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. All problems have the same weight.
3. If you need to make assumptions in order to solve some questions, please write them down explicitly.
4. Figures are on a separate sheet, for your convenience.
5. No documents, no electronic equipments are allowed.
6. Justify every answer with a short explanation.

PROBLEM 1

Consider the network in Figure 1. A, B and C are hosts; R is a router, unless otherwise specified; X is a network box that can be configured in different ways, as explained below. The dotted circles identify observation points. The IPv4 addresses are indicated. The MAC addresses are $A, B, X1, X2$, etc. All links are Ethernet.

1. What is the 24^{th} bit of the IPv4 address of B? (the first bit = the most significant bit is the leftmost one).

2. In this question X is a bridge.

   (a) Give one possible value for the netmask at A and one for the netmask at B.

   (b) A sends one ping message to C. We assume that A has just booted and has an empty ARP table. We observe the traffic resulting from this activity at observation points 1, 2 and 3. At which of these points are the ARP Requests issued by A visible?

   What is the target IP address in the ARP request issued by A?

   We observe the ping packet sent by A to C at observation point 3. What are the MAC and IP source and destination addresses in this packet ? What is the TTL field, knowing that the TTL value is equal to 64 in all IPv4 packets generated by A ? Put your answers in the table below.

At observation point 3:				
MAC source	MAC dest	IP source	IP dest	TTL

(c) A video server runs at C. The user at B downloads a video file from C using HTTP. The video file is large and requires a large number of IP packets. Once the transfer is successfully started, at which observation points (1, 2, 3) are we able to capture the packets resulting from the transfer ?

3. In this question X is a multiport repeater (i.e. a hub).

(a) Are the netmasks at A and B obtained in the previous question still valid ?

(b) A sends one ping message to C. We assume that A has just booted and has an empty ARP table. We observe the traffic resulting from this activity at observation points 1, 2 and 3. At which of these points are the ARP Requests issued by A visible ?

(c) A video server runs at C. The user at B downloads a video file from C using HTTP. The video file is large and requires a large number of IP packets. Once the transfer is successfully started, at which observation points (1, 2, 3) are we able to capture the packets resulting from the transfer ?

4. In this question X is a bridge and R is a NAT box. The WAN port is R2; the local port is R1. As in the previous case, a video server runs at C and the user at B downloads a video file from C using HTTP. The video file is large and requires a large number of IP packets. Once the transfer is successfully started, we observe the packets resulting from this activity at observation points 2 and 4, and only in the direction from C to B. For one such packet (which, therefore, flows from C to B) what are, in each case, the MAC and IP source and destination addresses?

At observation point 2**, packet** $C \to B$**:**			
MAC source	MAC dest	IP source	IP dest

At observation point 4**, packet** $C \to B$**:**			
MAC source	MAC dest	IP source	IP dest

5. In this question X is a VLAN switch and R is a regular router (i.e. not a NAT). The VLAN switch gives different VLAN labels to A and B.

   (a) Are the netmasks at A and B obtained in Question 1 still valid ?

   (b) VLAN labels are correctly configured in X. What configuration changes need to be done at router R for this network to continue to work properly?

   We observe packets sent by A to B at observation point 2. What are the MAC and IP source and destination addresses in this packet ? What is the TTL field, knowing that the TTL value is equal to 64 in all IPv4 packets generated by A ? Put your answers in the table below.

At observation point 2**, packet** $A \to B$				
MAC source	MAC dest	IP source	IP dest	TTL

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PROBLEM 2

Consider the network in Figure 2 on the figure sheet.

- X_0 to X_4 are routers or bridges, depending on the question. S_0 to S_4 are hosts. All links are full duplex with same rate in both directions. The rates are 9 Mb/s for the links between (between X_i and $X_{(i+1) \bmod 5}$) and 10 Gb/s for the access links (between S_i and X_i).
- There is no other system than shown on the figure, and we neglect all flows other than those explicitly mentioned. We also neglect the impact of the acknowledgment flows in the reverse direction.
- 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 1125 Bytes = $9'000$ bits.

1. In this question we assume that X_0 to X_4 are routers, using RIP. The link costs are all equal to 1. Every source S_i ($i = 0..4$) sends one long-lasting flow of data destined to $S_{(i+2) \bmod 5}$ (*i.e.*, S_0 sends one flow destined to S_2, S_1 sends one flow destined to S_3, …, S_4 sends one flow destined to S_1).
   (a) Assume that some bandwidth manager is used, which allocates rates to flows according to max-min fairness. What is the rate allocated to every flow ?

