CS3640 Final Exam

Name:

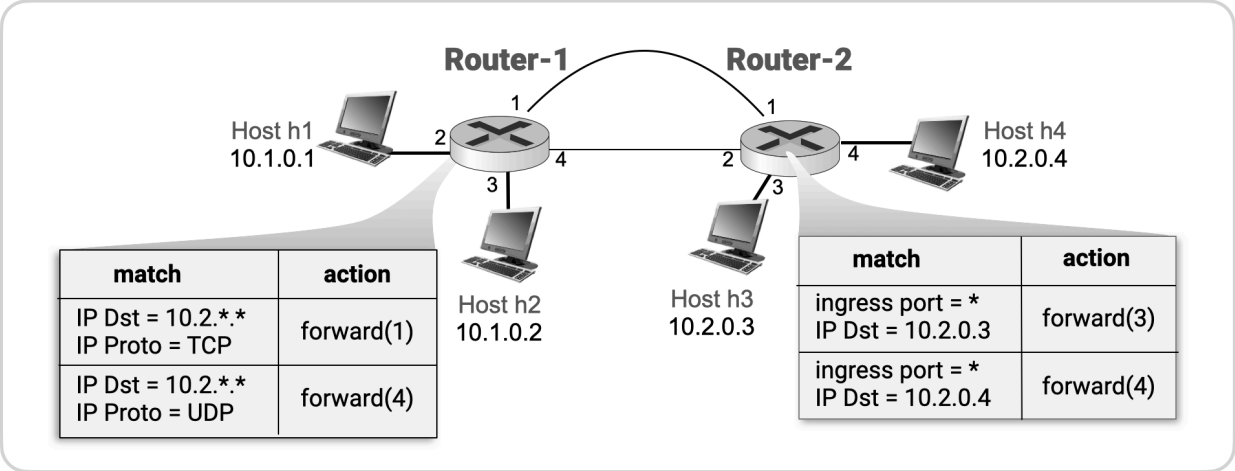
HawkID/university ID:

- This is a closed book, closed notes, closed electronics, but open minds exam
- You have four mandatory questions (Q1 — Q4), all of which carry 25 points
- There is an extra credit question (Q5). Points earned in Q5 can make up for points lost in other questions, but cannot take your score beyond 100
- Keep your answers brief and to the point. While the space provided here should be sufficient to write your answers, we will provide extra sheets if needed.
- You are welcome to clarify any doubts or concerns with the instructor, but cannot engage in discussions with your fellow students
- We expect you to exhibit highest levels of academic integrity and honesty

Q1. Software Defined Networking **25 points**

(a) What is SDN's core abstraction of *match-plus-action*? Explain with an example. (10 points)

(b) In the topology below, SDN flow tables at routers R1 and R2 govern how packets flow across the network. Use this understanding to explain how a TCP packet originating from host h1 and destined for host h4 would travel? Would anything change if the packet were to be of type UDP? (15 points)



match	action
IP Dst = 10.2.*.* IP Proto = TCP	forward(1)
IP Dst = 10.2.*.* IP Proto = UDP	forward(4)

match	action
ingress port = * IP Dst = 10.2.0.3	forward(3)
ingress port = * IP Dst = 10.2.0.4	forward(4)

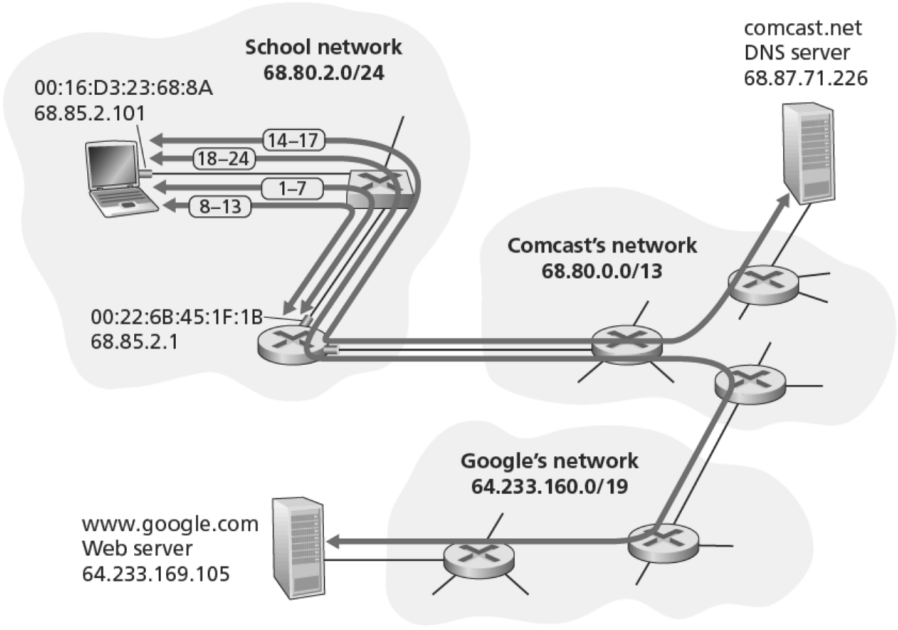
(a) Match-plus-action is the representation of generalized forwarding, where a router can match on multiple header field values associated with network-, transport-, and link-layer protocols; and then take an action on the packet including forwarding, dropping, rewriting, load balancing, copying for further inspection etc. *Description of any middlebox (NAT, firewall, IDS, load balancer etc) is acceptable.*

(b) A TCP packet from h1 reaches router-1 via link 2, then matches the first entry in its flow table and gets forwarded on link-1. At router-2, the packet arrives on link-1, then matches the second entry in its flow table and gets forwarded to h4 via link-4. On the other hand, a UDP packet would match the second entry in router-1 flow table, thereby getting forwarded on link-4. It arrives at link-2 on router-2, and matches the second entry just like the TCP packet, thereby getting forwarded to h4 via link-4.

