**Analyse and compare TCP Hybla, TCP Westwood+, and TCP YeAH-TCP performance. Select 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. Choose a packet size of 1.3 KB and perform the following tasks. Make appropriate assumptions wherever necessary.**
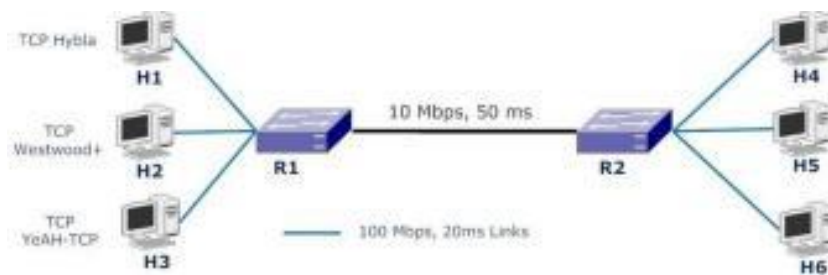
- In the NS-3 simulation framework, the network topology is established using the PointToPointHelper class to create both bottleneck and access links.

- For the access link, a data rate of 100 Mbps and a delay of 20 ms are specified, while for the bottleneck link, parameters are set to a data rate of 10 Mbps and a delay of 50 ms. The bandwidth delay product, determined to be approximately 49 packets for the bottleneck link, guides the setting of the queue size to match this value.

- To configure the network devices with the appropriate protocol stacks, the InternetStackHelper class is utilised. Specifically, TCP Hybla, Westwood+, and yeaH are installed in sender nodes 1, 2, and 3, respectively.

- The network topology consists of eight nodes interconnected as described, with the necessary point-to-point links established between them. Additionally, a class named ClientApp is instantiated and installed on the sending nodes to facilitate application-level communication. At the receiving end, a Sink Application is deployed to handle incoming data.

- Furthermore, the simulation includes three distinct flows:
    - Flow 1: Originating from node 2, traversing nodes 0 and 1, and terminating at node 5.
    - Flow 2: Initiated at node 3, passing through nodes 0 and 1, and concluding at node 6.
    - Flow 3: Originating from node 4, transiting nodes 0 and 1, and concluding at node 7.

This comprehensive configuration establishes a network environment suitable for simulating various communication scenarios and evaluating the performance of different TCP congestion control algorithms.

Start only one flow and analyse the throughput over sufficiently long duration. Mention how you select the duration. Plot the evolution of congestion window w.r.t. time. Perform this experiment with all the flows attached to all the three sending agents.