   (b) Assume that some bandwidth manager is used, which allocates rates to flows according to proportional fairness. What is the rate allocated to every flow ?

(c) Assume in this question that the flows are using TCP with ECN and that all routers support ECN. What is the rate obtained by each flow ?

Assume that the round-trip time for each flow is 12.2 ms. We observe all TCP headers received by S_0. What is the probability that one such header is marked as congestion experienced (*i.e.*, with the ECE flag set) ?

2. In this question we continue to assume that X_0 to X_4 are routers, using RIP and that the link costs are all equal to 1.
   Every source S_i ($i = 0..4$) now sends two long lasting flows of data: one flow (called "near flow")is destined to $S_{(i+1) \bmod 5}$ and the other (called "distant flow") is destined to $S_{(i+2) \bmod 5}$. In other words: S_0 sends a near flow to S_1 and a distant flow to S_2, S_1 sends a near flow to S_2 and a distant flow to S_3, $\ldots$, S_4 sends a near flow to S_0 and a distant flow to S_1.

   (a) Assume that some bandwidth manager is used, which allocates rates to flows according to max-min fairness. What is the rate allocated to every flow ?

   (b) Assume that some bandwidth manager is used, which allocates rates to flows according to proportional fairness. What is the rate allocated to every flow ?

(c) Can you infer from the previous questions what rates would be obtained with TCP if all flows (near and distant) would have the same RTT ?

(d) Assume now that all flows (near and distant) are using UDP without any congestion control. All sources send with the same rate for each flow, equal to $r = 16$ Mb/s, the same for near and for distant flows. What is the throughput at destination for each flow (near or distant) ? (Assume that packet dropping is proportional to the offered traffic at every link where the capacity is exceeded).

3. In this question we assume, as in question (a), that every source S_i ($i = 0..4$) sends one single long lasting flow of data destined to $S_{(i+2) \bmod 5}$ (*i.e.* S_0 sends one flow destined to S_2, S_1 sends one flow destined to S_3, …, S_4 sends one flow destined to S_1). However, unlike question (a), we assume now that X_0 to X_4 are bridges instead of routers.

   (a) Assume that some bandwidth manager is used, which allocates rates to flows according to max-min fairness. What is the rate allocated to every flow ?

   (b) Assume that some bandwidth manager is used, which allocates rates to flows according to proportional fairness. What is the rate allocated to every flow ?

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PROBLEM 3

Consider the network in Figure 3 on the figure sheet.

- $A1, A2, B1$ and $C1$ are BGP routers. $A3$ and $A4$ do *not* run BGP.
- A, B, and C are AS numbers. Thick lines indicate physical connections. There are no other BGP routers in AS A than shown on the figure. Also, all physical connections involving routers in AS A are shown on the figure. However, there *are* other BGP routers in ASs B and C that are not shown on the figure; similarly there are other ASs connected to B and C, 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 IPv4 is used.
- All routers inside AS A use RIP with route poisoning and split horizon. All link costs are 1 except for the link $A3 - A4$, which is equal to 2, as shown on the figure.
- Routers $A1$ and $A2$ each announce in RIP the destination `0.0.0.0/0` 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 into RIP and **no redistribution** of RIP into BGP.
- Recursive lookup is enabled in forwarding tables.

1. At time t_0, $A1$ boots. All other routers are up and running. At time $t_1 > t_0$, $A1$ receives from $B1$ the announcements:

```
33.33/16, AS path = B D X, NEXT-HOP=12.12.12.2
33.33.1/24, AS path = B, NEXT-HOP=12.12.12.2
```

   No other announcements were received by $A1$ before this one. Explain what actions are performed by BGP at $A1$ upon receiving these routes. Say in particular to which BGP routers, if any, $A1$ will send announcements as a result.

2. At time $t_2 > t_1$, $A1$ receives from $A2$ the announcement

   `33.33/16, AS path = C X, NEXT-HOP=13.13.13.2`

   Assume no other announcement than previously shown was sent by either $B1$ or $A2$. Explain what actions are performed by BGP at $A1$ upon receiving these routes. Say in particular to which BGP routers, if any, $A1$ will send announcements as a result.

