*College of Computing*

Georgia Institute of Technology

## CS 6250: Computer Networking: Fall 2011

# Quiz I

There are 13 questions (and one bonus question) and **??** pages in this quiz booklet (including this page). Answer each question according to the instructions given. You have **85 minutes**.

If you find a question ambiguous, write down any assumptions you make. **Be neat and legible.** If I can't understand your answer, I can't give you credit! There are three pretty challenging questions (clearly marked); you may want to look through the whole quiz and save those for last.

Use the empty sides of this booklet if you need scratch space. You may also use them for answers, although you shouldn't need to. *If you do use the blank sides for answers, make sure to clearly say so!*

**Note well: Write your name in the space below AND your initials at the bottom of each page of this booklet.**

**THIS IS AN "OPEN NOTES, OPEN PAPERS" QUIZ.**
**LAPTOPS ARE ALLOWED, BUT ONLY FOR REVIEWING PAPERS AND NOTES**
**NO OTHER MATERIALS, NO PHONES, NO PDAS.**
***ABSOLUTELY NO EMAIL OR MESSAGING OF ANY KIND!***
**MAKE SURE YOU'VE READ ALL THE INSTRUCTIONS ABOVE!**

*Initial here to indicate that (1) you've read the instructions and (2) you agree to abide by the Georgia Tech Honor Code:*

The last page has easy bonus questions, which you can answer outside of the allotted time. Rip the last page off of your quiz for five bonus points. Turn it in anonymously if you like.

*Do not write in the boxes below*

| 1-5 (xx/20) | 6-10 (xx/30) | 11-13 (xx/20) | Bonus (5+xx) | Total (xx/70) |
|---|---|---|---|---|
| | | | | |

**Name:**

# I Warmup

**1. [4 points]:** Which of the following is true about static configuration analysis (like the type in the *rcc* paper)?

**(Circle ALL that apply)**

**A.** Static configuration analysis never raises false alarms; that is, if it detects an error, it is always correct.

**B.** Sometimes the behavior of routing protocols depends on route message ordering, so static configuration analysis cannot detect all errors.

**C.** Static configuration analysis requires writing new tests for every routing protocol.

**D.** Data-plane analysis tools like Anteater often make it easier to understand how to correct a configuration error, since it checks the state of the data plane directly.

**E.** All of the above.

**Answer 1** The answer is: (B), (C). ■

**2. [4 points]:** Which of the following is true about S-BGP?

**(Circle ALL that apply)**

**A.** An S-BGP router signs the AS path including the *next* AS along the path, to prevent path shortening attacks.

**B.** S-BGP does not prevent an AS from falsely withdrawing a route advertisement.

**C.** S-BGP guarantees that data packets travel along the advertised AS path to the destination.

**D.** S-BGP requires a certificate authority that maintains accurate mappings of each portion of IP address space and the AS that owns it.

**E.** None of the above.

**Answer 2** The answer is: (A), (B), (D). ■

**3. [4 points]:** Which of the following most accurately describes the *most common* uses for eBGP, iBGP, and IGP?

**(Circle the BEST answer)**

**A.** eBGP is used within an AS for external destinations, iBGP is used between ASes for external destinations, and IGP is used within an AS for internal destinations.

**B.** eBGP is used between ASes for external destinations, iBGP is used within an AS for external destinations, and IGP is used within an AS for destinations within an AS.

**C.** eBGP is used between ASes for external destinations, iBGP is used within an AS for internal destinations, and IGP is used within an AS for external destinations.

**D.** None of the above

**Answer 3** The answer is (B). ■

**4. [4 points]:** Which of the following is true about the Kapela attack on BGP?

**(Circle ALL that apply)**

**A.** The attack requires the attacker's neighboring AS to accept a route advertisement for a prefix that the attacker does not own.

**B.** The attack depends on AS "sender-side loop detection" (i.e., checking the AS path for one's own AS before accepting the route).

**C.** The victim might be able to discover the attack by noticing a change in end-to-end latency along the path.

**D.** The victim might be able to discover the attack using traceroute.

**E.** None of the above

**Answer 4** The answer is: (A), (B), (C). ■

**5. [4 points]:** Which of the following can an AS use in its route advertisements to indicate to a neighboring "backup" upstream AS to tell the backup AS to send it traffic through a different "primary" AS (as opposed to sending it traffic directly)?

