SCIPER: ____________________

First name: ________________________ Family name: ________________________

EXAM
TCP/IP NETWORKING
Duration: 3 hours

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INSTRUCTIONS

1. Write your solution into this document and return it to us (you do not need to return the figure sheet). You may use additional sheets if needed. Do not forget to write your name on **each of the four problem sheets** and **all** additional sheets of your solution.
2. If you need to make assumptions in order to solve some questions, please write them down explicitly.
3. Figures are on a separate sheet, for your convenience.
4. No documents, no electronic equipments are allowed.
5. Justify every answer with a short explanation.

PROBLEM 1

Consider the network in Figure 1. A, B, C and D are hosts; $X0$, $X1$, $X2$, $X3$ and $X4$ are dual stack routers (unless otherwise stated). All link costs are equal to 1.

- A is IPv6 only
- B and D are IPv4 only
- C is dual stack.
- The dotted circles identify observation points.

1. What is the 24th bit of the IPv6 address of A ? of the IPv4 address of B ? Note that the first bit is the left-most bit of an IP address.

   Are the IPv6 addresses of A and C valid ? If so, give their non compressed forms.

2. Give possible values for the network masks at all hosts. Give your answer in the table below.

Host	IPv4 mask	IPv6 mask
A	NA	
B		NA
C		
D		NA

3. We assume in the rest of this problem that all hosts are configured with correct masks and default gateway and set the TTL or HL value to 64 when generating an IP packet. A video server runs at D; the user at B downloads a video file from D using HTTP. The video file is large and does not fit in one

IP packet. Once the transfer of the video file is successfully started, we observe all packets resulting from this activity at observation point 8, video server $\rightarrow$ host. For each of the packets, give the value of the following fields:

- MAC source address, MAC destination address (use the identifier of the machine on the figure to denote its MAC address; for example, $S1$'s MAC address is $S1$; a machine such as $X1$ has several MAC addresses; if necessary, specify for example $X1l$ for the left interface of $X1$, $X1t$ for the top, $X1b$ for the bottom and $X1r$ for the right).

- source IP address, destination IP address, Protocol or Next Header, TTL or Hop Limit.

At observation point 8:					
MAC source	MAC dest	IP source	IP dest	Protocol or Next Header	TTL or Hop Limit

4. The user at A also wants to download a video file from D using HTTP. C is configured as a dual stack application layer gateway acting as web proxy, so that A can access the video file at D via C. The video file is large and does not fit in one IP packet. Once the transfer of the video file is successfully started by A, we observe all packets resulting from this activity at observation points 6 and 0, video server $\rightarrow$ host. For each of the packets, give the value of the same fields:

At observation point 6:					
MAC source	MAC dest	IP source	IP dest	Protocol or Next Header	TTL or Hop Limit

At observation point 0:					
MAC source	MAC dest	IP source	IP dest	Protocol or Next Header	TTL or Hop Limit

5. In this question only, $X0$ is configured as 6to4 relay router and D enables IPv6 using 6to4 (the link between $X4$ and D is IPv4 only). Give a possible value of D's IPv6 address.

Since A and D are now both IPv6 capable, the user at A transfers a video file from D using IPv6 (and HTTP), without using any web proxy. The video file is large and does not fit in one IP packet. Once the transfer of the video file is successfully started by A, we observe all packets resulting from this activity at observation points 6 and 0, video server $\rightarrow$ host. For each of the packets, give the value of the same fields:

At observation point 6:				
MAC source	MAC dest	IP source	IP dest	Protocol or Next Header

At observation point 0:				
MAC source	MAC dest	IP source	IP dest	Protocol or Next Header

6. Boxes $X0, X1, X2, X3$ and $X4$ are now configured as bridges instead of routers. Give possible values of masks at all hosts (in this question, D is *not* using 6to4). Give your answer in the table below.

Host	IPv4 mask	IPv6 mask
A	NA	
B		NA
C		
D		NA

The user at B downloads a video file from D using HTTP. The user at A downloads a video file from D via C used as application layer gateway as in question 4. The video files are large and do not fit in one IP packet. Once the transfer of the video files are successfully started, we observe all packets resulting from this activity at observation points $1, 2, 3, 4$ and 5, in the direction video server $\rightarrow$ host. For each of the packets, indicate in the table below at which observation point the packet is observed and fill in the values in the table below:

Where observed	IP source	IP dest	Protocol or Next Header	TTL or Hop Limit

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PROBLEM 2

Consider the network in Figure 2 on the figure sheet.