The duration was selected to ensure that the pattern observed in the congestion window has reached a stable state. The flow statistics obtained from the ns3 flow monitor are as follows:

```
sunny@sunny-HP-ProDesk-600-G4-PCI-MT:~/Desktop/ns-allinone-3.40/ns-3.40$ ./ns3 run scratch/Group9_3rdAssign.cc
[0/2] Re-checking globbed directories...
ninja: no work to do.
--------------Initialising node containers------------
---------------Installing Internet Stack on the nodes---------------
-----------Setting up IP addressess to the nodes-----------------
-------------------------Initialization of network finished--------------------
Enter 1 for singleFlow, 2 for multiFlow : 1

----------------------------Single Flow starting ---------------------------------
Max Packets per trace file exceeded


----------------TCP Hybla-------------------
Flow of TCP Hybla 1 (40.1.0.1 -> 40.2.0.1)
Sent Packets : 11121
Received Packets : 11059
Congestion Loss : 817
Maximum Throughput : 673.24


--------------TCP WestWood+ -----------------

Flow of TcpWestwood+ 3 (40.1.1.1 -> 40.2.1.1)
Sent Packets : 12745
Received Packets : 12671
Congestion Loss : 1363
Maximum Throughput : 3672.43


------------------TCP YeAH----------------

Flow of TCP YeAH 5 (40.1.2.1 -> 40.2.2.1)
Sent Packets : 9230
Received Packets : 9168
Congestion Loss :  546
Maximum Throughput : 414.434
```
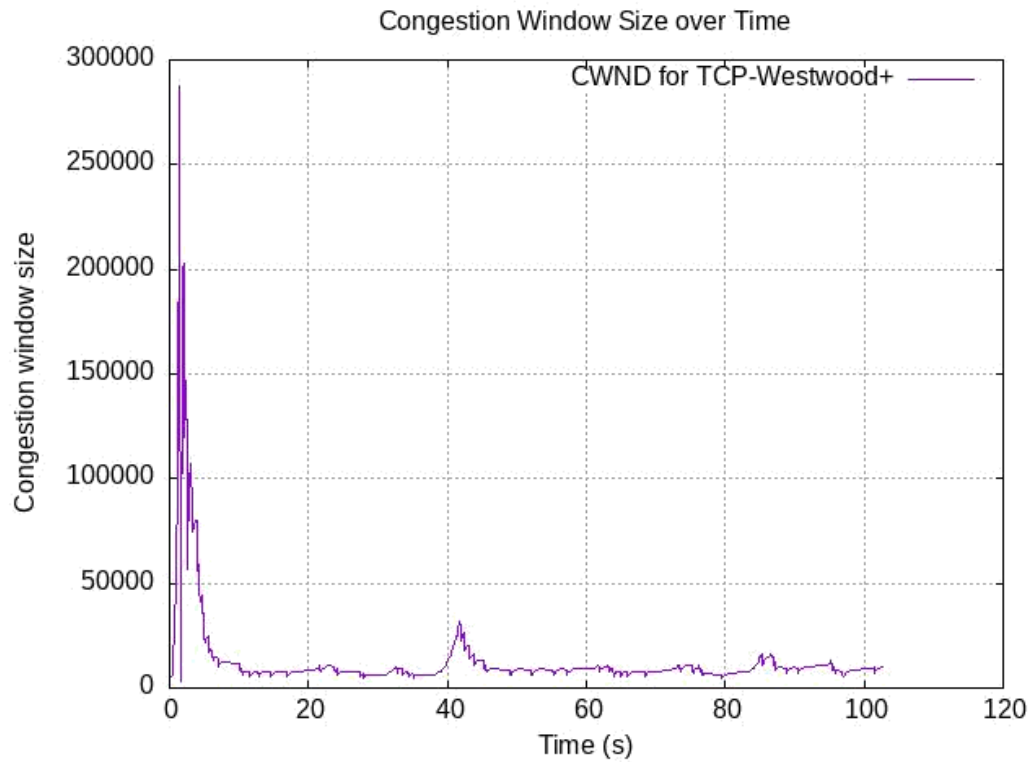
Flow 1 started at time 0 and is running till 100ms. The congestion window for the time frame is plotted below:

Congestion Window Size over Time
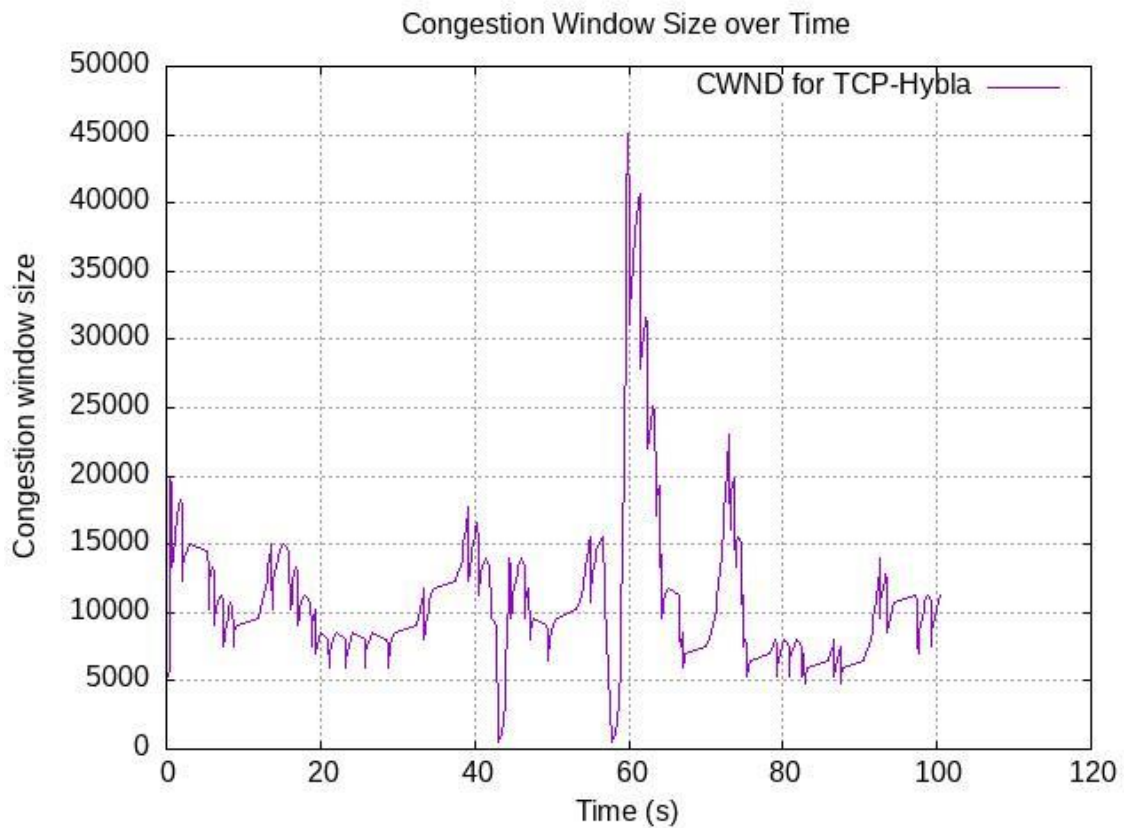
Flow 2 started at time 100ms and is running till 200ms. The congestion window for the time frame is plotted below:

Congestion Window Size over Time

Flow 3 started at 200ms and is running till 300ms. The congestion window for the time frame is plotted below:

Congestion Window Size over Time
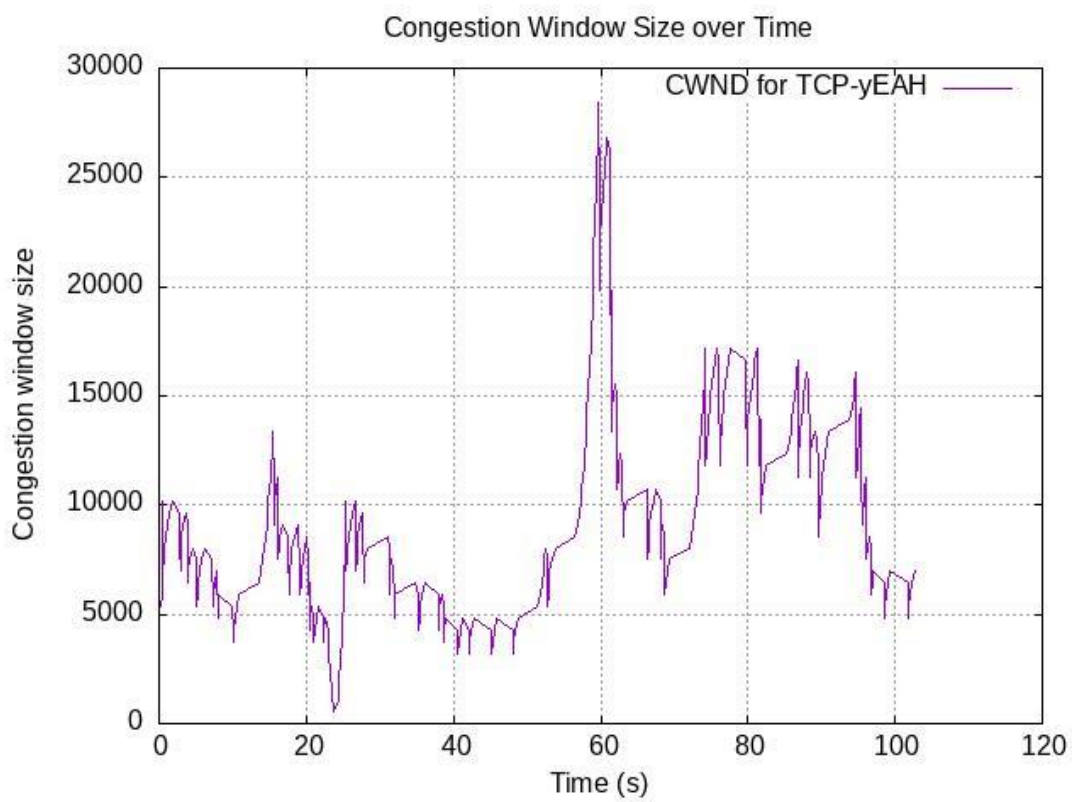
Below is the analysis of Throughput for each flow :

