SCIPER: ____________________

First name: ______________________ Family name: ______________________

EXAM
TCP/IP NETWORKING
Duration: 3 hours

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January 2019

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. You may need to make additional assumptions in order to solve some of the questions. If this happens, please describe such assumptions 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 for problem 1 in the figure sheet. A, B, C, D and E are hosts; $BR1, BR2$ and $BR3$ are bridges; N is an IPv4 NAT; $R1, R2$ and $R3$ are routers. $O1$ to $O6$ are observation points where we observe traffic in both directions of the link.

Hosts C and E are IPv6-only; D is IPv4-only; A and B are dual stack. All routers are dual-stack.

Some selected IP addresses are shown, as well as some selected MAC addresses (denoted with e.g. A, B, $BR1w$, ...,$R1e$,...). In some questions you might need to make assumptions about IP or MAC address values not shown in the figure.

All links are full duplex Ethernet. We assume that all machines are correctly configured (unless otherwise specified), proxy ARP is not used and there is no VLAN.

1. ISP6 delegates to Homer's network the prefix `2001:a:a::/60`. Inside Homer's network, all IPv6 netmasks are `/64`.

   (a) Give the uncompressed version of the address `2001:a:a:1::2`.

   (b) Give a possible value of z (in the IPv6 address of $R3$'s east interface).

   (c) Among the following addresses, which ones are possible for host C ? Put an X in the correct boxes in the table below, with a short justification.

address	possible	not possible
`2001::3`		
`2001:a:a:2::3`		
`2001:a:a:5::3`		
`2001:a:a:f::3`		
`2001:a:a:11::3`		

Justification:

(d) A downloads a huge file from a web server at E using HTTP. A uses the local port 4567. At the same time, C also downloads a file from E, also using HTTP. By coincidence, C uses the same local port number, namely 4567. We observe the IP headers in the packets resulting from this transfer at $O5$, in the direction from E to A and from E to C. Give possible values of the protocol, the source and destination port numbers, the source and destination IP addresses and MAC addresses. Give the answers in the tables below.

At observation point $O5$, from E to A and C:						
MAC src.	MAC dest.	IP source	IP dest	prot	src. port	dest. port

(e) A sends a ping message to B, B sends a ping message to C, and C sends a ping message to A, all three using IPv6. At observation points $O2, O3$ and $O4$, we observe the ping request packets resulting from this activity. What are the MAC and IP source and destination addresses in such packets ? What is the Hop Count field, knowing that the HC value is equal to 64 in all IP packets generated by all hosts in this problem ? Put your answers in the table below, with a short justification.

Ping Requests seen at observation point $O2$:				
MAC source	MAC dest	IP source	IP dest	HC

Ping Requests seen at observation point $O3$:				
MAC source	MAC dest	IP source	IP dest	HC

Ping Requests seen at observation point $O4$:				
MAC source	MAC dest	IP source	IP dest	HC

Justification:

2. ISP4 allocates to N the address `11.10.9.8`.

   (a) Give possible values of the network masks at N-west and at B.

   (b) Give a possible value for the complete IP address of A. Shortly justify your answer.

   (c) A downloads a huge file from a web server at D using HTTP. A uses the local port 4567. At the same time, B also downloads a file from D, also using HTTP. By coincidence, B uses the same local port number, namely 4567. We observe the IP headers in the packets resulting from this transfer at $O6$ and $O1$, in the direction from D to A and B. Give possible values of the protocol, the source and destination port numbers and the source and destination IP addresses. Give the answers in the tables below.

At observation point $O6$, from D to A and B:				
IP source	IP dest	protocol	source port	dest. port

At observation point $O1$, from D to A and B:				
IP source	IP dest	protocol	source port	dest. port

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PROBLEM 2

Consider the network for problem 2 in the figure sheet. There are three ASs, A, B and C with routers $A1, A2, A3, A4, B1, B2, B3, C1, C2, C3$ and $C4$. The physical links are shown with plain lines. Each AS uses OSPF with Equal Cost Multipath as IGP, and every router inside each AS uses OSPF. The cost of every link and every directly attached network is 1, except for three links shown of the figure, where the cost is 10.

The figure shows two stub networks, at routers $A3$ and $A4$, with their IPv6 address prefixes. The lower case symbols such as $b1w$, $b2se$ also represent IPv6 addresses.

Routers $A1, A2, B1, B2, B3, C1$ and $C2$ use BGP with their external neighbours and as required with their internal neighbours. Unless otherwise specified, the other routers do not use BGP. We assume that the BGP decision process use the following criteria in decreasing order of priority.

