CS 349: Networks Lab
(January-May 2019)

Assignment – 4: Network Simulation Using ns-3

Submission Deadline: 11:55 pm on Monday, 22nd April 2019 (hard deadline)

In this assignment you need to simulate a computer network for a given application using the discrete event network simulator **ns-3**. You can download the software and documentation of **ns-3** from the website https://www.nsnam.org. The assignment will be solved in groups where each group, comprised of 3 members, needs to work on an application assigned to it. The group membership information is given in pages 8-10 of this document. The applications' network specifications, the required experiments, and related questions are given in pages 2-7 of this document. Follow the general instructions given below and any specific instructions mentioned in the application description.

General Instructions:

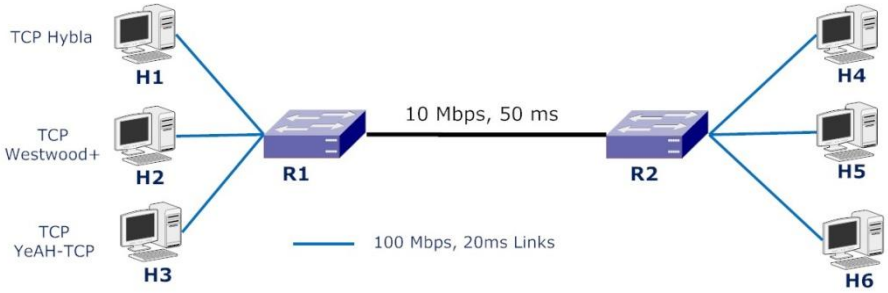
1. Each group needs to simulate one application assigned to it and make one single submission on Moodle. Only one member from a group needs to make the submission. The information about the allocation of applications to groups is contained in **Table 1** given below.
2. Install **ns-3** on your computer, write programs and simulate the network described in the given application assigned to you, perform the required experiments, and answer the given questions.
3. Use **ns-3**'s **Flow Monitor** module to collect and store the performance data of network protocols from the simulation. **Do not use PCAP + Wireshark for the trace collection**. No marks will be awarded if your application uses PCAP file for trace collection.
4. Submit your set of source code files, and your report containing the graphs and the answers, for the assigned application as a zipped file on Moodle (maximum file size is 1 MB) by the deadline of **11:55 pm on Monday, 22nd April 2019 (hard deadline)**. The **ZIP file's name should be the same as your group number**, for example, "Group_4.zip", or "Group_4.rar", or "Group_4.tar.gz".
5. The assignment will be evaluated through viva voce in your lab during your lab session on **Wednesday, 24th April 2019 (ML-3: 9:00 am to 11:55 am)** where you also need to explain your source codes and execute them before the evaluator (evaluation schedule and TA allocation will be notified in due time).
6. **Write your own source codes and do not copy from any source. Plagiarism and use of unfair means will be penalised by awarding NEGATIVE marks (equal to the maximum marks for the assignment).**

Table 1: Allocation of applications to groups

Application Number	Group Numbers
1	1, 7, 13, 19, 25, 31, 37, 43
2	2, 8, 14, 20, 26, 32, 38, 44
3	3, 9, 15, 21, 27, 33, 39, 45
4	4, 10, 16, 22, 28, 34, 40
5	5, 11, 17, 23, 29, 35, 41
6	6, 12, 18, 24, 30, 36, 42

Application #1:

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.