Q2. A Day in the Life of a Web Page Request **25 points**

Trinity boots her laptop up and plugs it into an Ethernet cable, which is connected to her department's Ethernet switch. Her goal is to use the website www.google.com

In steps 1 - 7, Trinity's laptop procures an IP address for itself, learns about the IP address of its first-hop router (68.85.2.1), and the IP address of the DNS server (68.87.71.226).

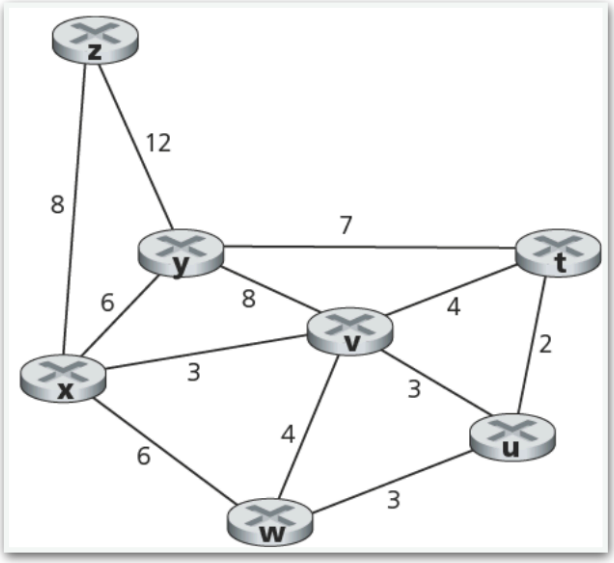


Explain steps 8—17 in full technical detail i.e., explain all the protocols, their control and data flows involved in resolving the DNS name of www.google.com into Google web server's IP address. *You do not have to number each step in your answer, but make sure all the key details are covered*. (25 points)

This is described in page 515 - 516 of the textbook.

Q3. Link-State Routing: Dijkstra's Algorithm — 25 points

Here is a network with seven routers.



(a) Use Dijkstra's algorithm to compute the shortest path from **u** to all other routers. Remember to clearly write your link-state table. (15 points)

(b) Based on the routing information you calculated above, compose the forwarding table for **u**. (10 points)

N'	*D(x), p(x)*	*D(t),p(t)*	*D(v),p(v)*	*D(w),p(w)*	*D(y),p(y)*	*D(z),p(z)*
u	∞	2,u	3,u	3,u	∞	∞
ut	∞	2,u	3,u	3,u	9,t	∞
utv	6,v	2,u	3,u	3,u	9,t	∞
utvw	6,v	2,u	3,u	3,u	9,t	∞
utvwx	6,v	2,u	3,u	3,u	9,t	14,x
utvwxy	6,v	2,u	3,u	3,u	9,t	14,x
utvwxyz	6,v	2,u	3,u	3,u	9,t	14,x

Dst	*Outgoing link*
t	(u, t)
v	(u, v)
w	(u, w)
x	(u, v)
y	(u, t)
z	(u, v)

Q4. Internet's Hourglass Model **25 points**

The original designers of the Internet protocols envisioned them as fitting an hour glass model.

(a) Name the protocol(s) at the waist of the hourglass, and explain why this is both **necessary** and **sufficient**. (15 points)

(b) How are middleboxes altering this model? Justify your answer by using an example middlebox. (10 points)

(a) Waist of the Internet hourglass consists of IP (and its new variant IPv6). This is **necessary** because IP provides the functionalities of routing and forwarding, both of which are essential for a packet switched network. This is **sufficient** because of the end-to-end principle, which advocates for the intelligence to lie at the end points (i.e., higher layers of the protocol), thereby leaving the core to be simplistic/dumb.

(b) Middleboxes are "expanding" the waist by performing additional functionalities at the network layer. For example, a NAT router rewrites the IP address and port number of outgoing packets without the explicit knowledge/permission of the communicating end hosts. *[Other example of middleboxes such as firewalls, IDS, load balancers are also ok].*

Q5. Bonus question **10 points**

This question concerns resource provisioning in datacenters.

(a) Define horizontal scaling. How is it different from vertical scaling. (5 points)

Horizontal scaling is the process of increasing the total capacity by adding more machines/ nodes to the existing infrastructure. In contrast, vertical scaling is when the existing machines are replaced with more powerful ones. Thus, the former is called *scaling out* versus the latter, which is referred to as *scaling up*.

(b) Why is it more challenging to horizontally scale networks as opposed to say, data storage or compute? (5 points)

Scaling the networks horizontally is challenging because simply adding another network card or another switch does not increase the overall end-to-end bandwidth of the network. To achieve that, one needs to add new capacity across the whole network (i.e., increase the bisection bandwidth). In contrast, for data storage, if we add a new 1TB disk to a rack, the overall capacity of the datacenter increases by 1TB.