



College of Computing

Georgia Institute of Technology

## Networking Qualifying Exam: Spring 2011

### Part I

This qualifying exam has six questions over two days. Each question has multiple sub-questions.

The exam has two parts. Part I has three questions and is to be completed by 5 p.m. on March 29, 2011. Part II has three questions and is to be completed by 5 p.m. on March 30, 2011. Your answers must be typed. Submit each part of the exam as a **single PDF** to `aglass@cc.gatech.edu`.

Some parts of each question are open-ended; you should do your best in providing as complete an answer as possible covering as many angles as you can see to the question.

### 1 Virtual Networking

- (a) Define what is meant by a “Virtual Network”. What is the difference between a *virtual network* and an *overlay network*, if any? *Note:* There are no universally accepted concise definitions for these terms. Nevertheless we are looking for you to provide definitions of these concepts from your understanding of the literature. Make sure to argue for the validity of your definitions from your readings. **Definitions without an accompanying discussion/argument will receive no credit.**
- (b) Describe prevalent technologies that are used to build virtual networks in today’s Internet.
- (c) Describe applications that make extensive use of virtual networks today.
- (d) Let’s classify Internet traffic today as either “native”, i.e., using native paths on the Internet or “virtual” that is running over a virtual network. One interesting question is “what is the proportion of traffic in each category?”
  1. How would you go about answering this question? (*Hint:* this has to start by making the question more precise.)
  2. Can you propose a hypothesis of what the proportion might be and provide some preliminary support of this hypothesis.

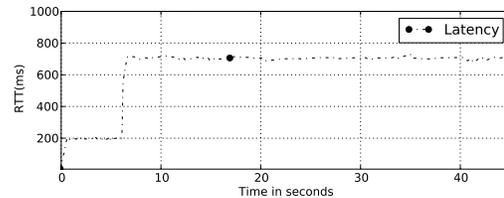
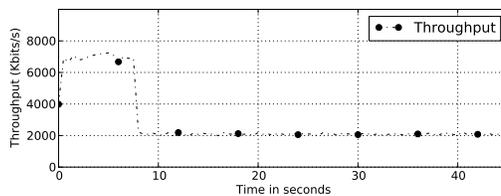
*Note:* There is no well-known answer to these questions. We are looking for your thought process here and how you would substantiate your hypothesis from your networking knowledge and from networking literature.

## 2 Traffic Shaping

- (a) Explain what traffic shaping is, and why a network operator might enable it on a network link.
- (b) Two common mechanisms for shaping traffic are a token bucket and a leaky bucket. Explain the difference between the two, and when each might be useful. What are some real-world examples where either of these is deployed? (Please cite any examples with a URL.)
- (c) A user who initiates a large upload may quickly exhaust all of the tokens in a “burst”. Packets that arrive at a token bucket filter that has insufficient available tokens could be subject to several policies:
- They might be dropped.
  - They might be put into an alternate queue.
  - They might be buffered.

For each of these actions, explain a case where that particular action might be desirable.

- (d) The figure below shows an example traffic trace from the *output* of a token-bucket traffic shaper, including both throughput, latency, and packet loss rates. Assume the following:
- throughput levels are 7000 Kbps and 2000 Kbps.
  - RTT levels are 200ms and 700ms
  - the drop in throughput and rise in RTT occurs at 7s



Based on these values: What is the bucket size? What is the size of the buffer? What is the rate at which the tokens fill the bucket?

- (e) One particular problem with a token bucket traffic shaper is that there is no way to explicitly limit the maximum sending rate. In practice, however, an ISP might also want to limit this peak rate. Design a scheme that allows a users to send traffic at a rate of up to 20 Mbits/sec and then throttles the user’s rate to 10 Mbits/sec after 30 seconds.
- (f) Shaping traffic with a token bucket might interfere with interactive traffic if the shaper uses a buffer that is too large. Explain the nature of the interference. Suppose that the buffering for the traffic shaper is somewhere in the network where you could not configure it yourself. Design a mechanism that allows interactive traffic to co-exist with bulk transfers in the presence of such a token bucket filter.

### 3 Internet Topology

This problem relates to Internet topology at the Autonomous System (AS) level.

- (a) People often infer the AS-level topology using BGP routing tables from several monitors at different ASes. Explain how this inference process works. In other words, how can you transform a set of BGP routing tables to an AS-level graph?
- (b) The previous inference process is far from perfect. Identify conditions where:
  1. the inferred graph may NOT include a certain AS,
  2. the inferred graph may NOT include a certain customer-provider (transit) link, and
  3. the inferred graph may NOT include a certain peering link.

Which of the previous three inference errors are more common in practice?

- (c) There has been a lot of discussion (and contradictory research papers) about an appropriate model for the AS-level topology. One proposed model is the preferential attachment model by Barabasi and Albert (you can find a short description of that model at Wikipedia; search for Barabasi-Albert model). What is the main characteristic of the AS-level topology that that model captures? Identify at least two major characteristics of the Internet topology that are not captured by the preferential attachment model.
- (d) An interesting observation (see Dhamdhere's paper "Ten years in the evolution of the Internet ecosystem" at *IMC 2007*) is that the average path length between ASes has remained practically constant during the last ten years, despite the large increase in the number of ASes. Identify three simple network models ("toy models") where: i) the average path length increases linearly with the network size, ii) the average path length increases logarithmically with the network size, iii) the average path length remains constant as the network size increases.