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Lehrstuhl Informatik VIII
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Master Course Computer Networks

Homework 4
(submission until December 17 into INBOX located in front of 03.05.052)

Note: Subproblems marked by * can be solved without preceding results.

Traceroute and routing paths

The lecture discussed topics regarding route selection in the Internet and presented *traceroute*, a tool to trace the path packets might take to a given destination. In this problem you will investigate how traceroute works and what its limitations are.

a)* Briefly explain the basic principle behind traceroute.

b) Traceroute uses by default ICMP or UDP payloads, depending on implementation. Argue why using TCP might be a good / bad idea.

One might expect to see the same paths in reversed order when mutually issuing traceroutes from two endpoints. However, in turns out that the paths seem to be quite different.

c)* Record the route between two systems under your control from *both* sides and sketch the paths. You can use, for instance, your VM and your local computer. Be sure to use your public IP address when recording the path to your local computer.

d) Have a close look at the IP addresses of both routes you just recorded. In particular, look for IP addresses that are close to each other in the address space. Is there any basis to assume that two different IP addresses belong to the same router?

e)* Assume that you have a suspicion that two IP addresses belong to the same router. Explain a concept to prove your suspicion.
Hint: Think about the identifier field in the IP header which is not chosen at random by most routers. You should also have a look at the paper *IP Alias Resolution Techniques* by Ken Keys (CAIDA).

Routing protocols

In the lecture you learned about different routing protocols. These can be grouped in different ways. For instance, there are *Interior* and *Exterior Gateway Protocols* (IGPs and EGPs). Another classification could be by means of the functioning principle, i. e., *distance vector* and *link-state protocols*. The protocols you should have some idea about are in particular RIP, OSPF, and BGP.

a)* Discuss the differences between RIP and OSPF. To which of the above mentioned classes do they belong?

b)* How does BGP differ from usual distance vector protocols?

c)* Explain the term *policy based routing*.

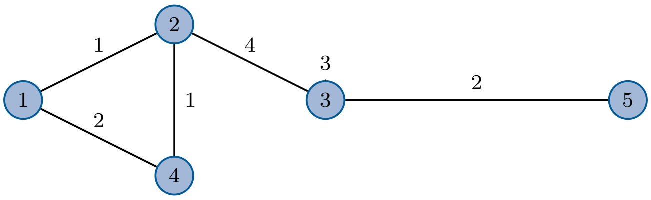

Figure 1: Sample topology

We now consider (generalized) distance vector protocols from a formal point of view. Have a look at the network depicted in Figure 1 which consists of a set of nodes $\mathcal{N}$ and a set of (undirected) edges $\mathcal{E}$. If two nodes $i, j \in \mathcal{N}$ are connected, then $(i, j) \in \mathcal{E}$. Since the edges are undirected, we have that $(i, j) = (j, i)$. The weight w_{ij} of an edge connecting $i, j \in \mathcal{N}$ represents the costs to send a packet, i. e., lower is better. The cost of a path between two non-adjacent nodes is the sum of the edge weights used. Let n denote the total number of nodes in the network. We define the one-hop *distance matrix* of the network as

$$\boldsymbol{D} = \begin{bmatrix} d_{11} & \dots & d_{1n} \\ \vdots & \dots & \vdots \\ d_{n1} & \dots & d_{nn} \end{bmatrix} \in \mathbb{N}_0^{n \times n}, \quad \text{with } d_{ij} = \begin{cases} w_{ij} & \text{if } \exists (i,j) \in \mathcal{E}, \\ 0 & \text{if } i = j, \\ \infty & \text{otherwise.} \end{cases}$$

Obviously, the element d_{ij} in the i-th row and j-th column of $\boldsymbol{D}$ denotes the distance between two neighboring nodes over exactly one hop and becomes ∞ if j is not reachable within a single hop.

d)* Cast $\boldsymbol{D}$ for the network depicted in Figure 1.

We define the m-th power of $\boldsymbol{D}$ with respect to the *min-plus product* as

$$\boldsymbol{D}^m = \boldsymbol{D}^{m-1}\boldsymbol{D} \text{ where } d_{ij}^m = \min_{k \in \mathcal{N}} \left\{ d_{ik}^{m-1} + d_{kj} \right\}. \tag{1}$$

Note, that Equation (1) represents the Bellman-Ford equation discussed in the lecture.

e) Calculate $\boldsymbol{D}^m$ for $m \to \infty$. (can be done by hand)

f) Give a general proof that, for $m \to \infty$, the element in row i and column j of $\boldsymbol{D}^m$ yields the distance between $i, j \in \mathcal{N}$.