ASSIGNMENT-4
Application-4
Network Simulation using ns3
Group-10

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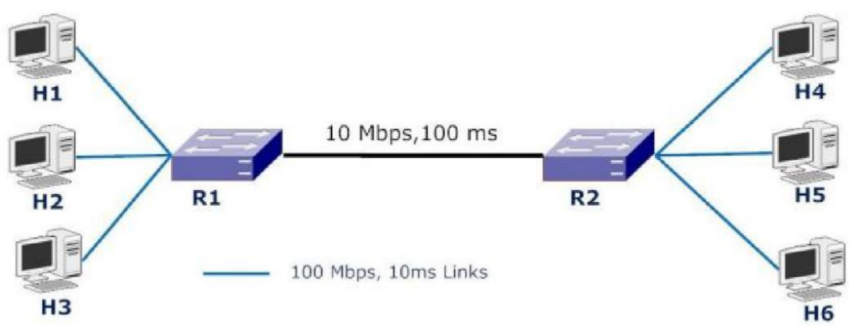
Network Configuration



Dumbbell topology with two routers R1 and R2 connected by a (10 Mbps, 100 ms) link.

- Two routers R1 and R2 connected via (10 Mbps, 100ms) link
- Three hosts connected to each router via a (100 Mbps, 10 ms) link
- R1 and R2 use drop-tail queues with equal queue size set according to bandwidth delay product
- The packet size is taken to be 1.5 KB

We created 6 connections (4 TCP and 2 UDP) so that these connections cover all the possible given hosts to us.

TCP Reno-Flows:

(1) H2 to H1
(2) H3 to H6
(3) H4 to H6
(4) H5 to H2

CBR over UDP Flows:

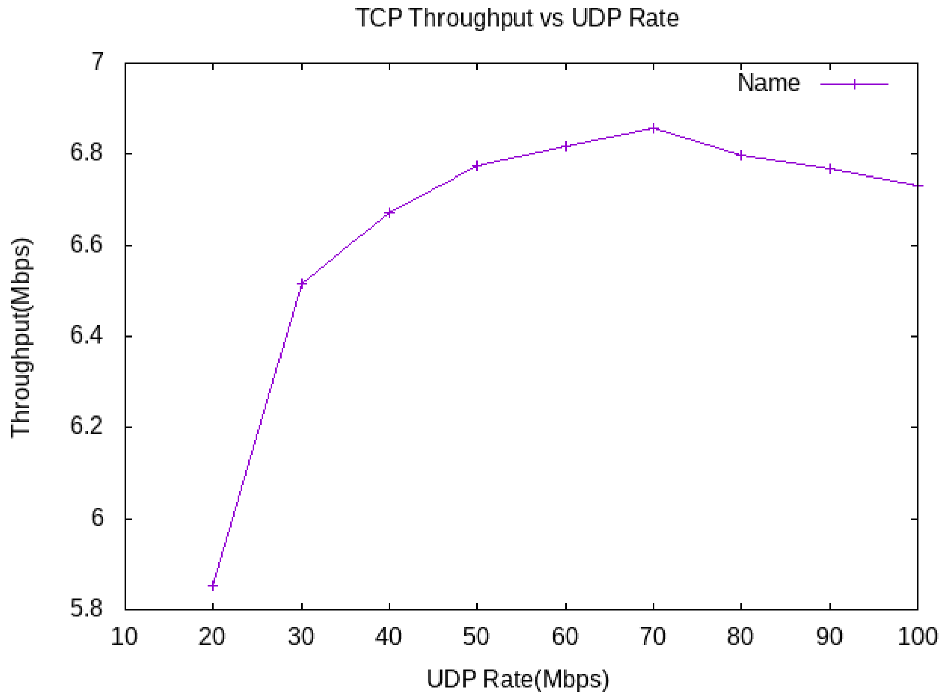
(1) H3 to H4
(2) H3 to H1

FIRST PART:

All the given connections have an initial rate of 20 Mbps. Keeping the buffer size constant, the rate of second UDP-flow is increased from 20 Mbps to 100 Mbps in steps of 10. The TCP throughput is calculated for this variation and a graph of it is plotted. The graph comes out as follows:

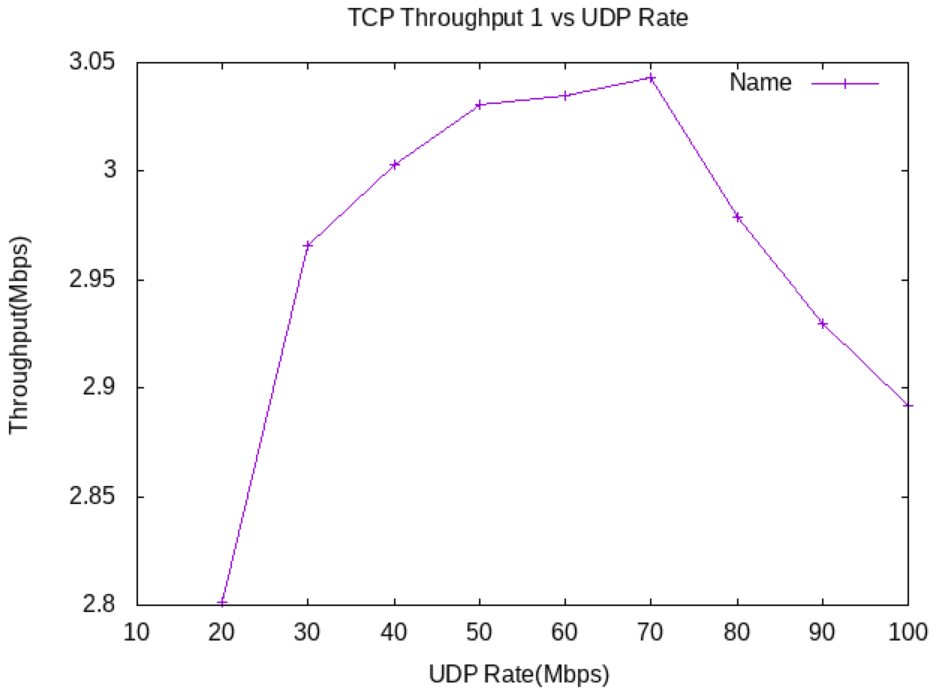
GRAPH OF OVERALL TCP THROUGHPUT WITH UDP-2 RATE:

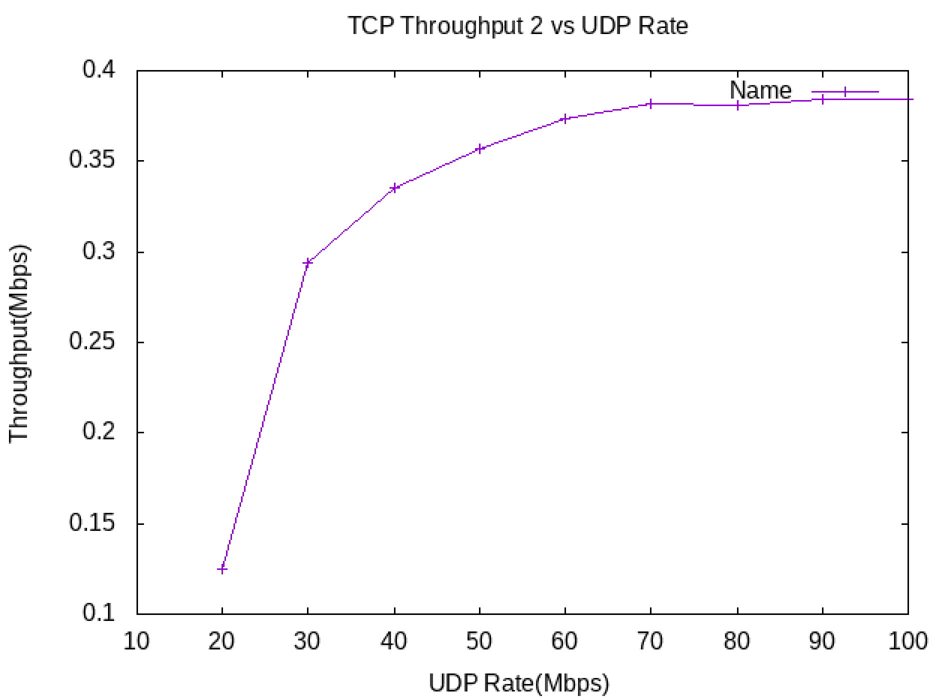
UDP rate	TCP throughput
20	5.85223
30	6.5165
40	6.67087
50	6.77426
60	6.81674
70	6.85783
80	6.79928