1. Shortest AS-PATH
2. Lowest MED, if taken seriously by this network
3. E-BGP $>$ I-BGP
4. Shortest path to NEXT-HOP, according to IGP
5. Lowest BGP identifier

Furthermore, we assume that no optional BGP attribute (such as MED, LOCAL-PREF etc.) is used in any BGP message and that no aggregation is performed.

In the entire problem we assume that each AS redistributes internal OSPF destinations into BGP.

1. At time t_0, we assume that each AS is configured to redistribute E-BGP routes into OSPF. When redistributing E-BGP into OSPF, the OSPF cost of the redistributed route is set to the OSPF cost to the BGP next-hop plus 100.
   Furthermore, the policy in A, B, C is such that all available routes are propagated to neighbouring ASs.

   (a) At time $t_1 > t_0$, BGP and OSPF have converged in all ASs. At this time:

      i. Which routes are selected by BGP at $B3$ and $C1$? Give the answers in the tables below, with a short justification.

At B3	DESTINATION NETWORK	BGP NEXT-HOP	AS-PATH
	2001:1::/32		
	2001:2::/32		
At C1	DESTINATION NETWORK	BGP NEXT-HOP	AS-PATH
	2001:1::/32		
	2001:2::/32		
Justification:			

ii. In the forwarding tables of $B3$ and $C3$, what are the entries for the destinations `2001:1/32` and `2001:2/32` ? Give the answers in the tables below, with a short justification.

At B3	DESTINATION NETWORK	NEXT-HOP	DISTANCE
	2001:1::/32		
	2001:2::/32		
At C3	DESTINATION NETWORK	NEXT-HOP	DISTANCE
	2001:1::/32		
	2001:2::/32		
Justification:			

(b) At time $t_2 > t_1$, router $A2$ crashes. At time $t_3 > t_2$, BGP and OSPF have converged again in all ASs and $A2$ is not yet repaired. At this time:

i. Which routes are selected by BGP at $B3$ and $C1$? Give the answers in the tables below, with a short justification.

At B3	DESTINATION NETWORK	BGP NEXT-HOP	AS-PATH
	2001:1::/32		
	2001:2::/32		
At C1	DESTINATION NETWORK	BGP NEXT-HOP	AS-PATH
	2001:1::/32		
	2001:2::/32		
Justification:			

ii. In the forwarding tables of $B3$ and $C3$, what are the entries for the destinations `2001:1/32` and `2001:2/32` ? Give the answers in the tables below, with a short justification.

At B3	DESTINATION NETWORK	NEXT-HOP	DISTANCE
	2001:1::/32		
	2001:2::/32		
At C3	DESTINATION NETWORK	NEXT-HOP	DISTANCE
	2001:1::/32		
	2001:2::/32		
Justification:			

(c) At time $t_4 > t_3$ router $A2$ is repaired. At time $t_5 > t_4$, $B3$ is compromised and now sends to $C1$ the (bogus) BGP announcements