**(Circle ALL that apply)**

**A.** the BGP "community" attribute

**B.** Multiple exit discriminator

**C.** Local preference

**D.** AS path prepending

**E.** All of the above

**Answer 5** The answer is: (A), (D). ■

**Name:**

# II Potpourri

**6. [5 points]:** In his paper, *The Design Philosophy of the DARPA Internet Protocols*, Clark explains how fate-sharing allows the network architecture to survive failures. (1) Explain how storing connection state information at end hosts constitutes fate sharing. (2) Does the 4D architecture of separating the control plane from the data plane violate fate sharing? Why or why not?

**(Answer legibly in the space below.)**

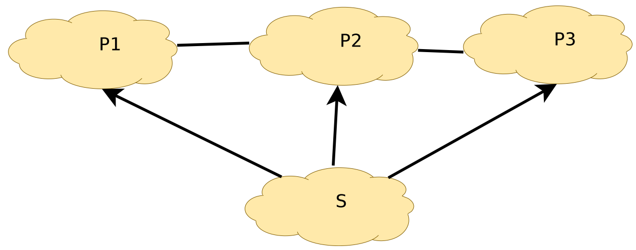
**Answer 6** (1) Storing connection state at end hosts constitutes fate sharing because the state associated with the connection is only lost with the entities associated with the connection itself (i.e., connection state is only lost if a host fails).
(2) It depends on where the state is stored. All of the designs we discussed in class do not violate fate sharing because the state associated with forwarding traffic is still stored in the switches themselves. However, if the 4D controller stored some state that could be lost during a failure that would prevent packet forwarding, then the design could violate the fate sharing principle. ■

**7. [3 points]:** Describe the *end-to-end argument*. Give one example of a network protocol or technology that violates the end-to-end argument (and explain the violation).

**(Answer legibly in the space below.)**

**Answer 7** The end-to-end argument states that functions that can be implemented at the ends of a connection should be implemented at the endpoints, rather than at intermediate points between the endpoints. The rationale for this argument includes robustness and reliability, avoiding duplication of function, and so forth. One technology that violates the end-to-end argument is NAT, because it involves keeping state about the connections in the middle of the path. Hop-by-hop congestion control is another example of a violation. ■

**8. [6 points]:** Consider the AS graph below, which shows a set of ASes and their business relationships. Consider the following questions about their relationships.




**A.** Explain why, in the common case, the stub AS, $S$ would not readvertise routes it learned from provider $P1$ to its other provider, $P2$.

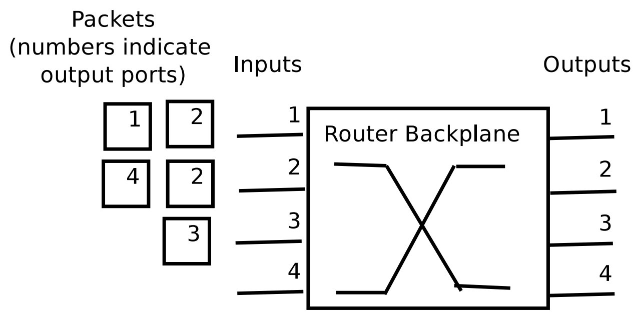
**B.** Explain why, in the common case, $P2$ would not readvertise routes that it learns from its peer $P1$ to its other peer, $P3$.

**C.** Describe a scenario involving "regional peering" where $P2$ might readvertise some of the routes that it learned from $P1$ to $P3$. State specifically which set of routes it might readvertise.

**(Answer legibly in the space below.)**

**Answer 8** In the common case, a stub AS would not readvertise routes it learned from provider $P1$ to provider $P2$ because it pays for connectivity from both providers, regardless of the direction of traffic flow. For a similar reason, routes are not advertised between peers: $P3$ is not paying $P2$ to carry traffic for it to $P1$; doing so effectively incurs $P2$ some cost (e.g., more traffic on its peering connection, which could disrupt peering ratios, etc.). Suppose that $P1$ and $P3$ need connectivity to one another but do not have connectivity in the same city: they might ask $P2$ to provide connectivity between each other's customers, but only for prefixes in a particular city. ■

**9. [8 points]:** Consider the router backplane below, with packets arriving as shown. The number on each packet designates its intended output port. Suppose that each input and output port have a rate of 1 Gigabit per second.




**A.** Suppose the router has a *bus backplane* with throughput of 2 Gigabits per second. What is the total maximum throughput that the router can achieve?

**B.** The example shows an example of head-of-line blocking. Explain why, and explain how virtual output queueing can fix the problem.