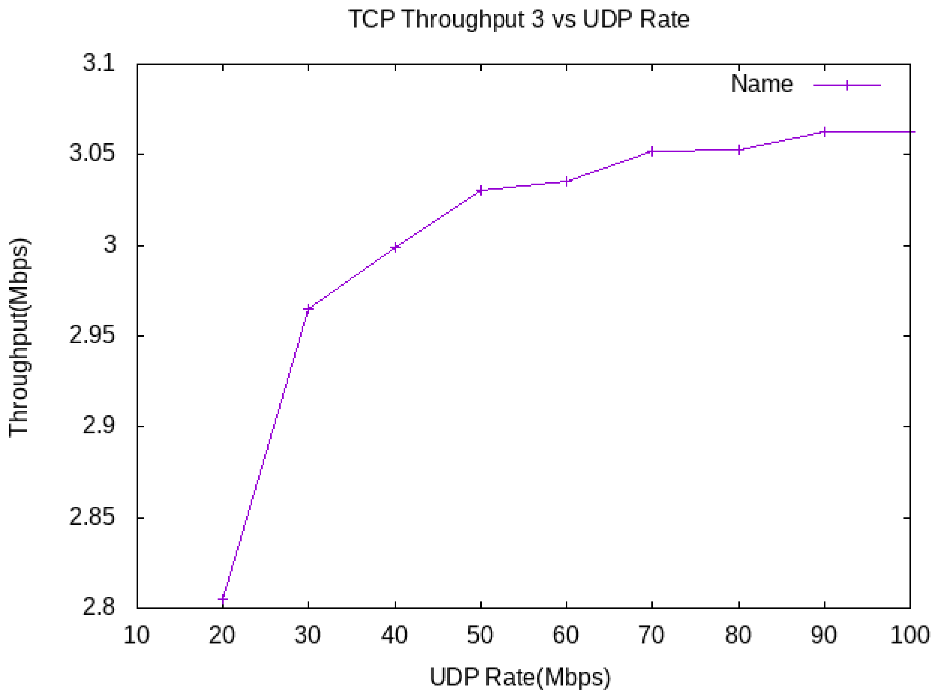


The above graph illustrates the effect of increasing UDP rate of Flow on the throughput of the TCP connections. Initially , TCP throughput increases very rapidly. However , with increasing UDP rate, the shared links gets more congested with UDP traffic ,thereby slowing down the rate at which TCP throughput was changing. Hence as we change the UDP rate linearly from 20 Mbps to 100 Mbps, the rate of TCP throughput increment decreases. Further, after reaching a peak value, TCP throughput is found to saturate and (may) decrease a bit because of the increasing interference of UDP connection flow in the links.