3. At time $t_3 > t_2$, BGP has stabilized again inside ASs A, B, C. Still at time t_3, $A3$ has two IP packets to forward, one with destination address `33.33.1.1` and the other with destination address `33.33.2.2`. Which path will each of these packets follow ?

4. At time $t_4 > t_3$, $A1$ receives from $B1$ the announcement

   WITHDRAW `33.33/16, AS path = B D X, NEXT-HOP=12.12.12.2`

   Explain what actions, if any, are performed by BGP at $A1$ as a result. Say in particular to which BGP routers, if any, $A1$ will send announcements as a result.

5. At time $t_5 > t_4$, BGP has converged again; still at time t_5 the link between $A1$ and $A2$ fails. RIP at $A1$ immediately detects the failure. Explain what actions, if any, are performed by RIP at $A1$ as a result. Say in particular what distance vector is announced by $A1$ to $A3$. Also say what routes to `13.13.13.2` and `0.0.0.0/0` are computed by RIP at $A3$ immediately after receiving this distance vector.

6. At time $t_6 > t_5$, BGP and RIP have stabilized again. $A3$ has again two IP packets to forward, one with destination address `33.33.1.1` and the other with destination address `33.33.2.2`. Which path will each of these packets follow ?

7. Lisa, Bart and Homer each propose a modification to the configuration in AS A.
   - Lisa proposes to run BGP in $A3$ and $A4$ (the rest is identical to the initial configuration);
   - Bart proposes to redistribute BGP into RIP (the rest is identical to the initial configuration);
   - Homer proposes to redistribute RIP into BGP (the rest is identical to the initial configuration).

   Which of these solutions solve the problem in $Q6$. Discuss the pros and cons of each of these three proposals. Is any modification preferable to the initial configuration ?

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PROBLEM 4

Consider the network in Figure 4.

- A is an IPv4-only host, B is an IPv6-only host;
- G and D are dual-stack hosts. G is a web proxy. D is a DNS server that serves requests for A and AAAA records, both over IPv4 and IPv6;
- $X1$ and $X2$ are ethernet switches (unless otherwise specified);
- $R1$ is an IPv4-only router and $R2$ is an IPv6-only router;
- $R3$ is a dual-stack router.
- The circled 1 and 2 are observation points.
- The value of the TTL or HL field put at the source is 64 for all systems in the figure.
- The IPv4 default gateway at A and D is $R1$. The IPv6 default gateway at B and G is $R2$.
- Shortest path routing is used with all link costs equal to 1 and all routing tables are setup with correct values in all systems.

1. What are the 3rd and 4th bits of B's IPv6 address ? (the first bit is the leftmost one).

   Give the non compressed form of B's IPv6 address.

   Give a possible value for the IPv6 network masks at B and at G.

2. A would like to download a video file from the web server at B; this server responds to the DNS name `waow.ao`. To this end, A would like to use G as a web proxy but we would not like to configure anything special (other than the normal IPv4 configuration) at A.

   (a) Is this possible ? Justify your answer.

   (b) We assume A found a way to use G as a web proxy and downloads a video file from B using HTTP. Once the transfer is successfully established, we observe the packets resulting from this activity at points 2 and 1, in the direction $B \to A$. What are the IP addresses, protocol type/next header and TTL/HL that we see ? Put your answers in the table below.

IP source	IP dest	Protocol/Next Header	TTL / HL
At observation point 2**, packets** $B \to A$**:**			
At observation point 1**, packets** $B \to A$**:**			

   (c) One of the packets resulting from the download is lost on the link $X1 - R1$ (*i.e.*, at point 1). There is no other packet loss in this scenario. Explain by which mechanism in which machines the loss will be repaired.

3. In this question only A uses 6to4 to connect to the IPv6 internet and $R3$ is configured as a 6to4 relay-router.

   (a) Give a possible value for A's 6to4 IPv6 address and for its IPv6 default gateway.

   (b) A downloads a video file from B using HTTP over IPv6. No application layer gateway is used. Once the transfer is successfully established, we observe the packets resulting from this activity at points 2 and 1, in both directions. **If a packet is tunneled, we observe only the outer IP headers, i.e. the IP headers that are directly in the MAC payload.** What are the IP addresses, protocol type/next header and TTL/HL that we see ? Put your answers in the table below.

