CS 349 – Assignment 4
Application - 1

Group Number- 43
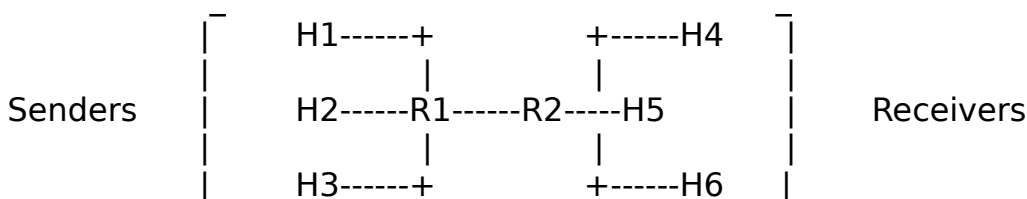Sakshi Sharma - 170123044
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Details of the application:
Analyses and compares TCP Hybla, TCP Westwood+, and TCP YeAH-TCP performance.
Selecting a Dumbbell topology with two routers R1 and R2 connected by a (10 Mbps, 50 ms) wired link. Each of the routers is connected to 3 hosts, i.e. H1, H2, H3 (i.e. senders) are connected to R1, and H4, H5, H6 (i.e. receivers) are connected to R2. The hosts are attached with (100 Mbps, 20 ms) links. Both the routers use drop-tail queues with queue size set according to bandwidth-delay product. Senders (i.e. H1, H2 and H3) are attached with TCP Hybla, TCP Westwood+, and TCP YeAH-TCP agents, respectively.

Implementation detail:

```
        _                                _
       |      H1------+        +------H4   |
       |              |        |           |
Senders|      H2------R1------R2-----H5    |    Receivers
       |              |        |           |
       |_     H3------+        +------H6   _|
```

Dumbbell topology is used with
Senders (left side of dumbbell) : H1, H2, H3
Receivers (right side of dumbbell) : H4, H5, H6
and Routers R1 and R2 form the bridge of dumbbell.
H1--H4 -> TCP Hybla
H2--H5 -> TCP Westwood+
H3--H6 -> TCP Yeah

Details about the links:
Hi---Rj= P2P (100 Mbps, 20ms) i=1,2...,6 j=1,2
R1---R2= P2P (10 Mbps, 50ms)
Bandwidth Delay Product (BDP)= number of bits that can fill up a network link
= Bandwidth * Delay
BDP for HiRj = 100 Mbps * 20 ms = 2000000 bits
BDP for R1R2 = 10 Mbps * 50 ms = 500000 bits
Packet size= 1.5 KB
Number of packets = Queue size= Bandwidth Delay Product / Packet size

We used ns-3 3.30.1 flow monitor module to collect and store performance data from the simulation.
We used gnuplot to plot all the graphs, using data stored while simulation.

Providing drive link for simulation output data due to size limitations on Moodle:
https://drive.google.com/drive/folders/1tApJgcXVTrLp1SUJ-2Fo3WAeJ2q_IRco?usp=sharing

PART A:

Includes part 1 and 3 of the question given in assignment:
Started only one flow and analysed the throughput over sufficiently long duration.Mentioned how we selected the duration. Plotted the evolution of congestion window w.r.t. time. Performed this experiment with all the flows attached to all the three sending agents.
Also measured the congestion loss and the goodput over the duration of the experiment for each of the flows.

Plots and observations:
The observations were taken until there was no appreciable difference noted in the pattern of the output of a flow and at time greater than the stable output observation we set the starting time of the next flow . Once the outputs had monotonised or fallen into a repetitive pattern, we stopped recording observations.

