CS 549: Performance Analysis of Computer Networks
Mini Projects

Assigned: April 22, 2025 *Review*: April 28, 2025 *Due*: May 14, 2025

There are 3 types of mini-projects: experimental, simulation and theory/analysis. You may either choose one from any category or you may propose your own. You may work in groups of 3 for the project.

For the experimental mini-projects: In some projects you are required to use MeasurementLab [1], in some you will set up your own network. Your network may be a virtual network where the nodes are network namespaces + MACVLAN configured on your laptop, or a real network where the nodes are PCs/Laptops which are connected by Ethernet in a lab. In both these networks, you can use `tc` to cause packet delay and loss, emulating conditions in a real network. For a description of various components required to setup a virtual network using network namespaces, see [3].

For the simulation mini-projects: You will need to use NS2 or NS3 (as applicable). For an overview of NS2 architecture and installation instructions, see [4]. The NS2 manual [5] has detailed instructions and sample scripts. For an overview of the NS3 platform, see [6]. The NS3 manual [7] has detailed instructions and sample scripts.

In the experimental and simulation mini-projects, (1) start with design of experiments: list all the system parameters and the range over which you plan to vary each one. Estimate the total number of experiments to be run, and the time it will take you. (2) Sketch graphs showing the expected results. (3) Run the experiments. (4) Plot and analyse the results. Depending on the outcome, you may need to iterate over some more experiments. In all problems, you must explore sufficiently that you learn beyond the lectures and assignments.

1 Experimental projects

1. Configure a network with N+1 nodes. Designate one node as the server and the other N nodes as clients. Choose any file transfer server such as ftpd, sshd. Vary the rate, loss and delay on the client to emulate some real network scenario. Have the clients generate requests to the server for this scenario. Measure the performance, analyse and draw inferences.

2. Similar to (1) except use Apache or other web server.

3. Similar to (1) except write your own client-server code using TCP or UDP sockets.

4. Similar to (1) except choose file sizes from two categories: (i) small files (few kBs) and (ii) large files (few 100s of MBs). Vary the loss and delay, analyse the impact of these factors on the two types of file transfers.

5. Similar to (1) except choose two categories of data flow: (i) file transfer using TCP and (ii) dummy packets using UDP. Vary the loss and delay, analyse the impact of these factors on the two flows.

6. MeasurementLab provides a simple browser-based tool that anyone can run in a few seconds to measure the throughput and latency of their Internet connection [1]. Data from all measurements is stored in a cloud repository and available for anyone to use. The repository contains data from almost every country in the world. In this project, you will make use of this database to do a comparative analysis. Do the following using MeasurementLab:

   (a) use the global dashboard to compare India with a few other countries.

   (b) download the raw data for India for some period and compute performance stats for each ISP (BSNL, Airtel, Reliance, etc.) using the client IP address to identify the ISP. Compare the performance of different ISPs. Metrics for comparison to include mean/median, min, max etc. of download and upload throughput, throughput vs. latency, loss/error %.

7. MeasurementLab provides a simple browser-based tool that anyone can run in a few seconds to measure the throughput and latency of their Internet connection [1]. Data from all measurements is stored in a cloud repository and available for anyone to use. The repository contains data from almost every country in the world. In this project, you will make use of this database to do a comparative analysis. Do the following using MeasurementLab:

   (a) use the global dashboard to compare India with a few other countries.

   (b) download the raw data for India for some period and compute performance stats for at least 5 states of your choice, using the client IP address to identify the ISP. Compare the performance of the network in these states. Metrics for comparison to include mean/median, min, max etc. of download and upload throughput, throughput vs. latency, loss/error %.

8. Use your cellphone or laptop to systematically measure the RSSI inside and outside your hostel. Draw an RSSI contour map on a drawing of the building, showing the locations of APs. Propose changes to the APs to improve coverage.

9. Cellular providers such as Airtel, Vi and Jio try to ensure that signal strength is good everywhere, to keep their customers happy. They have to place 4G/5G base-stations (called "eNodeB" in LTE parlance) strategically to ensure this. The wireless signals undergo attenuation due to (1) obstacles, and (2) multipath effect. Because of this, it is not easy to theoretically predict exactly what the signal strength will be at all locations, given the placement of base-stations. Some Android apps such as NetMonitor Cell Signal Logging Lite allow one to measure the signal strength received at a particular place. Use this app to measure the signal strength in various places on campus, including indoor and outdoor areas. Draw inferences by comparing the signal strength. Use an app

that helps you locate the position of the nearest mobile tower, and use this information to enhance the inferences drawn above. Repeat the experiment for a total of 3 service providers.

