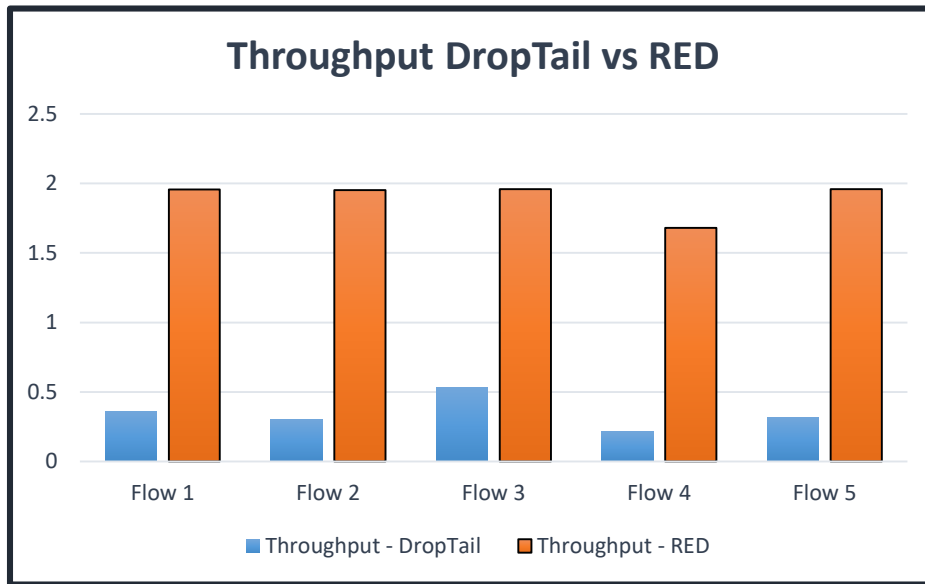
- **Throughput vs Buffer Size for Drop Tail**



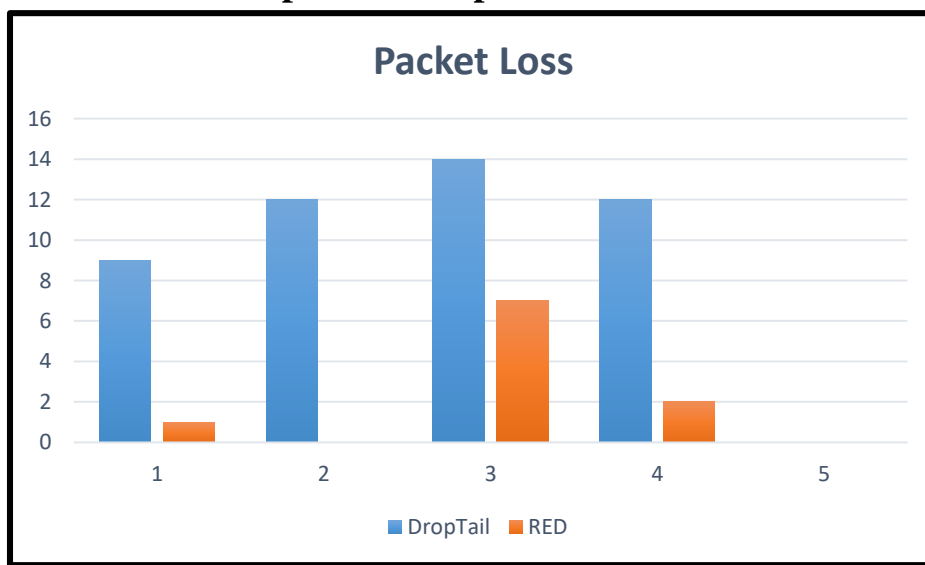
where B1=1400, B2=2800, B3=4200, B4=5600, B5=7000

- **Throughput Comparison Drop Tail vs RED**

Buffer Size - 1400		
Flow	Throughput - DropTail	Throughput - RED
Flow 1	0.358414	1.95657
Flow 2	0.305268	1.95182
Flow 3	0.535283	1.95808
Flow 4	0.217616	1.67985
Flow 5	0.319576	1.95841

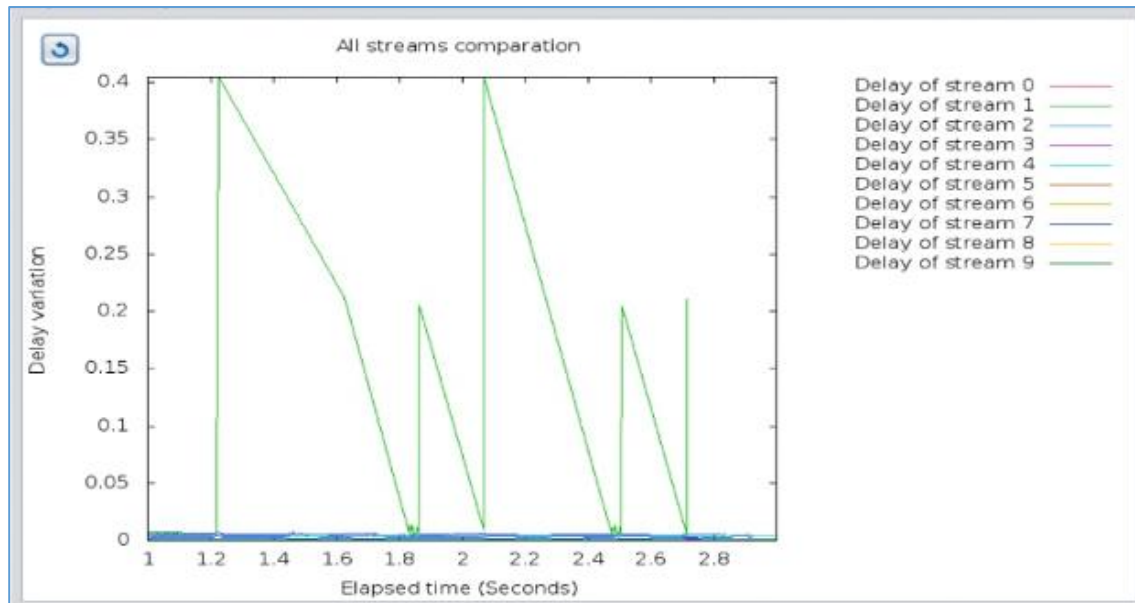


- **Packet Loss Comparison Drop Tail vs RED**



- Delay Variation Drop Tail vs RED

Using trace metrics for buffer size = 2800 (Drop Tail)



Using trace metrics for buffer size = 2800 (RED)