TCP Hybla

** TCP Hybla Flow **
Flow ID :1
Maximum throughput: 3716.48
Source IP: 15.1.0.1 -> Destination IP: 15.2.0.1
Total number of packets transmitted: 10000000
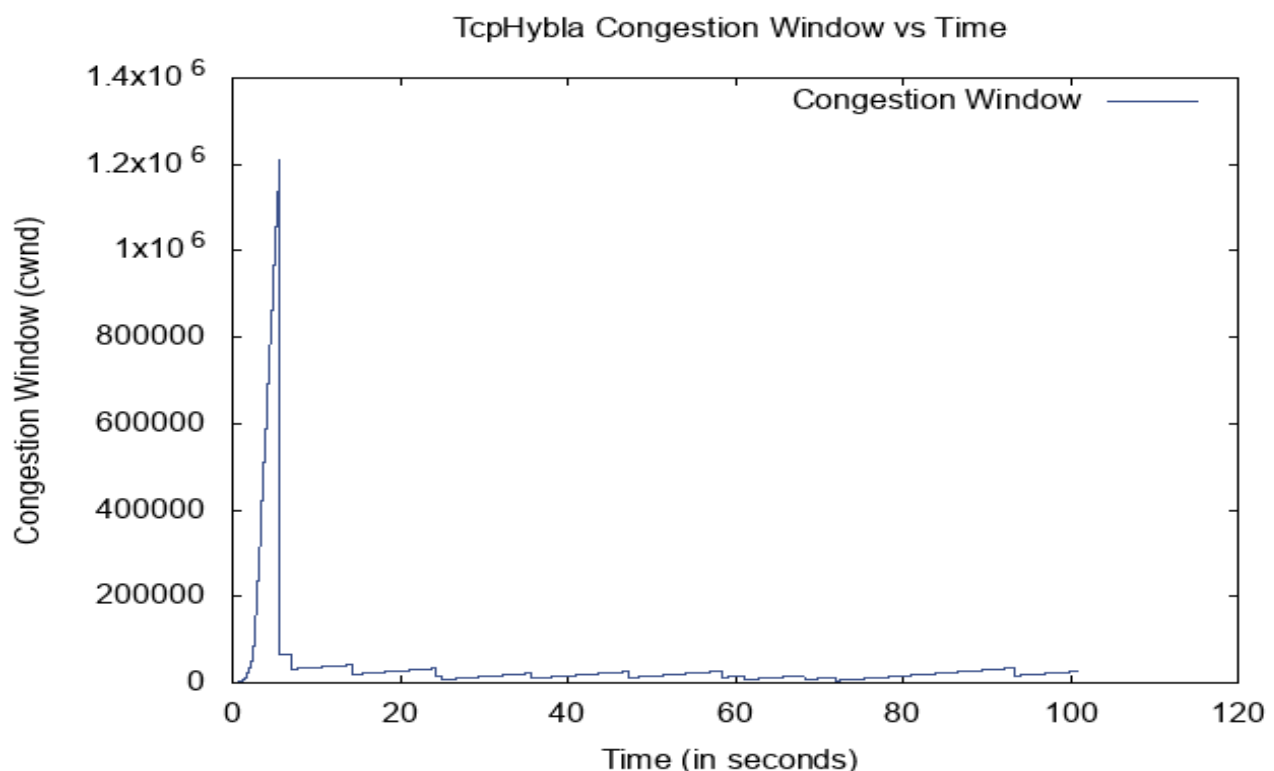Total number of packets lost: 13
Number of packets transferred successfully: 9999987
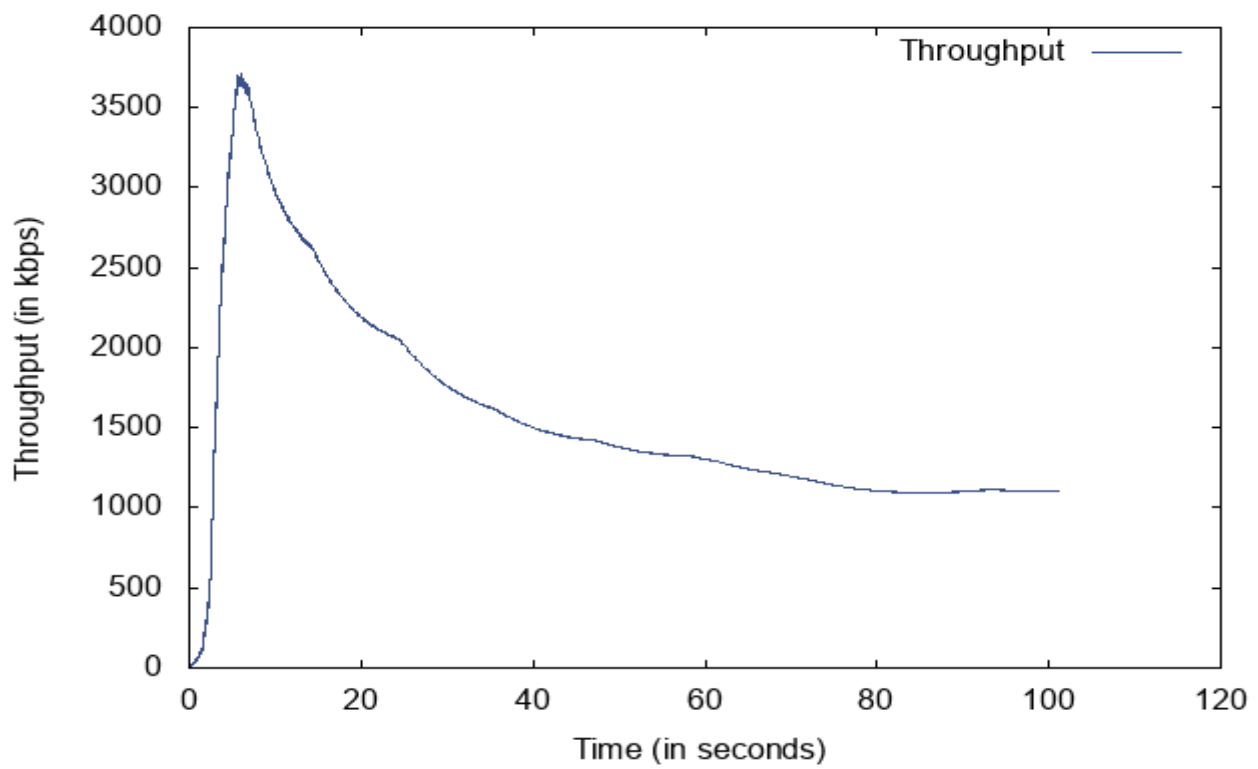Number of packets lost due to buffer overflow: 0
Number of packets lost due to congestion: 13
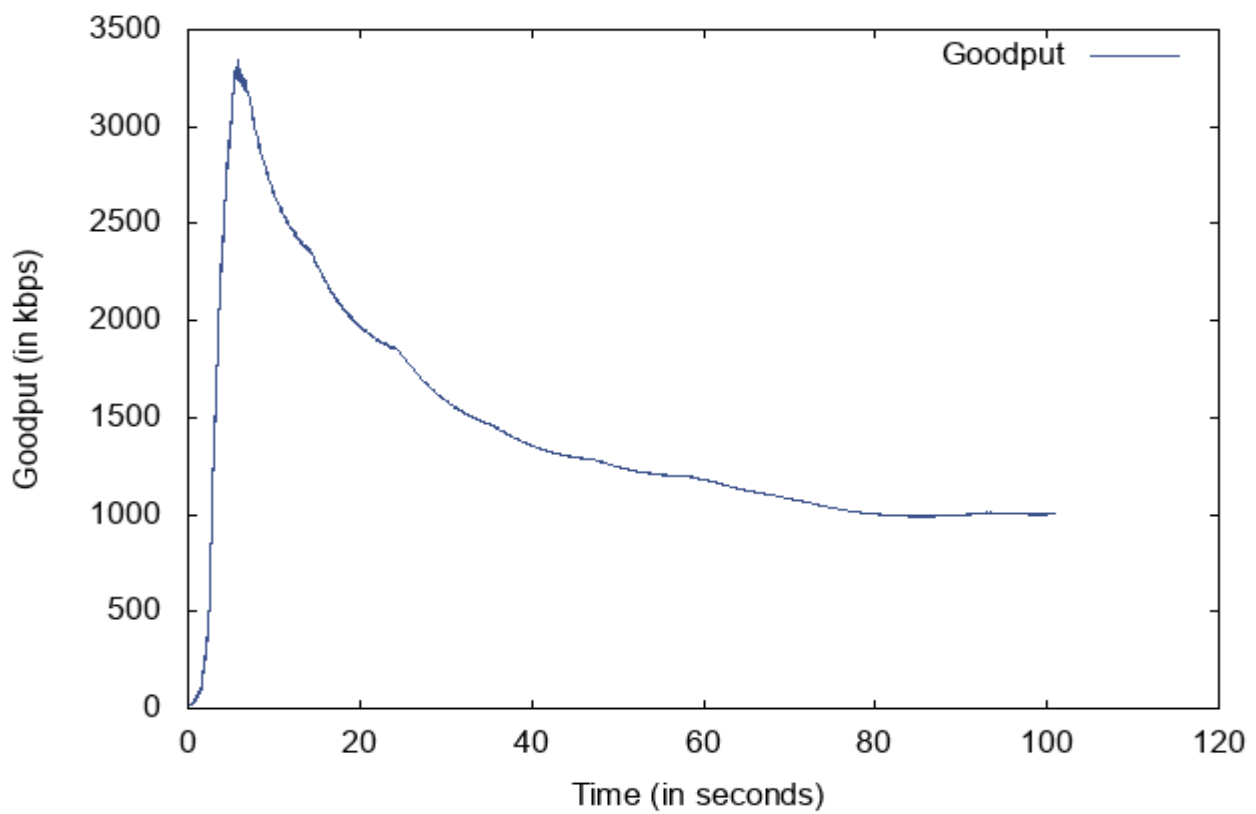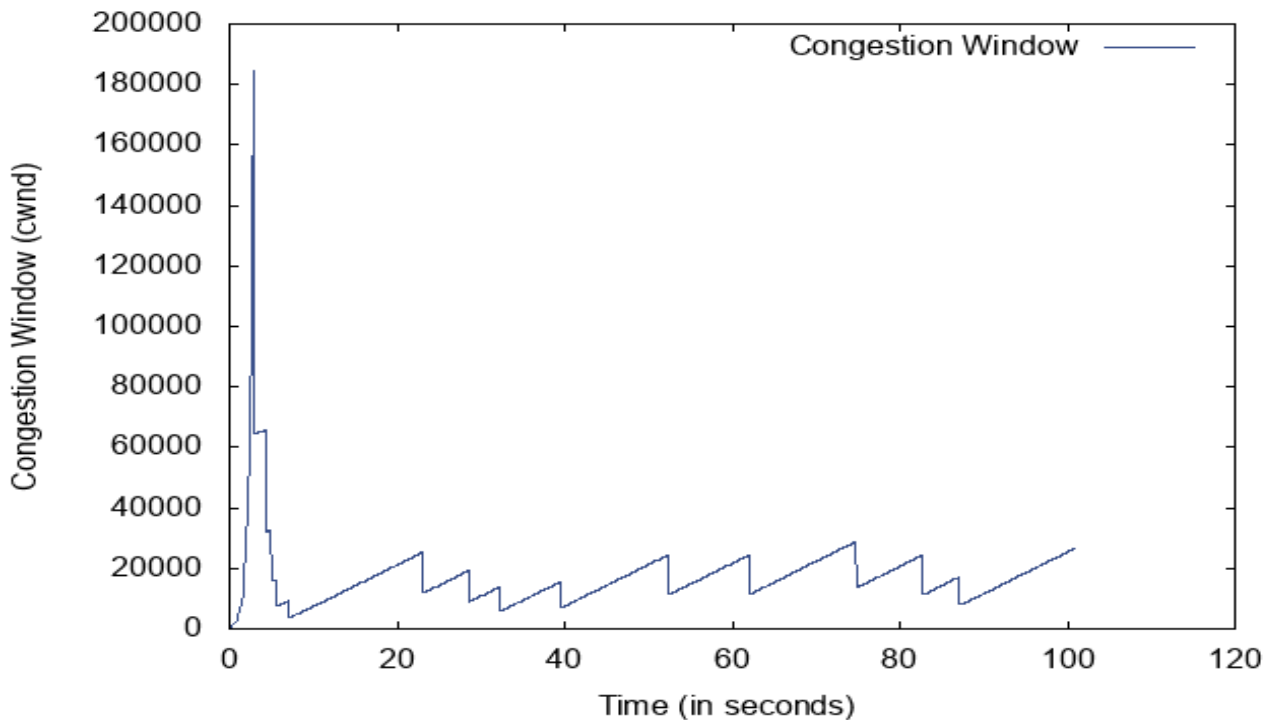% loss due to buffer overflow: 0
% loss due to congestion: 0.00013

