1 Learning Switches

The diagram above shows an L2 network that uses learning switches. Initially, none of the switches have any forwarding state. The following questions describe events that happen in sequential order, i.e. the events in question 2 occur after the events in question 1, etc.

1. **Host A** sends a packet to **Host D**. List all switches that receive this packet during the sending process.

   Solution: v, w, z, y, x (The packet is flooded.)

2. **Host A** sends another packet to **Host D**. List all switches that receive this packet during the sending process.

   Solution: v, w, z, y, x (The packet is still flooded. In question 1, none of the switches learned anything about **Host D**)

3. **Host E** sends a packet to **Host A**. List all switches that receive this packet during the sending process.

   Solution: z, v (Both **Switch z** and **Switch v** learned about **Host A** from part (1)).
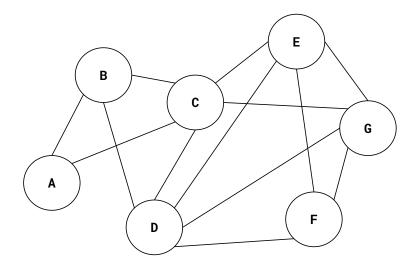
4. **Host D** sends a packet to **Host E**. List all switches that receive this packet during the sending process.

   Solution: y, x, z (**Host D** sends the packet to **Switch y**, which floods the packet to **Switch x** and **Switch z**. **Switch z** already knows about **Host E**, so it directly sends the packet to **Host E**.)

5. Suppose the link between **Host A** and **Switch v** goes down, and **Host A** then attaches itself to **Switch z** using a new link. **Switch v** deletes **Host A** from its forwarding state. No changes are made to the forwarding states of any other switch. What happens when **Host B** sends a packet to **Host A**?

   Solution: The packet arrives at **Switch w**, which then sends the packet to **Switch v**, which then floods the packet because it has no entry for **Host A**. Note that **Switch v** will only send the packet to **Switch z**. **Switch z** will then drop the packet to avoid sending the packet back the way it came from.

2 Spanning Tree Protocol

The diagram above shows a L2 network where all links have equal cost. We want to apply the Spanning Tree Protocol. Choose the switch with the lowest alphabetical ID as the root, and when there are multiple shortest paths to the root, choose the path that uses the neighbor switch with the lowest alphabetical ID.

(1) Let **XY** denote the link that connects **Switch X** and **Switch Y**. List all links that are a part of the spanning tree after the STP protocol converges.

Solution: AB, AC, BD, CE, CG, DF

(2) Assume that at some point during the STP protocol, **Switch F** believes that **Switch A** is the root and **Switch D** believes that **Switch B** is the root. Is it possible that **Switch C** also believes that **Switch B** is the root?

Solution: No. Either **Switch G** or **Switch E** must have advertised to **Switch F** that **Switch A** was the root. Since **Switch D** still thinks that **Switch B** is the root, this advertisement of **Switch A** as the root must have come from **Switch C**.

(3) After the STP protocol has converged, **Switch A** and all links directly connected to **Switch A** go down. List all links that are a part of the new spanning tree after the STP protocol converges again.
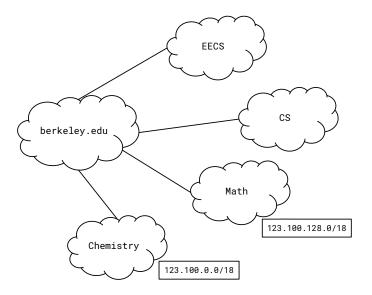
Solution: BC, BD, CE, CG, DF

(4) **Switch A** and all links connected to **Switch A** finally come back up, and the STP protocol begins to run again. However, **Switch F** forgets to send any update messages to its neighbors. After the protocol converges, does the resulting set of links form a valid spanning tree?

Solution: Yes. In fact, the resulting set of links is the same as the one from problem 1. This is because **Switch F** is not a part of the shortest path to **Switch A** from any other switch.

3 IP Addressing

Suppose **berkeley.edu** is the Provider AS for EECS, CS, Math, and Chemistry, and needs to assign IPv4 addresses to them.

Assume that the CIDR (Classless InterDomain Routing) addressing scheme is used, and that **berkeley.edu** has the 123.100.0.0/16 prefix reserved.

(1) Which addresses are included in the Math department's prefix? How many addresses are in this range?