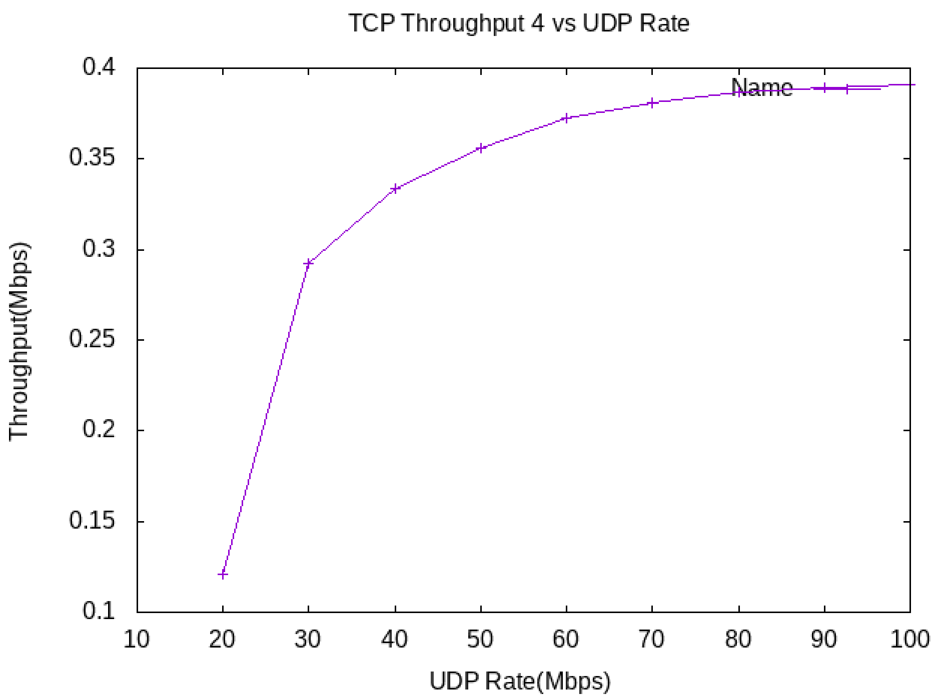
A similar nature is obtained for the variation of the individual TCP connection throughputs with UDP-2 rate. The required 4 curves are as follows:


TCP Throughput 1 vs UDP Rate
3.05
3
2.95
2.9
2.85
2.8
10
20
30
40
50
60
70
80
90
100
Throughput(Mbps)
UDP Rate(Mbps)
Name


TCP Throughput 2 vs UDP Rate
0.4
0.35
0.3
0.25
0.2
0.15
0.1
10
20
30
40
50
60
70
80
90
100
Throughput(Mbps)
UDP Rate(Mbps)
Name



TCP Throughput 3 vs UDP Rate
Name
Throughput(Mbps)
3.1
3.05
3
2.95
2.9
2.85
2.8
10
20
30
40
50
60
70
80
90
100
UDP Rate(Mbps)



