First name: ____________________ Family name: ____________________

FINAL EXAM - SLOT 2
TCP/IP NETWORKING
Duration: 90 min.
With Solutions

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2009 January 30

The exam is in two time slots. Slot 2 covers part 1 of the course.

Reminder: Your final theory grade is

$$T = \frac{\max(M_1, F_1) + F_2}{2}$$

where F_1, F_2 are your grades at this exam, and M_1 is your grade at the mid term. Slot 1 gives you grade F_2, slot 2 gives grade F_1.

Write your solution into this document and return it to us. You may use additional sheets if needed. Do not forget to put your name on this document and *all* additional sheets of your solution.

If you need to make assumptions in order to solve some questions, please write them down explicitly.

No documents, no electronic equipments are allowed.

You can write your solution in English or French.

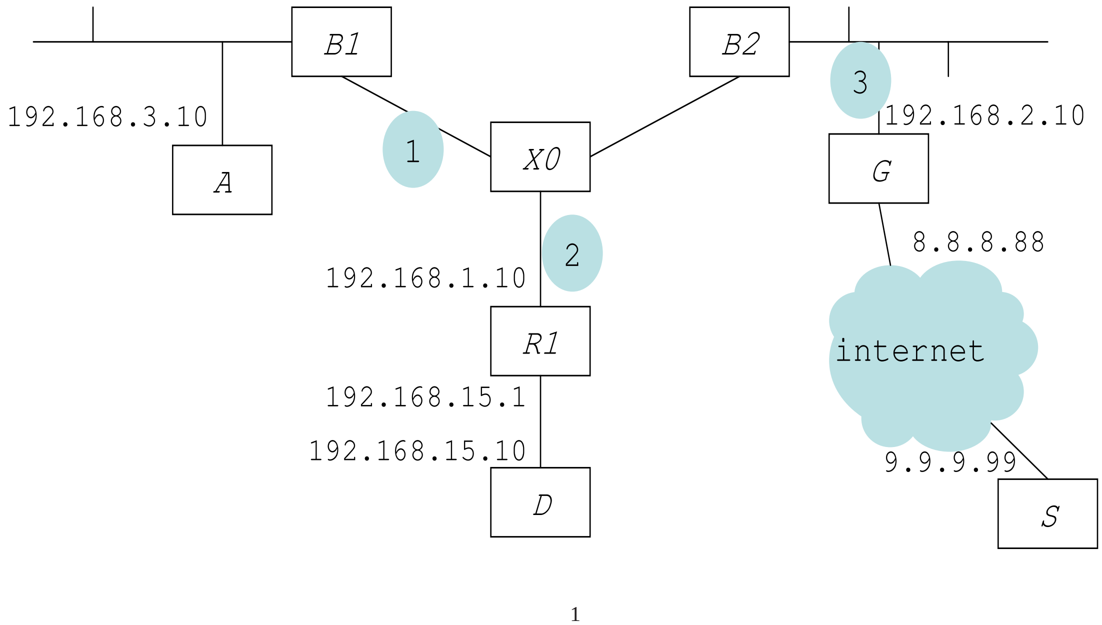

Figure 1: The network used in Question 2.1

QUESTION 2.1

Consider the network in Figure 1. The version of IP used is IPv4.

- $B1$ and $B2$ are bridges
- $R1$ is a router
- G is an application layer gateway
- A, D and S are hosts. S is running a web server.
- Some of the IP addresses are shown on the figure. If you need to make assumptions about IP or MAC addresses, please write them down on the figure.
- all hosts generate packets with TTL=64.

1. Assume $X0$ is configured as a router.
   (a) Give a possible set of values for the subnet masks at A and G.
   A : 255.255.255.0
   G : 255.255.255.0
   Others are also possible.
   (b) A sends one single ping packet to D. We assume that all caches are initially empty. We observe all packets resulting from this activity at observation points 1, 2 and 3. Give the MAC source and destination addresses observed in all of these packets. For those packets that are IP packets, also give the IP source and destination addresses as well as the value of the TTL. Write your solution in the table below.

