Assignment 4

CS224M

Note: *Solve all problems on your own.* Upload your solutions as a single pdf file to Moodle. You can scan handwritten solutions and upload if required. Approach the instructor for clarifications.

1. AS1 in Figure 1 has the following characteristics.

   - All routers run OSPF as the interior gateway protocol (IGP). Recall that OSPF is a link-state routing protocol.
   - Only the border routers connecting AS1 to neighbouring ASes run BGP.
   - Link weights are static and specified in the diagram.

   State any assumptions that you make to solve the problems.

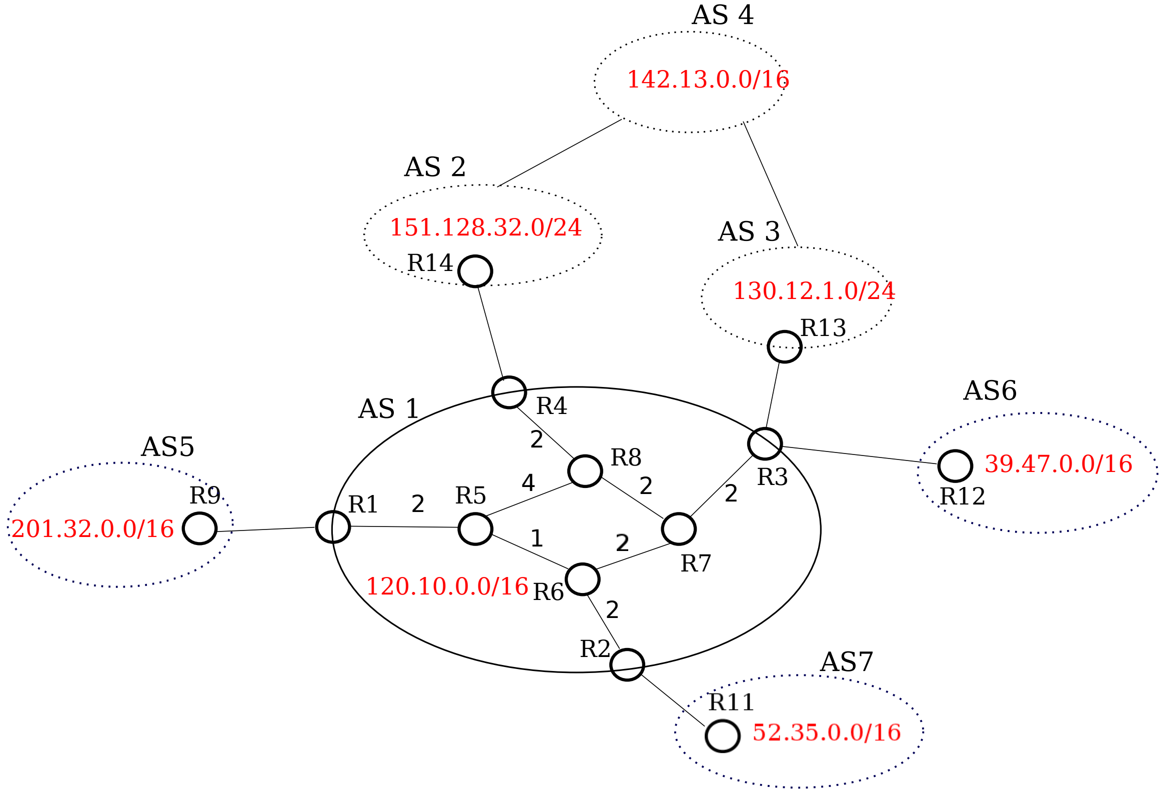

Figure 1: Routing topology

   (a) (8 marks) Using Djikstra's algorithm determine the shortest path from R1 to all other routers within AS1. Give details of the different stages in creation of the routing tree using diagrams. Similarly determine the shortest path from R2 to all other routers, and show your working with diagrams.

   (b) Corresponding to each of the ASes is an IP-prefix as shown. R14 of AS2 advertizes the paths `[151.128.32.0/24 AS2]`, `[142.13.0.0/16 AS2-AS4]` and `[130.12.1.0/24 AS2-AS4-AS3]` to router R4 of AS1. R13 of AS3 advertizes the paths `[130.12.1.0/24 AS3]`, `[142.13.0.0/16 AS3-AS4]` and `[151.128.32.0/24 AS3-AS4-AS2]` to R3 of AS1.