TCP Throughput 4 vs UDP Rate
Name
Throughput(Mbps)
0.4
0.35
0.3
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20
30
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50
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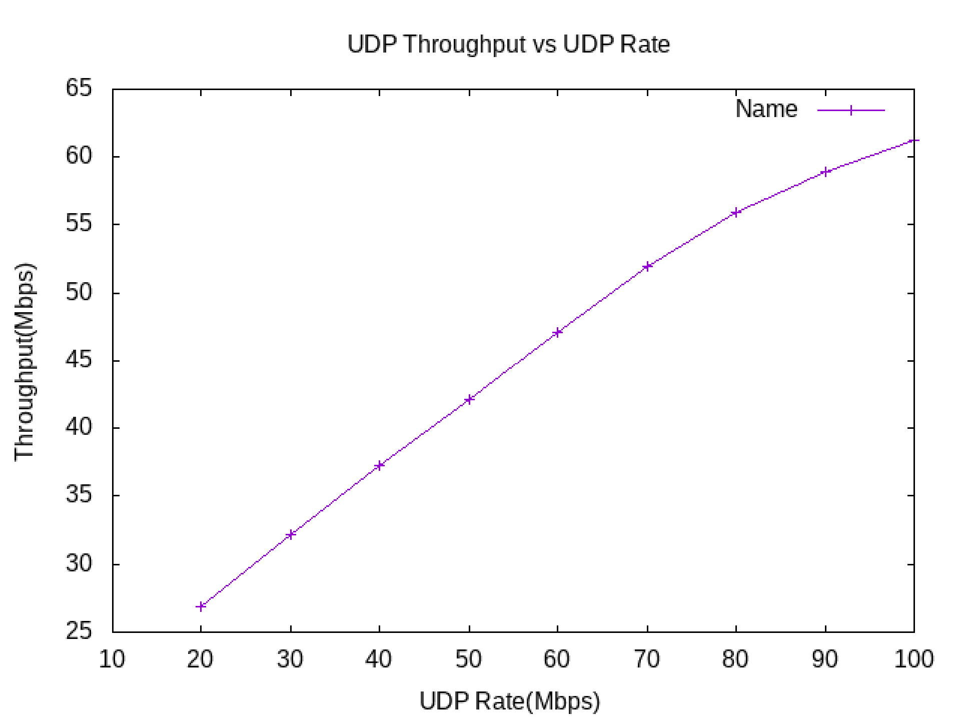
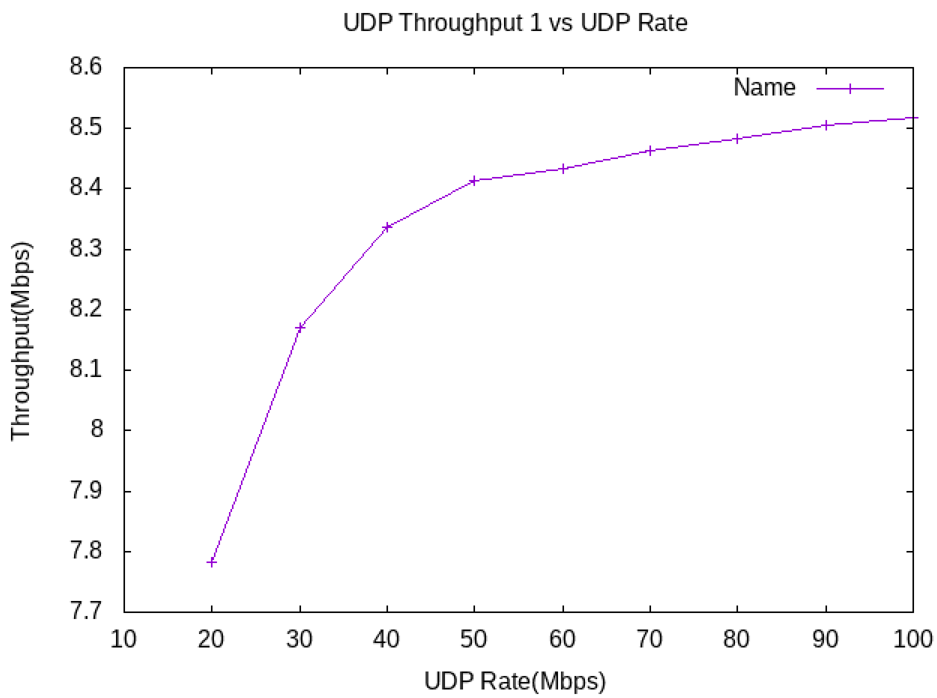
100
UDP Rate(Mbps)

VARIATION OF OVERALL UDP THROUGHPUT WITH UDP-2 RATE:



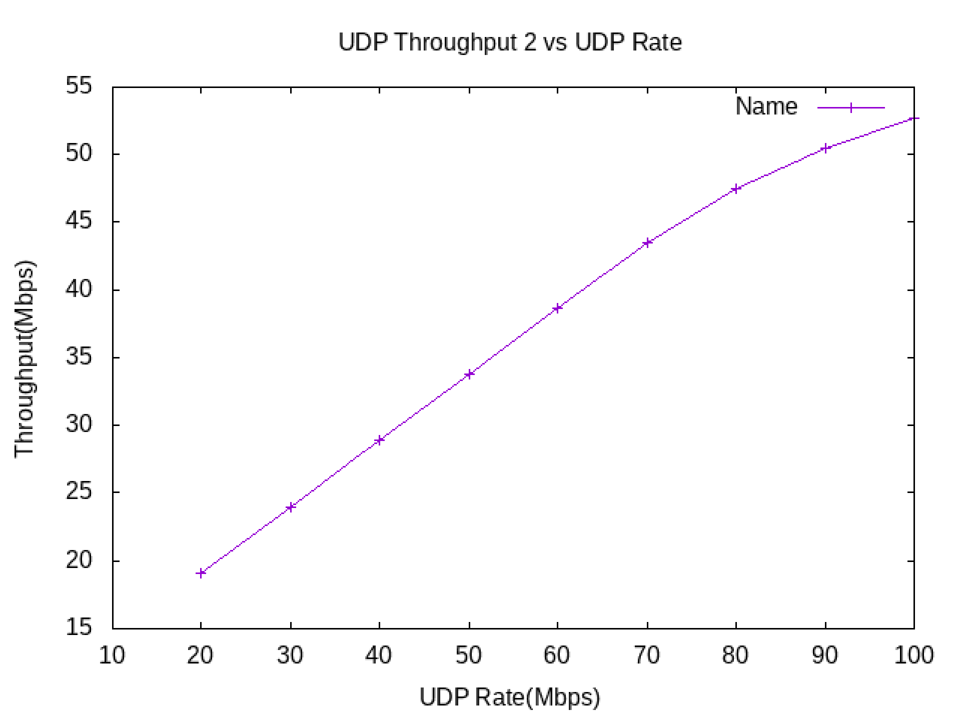
The above graph depicts the plot of overall UDP throughput change with increasing UDP rate of the second UDP flow. The overall UDP throughput is a measure of both the UDP connections taken combined, and hence if we linearly increase the rate of one of the UDP flows it is going to have a direct proportional impact on the overall UDP throughput as well. This is because more UDP packets are propagated per unit time.

VARIATION OF UDP-1 THROUGHPUT WITH UDP-2 RATE:



The above graph is a plot of how throughput of the first UDP connection changes with increasing rate of second UDP connection. As the shared links are getting occupied more and more by the UDP packets of the second UDP Connection, we can see that the rate of increase of UDP Connection-1 Throughput declines. Because of the aforementioned factor, even though a first UDP connection's throughput is increasing, its rate of increment is decreasing.

VARIATION OF UDP-2 THROUGHPUT WITH UDP-2 RATE:

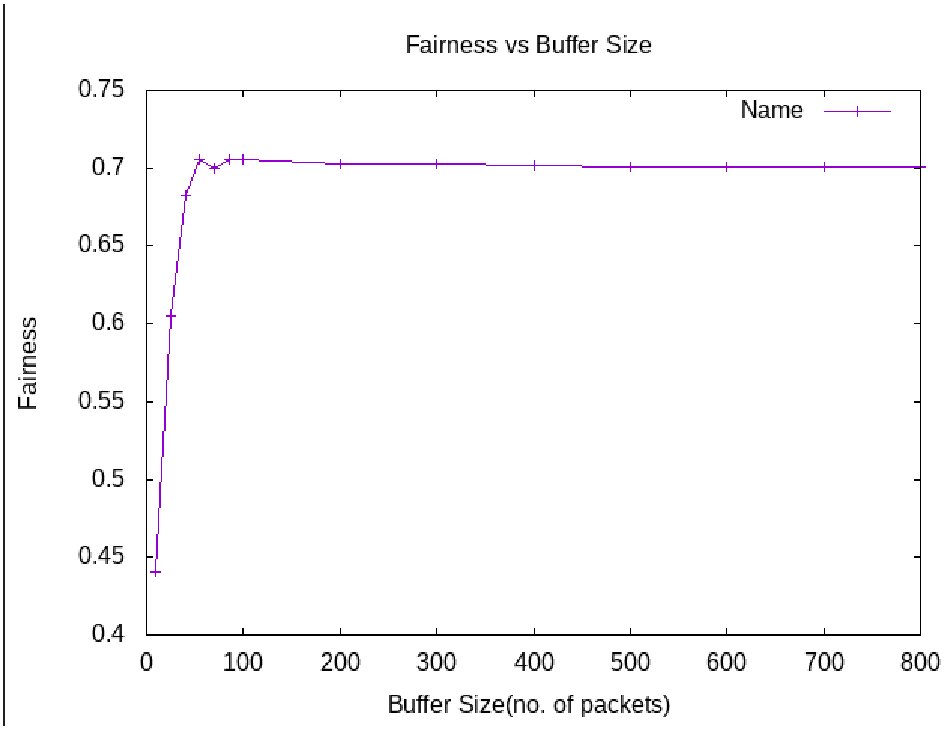


The above graph is a plot of how throughput of the second UDP connection changes with increasing rate of second UDP connection. There is a linear correlation between UDP Connection-2 Throughput and UDP Connection-2 Rate. Because , if we increase UDP rate for a particular connection, the number of UDP packets propagating from that particular connection increases , which has a direct impact on the throughput of that particular connection.

SECOND PART:

In this part of the assignment, we vary the buffer size. Initially buffer size is varied linearly from 10 packets to 100 packets at intervals of 15 packets. From 100 packets onwards, the interval of linear variation changes to 100 packets. In this way, we further increase the size from 100 packets till 800 packets.

VARIATION OF FAIRNESS INDEX VS BUFFER SIZE:

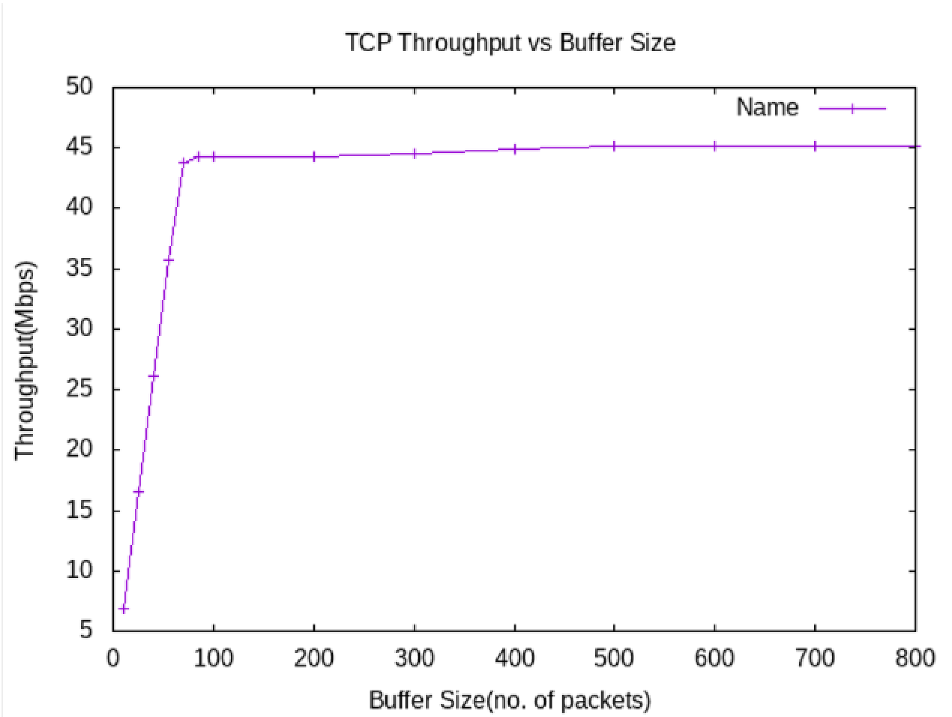


Fairness index is a measure of how equally is the overall bandwidth distributed across all 6 connections.

$$\text{Fairness Index} = \left(\sum_{1}^{6} Tput\right)^{2} \div 6 * \sum_{1}^{6} Tput^{2}$$