- $A1, A2, B, S1$ and $S2$ are hosts; $R1, R2$ and $R3$ are routers with ECN and RED enabled. The user at $A1$ is sending a very large file to $S1$ and similarly, the user at $A2$ is sending a very large file to $S2$. The user at B is either doing nothing or sending a very large file to $S2$, as indicated later.
- The link rates are indicated on the figure.
- All links are full duplex with same rate in both directions.
- There is no other system than shown on the figure, and we neglect all flows other than from $A1, A2$ or B to $S1$ and $S2$. We also neglect the impact of the acknowledgment flows in the reverse direction.
- All round trip times ($A1 \to S1$, $A2 \to S2$, and $B \to S2$) are equal to 100 ms. This number includes all processing times.
- We neglect all overheads and assume that the link capacities can be fully utilized.
- The MSS is the same for all flows and is equal to 1250 Bytes = 10^4 bits.

1. Assume that some bandwidth manager is used, which allocates rates to flows according to max-min fairness. In this question, we assume that B is not sending any traffic, i.e. the rate of the flow $B \to S2$ is 0. What are the values of the rates of the flows $A1 \to S1$ and $A2 \to S2$?

2. Same question with proportional fairness instead of max-min fairness (in this question, we continue to assume that B is not sending any traffic, i.e. the rate of the flow $B \to S2$ is 0). What are the values of the rates of the flows $A1 \to S1$ and $A2 \to S2$?

3. We now assume that the two flows $A1 \to S1$ and $A2 \to S2$ are using TCP with ECN enabled. We continue to assume that B is not sending any traffic, i.e. the rate of the flow $B \to S2$ is 0. What are the values of the rates of the flows $A1 \to S1$ and $A2 \to S2$?

We observe the IP headers of packets on the link from $R1$ to $R2$. For each of the two flows, which proportion of packets do we see marked as “Congestion Experienced” ?

4. We now assume that the two flows $A1 \to S1$ and $B \to S2$ are using TCP with ECN enabled. The flow $A2 \to S2$ is now using UDP without any traffic control at a constant rate equal to 6Mb/s. What are the values of the rates of the flows $A1 \to S1$ and $B \to S2$?

5. We now assume that the two flows $A1 \to S1$ and $A2 \to S2$ are using TCP with ECN enabled. Also, the flow $B \to S2$ is now using UDP without any traffic control at a constant rate equal to 6Mb/s. What are the values of the rates of the flows $A1 \to S1$ and $A2 \to S2$?

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PROBLEM 3

Consider the network in Figure 3 on the figure sheet.

- $A1, B1, C1, C2, C3$ and $C4$ are BGP routers (unless otherwise specified). A, B, C, and X are AS numbers. Thick lines indicate physical connections. There are no other BGP routers in AS C and no other physical connections than shown on the figure. There **are** other BGP routers in ASs A, B, and X that are not shown on the figure.
- Some IP addresses are shown. If you need any IP addresses that are not indicated, please mention them in your solution.
- Only IPv6 is used.
- RIPng is run inside AS C and all link costs are equal to 1.
- Routers $C1$ and $C2$ each announce in RIPng the destination `::/0` with cost $= 1$.
- Routers do not perform aggregation, unless explicitly mentioned.
- BGP routers inject the routes they have learned from BGP into their routing tables.
- There is **no redistribution** of BGP in RIPng and **no redistribution** of RIPng in BGP.
- Recursive lookup is enabled in forwarding tables.

1. At time t_0, $C2$ boots. All other routers are up and running. At time $t_1 > t_0$, $C2$ receives from $B1$ the announcements:

```
2003::/16, AS path = B X, NEXT-HOP=2001:bc::b
2003:1::/32, AS path = B A, NEXT-HOP=2001:bc::b
```

   No other announcements were received by $C2$ before this one. Explain what actions are performed by $C2$ upon receiving these routes. Say in particular to which BGP routers, if any, $C2$ will send announcements as a result.

2. At time $t_2 > t_1$, $C2$ receives from $C1$ the announcement

```
2003::/16, AS path = C A X, NEXT-HOP=2001:ac::a
2003:1::/32, AS path = C A, NEXT-HOP=2001:ac::a
```

   Assume no other announcement than previously shown was sent by either $B1$ or $C1$. At time $t_3 > t_2$ BGP has stabilized again inside ASs A, B, C. Explain what actions are performed by $C2$ upon receiving these routes. Say in particular to which BGP routers, if any, $C2$ will send announcements as a result.

3. Still at time t_3, $C3$ has an IP packet to forward with destination address `2003:1::baba`. Which path will this packet follow ?

