CSC358H5: Principles of Computer Networking — Winter 2025

Worksheet 9 Solution: Intra-Domain Routing and Inter-Domain Routing

Q0 Knowledge Check (from Week 01-09 Lectures)

0.a Which of the following statements are True? Choose all that apply.

- ☑ Intra-domain routing protocols operate within a single AS.
- ☐ Inter-domain routing focuses on finding the shortest path within an AS.
- ☐ OSPF and RIP are examples of an inter-domain routing protocol.
- ☑ BGP is used for routing between different autonomous systems.

0.b Which of the following statements are True? Choose all that apply.

- ☐ In intra-domain routing, routers will never share information about the entire network topology.
- ☑ An AS is a collection of networks under a single administrative domain that uses a common intra-domain routing protocol.
- ☑ Inter-domain routing generally prioritizes policies and agreements over shortest path calculations or efficiency.
- ☑ BGP uses a path vector approach rather than distance vector or link-state mechanisms.

0.c Which of the following statements are True? Choose all that apply.

- ☐ iBGP is used for intradomain routing.
- ☑ Avoiding loops is one reason why BGP uses path vector.
- ☐ BGP always advertises a shortest path.
- ☑ BGP route advertisements use classless addressing.

0.d Consider the DV algorithm below, which we studied in lecture.

Listing 1: DV Algorithm

```
1  for each destination do
2    if you hear an advertisement,
3      if the destination isn't in the table, update table and reset TTL
4      if advertised (cost + link cost to neighbor) < best-known cost, update table and reset TTL
5      if from the advertisement is from current next-hop, update table and reset TTL
6  if a table entry expires, make the entry poison and reset TTL
7  if the distance vector updates, and periodically
8    for each neighbor n
9      for each row (destination, cost, next hop, TTL) in your table
10       if n is the next hop, advertise poison back
11       else if cost ≥ 16, advertise ∞.
12       else advertise cost.
```

0.d. i What is the functionality of line 3? Choose one.

- ☑ It allows us to update when we learn about a new destination.
- ☐ It allows us to update when we learn about a better path.
- ☐ It allows us to realize if the topology is changed.
- ☐ It allows us to overcome DV messages getting dropped.

0.d. ii What is the functionality of line 4? Choose one.

- ☐ It allows us to update when we learn about a new destination.
- ☑ It allows us to update when we learn about a better path.
- ☐ It allows us to realize if the topology is changed.
- ☐ It allows us to overcome DV messages getting dropped.

0.d. iii What is the functionality of line 5? Choose one.

- ☐ It allows us to update when we learn about a new destination.
- ☐ It allows us to update when we learn about a better path.
- ☑ It allows us to realize if the topology is changed.
- ☐ It allows us to overcome DV messages getting dropped.

0.d. iv What is the functionality of poisoning in line 6? Choose one.

- ☑ It allows for faster route expiry.
- ☐ To avoid length-2 routing loops while during convergence. A length-2 routing loop is occurs when router A forwarding to router B and router B forwarding to router A.
- ☐ To avoid length-3 loops while during convergence.
- ☐ To avoid count-to-infinity problem.

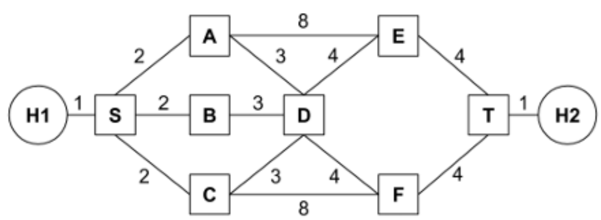
0.d. v What is the functionality of poisoning in line 10? Choose one.

- ☐ It allows for faster route expiry.
- ☑ To avoid length-2 routing loops while during convergence. A length-2 routing loop is occurs when router A forwarding to router B and router B forwarding to router A.
- ☐ To avoid length-3 loops while during convergence.
- ☐ To avoid count-to-infinity problem.

0.d. vi What is the functionality of poisoning in line 11? Choose one.

- ☐ It allows for faster route expiry.
- ☐ To avoid length-2 routing loops while during convergence. A length-2 routing loop is occurs when router A forwarding to router B and router B forwarding to router A.
- ☐ To avoid length-3 loops while during convergence.
- ☑ To avoid count-to-infinity problem.