Throughput over Time
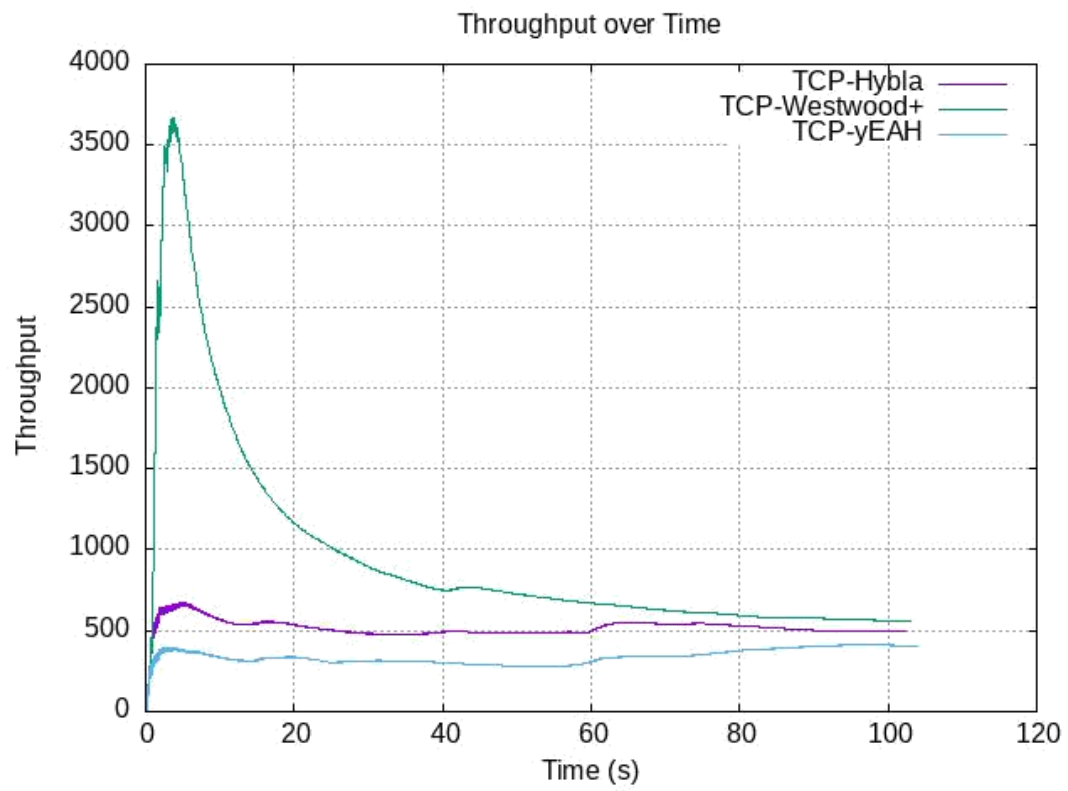
In the next experiment, start 2 other flows sharing the bottleneck while the first one is in progress and measure the throughput(in Kbps) of each flow. Plot the throughput and evolution of the TCP congestion window for each of the flows at a steady-state. Report the maximum throughput observed for each of the flows.