4. At time $t_4 > t_3$ the link between $A1$ and $C1$ fails. Explain what actions, if any, are performed by $C1$ as a result. Say in particular to which BGP routers, if any, $C1$ will send announcements as a result.

5. At time $t_5 > t_4$ BGP has stabilized. $C1$ has two IP packets to forward. One with destination address `2003:1::baba` and the other one with destination address `2003:2::baba`. Which paths will each of these packets follow ?

6. At time $t_6 > t_5$ the BGP processes at routers $C3$ and $C4$ are killed – BGP is disabled in these two routers. From now on, routers C3 and C4 do *not* run BGP and they forget all routes learned via BGP (they run only RIPng). All other routers continue to work correctly and RIPng continues to work correctly in all routers inside AS C. In particular, $C1$ and $C2$ continue to announce the destination `::/0` with cost $= 1$ in RIPng inside AS C.
   Explain what actions, if any, are performed by $C1$ as a result of this change. Say in particular to which BGP routers, if any, $C1$ will send announcements as a result.

   At time $t_7 > t_6$ BGP has converged again. $C3$ has an IP packet to forward with destination address `2003:1::baba`. Which path will this packet follow ?

7. At time $t_8 > t_7$ the link between $C1$ and $C2$ fails. Explain what actions, if any, are performed by $C1$ as a result. Say in particular to which BGP routers, if any, $C1$ will send announcements as a result.

At time $t_9 > t_8$ BGP and RIPng have converged again. $C4$ has an IP packet to forward with destination address `2003:1::baba`. Which path will this packet follow ?

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PROBLEM 4

The Simpson Routing Protocol (SRP) is a variant of distance vector routing, which works as follows.

- Every SRP router has a 16 bit "router id" and keeps a record of the router ids of all other SRP routers.
- An SRP router knows all its directly-attached prefixes. The router with id i, is configured with the (static) cost $c(i, j)$ of going from i to j, for every SRP router j that is a neighbor of i. We assume that $c(i, j) = 1$ when i and j are neighbors (*i.e.*, when i and j are directly connected).
- An SRP router periodically (every T_1 seconds) sends to all neighbors the list of all IPv4 and IPv6 destination prefixes it knows of and the distance to such destinations. Such information is read from the routing table and is called a "distance vector"
- An SRP router keeps one RIB-IN table for each neighboring router, which contains the list of all IP destinations and the associated distances advertised by the neighbor.

Consider as example the network in Figure 4 on the figure sheet, where $R1, R2, R3, R4$ and $R5$ are SRP routers, with router ids 1, resp. $2, 3, 4$ and 5. When the routing protocol has converged, the RIB-INs and the routing table at router R1 are shown below.

Routing table at 1		
destination	distance	next-hop
12.12.12/24	1	direct
14.14.14/24	1	direct
23.23.23/24	2	2
25.25.25/24	2	2
35.35.35/24	3	2
45.45.45/24	2	4

RIB-IN at 1 for neighbor 2	
destination	distance
12.12.12/24	1
14.14.14/24	2
23.23.23/24	1
25.25.25/24	1
35.35.35/24	2
45.45.45/24	2

RIB-IN at 1 for neighbor 4	
destination	distance
12.12.12/24	2
14.14.14/24	1
23.23.23/24	3
25.25.25/24	2
35.35.35/24	2
45.45.45/24	1

- When an SRP process boots or when a new neighbor appears, the corresponding RIB-IN is initially empty and the routing tables contain only the directly-attached prefixes.
- An SRP router runs a "decision process" whenever it receives a new distance vector from a neighbor. The decision process does the following.

  ```
  i = router id of this router
  for every destination prefix n that is in the received distance vector
        find a neighbor j that minimizes D_j(n) + c(i,j)
            call j_0 such a neighbor
        set the distance to n in routing table to D_i(n) = D_{j_0}(n) + c(i, j_0)
        set the next-hop to n in routing table to j_0
  ```

  In the above, $D_j(n)$ is the distance to destination n stored in the RIB-IN at i for neighbor j if it exists; if there is no entry for destination n stored in the RIB-IN at i for neighbor j, then we take $D_j(n) = +\infty$. If there are several neighbors j that minimize $D_j(n) + c(i, j)$, the one with the smallest router id is selected.
- When an SRP router has not received any distance vector from a neighbor j_0 for a duration $T_2 > 3T_1$, it clears the RIB-IN for neighbor j_0 and applies the decision process, with $D_{j_0}(n) = \infty$ for all n.