10. Nagios Core is an open source system and network monitoring and control (NMS) platform [14]. It periodically polls the hosts and services specified. It alerts the system administrator in case of faults. It provides a web interface to access all the statistics of the network. Configure it to discover all the hosts, servers, routers and other network elements in your campus. In case of failure of any service, configure Nagios to attempt to correct the problem that caused the failure and then to automatically restart the service. Monitor the traffic and performance of some routers and services over a period of one week or more. What inferences can you make about these services/routers? Note: you will need to get SNMP access to selected network elements from your network administrator.

2 Simulation projects

In the simulation mini-projects, compare the simulation results with analytical results given in the textbooks, where available.

11. In linear incremental backoff (LIB) in which the number of slots is increased by a fixed amount on each successive collision. This is slightly different from the binary exponential backoff (BEB) used in Ethernet. Use your favourite programming tool to write a simulator that can simulate LIB and BEB. Compare the performance of the two. Vary the number of nodes and the traffic rate from each node.

12. Destination Sequenced Distance Vector (DSDV) is a routing protocol that is based on the Bellman-Ford algorithm. Conduct simulations on NS3 to analyse DSDV. Choose various factors for parameters: number of nodes, movement of nodes, type of traffic etc. Record delay, throughput and packet loss and draw inferences from the results.

13. Repeat (9) for Ad-hoc On-demand Distance Vector (AODV) protocol.

14. Using NS3, compare the performance of Slotted ALOHA and 1-persistent CSMA. Vary the number of nodes and the traffic rate from each node.

15. Using NS3, simulate a hybrid network where some nodes use wired medium and others use wireless medium. Vary the number of nodes, data rates of the media, type of traffic and evaluate the network performance in terms of select choice of metrics.

16. The evolution of the queue in a router depends on the number of hosts and the bandwidth of the access links that connect the hosts to the router. In

this exercise we will evaluate the performance of the router using NS2/NS3 simulations. Simulate a network of queues with 2 edge routers and 1 core router. The edge routers have service capacity of C_1 and C_2 Mbps, and serve N_1 and N_2 hosts. The access links connecting the hosts to the edge routers must handle a maximum rate X_i Mbps, such that $N_i \times X_i > C_i$, say $X_i = 1.2C_i/N_i$. The core router must have a service capacity larger than each C_i but smaller than $C_1 + C_2$. For fixing the size of the router buffers (B), use the bandwidth-delay product rule $B = C \times RTT$ [8], where you may fix RTT as 250 ms. Each host in the network performs FTP using a variant of the TCP Reno protocol known as TCP NewReno. Choose three distinct combinations of N and X for each edge router that satisfy the above equation. Conduct simulations for each combination of (N, X), and record queue length, link utilization and packet drop probability.

17. Google deploys the BBR Congestion Control protocol in its cloud servers [15]. This protocol, while being loosely based on the conventional TCP, it is more complex. Understand the working of the protocol. Using NS3 simulate a network of 2 hosts connected over a wired medium where one host transfer a file using BBR to the other. Use the results from the simulations to substantiate/verify your understanding of the protocol.

18. The IEEE 802.11p standard dictates protocols and data unit formats for vehicular communications. At the MAC layer, this standard uses priority queueing, and using Enhanced Distributed Channel Access to ensure that transmitting stations can access the shared medium and transmit based on the priorities assigned to the enqueue packets, see Section III-A of [16]. Using NS3, simulate a network of mobile nodes that generate two categories of packets: (i) high priority and (ii) low priority as per random processes governed by pre-defined parameters. Each node broadcasts these packets to all the other nodes in the network. Considering various factors and levels, analyse the performance of the network for packets from both the categories, using packet delay as a metric.

19. Simulate an M/M/1/B queue using your favorite programming tool, compare the blocking probability and delay observed with the analytical results. Extend this observation to cases where the service process follows a general distribution. Guided by the simulations, can your derive analytical results for the M/G/1/B queueing system.

3 Theory/analysis projects

The following are theory/analysis based miniprojects. For these, you are expected to do/repeat the analysis and extend the plots (if any) in the given references. You may extend the research in interesting directions.

20. IEEE 802.11ad specifies a hybrid MAC protocol that comprises contention- and non-contention-based mechanisms. A three-dimensional Markov chain model,

for such a protocol, and its analysis are discussed in [9]. Repeat the modelling and analysis.