TcpHybla Throughput vs Time

TcpHybla Goodput vs Time

TCP Westwood+

** TCP Westwood+ Flow **
Flow ID :3
Maximum throughput: 2003.75
Source IP: 15.1.1.1 -> Destination IP: 15.2.1.1
Total number of packets transmitted: 10000000
Total number of packets lost: 14
Number of packets transferred successfully: 9999986
Number of packets lost due to buffer overflow: 0
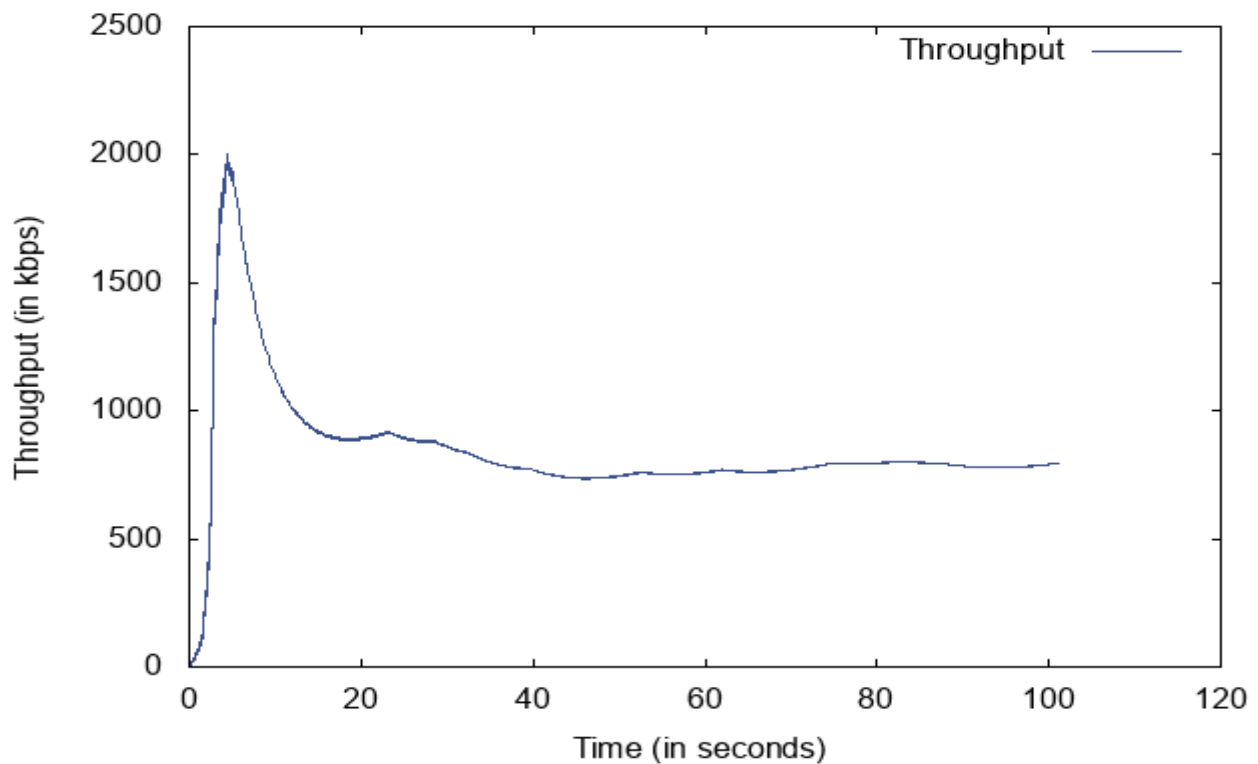Number of packets lost due to congestion: 14
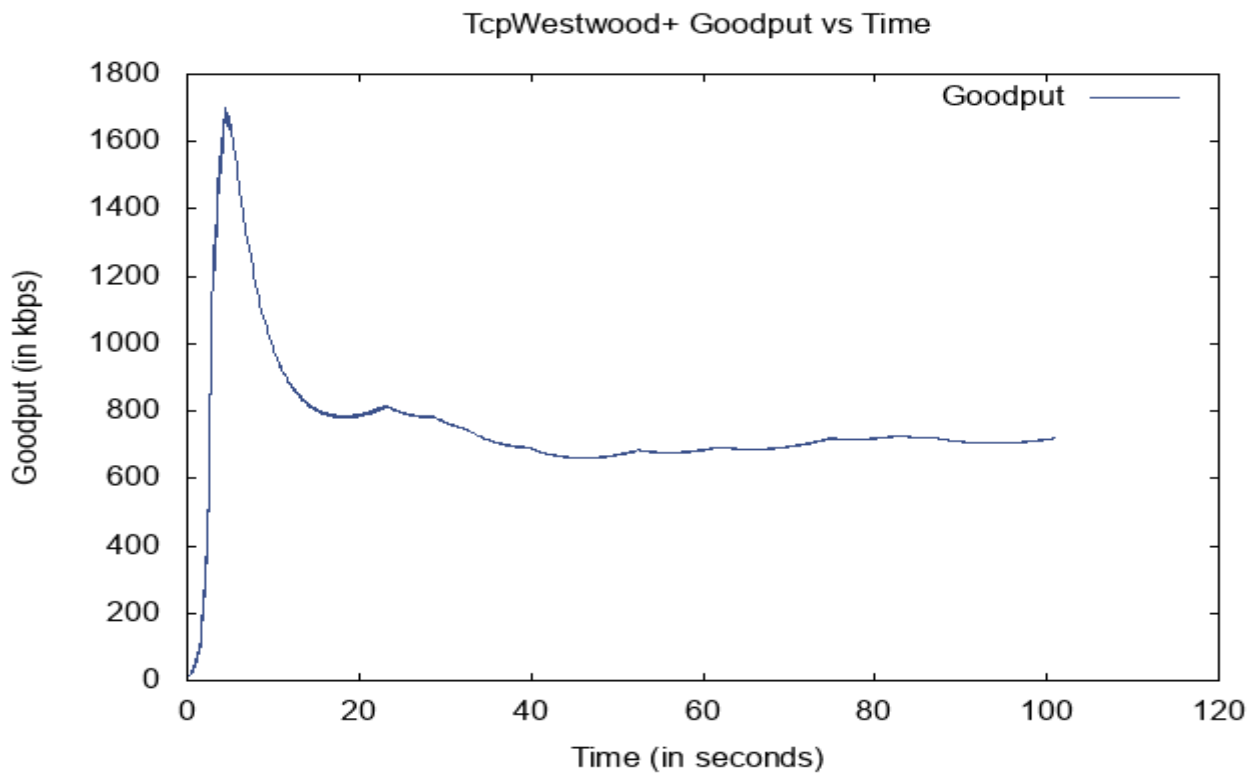% loss due to buffer overflow: 0
% loss due to congestion: 0.00014