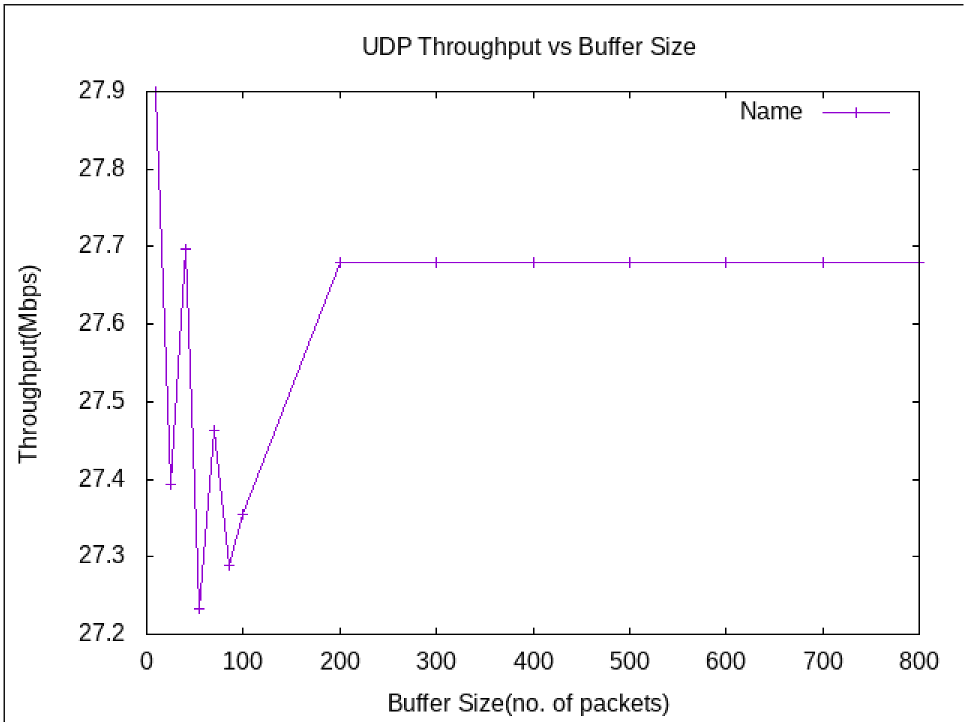
On increasing the buffer size, the fairness index increases, which indicates that the share of bandwidth is increasingly fair among the 6 connections with increase in buffer size. Note that in an ideal case, an index of 1 symbolizes that all connections have equal distribution in overall bandwidth. But we have already observed that the throughput of each connection is upper bounded by its corresponding link bandwidth. Hence, the fairness index is expected to saturate to a value after some time of increment of buffer size. The same is seen in the above curve. Beyond the saturation point, increment in buffer size has no effect on the fairness index.

VARIATION OF TCP THROUGHPUT WITH BUFFER SIZE:



Above graph illustrates the variation of combined TCP throughput (of Connections 1,2,3,4) with increasing buffer size. As we increase the buffer size the throughput has increased up to a limit and then reached saturation. Because, when buffer size is small, too many packets compete for the waiting-queue(congestion). Due to this congestion, many packets might get dropped or face unnecessary delays. Hence there is low throughput. When buffer size is increased, the congestion in the link decreases and hence both packet loss rate and queuing delays decrease. Hence the throughput increases. The saturation occurs because of the upper bound of link bandwidth. The variation above doesn't see any major external interference because TCP has a link-congestion mechanism and is a connection-oriented protocol.

VARIATION OF UDP THROUGHPUT WITH BUFFER SIZE:



With increasing buffer size, the UDP flow throughput (UDP1 + UDP2) is found to decrease as a general trend (though there are some anomalies). After some decrement, the UDP throughput is reaching a saturation level after which the increase the buffer size has no effect on the UDP throughput. This behavior is majorly due to the connectionless nature of UDP and no congestion control mechanisms unlike TCP. Since the TCP throughput is increasing with increase in buffer size, network traffic will increase which will also be a factor in decrease of rate initially in case of UDP.