Solution: Math's address prefix, in binary (with the prefix bolded), is:
01111011 . **01100100** . **10**000000 . 00000000
The range of allowed addresses is thus:
01111011 . **01100100** . **10**000000 . 00000000
. . .
01111011 . **01100100** . **10**111111 . 11111111
which in decimal is [123.100.128.0, 123.100.191.255].

If Math's prefix is 18 bits long, and IPv4 address are 32 bits long, then there are $32 - 18 = 14$ bits available to uniquely identify hosts, so this prefix contains 2^{14} addresses.

(2) 123.100.192.0/18 is reserved for EECS and CS. Assign equal halves of this address space to the two departments.

Solution: This address space has the prefix:
01111011 . **01100100** . **11**000000 . 00000000

To divide this /18 prefix in two, we can assign one /19 prefix to each department:

EECS:
01111011 . 01100100 . 11**0**00000 . 00000000
123.100.192.0/19
CS:
01111011 . 01100100 . 11**1**00000 . 00000000
123.100.224.0/19
(or vice versa)

(3) You want to start a new department, Floriology, and assign it an unused address range. You foresee that no more than 50 people will enroll. Assuming one address per person, what prefix would you assign to it?

Solution: A 64-address prefix will hold enough addresses for Floriology, which requires 6 bits for hosts. Thus we need a $(32 - 6) = /26$ prefix.

4 BGP

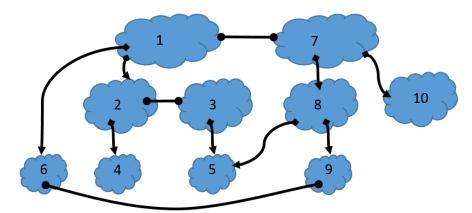Consider the following configuration of autonomous systems and their relationships.

Figure 1: autonomous system Relationships

A square-triangle line indicates a provider-customer relationship, and a circle-circle line indicates a peer relationship. We have two tier 1 providers (1 and 7).

Assume we are using the following selection and export rules for all ASes:
Selection: Prefer to send data through customers > peers > providers in order to minimize costs.
Export: To customers, advertise all paths. To all other ASes, advertise only paths to customers (and paths to your own AS, of course).

(1) A user in AS 4 tries to send data to a friend in AS 5. What path (if any) would the data take in order to get to the friend?

Solution: 4, 2, 3, 5

(2) A user in AS 6 tries to send data to a friend in AS 5. What path (if any) would the data take in order to get to the friend?

Solution: 6, 1, 7, 8, 5. This is trickier since 2 won't advertise its peer's (3's) path (about how to reach 5) to its provider (1), so 1 doesn't know it can reach 5 through 2.

(3) A user in AS 1 tries to send data to another user in AS 9. What path (if any) would the data take in order to get there?

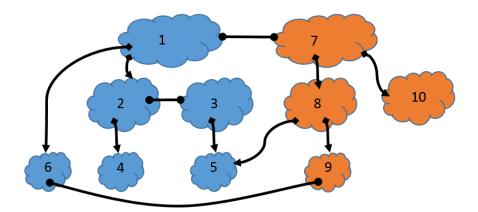**Solution:** 1, 7, 8, 9. Same reasoning as part 2.

Figure 2: Affiliations

Now assume all autonomous systems are using the same selection policy but also adopting new export rules because they are part of nation states in an information war. autonomous systems ranging from 1 to 6 form a group of allies, and autonomous systems ranging from 7 to 10 form another group of allies:

Export:
1. To a customer AS that is an ally, advertise all paths.
2. To all other ASes that are allies, advertise only paths to customers.
3. Advertise nothing to ASes that are not allies.

(4) A user in AS 6 tries to send data to their friend in AS 5. Will the friend receive the data?

Solution: No. Similar to part 2, but this time, 7 is not advertising its path to 5.

(5) Will a user in AS 9 be able to receive data from another in AS 1?

Solution: No. 7 advertises nothing to 1 because they are not allies.

(6) Imagine AS 10 set up a deal with AS 1 in which AS 1 is to act as a spy for AS 10's alliance. AS 1 will advertise all customer paths to AS 7. With this new agreement, AS 10 now wants to report its findings to AS 5. Will the data be able to get from AS 10 to AS 5? If so, what path would the data take?

Solution: No. Even if AS 10 established this deal, 2 won't advertise to 1 about its path to 5, so 10 cannot talk to 5.