Suppose the administrator of AS1 has set LOCAL_PREF to the same value for all BGP advertisements and assume that the MED attribute has not been set in any of the advertisements.

i. (2 marks) Explain which NEXT_HOP router does each BGP router in AS1 use to send packets to destination prefix 151.128.32.0/24. Give the reasons for these choices. Recall that the NEXT_HOP router for a BGP advertisement is the router in the neighbouring AS which sent the corresponding advertisement to a router in AS1. Examples of these are R14, R13 etc.[1]

ii. (2 marks) Explain which NEXT_HOP router does each BGP router in AS1 use to send packets to destination prefix 130.12.1.0/24. Give reasons for these choices.

iii. (2 marks) Explain which NEXT_HOP router does each BGP router in AS1 use to send packets to destination prefix 142.13.0.0/16. Give reasons for these choices.

iv. (2 marks) In case the administrator of AS1 wants all BGP routers to use NEXT_HOP router R14 to send packets to destination prefix 142.13.0.0/16, how can he accomplish this by setting attributes of the BGP advertisement?

(c) Assume that Encapsulation is the solution used by AS1 for BGP-IGP interaction. The BGP routing table at each BGP speaker contains a list of IP prefixes learned using eBGP or iBGP and the corresponding exit routers. Every router in AS1 has an IGP (which is OSPF here) routing table which contains the IP address of all other routers within AS1 and the corresponding next hop on the shortest paths to those routers.

Suppose a packet P1 is forwarded to R1 from AS5 with destination 142.13.5.4. Explain how the routers of AS1 encapsulate and forward this packet toward its destination. Your answer should explain at each router along the path in AS1 the following.

i. (3 marks) Explain which router encapsulates P1 and which router eventually de-encapsulates it. Call the new packet formed after encapsulation P2. Explain which router the destination IP of P2 corresponds to.

ii. (3 marks) Which forwarding table(s) the various routers look up in order to find the next hop to forward P2 (you can say if it is IGP, BGP or both, and also state which router should be there in the next hop of the table)

2. (10 marks) We studied in class how TCP-Vegas reduces packet drops and queuing delays and improves throughput when compared to TCP-Reno. However, if TCP-Vegas flows share a network path with TCP-Reno flows then Reno flows tend to significantly reduce the throughput of the Vegas flows.

Your task is to design a new variant of TCP with the following properties. We will ignore Slow Start for this problem and assume that all TCP flows only employ congestion avoidance. In your solution you will have to give the window increase and

[1] Technically, the NEXT_HOP attribute is the IP address of the interface from which the BGP advertisement reached AS1. To simplify matters, we are here just using the router name instead of the IP address of its interface.

decrease rules for this new variant of TCP and also explain how it satisfies all the properties below. State any other assumptions you make.

(a) It is purely an end-to-end congestion control protocol, that is, it does not require any special information from routers or explicit information about other TCP flows in order to perform congestion control.

(b) It behaves like TCP-Vegas if all other competing flows on its network path employ TCP-Vegas. Let us assume that all TCP flows have the same RTT on the network path.

(c) It behaves like TCP-Reno if there are some competing flows on its network path that employ TCP-Reno.

(d) It adjusts its CongestionWindow based on inference of packet losses and/or queuing delays in the network.

3. (6 marks) In this problem we study "RTT-fairness" issues in TCP, that is do two TCP flows with different RTT's get the same bandwidth or not. Label two TCP flows $i = 1, 2$. Flow i has congestion window $w_i(t)$ bits at time t, RTT (which does not vary with time) of T_i sec, and instantaneous bitrate of $w_i(t)/T_i$. Assume that $w_i(0) = 0$. Both flows share the bandwidth C bits/sec of a particular link of the network. We say that both flows face "loss" at time t iff $\sum_i w_i(t)/T_i = C$ following which their congestion windows are immediately reset to 0. At all other time instants, the windows are incremented in an additive-increase fashion according to

$$\frac{dw_i(t)}{dt} = \frac{1}{T_i}.$$

Note that this is a toy model of TCP Reno in the additive increase phase, where T_i represents the RTT (indeed Reno tries to increase the window by 1 every RTT). We have, of course, ignored Slow Start in this analysis.

Compute and compare the total amount of data in bits transmitted by the two flows between consecutive "loss" events. How is the total amount of data of a flow dependent on its RTT? Is TCP Reno fair, in the sense that both competing flows get the same throughput?