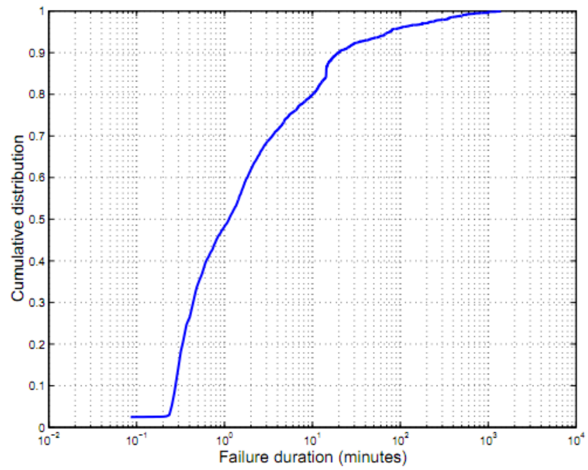
**C.** Now suppose the router has a *crossbar switch backplane* with a throughput of 2 Gigabits per second (a "speedup" of 2) and virtual output queueing. Given the packet arrival pattern shown in the figure, give a sequence of matchings of input ports to output ports that results in 100% utilization (to save time, simple notation like "Round 1: $1 \to 2$" is sufficient to indicate that you match input one to output two in round one).

**(Answer legibly in the space below.)**

**Answer 9** The first question is a bit of a trick question: The total maximum throughput is 1 Gigabit per second: only one input and output port can be occupied on a *bus* for any given timeslot, so no parallelization is possible. Head-of-line blocking exists in this case because inputs 1 and 2 both have packets destined for output 2; however, in a crossbar backplane, either input 1 or input 2 could be matched to output 2 or output 4, respectively. A matching that could achieve 100% utilization is: round 1: $1 \to 2$, $2 \to 4$, $3 \to 3$, round 2: $1 \to 1$, $2 \to 2$. ■

**Name:**

**10. [8 points]:** Consider the CDF below, which shows the distribution of IS-IS failure durations in the a large IP backbone network over a four-month period.




**A.** What is the median failure duration?

**B.** About what fraction of failures last longer than 20 minutes? What is one possible cause of the failures that last longer than 20 minutes?

**C.** From Problem Set 1 (where you were asked about systems for measuring IS-IS traces), how were these measurements likely collected?

**D.** Paxson's paper *Strategies for Sound Internet Measurement* suggests cross-validation of measurements as a means for sanity-checking measurement results. Describe one source of inaccuracy for the measurements below, and one way to cross-validate the measurements.

**(Answer legibly in the space below.)**

**Answer 10** The median failure duration is about 1 minute. About 10% of the failures last longer than 20 minutes; one likely cause for these long-lived outages is fiber cuts. These measurements were likely collected using an IS-IS "monitor"—since IS-IS is a link-state protocol that is flooded, a single monitor on the network would be able to hear all link-state announcements. One possible source of inaccuracy might be timing syncrhonization problems that might result from the fact that the LSAs are only captured from one place in the network. Possible ways of cross-validating these failure durations might be inserting a second IS-IS monitor at a different place in the network, or using a different technique altogether (e.g., probing in the data plane, using traceroute, etc.) ■

**Name:**

# III Measuring Broadband Access Networks

**11. [6 points]:** The output below shows Netalyzr's measurements of buffering on an access link.

> **Network buffer measurements (?): Uplink 7000 ms, Downlink 1300 ms**
>
> We estimate your uplink as having 7000 msec of buffering. This is quite high, and you may experience substantial disruption to your network performance when performing interactive tasks such as web-surfing while simultaneously conducting large uploads.

**A.** Suppose that the *uplink* bandwidth on this access link is 500 kilobits per second. Compute the amount of buffering on the access *uplink*, in bytes.

**B.** Where might this buffering be occurring?

**C.** Explain how this amount of buffering might cause TCP senders to send at rates that are too high for the access link.

**(Answer legibly in the space below.)**

**Answer 11** The amount of buffering is 500 kbits/second · 7 seconds · 1/8 bytes/bit: 437.5 kbytes. This buffering is likely occurring at the bottleneck link along the path, which is the access network uplink in this case. This amount of buffering slows feedback to TCP senders because they will receive information about lost packets much later than they would without buffering; as a result, a TCP sender could open up its TCP window far too much before seeing the first packet loss. ■

**Name:**

**12. [6 points]:** The traceroute below shows the output of a traceroute from the Netalyzr servers back to a home access network that was running the Netalyzr tool.