Flow 1 started at 0ms and Flow 2 and 3 started running at 20ms. The congestion window for the time frame is plotted below:
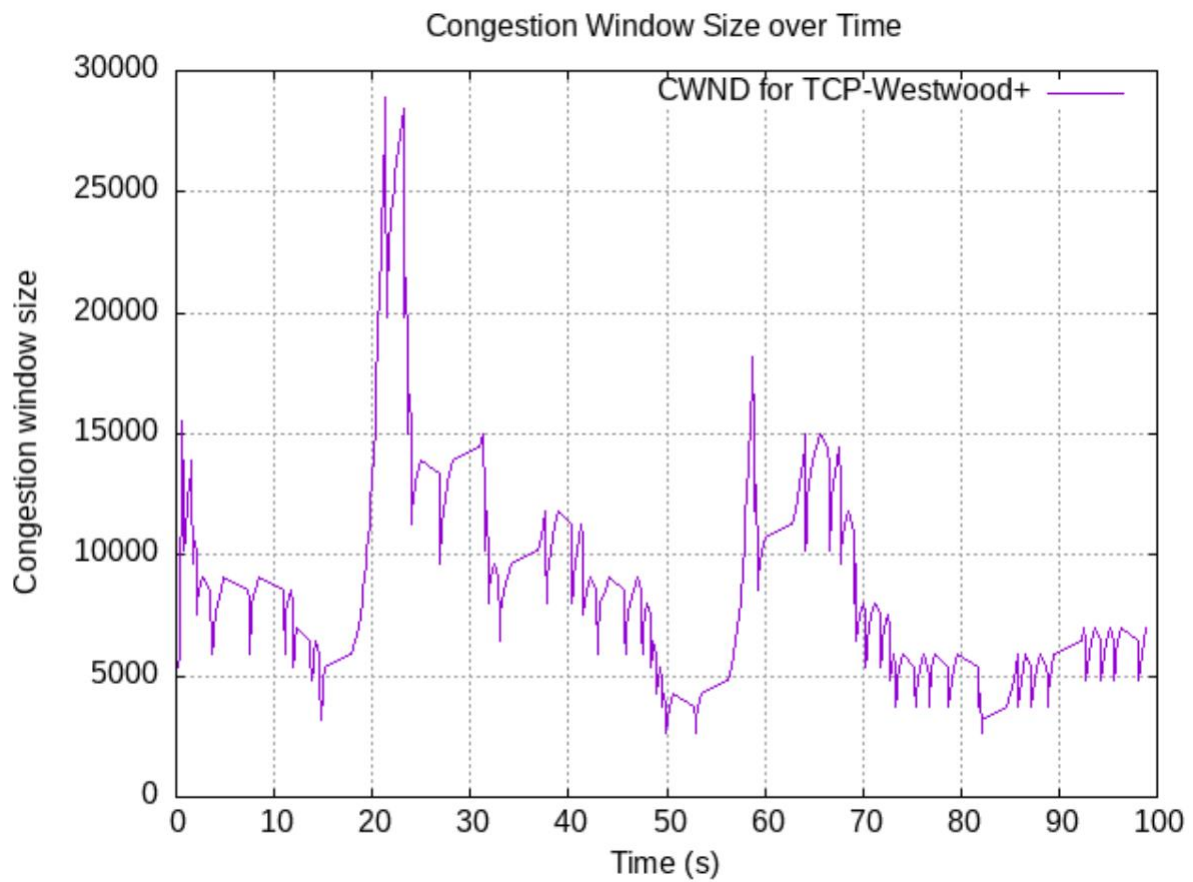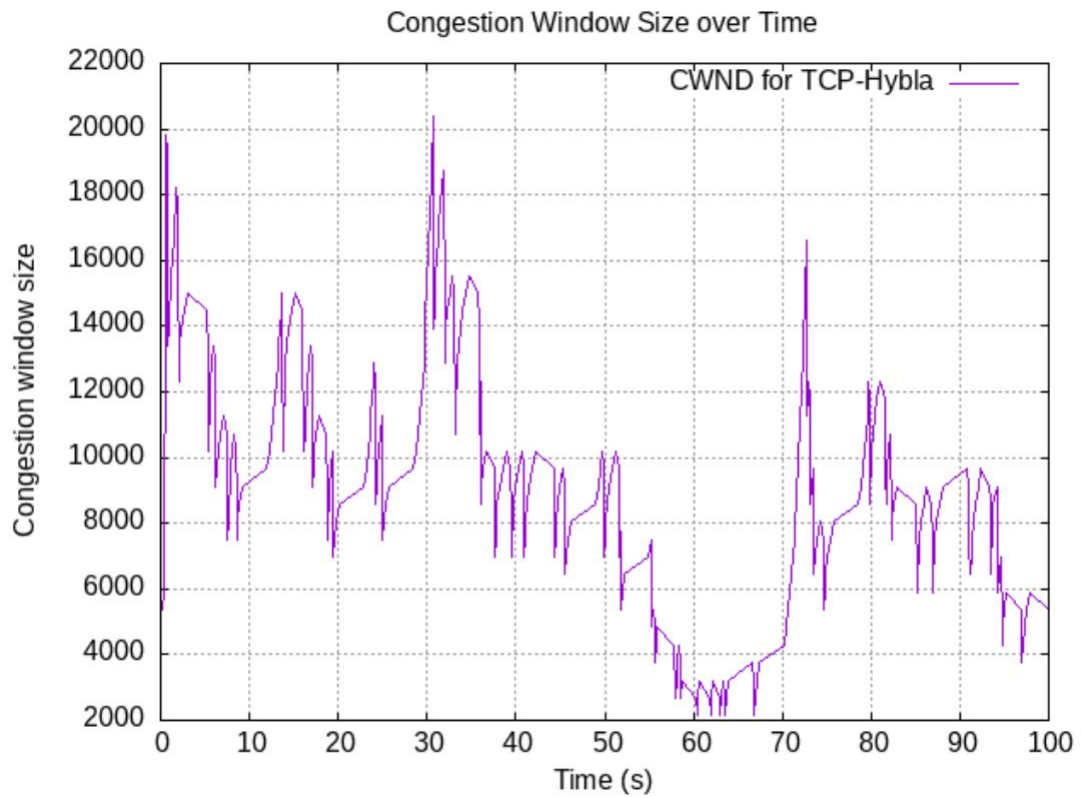
```
sunny@sunny-HP-ProDesk-600-G4-PCI-MT:~/Desktop/ns-allinone-3.40/ns-3.40$ ./ns3 run scratch/Group9_3rdAssign.cc
[0/2] Re-checking globbed directories...
ninja: no work to do.
--------------Initialising node containers------------
---------------Installing Internet Stack on the nodes----------------
----------Setting up IP addressess to the nodes-----------------
-------------------------Initialization of network finished--------------------
Enter 1 for singleFlow, 2 for multiFlow : 2