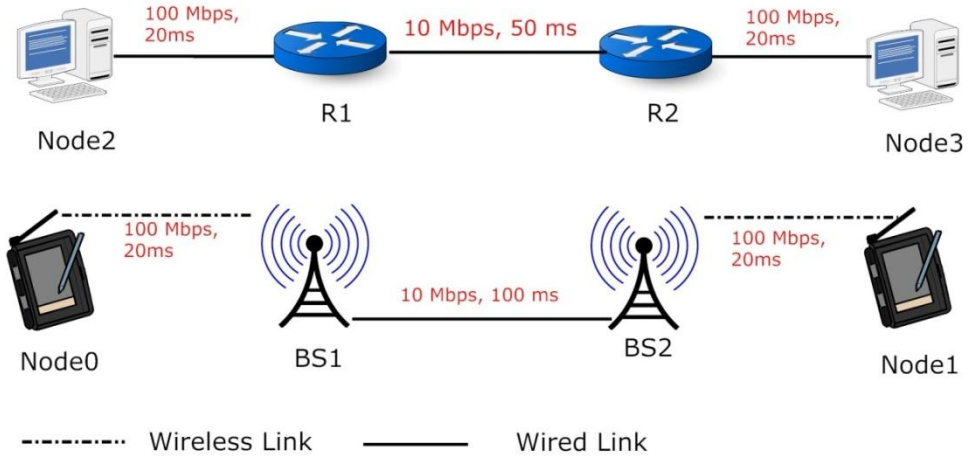
1. Start only one flow and analyse the throughput over sufficiently long duration. Mention how you select the duration. Plot the evolution of congestion window w.r.t. time. Perform this experiment with all the flows attached to all the three sending agents.

2. 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 flow at a steady-state. Report the maximum throughput observed for each of the flows.

3. Measure the congestion loss and the goodput over the duration of the experiment for each of the flows.

Application #2:

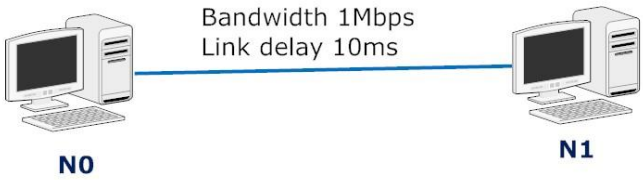
Compare the performance of TCP over wired and wireless networks. Consider a topology as described below. The network consists of two TCP sources Node0 and Node2, corresponding to two TCP destinations Node1 and Node3 respectively. Node2 and Node3 come in wired domain with two routers R1 and R2 (connected by a {10 Mbps, 50 ms} wired link) between them. Both the routers use drop-tail queues with queue size set according to bandwidth-delay product. Node0 comes in domain of Base Station 1 (BS1) and Node1 comes in domain of Base Station 2 (BS2). BS1 and BS2 are connected by a (10 Mbps, 100 ms) wired link. The hosts, i.e. Node0, Node1, Node2, Node3 are attached with (100 Mbps, 20ms) links to routers or base stations (as shown in the figure below). The sources (Node0 and Node2)) use three TCP agents (i.e. TCP Westwood, TCP Veno and TCP Vegas) to generate three different TCP flows. Study and plot the fairness index (Jain's fairness index) and throughput change when the TCP packet size is varied; all the other parameter values are kept constant. You should use the following TCP packet size values (in Bytes): 40, 44, 48, 52, 60, 552, 576, 628, 1420 and 1500 for your experiments. The throughput (in Kbps) and fairness index must be calculated at steady-state. Make appropriate assumptions wherever necessary.



Application #3:

Create a topology of two nodes N0 and N1 connected by a link of bandwidth 1 Mbps and link delay 10 ms. Use a drop-tail queue at the link. Set the queue size according to bandwidth-delay product. Create a TCP agent (type of the agent specified below) and FTP traffic at N0 destined for N1. Create 5 CBR traffic agents of rate 300 Kbps each at N0 destined for N1. Make appropriate assumptions wherever necessary. The timing of the flows are as follows:

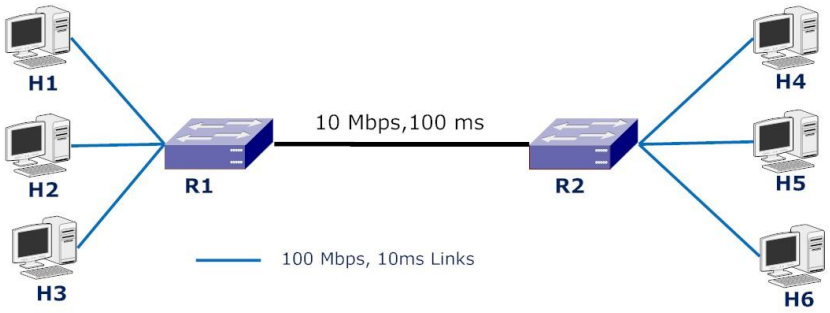
- FTP starts at 0 sec and continues till the end of simulation.
- CBR1 starts at 200 ms and continues till end.
- CBR2 starts at 400 ms and continues till end.
- CBR3 starts at 600 ms and stops at 1200 ms.
- CBR4 starts at 800 ms and stops at 1400 ms.
- CBR5 starts at 1000 ms and stops at 1600 ms.
- Simulation runs for 1800 ms.



1. Plot graph(s) of TCP congestion window w.r.t. time for following 5 TCP congestion control algorithm implementations, and describe the TCP congestion control algorithms' behaviour.
    - Case 1: use TCP New Reno
    - Case 2: use TCP Hybla
    - Case 3: use TCP Westwood
    - Case 4: use TCP Scalable
    - Case 5: use TCP Vegas
2. Draw a graph showing cumulative TCP packets dropped w.r.t. time comparing above 5 TCP congestion control algorithm implementations.
3. Draw a graph showing cumulative bytes transferred w.r.t. time comparing above 5 TCP congestion control algorithm implementations.

Application #4:

Compare the effect of buffer size on TCP and UDP flows. Select a Dumbbell topology with two routers R1 and R2 connected by a (10 Mbps, 100 ms) link. Each of the routers is connected to 3 hosts, i.e. H1, H2, H3 are connected to R1, and H4, H5, H6 are connected to R2. All the hosts are attached to the routers with (100 Mbps, 10 ms) links. Both the routers (i.e. R1 and R2) use drop-tail queues with equal queue size set according to bandwidth-delay product. Choose a packet size of 1.5 KB. Start 4 TCP New Reno flows, and after a while start 2 CBR over UDP flows each with 20 Mbps. These flows are randomly distributed across H1, H2 and H3. Increase the rate of one UDP flow up to 100 Mbps and observe its impact on the throughput of the TCP flows and the other UDP flow. Vary the buffer size in the range of 10 packets to 800 packets and repeat the above experiments to find out the impact of buffer size on the fair share of bandwidth and plot the necessary graphs. Make appropriate assumptions wherever necessary.

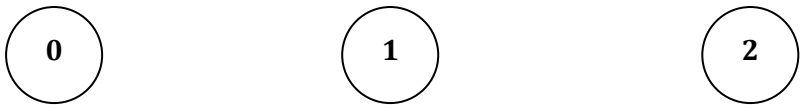


Application #5:

Using the network simulator ns-3, study the characteristics of IEEE 802.11. For the purpose of experiment, use the topology as follows. There are 3 nodes in the network located in a straight line at locations 250*i, with i=0, 1, 2. Node 0 and Node 2 both have TCP traffic to Node 1 (started randomly within 1 to 5 seconds of starting the simulation). Consider TCP Westwood+ or TCP Hybla for the TCP agents at Node 0 and Node 2, respectively. You have to run the simulations and measure the following from the trace output (the averages are taken over all the nodes). Do not use PCAP file for collecting the trace. Use Flow Monitor module in ns-3 for trace collection. *No marks will be given if you consider PCAP trace with Wireshark*.

1. Average bandwidth spent in transmitting RTS, CTS, and ACK.
2. Average bandwidth spent in transmitting TCP segments and TCP acks.
3. Average bandwidth wasted due to collisions.
4. TCP throughput (number of acknowledged bytes per unit time) at each node.

You have to run the simulations for 50 seconds each with different RTS thresholds (i.e. 0, 256, 512 and 1000 bytes) and TCP segment size of 1000 bytes. You can use scripts for trace file analysis and to plot the results. Make appropriate assumptions wherever necessary.