TcpWestwood+ Goodput vs Time

TCP Yeah-TCP

** TCP YeAH-TCP Flow **
Flow ID :5
Maximum throughput: 2989.79
Source IP: 15.1.2.1 -> Destination IP: 15.2.2.1
Total number of packets transmitted: 10000000
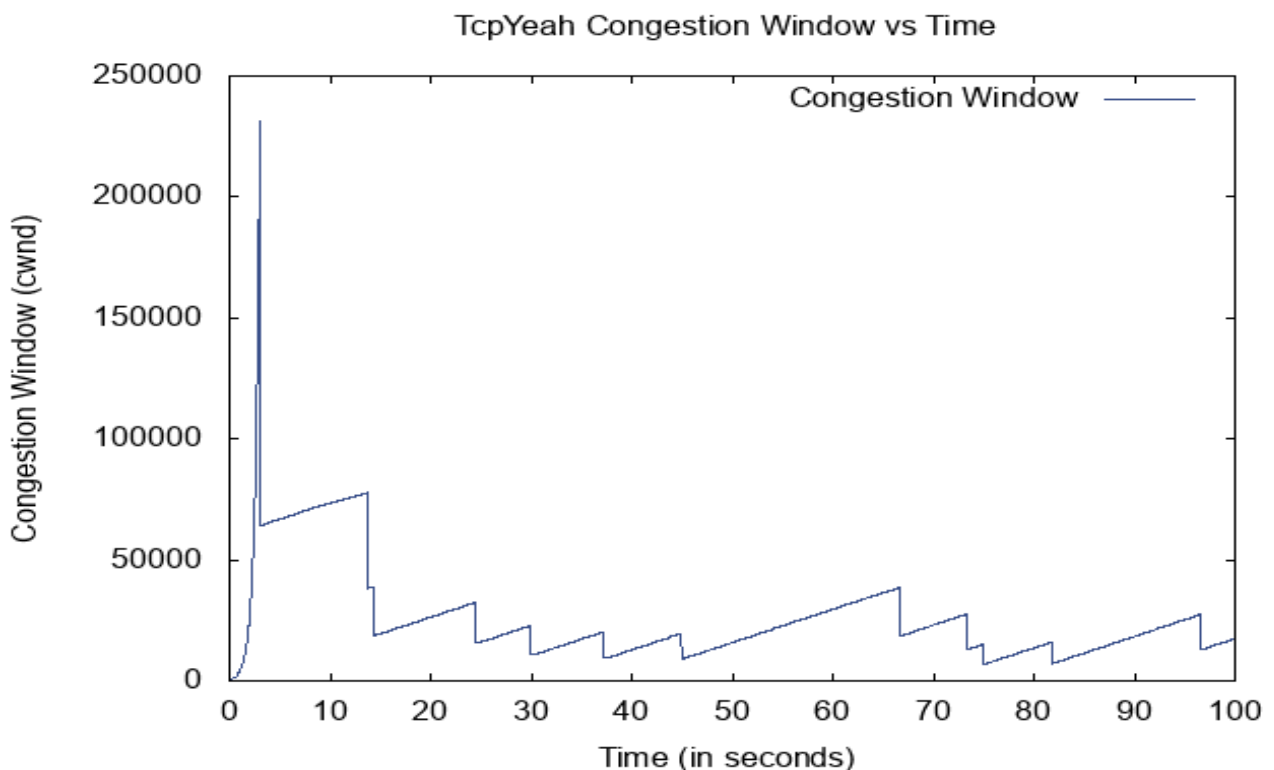Total number of packets lost: 11
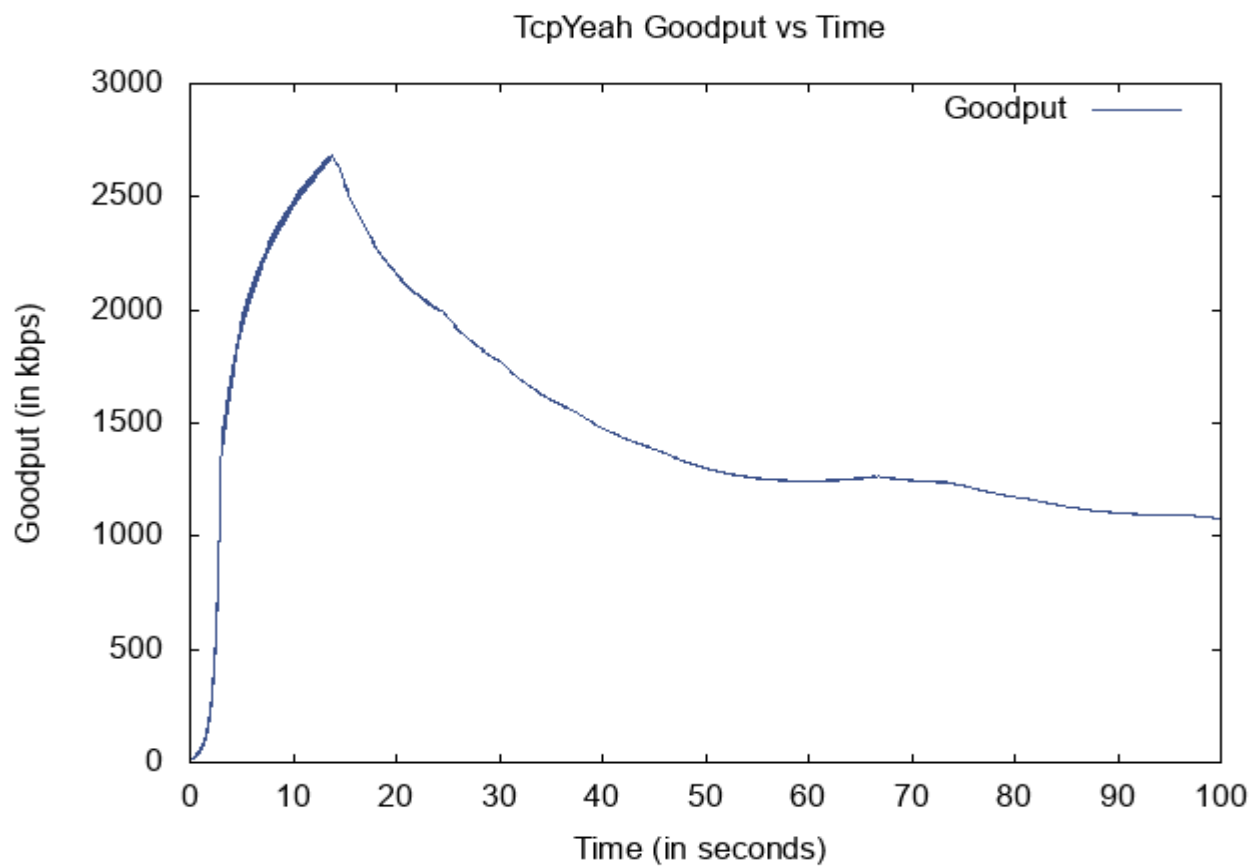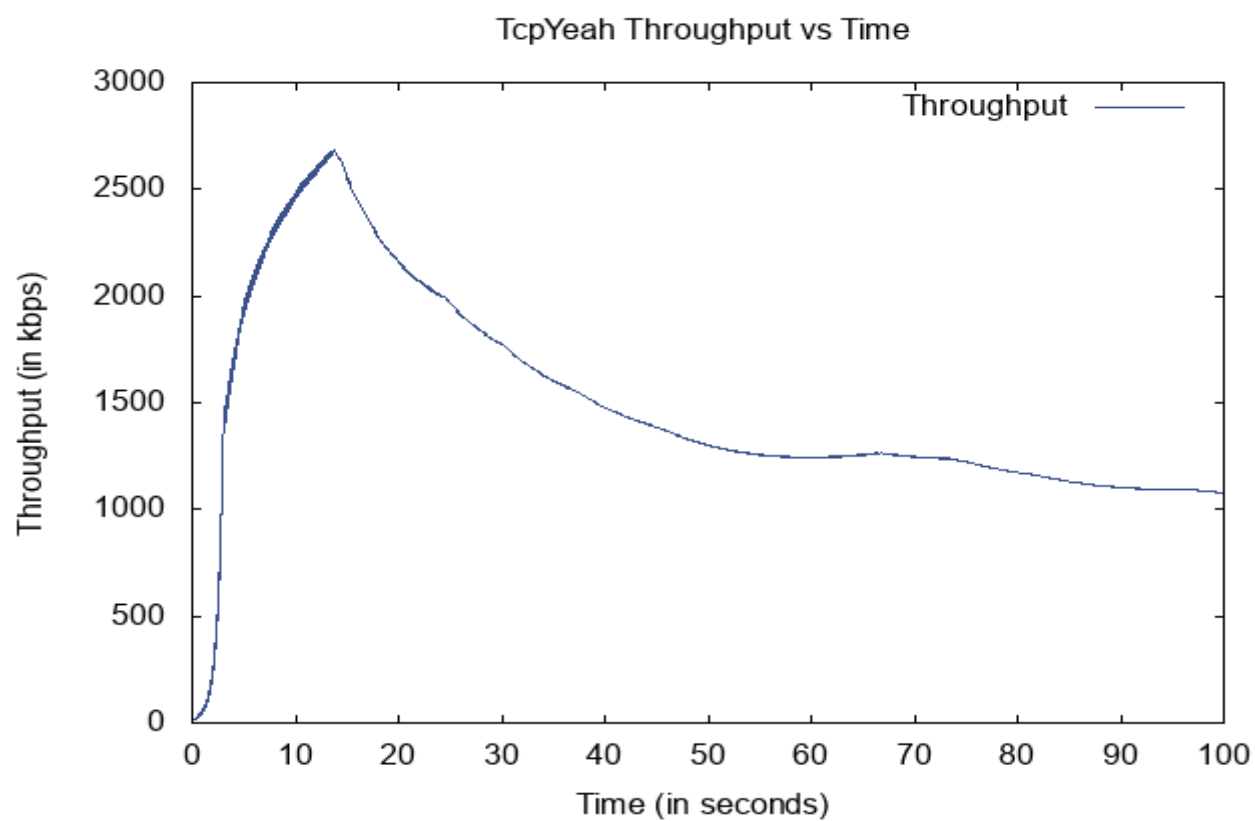Number of packets transferred successfully: 9999989
Number of packets lost due to buffer overflow: 0
Number of packets lost due to congestion: 11
% loss due to buffer overflow: 0
% loss due to congestion: 0.00011

TcpYeah Congestion Window vs Time

TcpYeah Throughput vs Time

TcpYeah Goodput vs Time

PART B:

Includes part 2 and 3 of the question given in assignment:
Started 2 other flows sharing the bottleneck link while the first one is in progress and measured the throughput (in kbps) of each flow. Plotted the throughput and evolution of the TCP congestion window for each of the flow at a steady-state. Reported the maximum throughput observed for each of the flows.
Also measured the congestion loss and the goodput over the duration of the experiment for each of the flows.