-----------------------------Multi Flow starting ----------------------------------
Max Packets per trace file exceeded


-----------------TCP Hybla-------------------
Flow of TCP Hybla 1 (40.1.0.1 -> 40.2.0.1)
Sent Packets : 8786
Received Packets : 8730
Congestion Loss : 537
Maximum Throughput : 673.24


--------------TCP WestWood+ ------------------

Flow of TcpWestwood+ 3 (40.1.1.1 -> 40.2.1.1)
Sent Packets : 8590
Received Packets : 8527
Congestion Loss : 532
Maximum Throughput : 504.228


------------------TCP YeAH---------------
Flow of TCP YeAH 4 (40.1.2.1 -> 40.2.2.1)
Sent Packets : 13642
Received Packets : 13582
Congestion Loss :  1301
Maximum Throughput : 2446.55
```
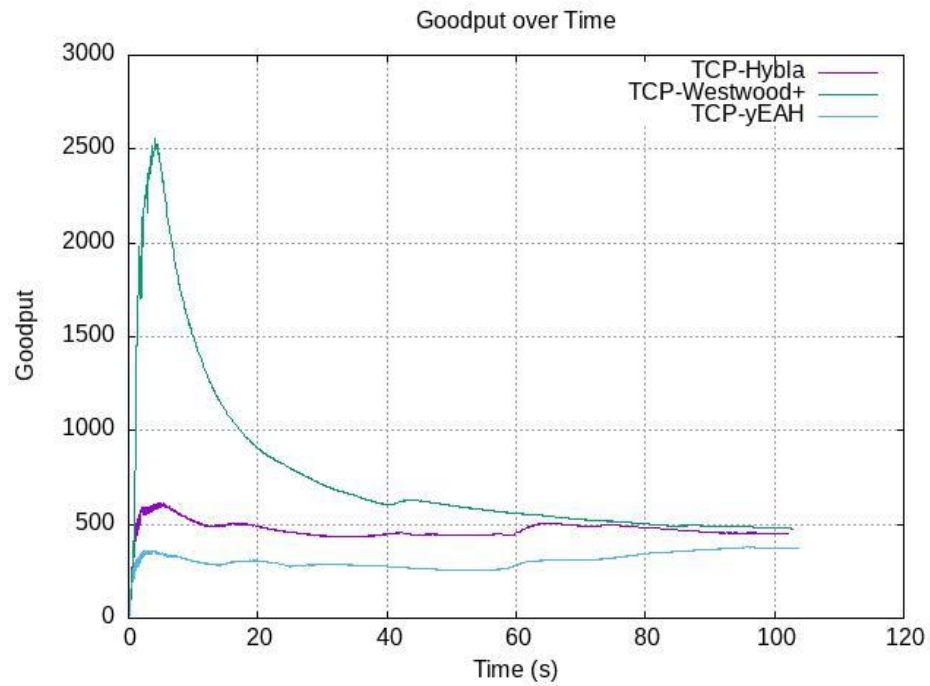
Congestion Window Size over Time