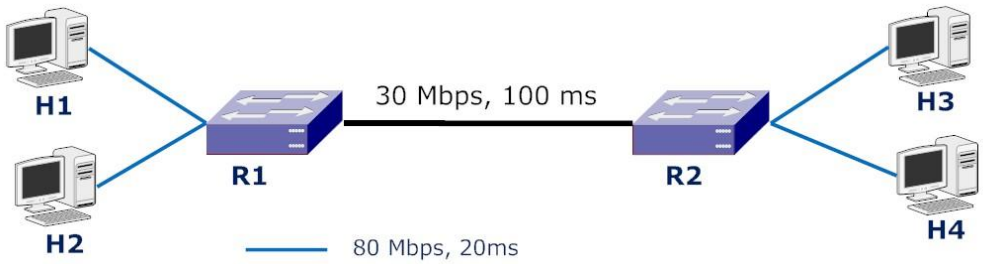


Application #6:

The objective is to compare the effect of CBR traffic over UDP agent and FTP traffic over TCP agent. Consider a TCP agent from TCP HighSpeed, TCP Vegas and TCP Scalable for the FTP traffic. Consider a Dumbbell topology with two routers R1 and R2 connected by a wired link (30 Mbps, 100 ms), and use drop-tail queues with queue size set according to bandwidth-delay product of the link. Each of the routers is connected to 2 hosts, i.e. H1, H2 are connected to R1, and H3, H4 are connected to R2. The hosts are attached to the routers with (80 Mbps, 20ms) links. The CBR traffic over UDP agent and FTP traffic over TCP agent are attached to H1 and H2 respectively. Choose appropriate packet size for your experiments and perform the following:

1. Compare the delay (in ms) and throughput (in Kbps) of CBR and FTP traffic streams when only one of them is present in the network. Plot the graphs for the delay (in ms) and throughput (in Kbps) observed with different packet sizes.

2. Start both the flows at the same time and also at different times. Also, compare the delay (in ms) and throughput (in Kbps) of CBR and FTP traffic streams. Plot the graphs for the delay (in ms) and throughput (in Kbps) observed with different packet sizes.



Make appropriate assumptions wherever necessary.

Group Number	Group Members	
	Roll Number	Name
1	160101008	Abhishek Ranjan
	160101018	Avinash Uchchainiya
	160101034	Hemant Yadav
2	160101019	Tushara Langulya
	160101020	Bedadhala Manoj Reddy
	160101040	Bhargav Mallala
3	160101048	Nitin Kedia
	160101005	Abhinav Mishra
	160101049	Rohit Pant
4	150123023	Md Imtiyaz
	150101008	Ankit Vyas
	150101030	Krishna Kumar
5	160101066	Shivam Kumar
	160101067	Shreyanshi Bharadia
	160101059	Samyak Jain
6	160123047	Atharva Amdekar
	160123046	Rajat Paliwal
	160123051	Saurabh Rai
7	160123032	Rakshit Tiwari
	160123035	Satyam Kumar
	160123008	Eswar Modala
8	160101045	Lakshmi Sai Durga Myneni
	160101064	Pradeepa Seelam
	160101029	Ajay Ram Gudala
9	160123054	Deepak Kumar Gouda
	160101085	Akul Agrawal
	160123044	Yash Kothari
10	160101076	Vivek Raj
	160101039	Kapil Goyal
	160101057	Sahib Khan
11	160123024	Neelabh Tiwari
	160123048	Uddeshya Mathur
	160123049	Himanshu Raj
12	160101071	Siddharth Sharma
	160101054	Ravi Venkata Naga Pavan Kumar
	160101052	Poreddy Sai Kiran Reddy
13	160123039	Shreya Jain
	160123021	Muskan Agarwal
	160123014	Kartikey Kant
14	160101012	Ansh Sood
	160101031	Harshit Gupta
	160101038	Kanika Agarwal
15	160101070	Shubhanker Jauhari
	160101068	Shubhendu Patidar
	160123031	Rajan Sukanth
16	160101037	Kakustham Anurag
	160123015	Kodali Naga Sai Anirudh
	160123053	Shiva Reddy