**Traceroute (?): OK**

It takes 20 network hops for traffic to pass from our server to your system, as shown below. For each hop, the time it takes to traverse it is shown in parentheses.

```
 1. 10.248.108.3 (0 ms)
 2. ec2-75-101-160-166.compute-1.amazonaws.com (0 ms)
 3. 216.182.232.64 (0 ms)
 4. *
 5. *
 6. *
 7. *
 8. xe-0-4-0-6.r01.asbnva02.us.bb.gin.ntt.net (1 ms)
 9. ae-1.r21.asbnva02.us.bb.gin.ntt.net (1 ms)
10. p64-0-1-0.r21.atlnga05.us.bb.gin.ntt.net (20 ms)
11. *
12. 192.205.36.157 (20 ms)
13. cr2.attga.ip.att.net (21 ms)
14. 12.122.141.185 (20 ms)
15. 74.175.192.69 (20 ms)
16. 12.81.16.16 (22 ms)
17. 12.81.16.33 (21 ms)
18. 70.159.176.113 (21 ms)
19. *
20. adsl-145-179-103.asm.bellsouth.net (30 ms)
```

**A.** Why are there lines in the traceroute that list "*"?

**B.** Give one reason why the hops shown might not be the same hops as the path that data packets actually travel.

**C.** Using your knowledge from the *50 Gbps Router* paper about packet processing, give one reason why the time shown might be inaccurate.

**(Answer legibly in the space below.)**

**Answer 12** The lines in the traceroute with "*" are simply cases for which a TTL-limited UDP probe never saw a time exceeded message. This could be caused by a number of factors: a lost UDP probe, a lost time exceeded message on the reverse path, a firewall along the reverse path blocking ICMP messages, etc. As discussed in lecture, two reasons why the hops shown might not be the same hops as the path that data packets travel is: (1) load balancers can send packets along different paths, depending on things like the destination port; (2) the IP address may be the source IP address of the time exceeded message, depending on the implementation. Because ICMP is processed on the router's slow path (as discussed in the referenced paper), the times reported by traceroute may be inaccurate. ■

**13. [8 points]:** George Burdell remembers from CS 6250 lecture that traceroute discovers paths by sending UDP packets by incrementing the destination port on each TTL-limited UDP packet.

**A.** Why does traceroute increment the destination port on each UDP packet?

**B.** George observes: "Incrementing the destination port on each outgoing packet could cause a firewall or intrusion detection system to raise an alarm." Is he right? Why or why not?

**C.** George also observes: "Incrementing the destination port on each outgoing packet could cause load balancers along the path to send each probe packet along a different path." Is he right? Why or why not?

**D.** What fields in the UDP header might you be able to use for traceroute probes that would be guaranteed not to trigger load balancers or firewalls?

**(Answer legibly in the space below.)**

**Answer 13** Some implementations of traceroute increment the destiantion port on each UDP packet because the ICMP time exceeded message that the router returns must be matched to the appropriate hop; that time exceeded message is returned with a portion of the original packet header. Incrementing the destination port allows the header for each UDP probe to be unique. This can sometimes trip firewalls, since sending packets with sequentially increasing port numbers can look like a "port scan". It can also cause load balancers to send each probe packet along a different path, since many load balancers use a 5-tuple (src/dest IP and port, plus protocol) to load balance along equal-cost paths. Other tools, such as Paris traceroute, use the checksum as a unique identifier, rather than the 5-tuple (Paris traceroute was not presented in class, but this question was mainly to see what you could think of; many answers are acceptable for part D.). ■

**14. [6 points]: Bonus.** Suppose that you would like to measure the downstream throughput for an access link for which you do not have direct access. You have access to servers on the Internet and can "ping" the router that is on the downstream side of the access link, but you don't have direct access to either the router, or any devices downstream from the access router. Design a probing scheme that you could send from servers on the Internet to estimate the downstream throughput of the access link. State your assumptions and possible sources of inaccuracy.

**(Answer legibly in the space below.)**

One possibility would be to send giant TCP ACK packets to each host/router on the other side of the access link; the host/router should respond with a small TCP RST packet. In this way, the probing method could saturate the downstream link without saturating the upstream link. If you are curious, this method and others are described in some detail in *Characterizing Residential Broadband Networks*, by Dischinger *et al.*.

# IV Bonus: Anonymous Course Feedback

**This page is anonymous.** Rip this off from your exam, and turn it in separately if you like. You'll get five points for simply ripping off the last page of the exam, but I'd prefer if you fill it out and hand it in in a separate stack.

What are the things you like most about the course so far? Anything is fair game here (topics, course structure, board technique, etc.).

What are the things you like least about the course so far? Again, anything is fair game.

What topics would you like to see covered?

**Name:**