Aril 2011

**Suggested Answer for EE3320 Test 2**

**Total Marks = 100**

**Question 1.** (50 marks)

(a) Describe the motivation and the key idea for Hierarchical Routing. [10 marks]

Motivation

* large networks need large routing tables
* more computation to find shortest paths
* more bandwidth wasted on exchanging routing information (e.g. distance vectors and link state packets)

Key idea

* divide network into a set of domains/regions
* gateways (or gateway routers) connect domains
* routers only aware routers within domain but unaware of outside routers
* gateways know only about other gateways
* each router knows the best path to the destination router which is in the same domain and know the best path to the region of the destination router which is not in the same domain

(b) Discuss how a hierarchical organization of the Internet has made it possible to scale to millions of users. [8 marks]

Routers are aggregated into autonomous systems (ASs). Within an AS, all routers run the same intra-AS routing protocol. Special gateway routers in the various ASs run the inter-autonomous system routing protocol that determines the routing paths among the ASs. The problem of scale is solved since an intra-AS router needs only to know about routers within its AS and the gateway router(s) in the various ASs.

(c) Figure Q. 1.1 shows a network using Hierarchical Routing. Draw the network topology from Node 5D’s point of view under the use of Hierarchical Routing. Write down the routing table for Node 5D. Note that for each destination, “next hop” and “number of hops” (to that destination) should be included. Write down the minimum-hop paths from 5D to destination 3A with and without the use of Hierarchical Routing, respectively. Provide interpretation of the results. [14 marks]



Figure Q. 1.1



Routing table for 5D

|  |  |  |
| --- | --- | --- |
| Destination | Next Hop | No. of Hops |
| 5D | - | - |
| 1D | 4D | 2 |
| 2D | 3D | 2 |
| 3D | 3D | 1 |
| 4D | 4D | 1 |
| A | 4D | 5 |
| B | 3D | 3 |
| C | 4D | 2 |

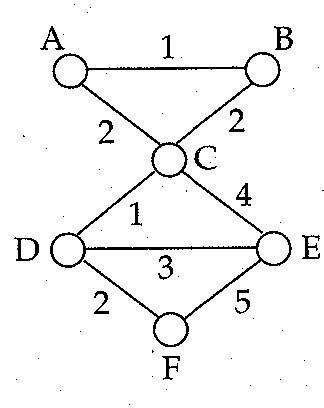
The minimum-hop paths from 5D to destination 3A with and without the use of Hierarchical Routing are 5D-4D-5C-4C-1C-4A-5A-3A and 5D-3D-2D-5B-4B-1B-3A, respectively. The path with the use of Hierarchical Routing is longer than that without the use of Hierarchical Routing. This means that Hierarchical routing may result in sub-optimal routing decisions.

(d) In Figure 1.2, assume that link DF has gone down for a long time, so that D and C routes to F through E. If D and C use split horizon, [18 marks]

1. What distance to F will E report to D and C?
2. What distance to F will D and C report to E?

Now, suppose the EF link goes down.

1. What distance to F will E report to D and C?
2. At the same time, what is the distance to F that C reports to D?
3. What does D then think the shortest path to F is?
4. What does D then tell E about its distance to F?
5. What is E's route to F now?
6. What does E then tell C?
7. When does this cycle end?
8. 5
9. ∞
10. E reports to D and C a distance of ∞ to F.
11. C reports to D a distance of 9 to F.
12. D thinks the shortest path is D-C-E-F.
13. Since E is no longer D’s next hop to F, D tells E that it has a path of length 10 to F.
14. E, therefore, thinks that its route to F should be through D (i.e. E-D-C-E-F).
15. E tells C that it has a path of length 13 to F through D.
16. The routers cyclically count to infinity till all routers set their distance to F as infinity, so that F is known to be unreachable.



**Figure 1.2**

**Question 2** (50 marks)

(a) Consider the MPLS network shown in Figure Q.2.1. [30 marks]

(i) Describe how the Ingress Label Switching Router in an MPLS domain handles an arriving IP packet.

(ii) Suppose that a packet with destination address 171.69.25.4 enters the MPLS network from the left. Show how the packet goes through the network using a diagram.

(iii) Suppose that we want to perform flow aggregation so that packets with destination network address 171.69.0.0 will join the same class of the packets with destination network address 128.89.0.0. Write down the three modified tables which would make this possible.

(iv) Suppose that another packet with destination address 171.69.25.4 enters the MPLS network from the left after flow aggregation mentioned in (iii). Show how the packet goes through the network using a diagram.

(v) In addition to the flow aggregation of (iii), suppose that we want to perform further flow aggregation so that packets with destination network address 117.59.0.0 will join the same class of the packets with destination network address 128.89.0.0. Write down the three modified tables which would make this possible.