0.e Assume the network below is running a LS routing protocol, minimizing total route cost. Suppose that a control message (*i.e.*, a message used by the routing algorithm) takes 1 second to propagate along a link, regardless of link cost. What individual link failure inside the network would cause the longest delay to reconvergence, and what is that delay?



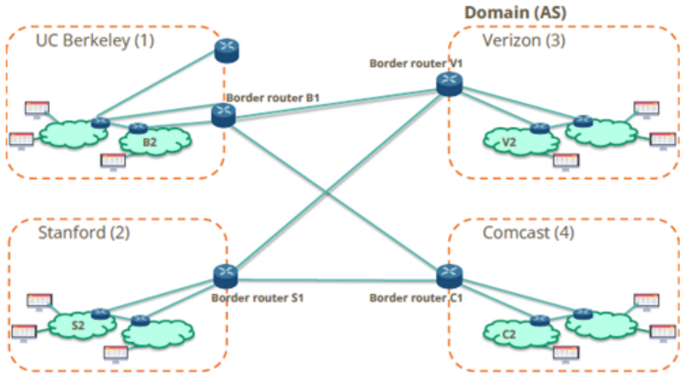
Answer. A link SB failure would cause a 3-second delay. The last node that learns about the failure is node T, and the update must traverse through at least 3 links to get to T, which will take 3 seconds. Any other link failure within the network can propagate to every other node in less than 3 seconds. Host links could also take 3 seconds to propagate.

0.f Consider the four ASes in the diagram above. ASes Berkeley, Verizon, Stanford and Comcast have border routers B1, V1, S1 and C1 respectively, and internal routers B2, V2, S2 and C2 respectively. Berkeley and Stanford both use Comcast's and Verizon's services. The (fake) cost metrics are 10/MB for using Comcast's bandwidth and 20/MB for using Verizon's bandwidth.

0.f. i Which one of eBGP, iBGP and IGP distributes externally learned routes internally, and which routers, if any, speak it?

Answer. iBGP. All routers speak iBGP.

0.f. ii Which one of eBGP, iBGP and IGP learn routes to external destinations, and which routers, if any, speak it?



Answer. eBGP. V1, C1, B1, S1. Only border routers speak eBGP.

0.f. iii Which one of eBGP, iBGP and IGP provides internal reachability, and which routers, if any, speak it?

Answer. IGP. All routers speak iBGP.

0.f. iv Which AS would Berkeley use to reach Stanford, in terms of cost effectiveness?

Answer. Comcast. It costs less amount of money.

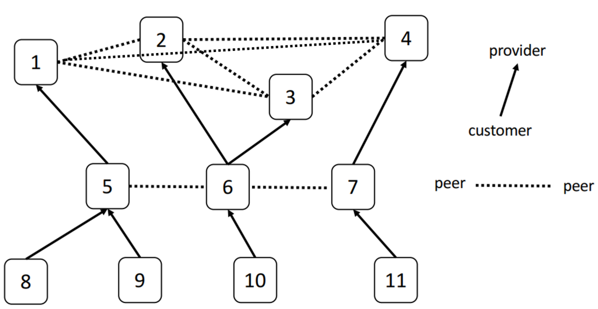
0.f. v Given now Comcast knows Berkeley and Stanford don't get along with each other, it doesn't advertise its route of Berkeley to Stanford, or the other way around. However, Verizon still remains neutral. Which AS would Berkeley use to reach Stanford now?

Answer. Verizon.

0.g Assuming Gao-Rexford rules for export policy, please fill out the table below to indicate whether a route imported from a neighbor of a given type should be sent to another neighbor of a given type or not. Answer by Yes or No.

		Route Sent To		
		Customer	**Provider**	**Peer**
Route Received From	**Customer**	YES	YES	YES
	Provider	YES	NO	NO
	Peer	YES	NO	NO

0.h Consider the diagram of ASes relationship shown here. Arrows point from customer up towards a provider, dashed lines connect peers.



0.h. i What possible valley-free paths are there from AS11 to AS10? A valley-free path is a path that follows a sequence of zero or more provider links, followed by at most one peer link, followed by a sequence of customer links. In a valley-free path, each intermediate AS will make money, since one of their customers will be part of the path.