1. Assume the network is as in in Figure 4 and the state (routing table, RIB-INs) of router R1 is as given above. At time t_1 R1 receives from R2 the information:

Received by 1 at time t_1 from neighbor 2	
destination	distance
12.12.12/24	1
14.14.14/24	2
23.23.23/24	1
25.25.25/24	1
35.35.35/24	1
45.45.45/24	2

Routing table at 1 at time t_2		
destination	distance	next-hop
12.12.12/24	1	direct
14.14.14/24	1	direct
23.23.23/24		
25.25.25/24		
35.35.35/24		
45.45.45/24		

As a result, R1 runs its decision process. Give in the table above the state of the routing table at R1 at time $t_2 > t_1$ when the decision process has completed.

2. Marge claims that SRP eventually computes the shortest paths to all destinations and is able to recover from topology changes. Is this true ?

☐ Yes ☐ No

Justify your answer (Be concise: 1 to 5 lines maximum).

3. Bart proposes to simplify SRP as follows. The RIB-INs are eliminated. The rest remains unchanged, except for the decision process, which, as before, is run whenever a new distance vector is received from a neighbor, but is now modified as follows

```
i = router id of this router
new distance vector is received from neighbor j
for every destination prefix n that is in the received distance vector
      if D_j(n) + c(i,j) < D_i(n)
           set the distance to n in routing table to
               D_i(n) = D_j(n) + c(i,j)
           set the next-hop to n in routing table to j
```

Does Marge's claim continue to hold with Bart's modification ?

□ Yes □ No

Justify your answer (Be concise: 1 to 5 lines maximum).

4. Mr. Burns proposes to ignore Bart's modification; instead, he proposes to replace the periodic sending of the distance vector by an update scheme, where only modifications to the routing table distances are announced. When a destination is removed from the routing table, this is considered as setting the distance to infinity and is therefore announced. All messages are transmitted via TCP; hence, no messages are lost. In addition, a keep-alive message is sent to every neighbor every T_1 second; if no keep-alive mechanism has been received by i from neighbor j for T_2 seconds, then i declares j as dead, clears the RIB-IN for j and runs the (unmodified) decision process.

   Does Marge's claim continue to hold with this modification ?

   □ Yes □ No

   Justify your answer (Be concise: 1 to 5 lines maximum).

TCP IP EXAM - FIGURES

For your convenience, you can separate this sheet from the main document. Do not write your solution on this sheet, use only the main document. Do not return this sheet.