**128.89**

**0**

**1**

**0**



**117.59**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**1**

**1**

**In  
Label**

**Out  
Label**

**1**

**117.59**

**128.89**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**0**

**0**

**In   
Label**

**Out  
Label**

**0**

**117.59**

**Address**

**Prefix**

**Out  
I'face**

**0**

**In   
Label**

**Out  
Label**

**1.**

**2**

**1**

**3**

**4**

**5**

**3**

**5**

**7**

**3**

**2**

**-**

**2**

**.**

**...**

**1**

**128.89**

**4**

**7**



**117.59**

**3**

**128.89**

**171.69**

**0**

**-**

**7**

**1**

Figure Q.2.1

(i)

* The Ingress Label Switching Router (LSR) will
  + identify the Forwarding Equivalency Class (FEC) which the packet belongs to,
  + assign the label associated with the FEC, and
  + identify the next LSR to which the packet is forwarded
* The Ingress LSR then forward the packet with the new label to the next LSR

(ii)

**128.89**

**0**

**1**

**0**



**117.59**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**1**

**1**

**In  
Label**

**Out  
Label**

**1**

**117.59**

**128.89**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**0**

**0**

**In   
Label**

**Out  
Label**

**0**

**117.59**

**.**

**Address**

**Prefix**

**Out  
I'face**

**0**

**In   
Label**

**Out  
Label**

**1.**

**7**

**2**

**1**

**3**

**4**

**5**

**3**

**5**

**7**

**3**

**2**

**-**

**2**

**.**

**...**

**171.69.25.4**

**Data**

**1**

**5**

**171.69.25.4**

**Data**

**128.89**

**4**

**7**



**117.59**

**171.69.25.4**

**Data**

**2**

**3**

**128.89**

**171.69**

**0**

**-**

**Data**

**171.69.25.4**

**3**

**1**

(iii)

**128.89**

**0**

**1**

**0**



**117.59**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**1**

**1**

**In  
Label**

**Out  
Label**

**1**

**117.59**

**128.89**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**0**

**0**

**In   
Label**

**Out  
Label**

**0**

**117.59**

**.**

**Address**

**Prefix**

**Out  
I'face**

**0**

**In   
Label**

**Out  
Label**

**1.**

**7**

**7**

**1**

**3**

**4**

**4**

**3**

**4**

**7**

**7**

**2**

**-**

**2.**

**...**

**1**

**128.89**

**4**

**7**



**117.59**

**7**

**128.89**

**171.69**

**0**

**-**

**1**

(iv)

**128.89**

**0**

**1**

**0**



**117.59**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**1**

**1**

**In  
Label**

**Out  
Label**

**1**

**117.59**

**128.89**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**0**

**0**

**In   
Label**

**Out  
Label**

**0**

**117.59**

**.**

**Address**

**Prefix**

**Out  
I'face**

**0**

**In   
Label**

**Out  
Label**

**1.**

**7**

**7**

**1**

**3**

**4**

**4**

**3**

**4**

**7**

**7**

**2**

**-**

**2.**

**...**

**1**

**128.89**

**4**

**7**



**117.59**

**7**

**128.89**

**171.69**

**0**

**-**

**1**

**171.69.25.4**

**Data**

**7**

**171.69.25.4**

**4**

**Data**

**4**

**171.69.25.4**

**4**

**Data**

**7**

**171.69.25.4**

**4**

**Data**

(v)

**128.89**

**0**

**1**

**0**



**117.59**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**1**

**1**

**In  
Label**

**Out  
Label**

**1**

**117.59**

**128.89**

**171.69**

**Address**

**Prefix**

**Out  
I'face**

**0**

**0**

**In   
Label**

**Out  
Label**

**0**

**117.59**

**.**

**Address**

**Prefix**

**Out  
I'face**

**0**

**In   
Label**

**Out  
Label**

**1.**

**7**

**7**

**7**

**4**

**4**

**4**

**4**

**4**

**X**

**X**

**X**

**-**

**X.**

**...**

**1**

**128.89**

**4**

**X**



**117.59**

**X**

**128.89**

**171.69**

**0**

**-**

**1**

(b) (i) In terms of label handling and packet forwarding, what are the differences among the Ingress MPLS router, Core MPLS router and Egress MPLS router. Assume no label sharing among traffic flows. [8 marks]

(ii) State the differences if we allow label sharing among traffic flows. [6 marks]

(i) No label sharing:

* In Ingress router, a label assigned to the packet associated with the Forwarding Equivalency Class (FEC) and normal IP forwarding is implemented using longest-match table lookup
* In Core router, the label value is changed/switched and packet forwarding is implemented using exact-match table lookup
* In Egress router, the label is removed and packet forwarding is implemented using exact-match table lookup

(ii) The difference if label sharing is allowed:

* In the Core router that is one hop prior to de-aggregation point (i.e. Egress router), the label is removed and packet forwarding is implemented using exact-match table lookup
* In Egress router, no label needs to handle and normal IP forwarding is implemented using longest-match table lookup

(c) Describe how Label Distribution Protocol (LDP) is used to distribute the labels when the Label Switched Path is setup. [6 marks]

* Egress router starts to distribute labels and passes them to its upstream Label Switching Routers (LSRs)
* Each LSR
  + Receives outgoing label from downstream LSR
  + Allocates and distributes incoming labels to upstream LSR