Answer. $11 \to 7 \to 6 \to 10$
$11 \to 7 \to 4 \to 3 \to 6 \to 10$
$11 \to 7 \to 4 \to 2 \to 6 \to 10$

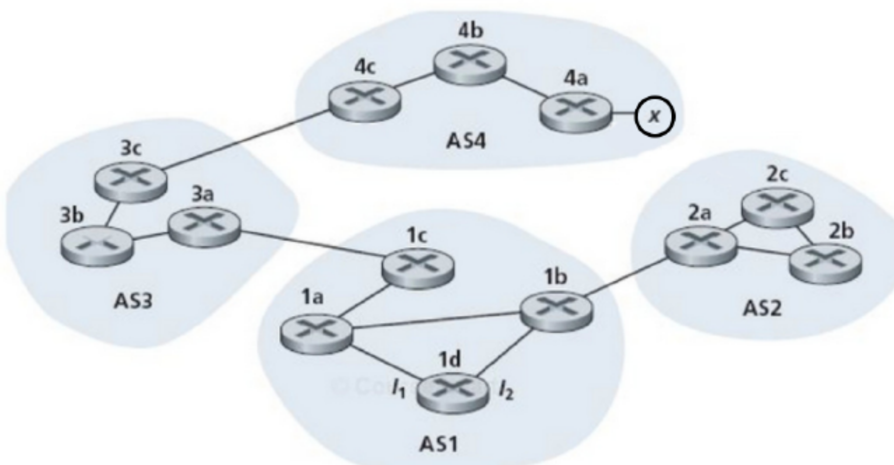
0.h. ii According to Gao-Rexfor Rules, which path will be used for sending traffic?

Answer. $11 \to 7 \to 6 \to 10$.

0.i

(CSC358H5S Final Exam, Winter 2022) Consider the network shown below. Suppose AS3 and AS2 are running OSPF for their intra-AS routing protocol. Suppose AS1 and AS4 are running RIP for their intra-AS routing protocol. Suppose eBGP and iBGP are used for the inter-AS routing protocol.

Given the routing protocols above (OSPF, RIP, eBGP, or iBGP), select one option for each of the following questions:



0.i. i Router 4b learns about the new subnet x from which routing protocol?

- ☐ OSPF
- ☑ RIP
- ☐ eBGP
- ☐ iBGP

0.i. ii Router 4c learns about the new subnet x from which routing protocol?

- ☐ OSPF
- ☑ RIP
- ☐ eBGP
- ☐ iBGP

0.i. iii Router 3c learns about the new subnet x from which routing protocol?

- ☐ OSPF
- ☐ RIP
- ☑ eBGP
- ☐ iBGP

0.i. iv Router 3b learns about subnet x from which routing protocol?

- ☐ OSPF
- ☐ RIP
- ☐ eBGP
- ☑ iBGP

0.i. v Router 1b learns about x from which routing protocol?