At	MAC addr, source	MAC addr, destination	IP addr, source	IP addr, destination	TTL
1	M_A M_{X0-B1} M_A M_{X0-B1}	broadcast M_A M_{X0-B1} M_A	 192.168.3.10 192.168.15.10	 192.168.15.10 192.168.3.10	 64 62
2	M_{X0-R1} M_{R1-X0} M_{X0-R1} M_{R1-X0}	broadcast M_{X0-R1} M_{R1-X0} M_{X0-R1}	 192.168.3.10 192.168.15.10	 192.168.15.10 192.168.3.10	 63 63
3					

(c) The user at A clicks on an HTML file that contains a link to a document located at S. We assume now that all caches contain correct values. We observe all packets resulting from this activity in the direction from A to S at observation points 1, 2 and 3, Give the MAC and IP source and destination addresses observed in all of these packets, as well as the value of the TTL. Write your solution in the table below.

At	MAC addr, source	MAC addr, destination	IP addr, source	IP addr, destination	TTL
1	M_A	M_{X0-B1}	192.168.3.10	192.168.2.10	64
2					
3	M_{X0-B2}	M_{G-B2}	192.168.3.10	192.168.2.10	63

More than one packet will be observed at 1 (with the same MAC, IP, and TTL information), because of the TCP handshake, HTTP request, etc. Similarly for 3.

2. Assume in this question that $X0$ is configured as a bridge.

(a) Give a possible set of values for the subnet masks at A and G.
A : 255.255.252.0
G : 255.255.252.0
Others are also possible.

(b) A sends one single ping packet to D. We assume that all caches are initially empty. We observe all packets resulting from this activity at observation points 1, 2 and 3. Give the MAC source and destination addresses observed in all of these packets. For those packets that are IP packets, also give the IP source and destination addresses as well as the value of the TTL. Write your solution in the table below.

At	MAC addr, source	MAC addr, destination	IP addr, source	IP addr, destination	TTL
1	M_A	broadcast			
	M_{R1-X0}	M_A			
	M_A	M_{R1-X0}	192.168.3.10	192.168.15.10	64
	M_{R1-X0}	M_A	192.168.15.10	192.168.3.10	63
2	M_A	broadcast			
	M_{R1-X0}	M_A			
	M_A	M_{R1-X0}	192.168.3.10	192.168.15.10	64
	M_{R1-X0}	M_A	192.168.15.10	192.168.3.10	63
3	M_A	broadcast			

3. Assume $X0$ is configured as a router. The netmasks at A, D and G are `255.255`. What additional function needs to be implemented at $X0$ for proper operation ?
   X0 needs to be configured as an ARP proxy.
4. Assume in this question that
   - we know that $X0$ works either as a bridge or as a router,
   - however, we do not know which of the two functions is activated, and it is impossible to log into $X0$ in order to read its configuration or get any other inside information.

   Can you find one mechanism that allows you to determine, by external observations, whether $X0$ works as a bridge or as a router ? Give all details.
   Ping D from A, and observe the TTL at 1 and at 2. X0 is a router if and only if the TTL at 2 is less than the TTL at 1. Other answers are possible.