Plots and observations:

TCP Hybla

** TCP Hybla Flow **
Flow ID :1
Maximum throughput: 3716.48
Source IP: 15.1.0.1 -> Destination IP: 15.2.0.1
Total number of packets transmitted: 10000000
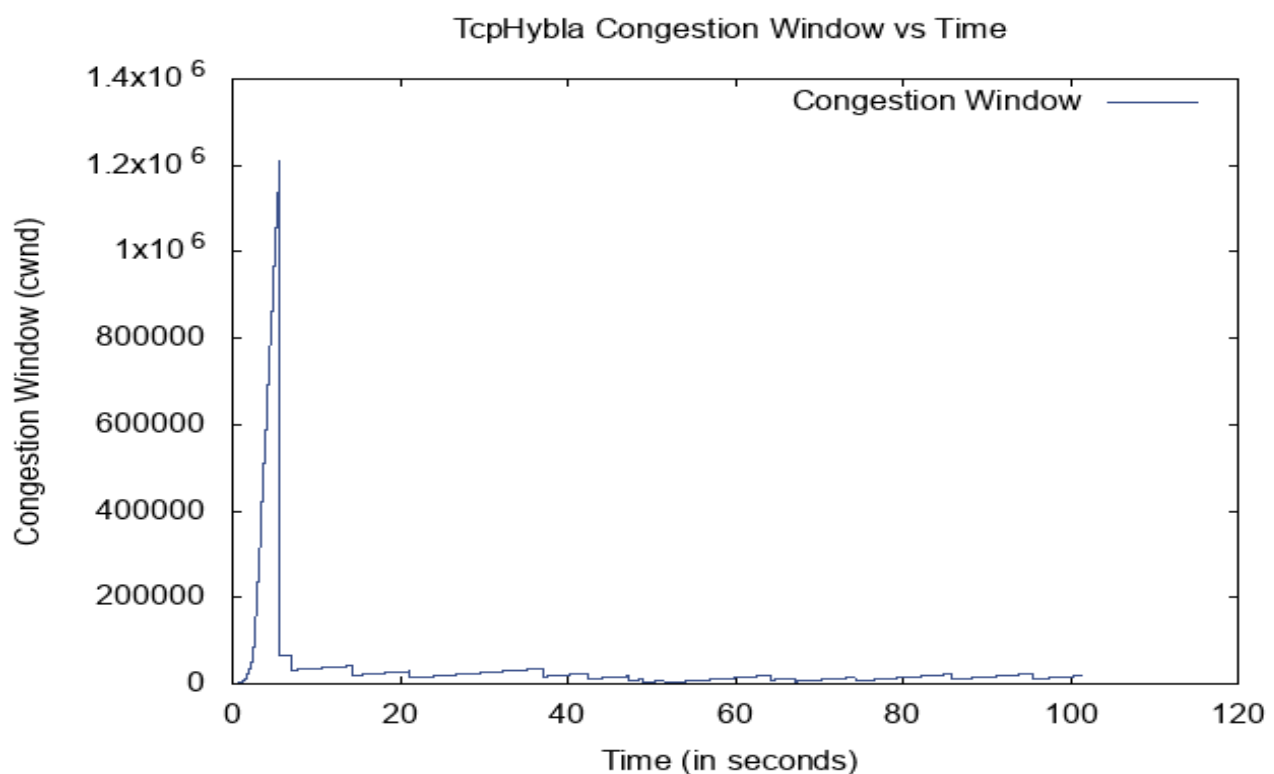Total number of packets lost: 16
Number of packets transferred successfully: 9999984
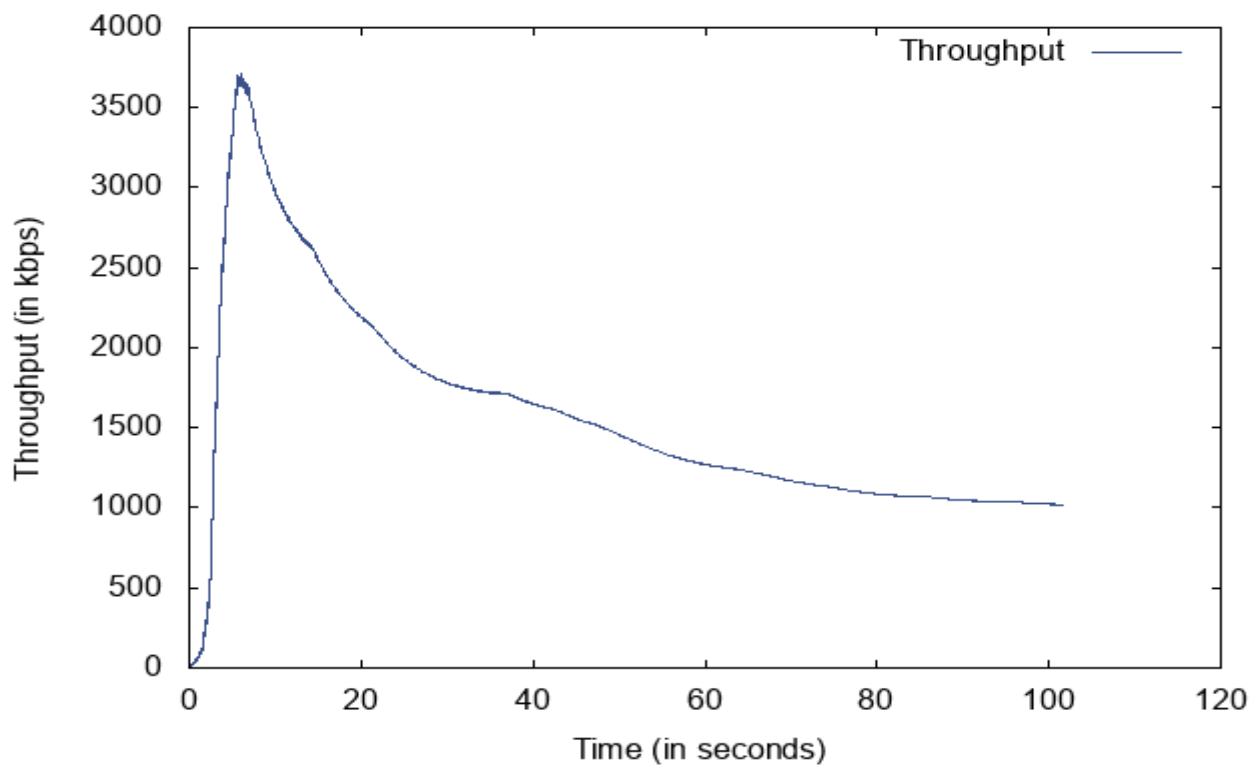Number of packets lost due to buffer overflow: 0
Number of packets lost due to congestion: 16
% loss due to buffer overflow: 0
% loss due to congestion: 0.00016