Congestion Window Size over Time

Congestion Window Size over Time

CWND for TCP-yEAH

Throughput over Time

TCP-Hybla
TCP-Westwood+
TCP-yEAH
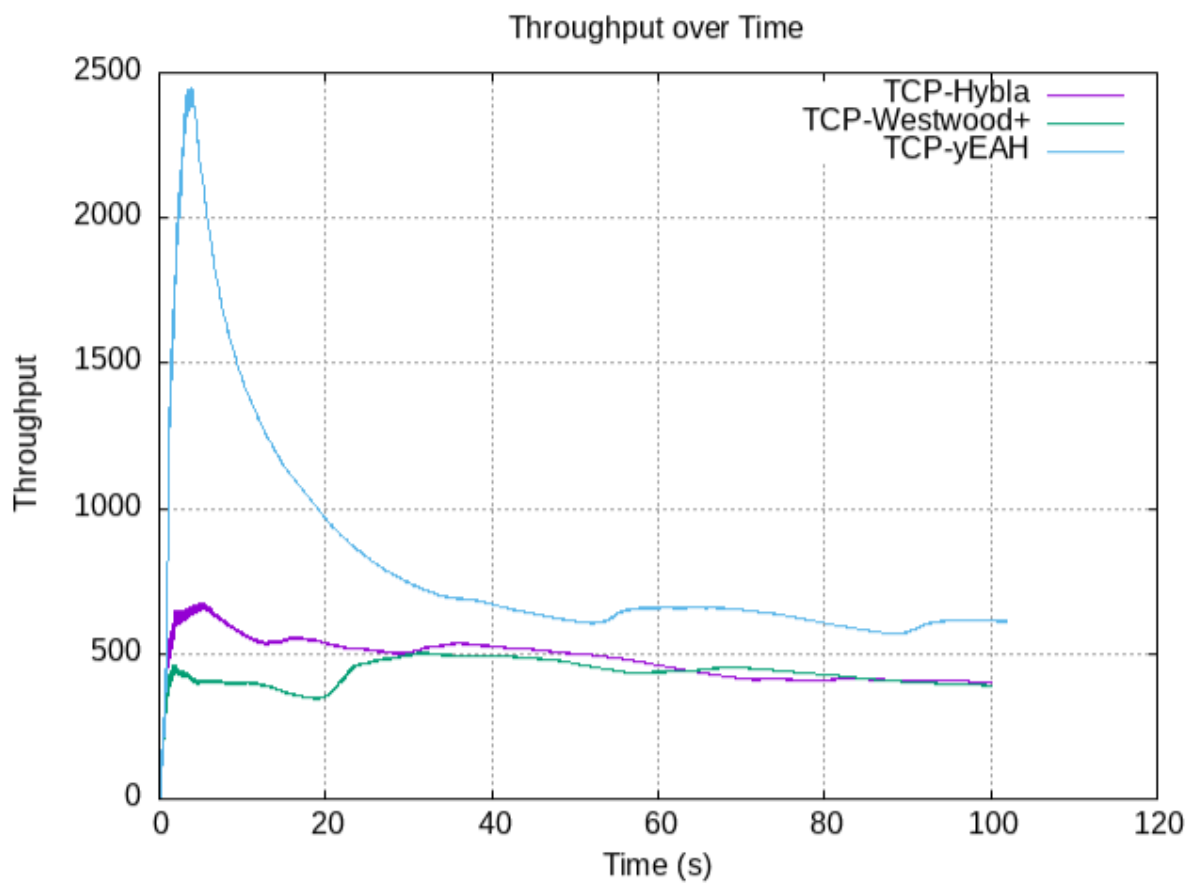