21. The IEEE 802.11p standard dictates protocols and data unit formats for vehicular communications. At the MAC layer, this standard uses priority queueing, and using Enhanced Distributed Channel Access to ensure that transmitting stations can access the shared medium and transmit based on the priorities assigned to the enqueue packets. The backoff procedure for each Access Category can be modelled using Markov Chains, as in [16]. Understand the analysis, and illustrate using computations.

22. In order to improve the energy efficiency of the Internet researchers have proposed several modifications to routing protocols. These enhanced protocols work by powering off links during low-traffic period. The work in [10] proposes one such modification to the link state routing protocol OSPF. Repeat the modelling and analysis, propose improvements/ alternative ways of doing it.

23. Reference [11] analyses the delay in a TDMA channel. Repeat the analysis and the numerical example.

24. As the number of Internet hosts grows, so does the size of the routing table. This demands more memory and reduces the packet forwarding speed thereby increasing the end-to-end delay. The work in [12] discusses 4 factors that influence the growth of routing tables. Examine the contribution of each of these factors on the size of the routing table. Add your own illustrative examples (numerical or simulation results).

4 BYOP Bring your own *project*

Propose any mini-project of your own:

25. It must be related to PACN, the level of difficulty must be similar to the above, and it must not be work that is submitted/to be submitted for any other course.

5 What to submit

Your submissions will have two components. A one-page review document, and a presentation. The review document must include detailed plans to how you will proceed with the project. The final presentation must include analysis, results, inferences (as applicable). The presentation must be submitted by due date. These must be self-made and not plagiarised in any way. To see what constitutes plagiarism, read reference [2]. There will be no *presentation* session. You will only be quizzed on the contents of the slides. The presentations will go through a plagiarism check on Turnitin. More instructions on the review documents and presentation will be sent in due course.

References

[1] Measurement Lab, available: https://www.measurementlab.net/.

[2] "What is plagiarism," available: https://www.plagiarism.org/article/what-is-plagiarism

[3] Anoushka Banerjee and Shaifu Gupta, "CS549: Quick Guide to Virtual Networking," IIT Mandi, Apr 2020.

[4] Slides on "The Network Simulator 2," borrowed from Communication Networks, Aug – Nov 2015, Department of Electrical Engineering, IIT Madras, available: https://cloud.iitmandi.ac.in/f/694ee8c99e7245849664/?dl=1

[5] E. Altman and T. Jimenez, "NS Simulator for beginners," Synthesis Lectures on Communication Networks, vol. 5.1, pp 1–184, 2012.

[6] Ns3 simulation platform. Available: https://www.nsnam.org/releases/ns-3-36/

[7] Ns3 - Network Simulation, Manual. Available: https://www.nsnam.org/docs/manual/ns-3-manual.pdf

[8] G. Raina and D. Wischik, "Buffer sizes for large multiplexers: TCP queueing theory and instability analysis," in Proc. of Next Generation Internet Networks, pp. 173–180, 2005.

[9] K. Chandra, R.V. Prasad and I. Niemegeers, "Performance analysis of IEEE 802.11 ad MAC protocol," IEEE communications letters, vol. 21.7, pp. 1513–1516, 2017.

[10] A. Cianfrani, V. Eramo, M. Listanti, M. Marazza and E. Vittorini, "An energy saving routing algorithm for a green OSPF protocol," in Proc. of IEEE Conference on Computer Communications Workshops (IEEE INFOCOM), pp. 1–5, 2010.

[11] S.S. Lam, "Delay analysis of a time division multiple access (TDMA) channel," IEEE Transactions on Communications, vol. 25.12, pp. 1489–1494, 1977.

[12] T. Bu, L. Gao and D. Towsley, "On routing table growth," ACM SIGCOMM Computer Communication Review, vol. 32.1, pp. 77–88, 2002.

[13] S. Shakkottai, R. Srikant, A. Ozdaglar and D. Acemoglu, "The price of simplicity," IEEE Journal on Selected Areas in Communications, vol. 26(7), pp.1269–1276, 2008.

[14] Install Nagios Core https://www.nagios.com/products/nagios\protect\discretionary{\char\hyphenchar\font}{}{}core/.

[15] N. Cardwell, et al. “BBR: Congestion-based congestion control.” Communications of the ACM 60.2 (2017): 58-66.

[16] J.Zheng and Q. Wu, “Performance modeling and analysis of the IEEE 802.11 p EDCA mechanism for VANET.” IEEE Transactions on Vehicular Technology, 65.4 (2015): 2673-2687.