TcpHybla Throughput vs Time

TcpHybla Goodput vs Time

TCP Westwood+

** TCP Westwood+ Flow **
Flow ID :3
Maximum throughput: 960.974
Source IP: 15.1.1.1 -> Destination IP: 15.2.1.1
Total number of packets transmitted: 10000000
Total number of packets lost: 11
Number of packets transferred successfully: 9999989
Number of packets lost due to buffer overflow: 0
Number of packets lost due to congestion: 11
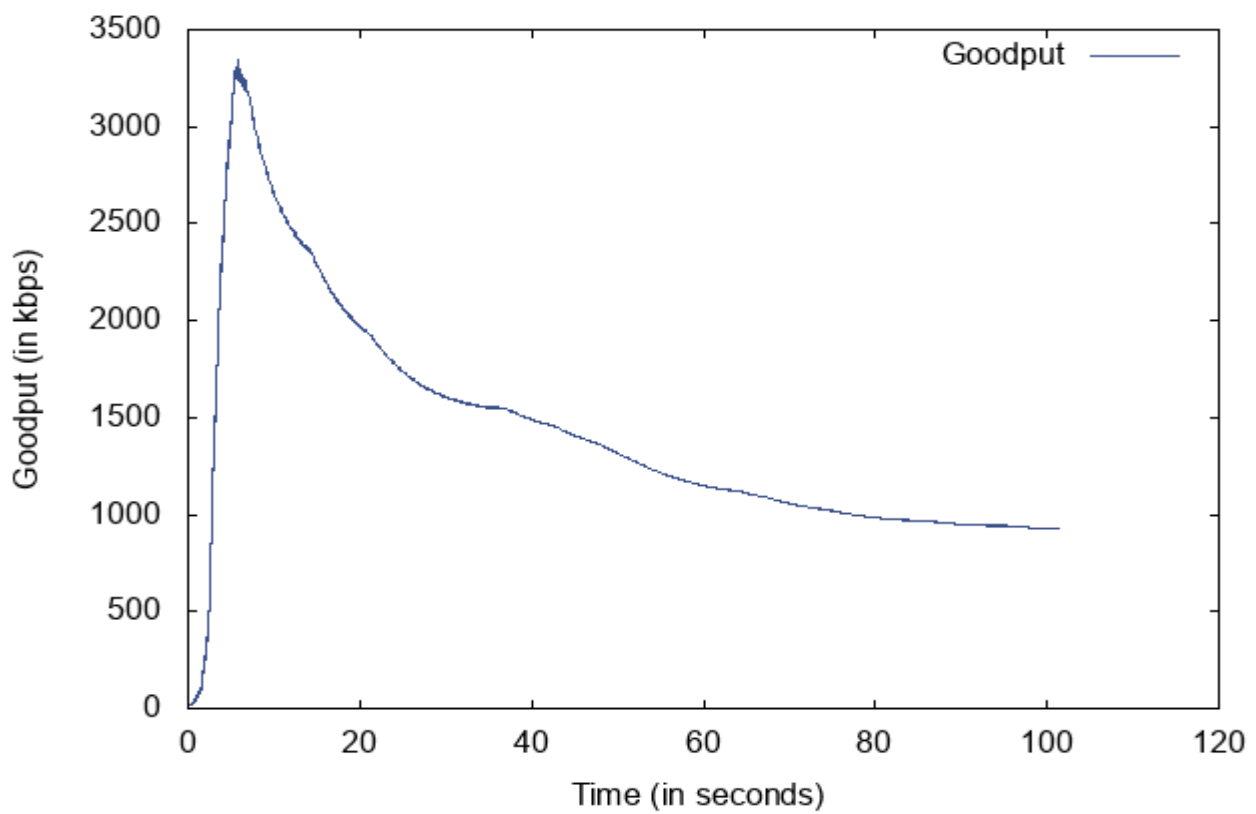% loss due to buffer overflow: 0
% loss due to congestion: 0.00011