IP source	IP dest	Protocol/Next Header	TTL / HL
At observation point 2**, packets** $B \to A$**:**			
At observation point 2**, packets** $A \to B$**:**			
At observation point 1**, packets** $B \to A$**:**			
At observation point 1**, packets** $A \to B$**:**			

4. In this question only, $R3$ is configured as a NAT64. 6to4 is not used and the web proxy is not used either. No application layer gateway is used.
A would like to download a video file from the web server at B; this server responds to the DNS name `waow.ao`. We would not like to configure anything special (other than the normal IPv4 configuration) at A and we would not like to use any web proxy.

   (a) How is this possible ? Justify your answer.

   (b) Once the transfer is successfully established, we observe the packets resulting from this activity at points 2 and 1, in both directions. **If a packet is tunneled, we observe only the outer IP headers, i.e. the IP headers that are directly in the MAC payload.** What are the IP addresses, protocol type/next header and TTL/HL that we see ? Put your answers in the table below.
   Specify any additional assumption you may need.

IP source	IP dest	Protocol/Next Header	TTL / HL
At observation point 2, packets $B \to A$:			
At observation point 2, packets $A \to B$:			
At observation point 1, packets $B \to A$:			
At observation point 1, packets $A \to B$:			

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.

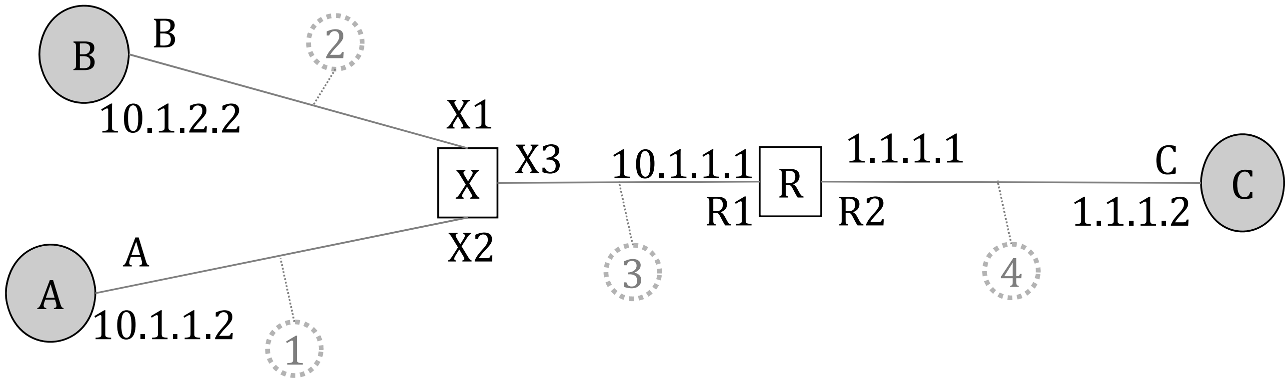

Figure 1: The network used in Problem 1

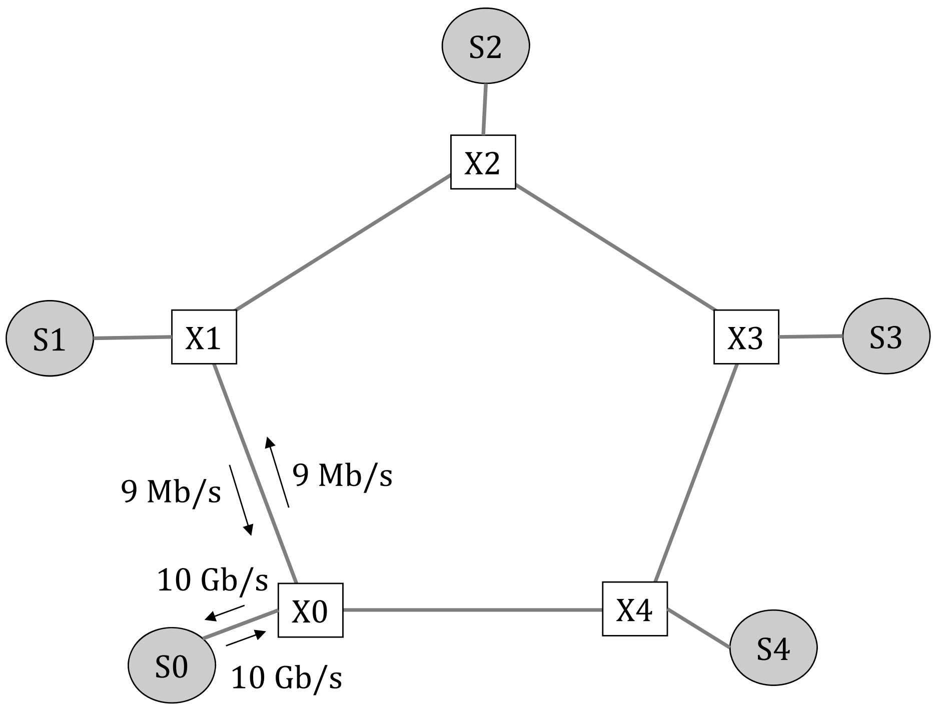

Figure 2: The network used in Problem 2. The figure shows only the link rates between $S_0 - X_0$ and between $X_0 - X_1$. The other link rates are similar.

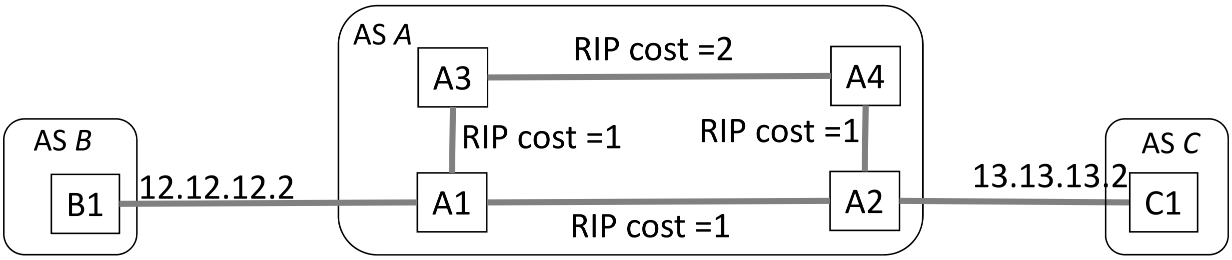

Figure 3: The network used in Problem 3

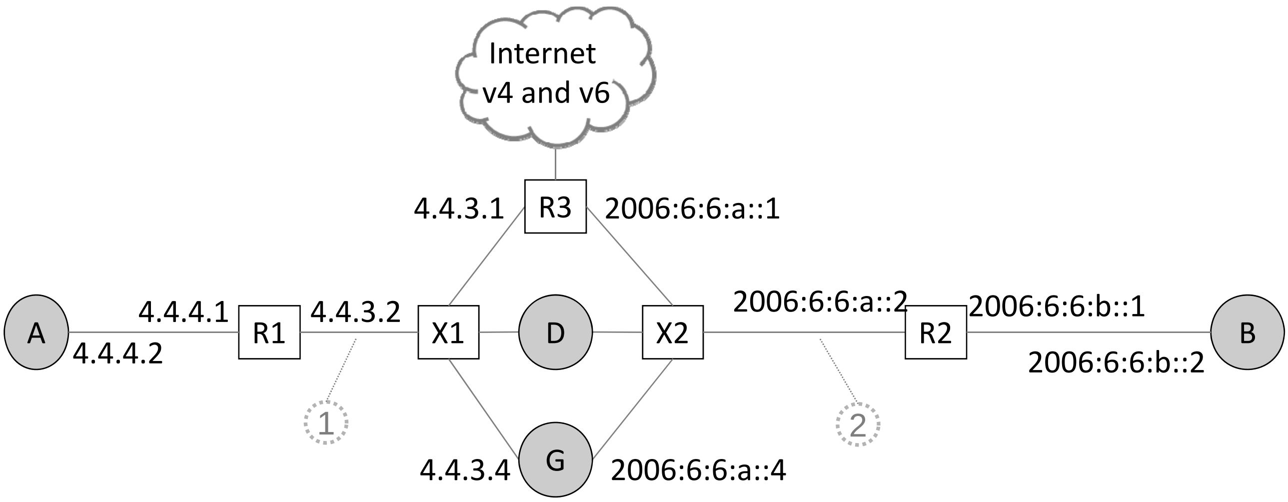

Figure 4: The network used in Problem 4