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DESTINATION = 2001:1::/32, AS-PATH = B
DESTINATION = 2001:2:baba::/48, AS-PATH = B
```

Also assume that $C1$ accepts these BGP announcements and that there are no other bogus announcements than these. At time $t_6 > t_5$ BGP and OSPF have stabilized again in all ASs. At this time, how is an IPv6 packet routed from $C3$ and $C4$ to `2001:1:bebe:bebe::1` and to `2001:2:baba:baba::1` ? Give only the exit point out of AS C by putting an `X` in the table below, with a short justification.

	Exit point out of AS C		
From $C3$ to	c1n	c2nw	c2w
`2001:1:bebe:bebe::1`			
`2001:2:baba:baba::1`			

	Exit point out of AS C		
From $C4$ to	c1n	c2nw	c2w
`2001:1:bebe:bebe::1`			
`2001:2:baba:baba::1`			

Justification:

2. We consider now a different scenario. At time t_0, we assume (as in the previous scenario) that each AS redistributes E-BGP routes into OSPF and that the OSPF cost of the redistributed route is set to the OSPF cost to the BGP next-hop plus 100. However, we now assume that the policy at B is such that routes imported from A are not propagated to C, and similarly, at C, routes imported from A are not propagated to B. In this scenario, $B3$ does not send any bogus BGP announcement.
We assume that router $A2$ works normally until time $t'_1 > t_0$, then crashes and is not repaired. At time $t'_2 > t'_1$, BGP and OSPF have converged in all ASs. At this time: Which routes are selected by BGP at $B3$ and $C1$? Give the answers in the tables below, with a short justification.

At B3	DESTINATION NETWORK	BGP NEXT-HOP	AS-PATH
	2001:1::/32		
	2001:2::/32		
At C1	DESTINATION NETWORK	BGP NEXT-HOP	AS-PATH
	2001:1::/32		
	2001:2::/32		
Justification:			

3. We consider yet another scenario. At time t_0, we assume that all routers, including $A2$, work normally. We also assume that the policy at B and C is the same as in the previous question. However, the configuration of AS C is modified: E-BGP is not redistributed into OSPF (but continues to be redistributed at A and B). In this scenario, $B3$ does not send any bogus BGP announcement.
Explain what can be done in AS C to maintain full connectivity, in particular, we would like all routers in AS C to be able to forward packets to all destinations in A (propose only one solution). Note that, in this question, you may make changes to the assumptions that we put at the beginning of Problem 2.

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PROBLEM 3

Consider the network for problem 3 on the figure sheet.

- The fours boxes are routers. The capacity of the links between them is shown on the figure. The links are full duplex with same rate in both directions.
- There are 4 unidirectional flows, as shown on the figure. There is no other system and no other flow than shown on the figure. There is no other capacity constraint than the link capacities shown on the figure. We also neglect the impact of the acknowledgement flows in the reverse direction.
- We neglect all overheads and assume that the link capacities can be fully utilized at bottlenecks.

1. Assume the rates x_0, x_1, x_2, x_3 of the four flows are allocated according to max-min fairness. Compute the values of x_0, x_1, x_2 and x_3.

2. Which of the following allocations, in Gb/s, are Pareto-efficient ? Justify your answer.

   (a) $x_0 = 1,\ x_1 = 1,\ x_2 = 5,\ x_3 = 5$
   (b) $x_0 = 1,\ x_1 = 1,\ x_2 = 3,\ x_3 = 5$
   (c) $x_0 = 1,\ x_1 = 1,\ x_2 = 4,\ x_3 = 6$

3. Is the following allocation, in Gb/s, proportionally fair ? Justify your answer.

   $x_0 = 1,\ x_1 = 1,\ x_2 = 4,\ x_3 = 6$

4. In this question flows 2 and 3 are shut down (i.e. $x_2 = x_3 = 0$). Flows 0 and 1 use TCP Reno with ECN. Queuing at all routers is FIFO with RED enabled. The round trip times are:

   - 300 ms for flow 0,
   - 100 ms for flow 1.

   These numbers include all processing times. The MSS is the same for all flows and is equal to 1250 Bytes = 10^4 bits. We assume that the offered window is very large. Compute the rates of flows 0 and 1.

5. Assume now that flows 0 and 1 use TCP Cubic with ECN instead of TCP Reno with ECN; the rest is as in the previous question. Can you guess how the allocation of rates would differ ? We don't ask you to compute the rates; simply put an X in the correct boxes in the table below, with a short justification.

the rate achieved with TCP Cubic and ECN is ...	flow 0	flow 1
higher		
same		
lower		

Justification:

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PROBLEM 4

1. A, B and S are IPv4-only hosts. A and B communicate with S via IPv6 using 464XLAT, as shown on the figure. The address block 2001:a:b.c:d::/80 is allocated to the CLAT to represent hosts such as A and B. The address block 2001:baba::/96 is used by PLAT to represent the IPv4 internet. The block 200.0.0/24 is used by PLAT to represent hosts such as A and B.
   A opens one TCP connection to S; the source port number used by A is 4444 and the destination port number is 443. B also opens one TCP connection to S; the source port number used by B is, by coincidence, also 4444, and the destination port number is also 443. We observe the IP and TCP packet headers for the packets resulting from this activity at observation points 1 and 2, in the direction from A and B to S. What are the protocol, IP source and destination addresses and port numbers ? Put your answer in the table below, with a short explanation of any assumption you are making.

At observation point 1, from A and B to S:				
IP source	IP dest	prot	src. port	dest. port

At observation point 2, from A and B to S:				
IP source	IP dest	prot	src. port	dest. port

Justification:

2. $R1$ is a router and uses RIP, a distance-vector routing protocol that implements the distributed Bellman-Ford algorithm. All link costs are equal to 1. At time t_0, the routing table at $R1$ contains

Destination Network	Next-Hop	Distance
9/8	2.2.2.2	2
9.9/16	2.1.1.1	3

The router $R2$ is a neighbour of $R1$ and has IP address 2.2.2.2. At $t_1 > t_0$, $R1$ receives from $R2$ the distance-vector message