TcpWestwood+ Goodput vs Time

TCP Yeah-TCP

** TCP YeAH-TCP Flow **
Flow ID :4
Maximum throughput: 844.435
Source IP: 15.1.2.1 -> Destination IP: 15.2.2.1
Total number of packets transmitted: 10000000
Total number of packets lost: 11
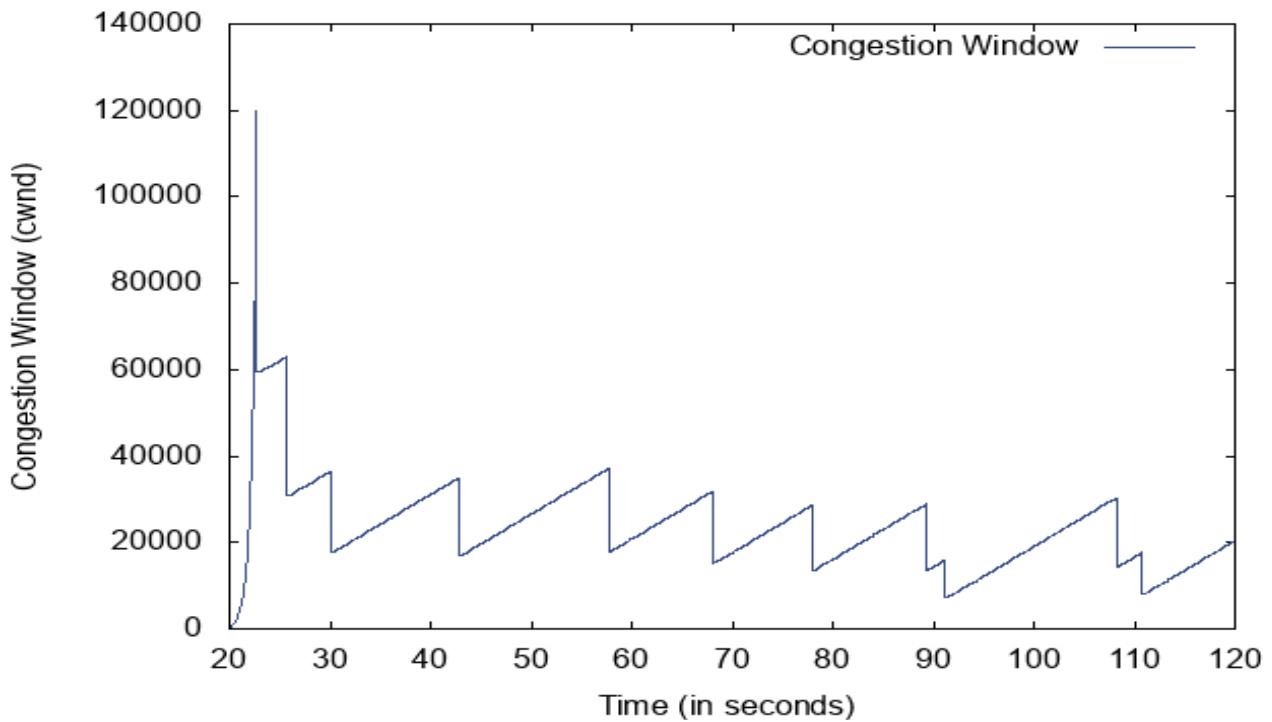Number of packets transferred successfully: 9999989
Number of packets lost due to buffer overflow: 0
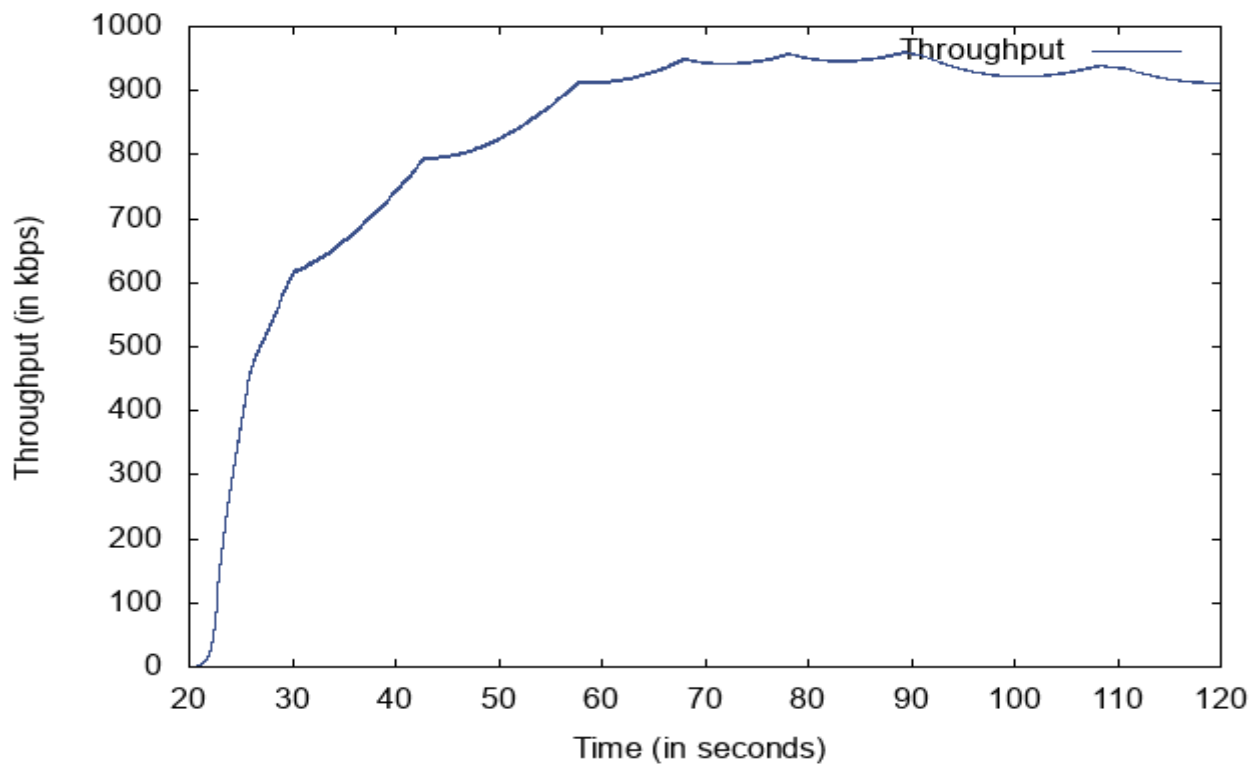Number of packets lost due to congestion: 11
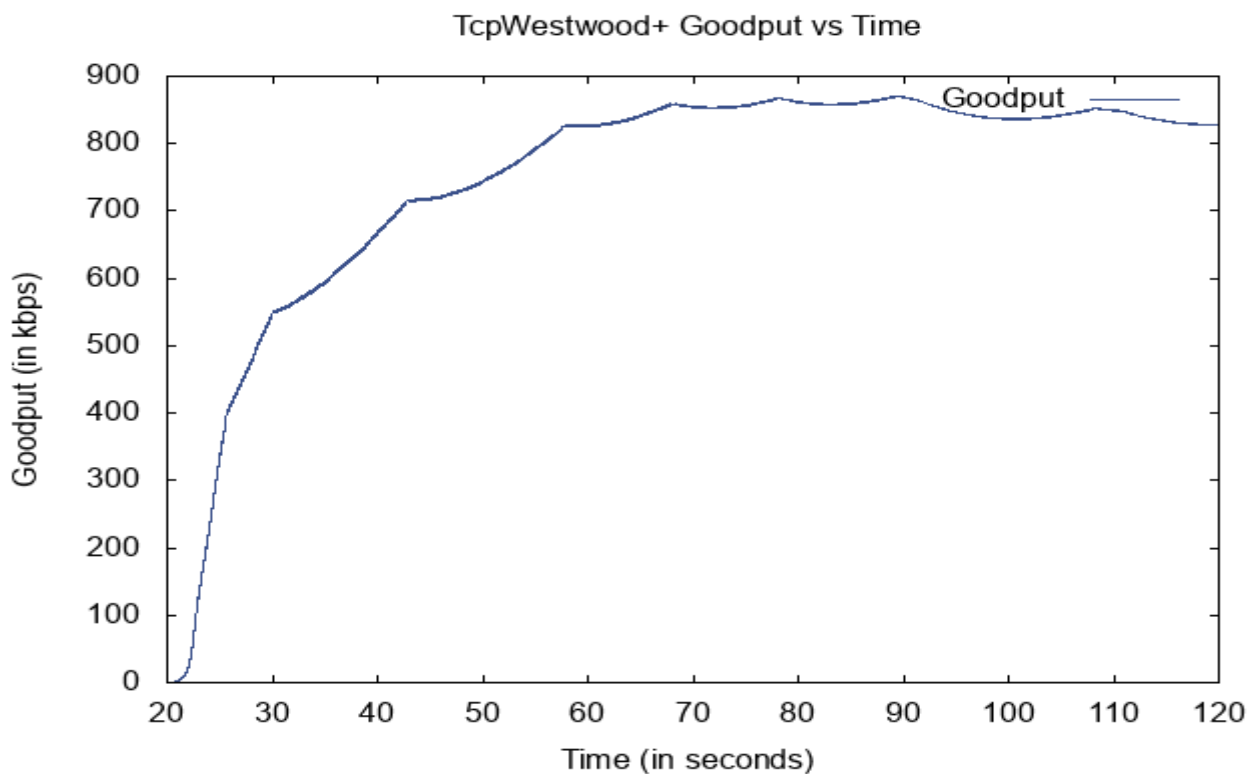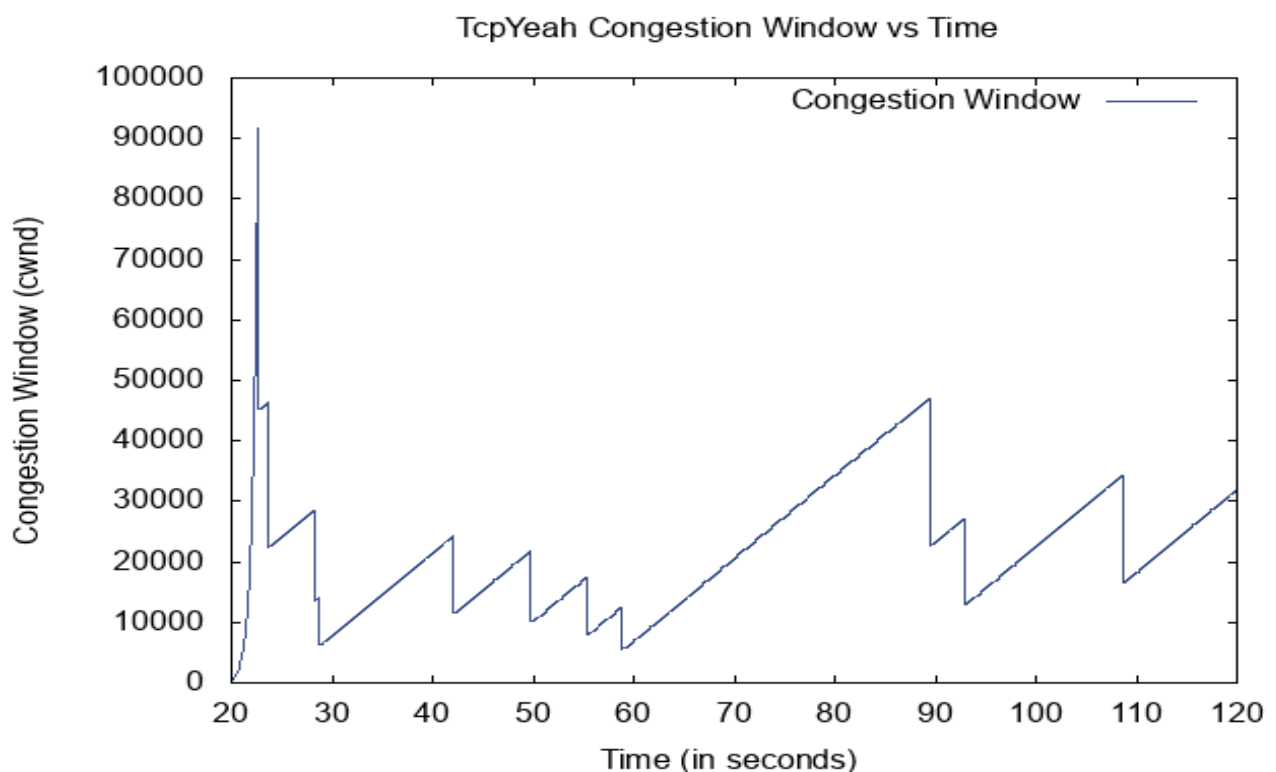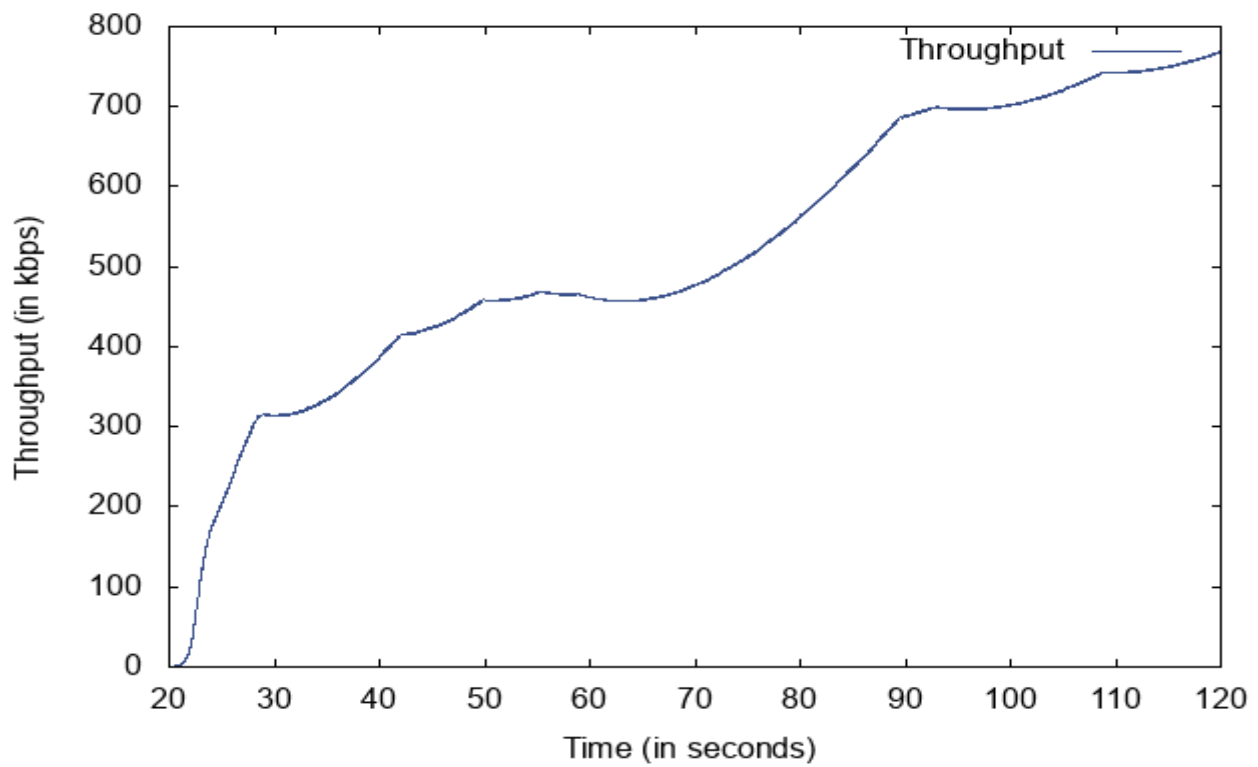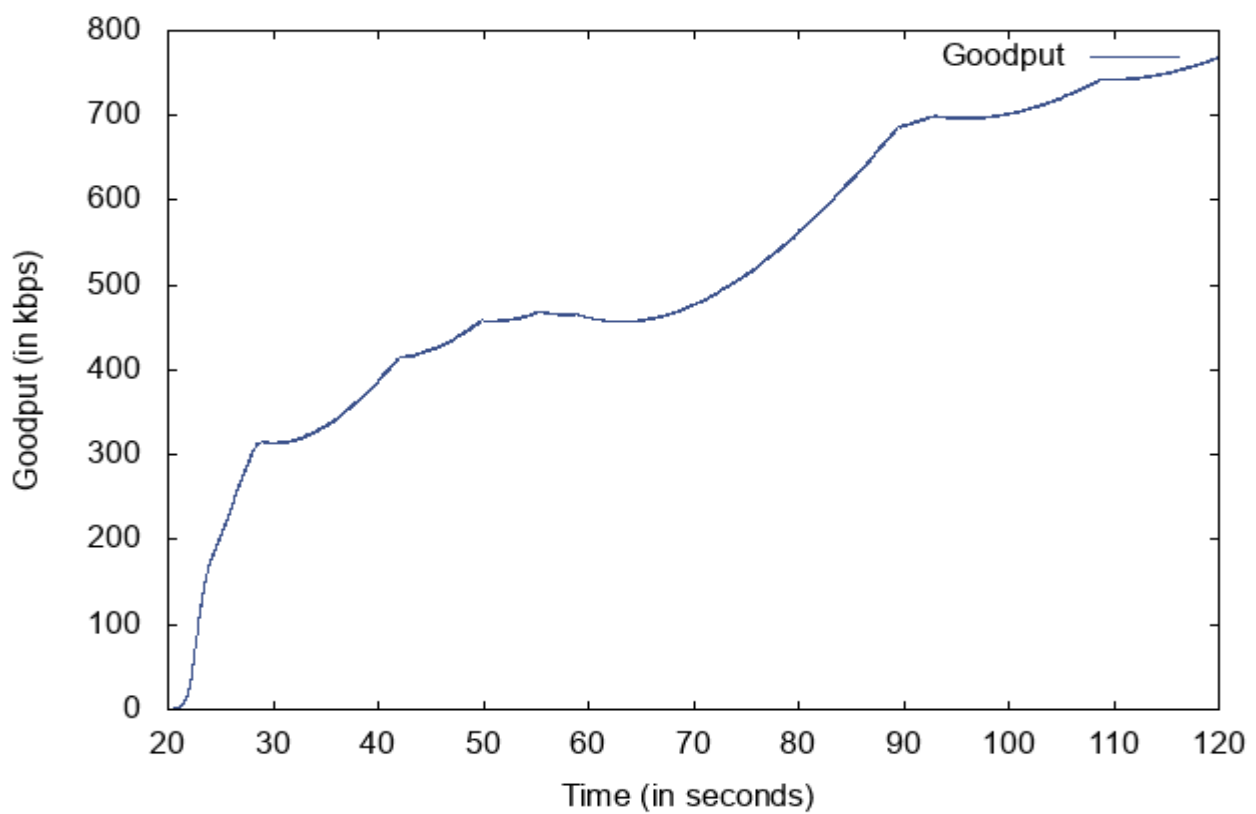% loss due to buffer overflow: 0
% loss due to congestion: 0.00011