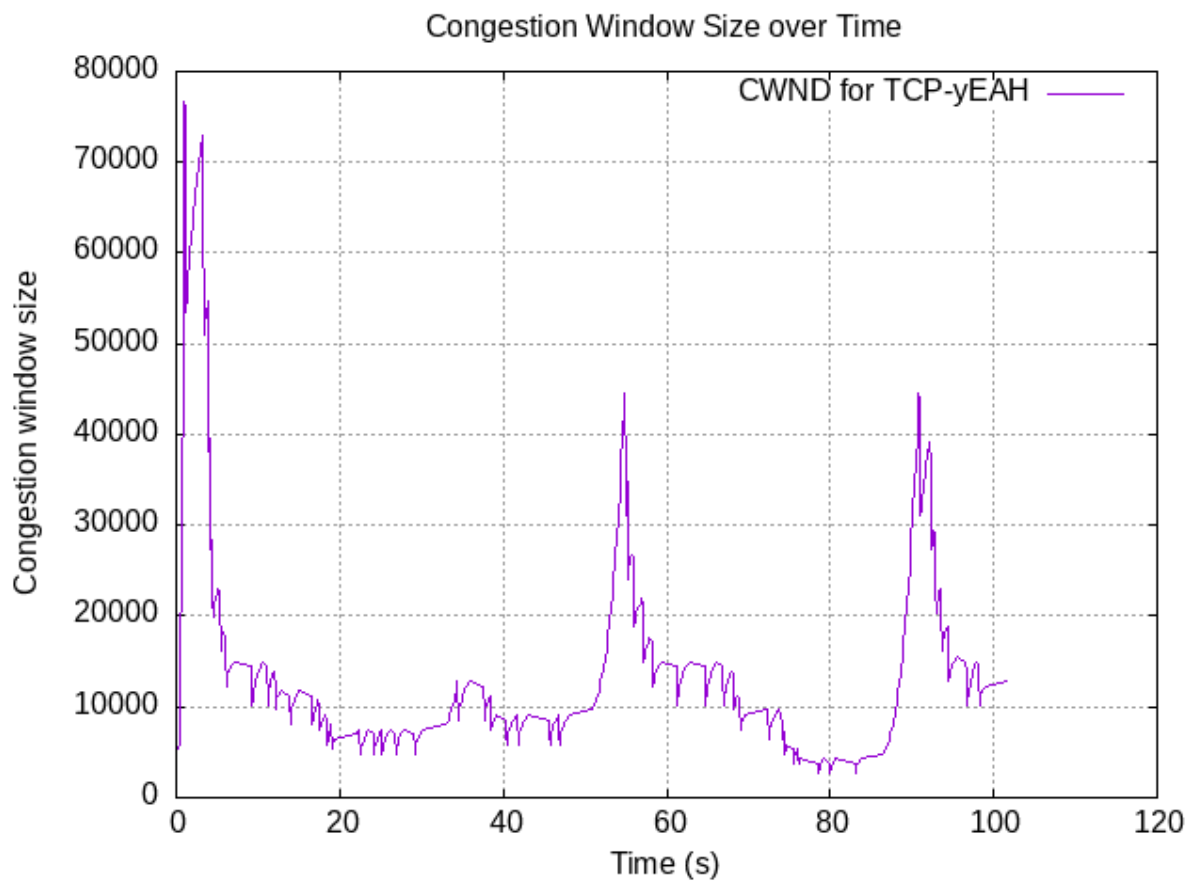
Measure the congestion loss and the goodput over the duration of the experiment for each of the flows.

A. Goodput for SingleFlow

B. Goodput for MultiFlow