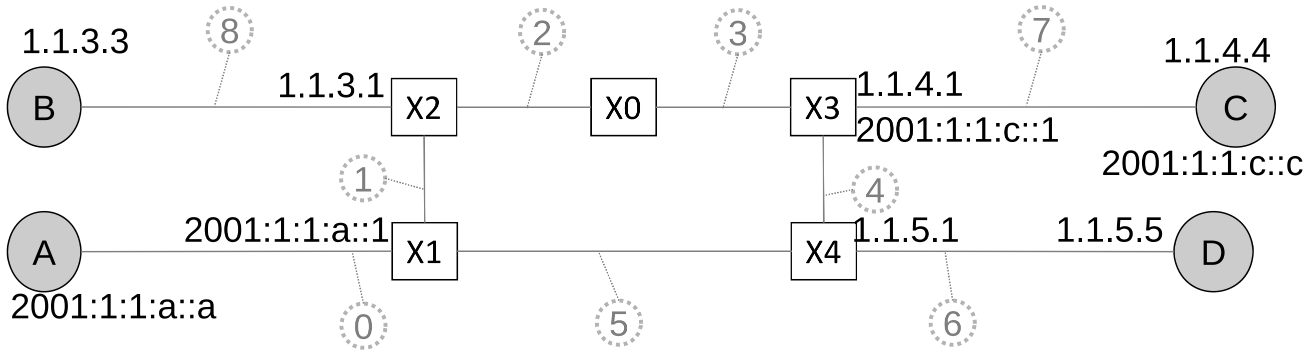

Figure 1: The network used in Problem 1

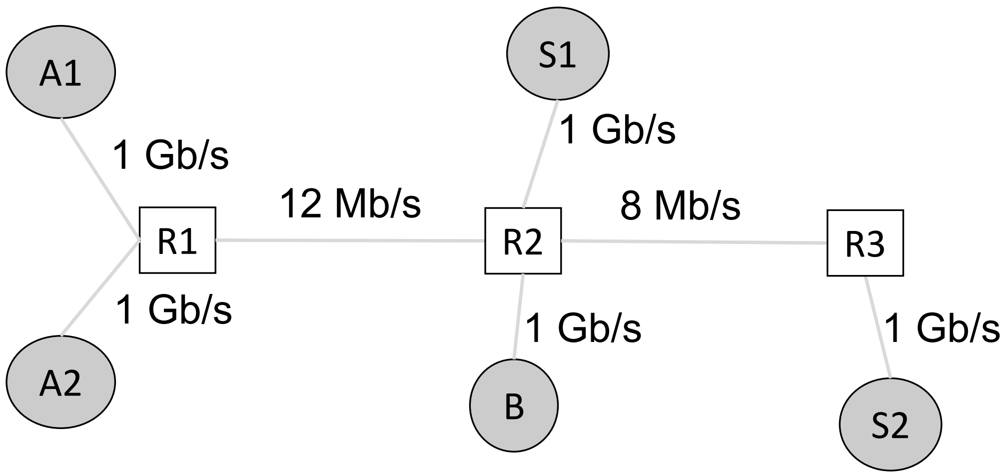

Figure 2: The network used in Problem 2

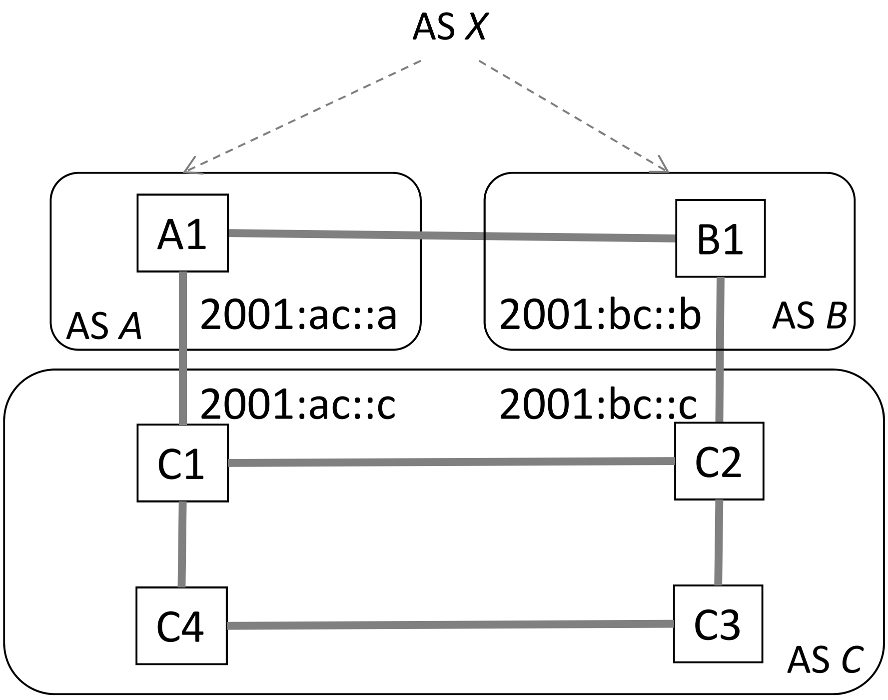

Figure 3: The network used in Problem 3

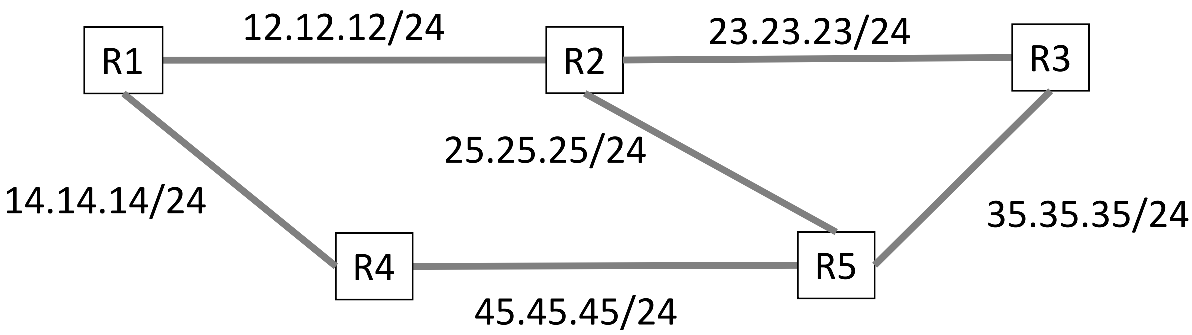

Figure 4: Network example for Problem 4