Second mini-project: Inter-domain routing

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I. Introduction

The Internet is an interconnected collection of networks, also called Autonomous Systems (ASs) or domains. Every pair of neighboring ASs establish a commercial agreement between. With some simplification, these commercial relationships belong to one of two types. In a *provider-customer* relationship the customer pays the provider to transit its traffic with the rest of the Internet, whereas in a *peer-peer* relationship the two peers exchange traffic between themselves and their customers without monetary compensations. We assume that there no provider-customer cycles, where each node is a customer of the next around the cycle. Therefore, the provider-customer relationships determine an hierarchy among the ASs, with providers at higher levels of the hierarchy than their customers. ASs without providers are called Tier-1; there are dozen of them. At the other extreme, ASs without customers are called stubs; there are tens of thousands of them. Figure 1 shows a small internet where a provider is joined to a customer by a solid line, and two peers are joined by a dashed line. For example, u_6 is a provider of both u_2 and u_3; u_6 and u_7 are peers. Nodes u_{10} and u_{11} are Tier-1 and nodes u_1, u_2, u_3, and u_4 are stubs.

II. Routing according to commercial routing policies

The commercial relationships between ASs determine the routing policies configured by the network operator of each AS. We assume that operators follow the so-called Gao-Rexford routing policies [1].

- An AS prefers a *customer route* (learned from a customer) to a *peer route* (learned from a peer), and prefers a peer route to a *provider route* (learned from a provider). The AS elects the most preferred of the routes learned from its neighbors.

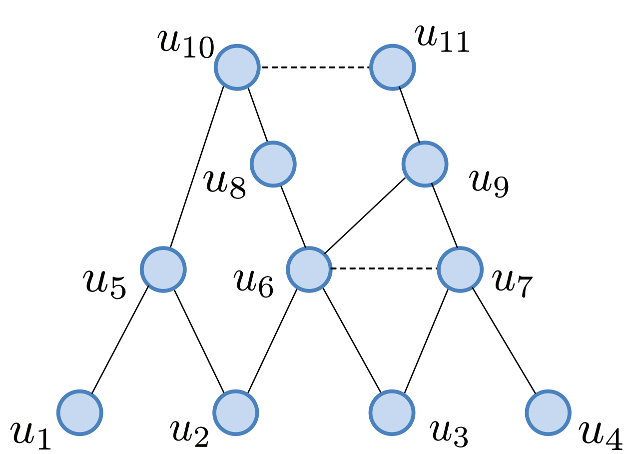

Fig. 1. An internet. Solid lines join providers to customers, with providers placed higher than customers. Dashed lines join peers.

- An AS exports all elected routes to its customers and exports elected customers routes to all its neighbors, these being the only exportations allowed.

Note, in particular, that not all elected routes are exported to all neighbors of an AS. As a consequence, some paths that physically exist in the network cannot be used to carry traffic. A *customer path* is a path all links of which join a provider to a customer. A *peer path* is a path of the form uvP where u and v are peers and P is a customer path. A *provider path* is a path of the form PQ where P is a non-trivial path all links of which join a customer to a provider and Q is either a customer or a peer path. Customer, peer, and provider paths are *usable*; all other paths are unusable. In Figure 1, $u_{10}u_8u_6u_3$ is a customer path, $u_{10}u_{11}u_9u_7u_4$ is a peer path, $u_1u_5u_{10}u_8u_6u_3$ is a provider path, and $u_5u_2u_6$ is unusable. It is easy to show the following correspondences between elected routes and paths.

- If u elects a customer route to reach t, then there is a customer path from u to t.
- If u elects a peer route to reach t, then there is not a customer path from u to t, but there is a peer path from u to t.
- If u elects a provider route to reach t, then there is neither a customer nor a peer path from u to t, but there is a provider path from u to t.
- If u does not elect any route to reach t, then all paths from u to t are unsusable.

In Figure 1, u_6 elects a customer route to reach u_3, a peer route to reach u_4, and a provider route to reach u_5.

An internet is *policy-connected* if every node elects a route to reach every other node. Equivalently, a network is policy-connected if there is a usable path from every node to every other. The internet of Figure 1 is policy-connected. It would not be policy connected if link $u_{10}u_{11}$ did not exist.

III. Your assignment

What you have to do.

- Design and implement an algorithm to compute the elected route with which a node reaches another node. The internet is given as a file in the format shown below.

4323	12122	1
12122	4323	3
7018	17228	1
17228	7018	3
29017	34309	2
34309	29017	2

  Each line represents a link. The first value is the identifier of the AS at the tail of the link. The second value is the identifier of the AS at the head of the link. The third value is 1 if the tail of the link is a provider of the head of the link; it is 2 if the tail of the link is a peer of the head of the link; and it is 3 is the tail of the link is customer of the head of the link. For example, in the table above, 4323 is a provider of 12122. The user of your program makes online queries with a source node and a destination node. (50% of the grade.)

- Given an internet in the same format as above, produce the statistics of the number of pairs of nodes that are connected by a customer path, by a peer path, by a provider path, and not connected at all by a usable path. (25% of the grade.)
- Design and implement an algorithm to test whether a given internet is policy connected. The internet is given in the format above. Clearly, you could iterate the algorithm you developed previously over all pairs of nodes. But, there might exist more efficient solutions! (25% of the grade.)

What do you have to deliver, how, and when.

- You have to deliver your code and a report with a cover page and no more than three other pages containing a text explanation of your algorithms, their pseudo-codes, their asymptotic complexities, the statistics required, and a short discussion.
- The code and the report should be sent in a .zip file to my email address with subject p2.<group number>.zip where <group number> is your group number.
- The deadline is November 14, 2014, 23:59.

How I will evaluate your assignment.

- Write your report and your pseudo-code clearly, and present a commented code.
- Be sure to test your code for correctness. I will take into consideration the efficiency of your algorithms.
- I will have a discussion with you about your report and will test your code at the end of the semestre, jointly with the other assignments.

References

[1] L. Gao and J. Rexford, "Stable Internet routing without global coordination," *IEEE/ACM Transactions on Networking*, vol. 9, no. 6, pp. 681–692, December 2001.