Group Number	Group Members	
	Roll Number	Name
17	160123007	Divya Kumari
	160101028	Ekta Dhan
	160123052	Sayani Kundu
18	160101051	Phool Chandra
	160101062	Savinay
	160101063	Savsani Kevin Mukesh Bhai
19	160101001	Aadil hoda
	160101065	Shimona Verma
	160101072	Sparsh Bansal
20	160101035	Inderpreet Singh Chera
	160101042	Mitansh Jain
	160101073	Sujoy Ghosh
21	160123004	Ankam Aman sai
	160123013	Kamana Vishnu Vardhan Reddy
	160123041	Thirthala Udayasri
22	160101003	Abhay Kshatriya
	160123002	Abhishek Dogra
	160101010	Aditya Chouhan
23	160101058	Sahil Garhwal
	160101060	Sanchit Jangir
	160101078	Wakade Yugandhar
24	160123038	Shrey Jain
	160123025	Neha Oraon
	160123050	Naveen Mathew
25	160101021	Rajas Bhadke
	160101007	Abhishek Kumar
	160101027	Durgesh Yadav
26	160101087	Archit Jugran
	160101083	Shubham Goel
	160101079	Yagyansh Bhatia
27	160101044	Mukul Verma
	160101050	Paranjay Bagga
	160101075	Varun Kumar Kedia
28	160101014	Arpan Konar
	160101015	Arpit Gupta
	160101081	Debangshu Banerjee
29	160101030	Harshit Agrawal
	160101032	Harshit Sharma
	160123005	Anurag Barfa
30	160101016	Ashveen Bansal
	160101006	Abhishek Bhardwaj
	160101026	Divyansh Sharma
31	160101009	Abhishek Suryavanshi
	160101082	Ameya Daigavane
	160101084	Nitesh Jindal
32	160123018	MARUPAKA SAITEJA
	160123045	YERNENA SRINIVAS NAIDU
	160101077	VYKUNTAM AKHIL

Group Number	Group Members	
	Roll Number	Name
33	160101002	Aayush Sanjay Agarwal
	160101024	Daman Tekchandani
	160101033	Harshit Srivastava
34	160101043	Mohit Singh
	160101047	Nikhil Kumar
	160101055	Ritik Agrawal
35	160123026	nipendra singh
	160101056	sachin chouhan
	160101069	shubham kumar koul
36	160123010	Harshit Singh
	160123016	Kshitij Nayar
	160123017	Kuldeep Sharma
37	160101046	Namit Kumar
	160101036	Jatin Goyal
	160101061	Saurabh Bazari
38	160101086	Shaurya Gomber
	160101088	Rishabh Jain
	160123036	Shashwat Jolly
39	160123006	Ashish Ranjan
	160123003	Animesh Kumar
	160123020	Mitanshu Mittal
40	160123027	Nishant Jain
	160123028	Pranav Jangir
	160123030	Rahul Kumar Gupta
41	160123011	Himanshu ranjan
	160123001	Aashutosh Agarwal
	160123019	Mohammad zatin meraz
42	160123043	Yash Kumar
	160101023	Chandra Prakash Meena
	160101025	Divyam Agarwal
43	160123009	Garikapati Ganesh
	160123022	Nalgonda Gnaneshwar kumar
	160101022	Boddu Hari
44	160101004	Abhinav Hinger
	160101013	Apurva N Saraogi
	160123012	Ishan Azad
45	150101028	JIGNYASU RASESH CHASMAWALA
	160101080	YASH RATHORE
	160123029	PRANAV SINGH MUKATI
	160101011	AKHIL CHANDRA PANCHUMARTHI

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