- ☐ OSPF

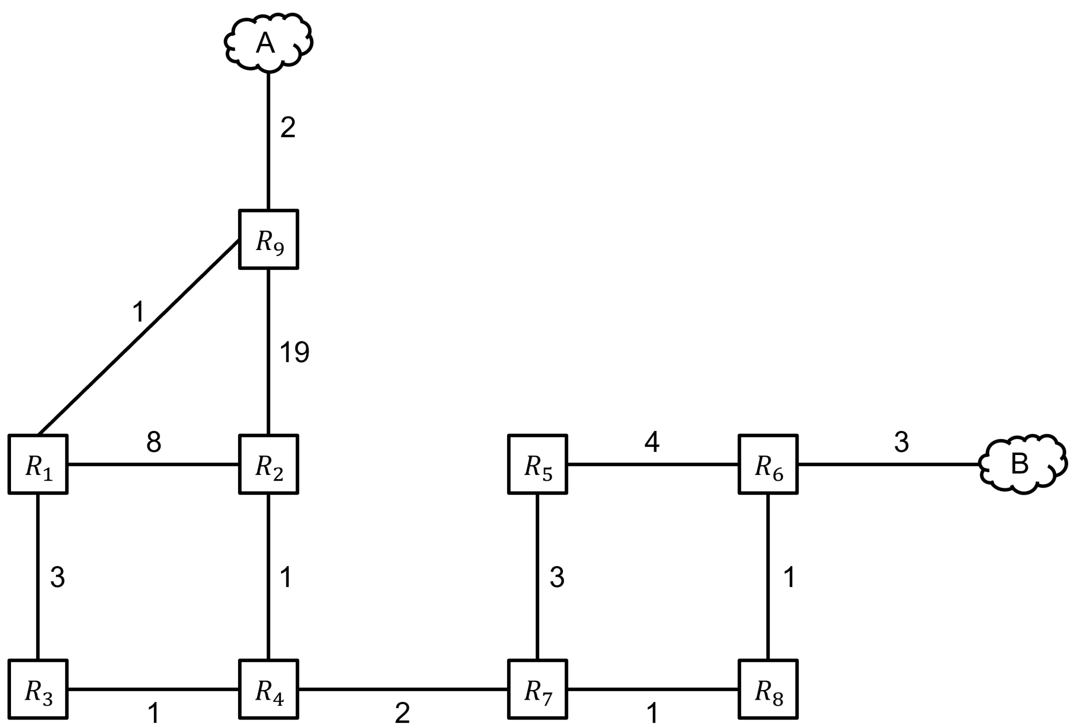
☐ RIP
☐ eBGP
☑ iBGP

0.i. vi Router 2a learns about x from which routing protocol?

☐ OSPF
☐ RIP
☑ eBGP
☐ iBGP

Q1

Assume the network below is running a LS routing protocol, minimizing total route latency. The following questions indicate events that happen consecutively



1.a After convergence, what route does Router R_4 think its packet will take to prefix B?

Answer. $R_4 \to R_7 \to R_8 \to R_6 \to B$

1.b **Event:** Link $R_7 - R_8$ goes down.

1.b. i Router R_7 and R_8 have recomputed their routes, but have not yet sent updates to other routers. What route does Router R_4 think its packet will take to B?

Answer. $R_4 \to R_7 \to R_8 \to R_6 \to B$

1.b. ii What route does it actually take?

Answer. $R_4 \to R_7 \to R_5 \to R_6 \to B$

1.b. iii Assume all nodes are now aware of the new network state and have recomputed their routes. What route does a packet take from Router R_2 to A?

Answer. $R_2 \to R_4 \to R_3 \to R_1 \to R_9 \to A$

1.c **Event:** The cost of link $R_1 - R_89$ increases to 100.

1.c. i Router R_1 and Router R_9 recompute their routes, but have not yet sent updates to other routers. What route does Router R_1 think its packet will take to A?

Answer. $R_1 \to R_3 \to R_84 \to R_2 \to R_9 \to A$

1.c. ii What route does it actually take?

Answer. $R_3 \to R_1 \to R_3 \to R_1 \to R_3 \to R_1 \to R_3 \to R_1 \to \ldots$ (loop)

1.c. iii Which additional routers must receive the routing updates and recompute their routes for all routers to be able to successfully send packets to A?

Answer. R_2, R_3, and R_4.

1.c. iv All routers except Router R_2 have received the routing updates and recomputed their routes. Which routers can successfully send packets to A?

Answer. Only Router R_9.

Q2

The Facebook outage of October 4, 2021, was a major global disruption that affected Facebook, Instagram, WhatsApp, and Messenger for about six hours. The Facebook outage of October 4, 2021, was a major global disruption that affected Facebook, Instagram, WhatsApp, and Messenger for about six hours. This incident is described in an article posted in Coudflare Blog.[1] It's good that you have taken CSC358 and learned about the principles of computer networks. With the knowledge you obtained in this course, you can easily read through this article and understand what the root cause of this incident was. Spend 5 minutes on reading this article and provide a summary of how Cloudflare engineers could identified the root cause of this incident.

Answer. At around 15:39 UTC, all Facebook services suddenly became inaccessible. Users were unable to load pages, send messages, or connect to servers. Cloudflare's 1.1.1.1 DNS resolver and Google's 8.8.8.8 DNS resolver could no longer respond to queries asking for the IP address of facebook.com. (*i.e.*, DNS resolvers return SERVFAIL for Facebook DNS lookup).