TcpYeah Congestion Window vs Time

TcpYeah Throughput vs Time

TcpYeah Goodput vs Time

Usage guidelines:

To run the code, paste the files Asgn4_Code.cc and header.h in the folder ns-allinone-3.30.1/ns-3.30.1/scratch and use the command "./waf --run scratch/Asgn4_Code" in the terminal in the location ns-allinone-3.30.1/ns-3.30.1. The data will be available in the folder ns-allinone-3.30.1/ns-3.30.1. (We are using ns-3 3.30.1, names will vary accordingly).
Screenshots are as follows:

```
dyan@sakshisharma:~/data/Workspace/ns-allinone-3.30.1/ns-3.30.1$ ./waf --run scratch/Asgn4_Code
Waf: Entering directory `/home/dyan/data/Workspace/ns-allinone-3.30.1/ns-3.30.1/build'
[2739/2790] Linking build/scratch/subdir/subdir
[2740/2790] Compiling scratch/Asgn4_Code.cc
[2750/2790] Linking build/scratch/Asgn4_Code
Waf: Leaving directory `/home/dyan/data/Workspace/ns-allinone-3.30.1/ns-3.30.1/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.773s)
Enter your choice: (1 or 2)
1. Execute part 1 and 3
2. Execute part 2 and 3
1
*** Executing part 1 and 3 ***
Queue Size for Host to Router links: 1302 Packets
Queue Size for Router to Router link: 325 Packets

Initialising node containers...
Adding and configuring links between nodes...
Installing internet stack on the nodes...
Assigning IP addresses to the nodes and initialising network interfaces...
Initialisation of network finished

Measuring Performance of each TCP variant one by one...
From H1 to H4 ::: Connection type: TcpHybla
From H2 to H5 ::: Connection type: TcpWestwood+
From H3 to H6 ::: Connection type: TcpYeah
Measuring performances finished

Populating Routing Tables...
Setting up FlowMonitor to enable IP flow monitoring on all the nodes...
Starting Simulation!
Checking for lost packets...
Collecting flow statistics...
Simulation finished! Data has been stored.
Do you want to perform another simulation? (Y/N)
Y
Enter your choice: (1 or 2)
1. Execute part 1 and 3
2. Execute part 2 and 3
2
*** Executing part 2 and 3 ***
Queue Size for Host to Router links: 1302 Packets
Queue Size for Router to Router link: 325 Packets

Initialising node containers...
Adding and configuring links between nodes...
Installing internet stack on the nodes...
Assigning IP addresses to the nodes and initialising network interfaces...
Initialisation of network finished

From H0 to H4 : Connection type: TcpHybla
From H1 to H5 : Connection type: TcpWestwood+
From H2 to H6 : Connection type: TcpYeah

Populating Routing Tables...
Setting up FlowMonitor to enable IP flow monitoring on all the nodes...
Starting Simulation!
Checking for lost packets...
Collecting flow statistics...
Simulation finished! Data has been stored.
Do you want to perform another simulation? (Y/N)
N
dyan@sakshisharma:~/data/Workspace/ns-allinone-3.30.1/ns-3.30.1$
```

Graphs were plotted using the file Plot_Graphs.plt by changing the variables accordingly for each plot.
Open terminal in location : ns-allinone-3.30.1/ns-3.30.1
Command: gnuplot Plot_Graphs.plt

```
dyan@sakshisharma:~/data/Workspace/ns-allinone-3.30.1/ns-3.30.1$ gnuplot Plot_Graphs.plt
dyan@sakshisharma:~/data/Workspace/ns-allinone-3.30.1/ns-3.30.1$ █
```

****