```
Destination = 9/8, distance = 5
Destination = 9.9/16, distance = 5
```

No other message is received between t_0 and t_1. Just after processing this message, what is the state of the routing table at $R1$? Give your solution by filling the empty cells in the table below, together with a short justification.

Destination Network	Next-Hop	Distance
9/8		
9.9/16		
Justification		

3. Homer uses a media server to stream music in his house. The audio server uses IP multicast, with source specific multicast. It uses the multicast address `ff35::1:2:3:4`. The music stream is unidirectional, from the media server to whomever is listening.
   Lisa and Bart receive the music stream, each on their own separate device. Homer also would like to receive the audio stream. Say what happens at the IP layer when Homer decides to receive the audio stream. In particular, among the following machines: the media server, Lisa, Bart and Homer's machines, say which have to send specific IP layer control messages for Homer to be be able to receive the audio stream. (Application layer messages are not considered here).

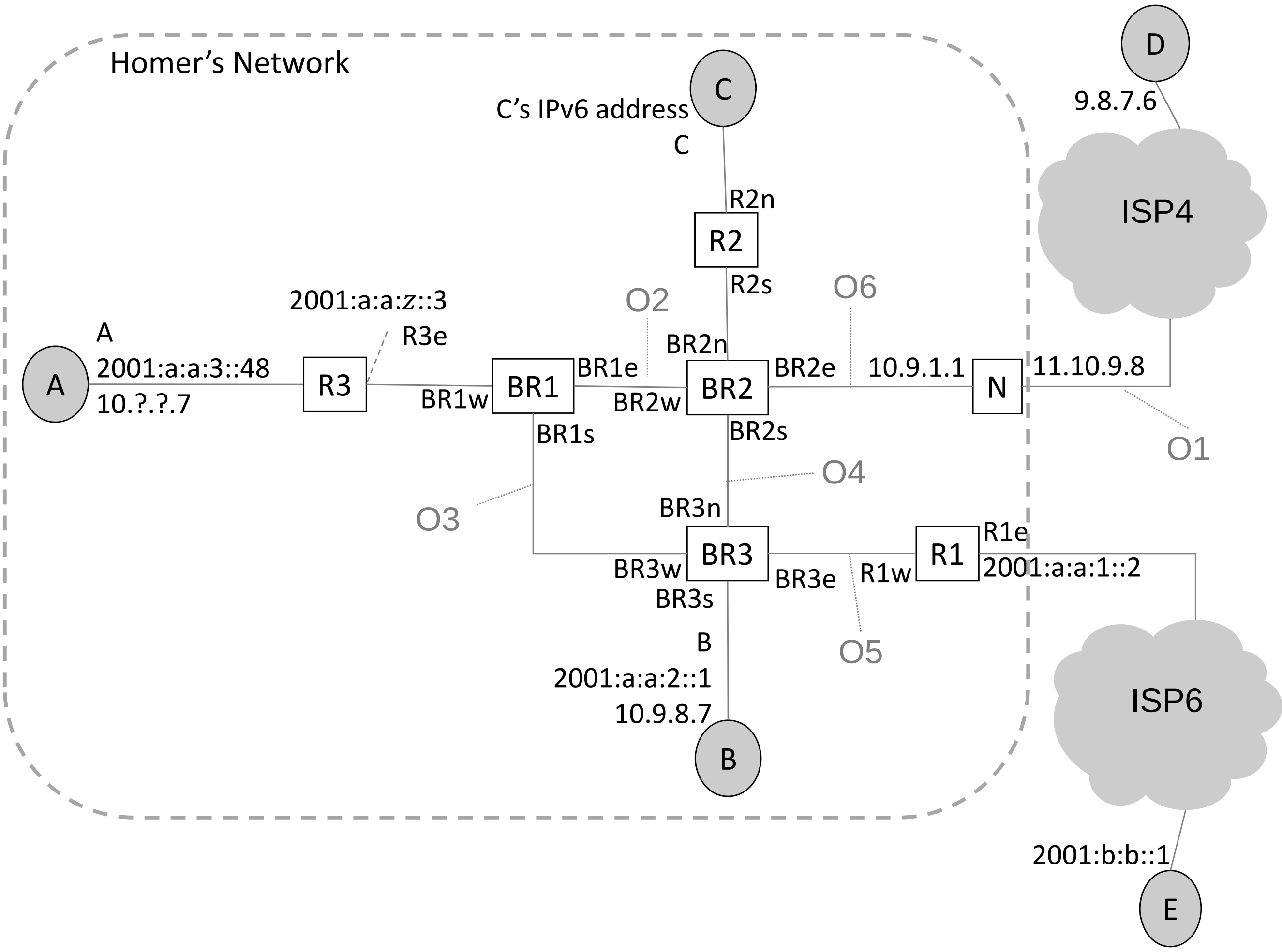
4. Say what is true about IP fragmentation (put true/false in the cells below).

	Host may fragment	Router may fragment	Router may re-assemble
With IPv4			
With IPv6			

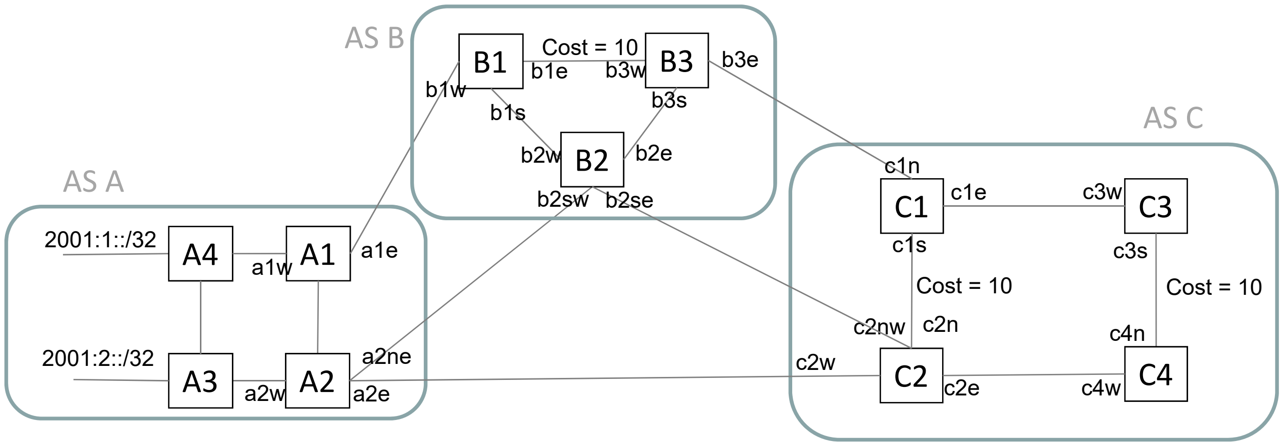
5. Sovkom's network uses OSPF with shortest paths. There are many equal-cost shortest path from several sources to destination. Could this have some negative side-effects ? If so, explain what could be done to avoid such side-effects.

TCP IP EXAM - FIGURES

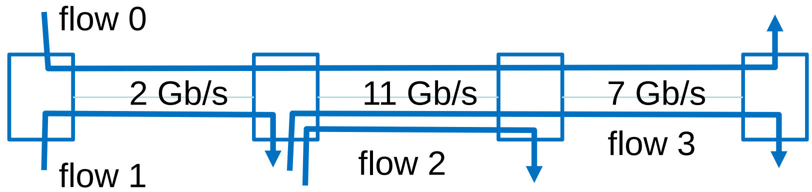
For your convenience, you can separate this sheet from the main document. Do not write your solution on this sheet, use only the main document. You do not need to return this sheet.



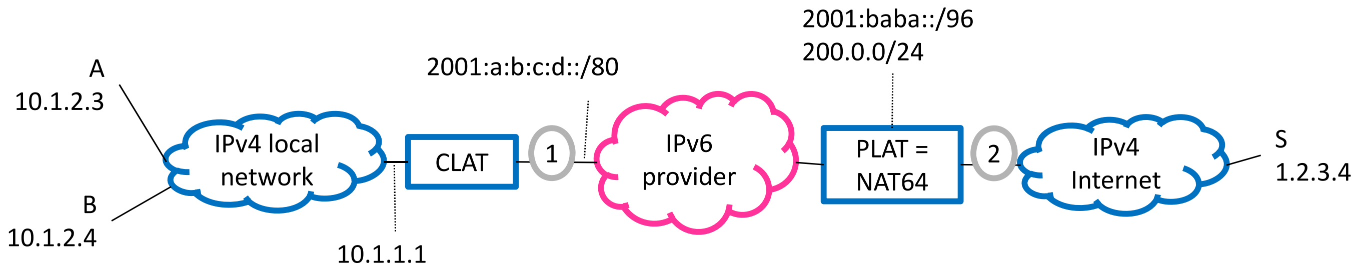
Problem 1



Problem 2



Problem 3



Problem 4, Question 1.