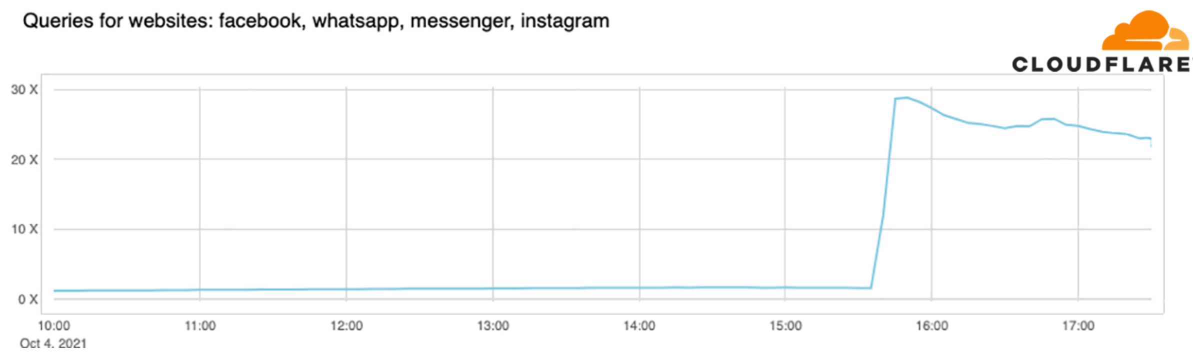
```
dig @1.1.1.1 facebook.com
;; ->>HEADER<<- opcode: QUERY, status: SERVFAIL, id: 31322
;facebook.com.   IN A

dig @1.1.1.1 whatsapp.com
;; ->>HEADER<<- opcode: QUERY, status: SERVFAIL, id: 31322
;whatsapp.com.   IN A

dig @8.8.8.8 facebook.com
;; ->>HEADER<<- opcode: QUERY, status: SERVFAIL, id: 31322
;facebook.com.   IN A

dig @8.8.8.8 whatsapp.com
;; ->>HEADER<<- opcode: QUERY, status: SERVFAIL, id: 31322
;whatsapp.com.   IN A
```

After investigating the rate of BGP update messages sent from Facebook. The Cloudflare engineers noticed that around 15:40 UTC there was a peak of routing changes from Facebook. Taking a closer look into the BGP update messages and separating routes announcements from routes withdrawals, they notice that almost all messages were withdrawals. This meant that routes were withdrawn, and Facebook's DNS servers went offline. With those withdrawals, Facebook and its sites had effectively disconnected themselves from the Internet.

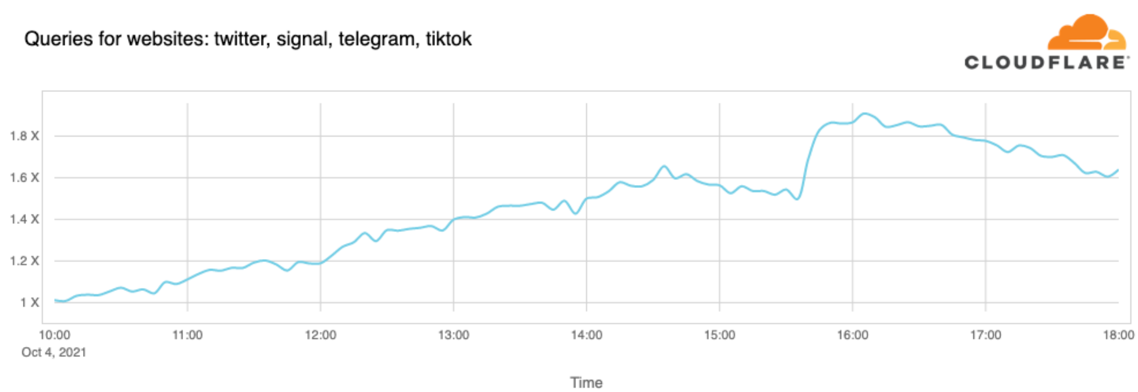
[1] https://blog.cloudflare.com/october-2021-facebook-outage/

The root cause was a faulty configuration change in Facebook's Border Gateway Protocol (BGP). Facebook engineers issued a routine maintenance command that unintentionally disconnected Facebook's data centers from the global internet. The issue originated from BGP misconfigurations, causing Facebook to withdraw key routing information from the internet. Since Facebook's internal networking and authentication systems relied on the same infrastructure, engineers were locked out of their own tools, making recovery difficult.

"Now human behavior and application logic kicks in and causes another exponential effect. A tsunami of additional DNS traffic follows." Apps start retrying, sometimes aggressively, and end-users start reloading the pages, or killing and relaunching their apps, sometimes also aggressively, when they could not connect to Facebook.com. This lead to DNS resolvers like Cloudflare's handling 30x more queries than usual and potentially causing latency and timeout issues.



Furthermore, people looked for alternatives and wanted to know more or discuss what's going on. thus, there was a significant increase in DNS queries to Twitter, Signal and other messaging and social media platforms.



Facebook engineers had to physically go to data centers and manually restart systems. Once BGP routes were restored, services slowly came back online.