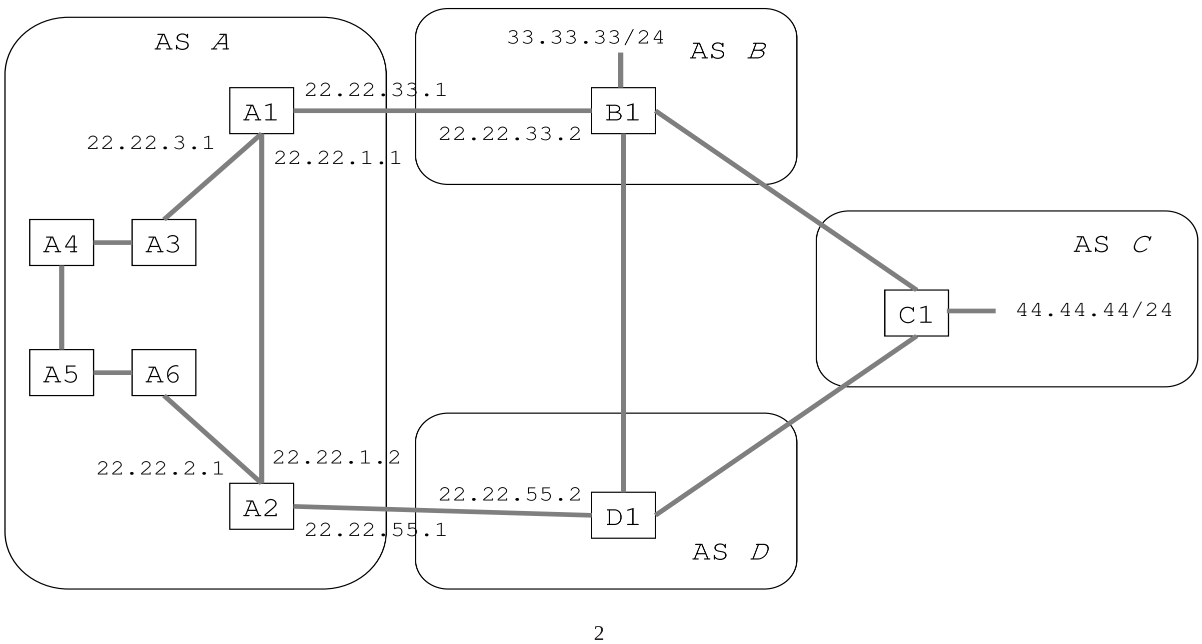

Figure 2: The network used in Question 2.2

QUESTION 2.2

Consider the network in Figure 2.

- $A1$ to $A6$, $B1, C1$ and $D1$ are routers. All physical links are shown with thick lines. There are no other routers than shown on the figure.
- Some of the IP addresses are shown. If you need some IP addresses that are not indicated, please write them down on the figure.
- All routers in AS A run RIP.
- All routers run BGP, unless otherwise specified. We do not re-distribute BGP into RIP.
- BGP routers ignore the values of `LOCAL-PREF`, `WEIGHT` and `MED`.

1. At time t_0, $B1$ sends to $A1$ the BGP announcements

   B1 to A1: `33.33.33/24, AS-PATH =B, NEXT-HOP=22.22.33.2`

   B1 to A1: `44.44.44/24, AS-PATH =B C, NEXT-HOP=22.22.33.2`

   Assume that, before t_0, $A1$ did not have any route in any of its `RIB-IN`s for these two destinations. Will $A1$ accept these routes ? To which routers will $A1$ announce a route to `33.33.33/24` ? to `44.44.44/24` ?

$A1$ has no other routes to these destinations so it will promote both routes to the Loc-RIB. $A1$ will announce both routes over IBGP to all routers inside AS A that talk BGP with $A1$.

2. At time $t_1 > t_0$, $D1$ sends to $A2$ the BGP announcements

    D1 to A2: `33.33.33/24, AS-PATH = D B, NEXT-HOP=22.22.55.2`

    D1 to A2: `44.44.44/24, AS-PATH = D C, NEXT-HOP=22.22.55.2`

    Say which routes to `33.33.33/24` and to `44.44.44/24` the decision process at $A2$ will choose. Justify your answer.

    $A2$ will choose `33.33.33/24, AS-PATH = B, NEXT-HOP = 22.22.33.2`, as this route has shorter AS-PATH than the one learned from $D1$ (`33.33.33/24, AS-PATH = D B, NEXT-HOP = 22.22.55.2`). It will also prefer `44.44.44/24, AS-PATH = D C, NEXT-HOP = 22.22.55.2` to `44.44.44/24, AS-PATH = B C, NEXT-HOP = 22.22.33.2`. The rule that is used here is (E-BGP > I-BGP).

    Same question for the decision process at $A5$.

    $A5$ has only one option for prefix `33.33.33/24`, as both $A1$ and $A5$ advertise the same route (`33.33.33/24, AS-PATH = B, NEXT-HOP = 22.22.33.2`), so it will add this route to its Loc-RIB. Out of the two choices for route to prefix `44.44.44/24` $A5$ will select `44.44.44/24, AS-PATH = D C, NEXT-HOP = 22.22.55.2`, because of the rule "shortest path to the NEXT-HOP according to IGP" (since IGP is RIP, hop count is what matters here).

3. Assume, in this question only, that at time $t_2 > t_1$ the link between $A1$ and $B1$ crashes. Explain what happens at all routers inside AS A. Which routes to `33.33.33/24` and to `44.44.44/24` will $A5$ now choose ?

   First of all, pay attention to the fact that the fact that this change applies to this question only (there is no link crash between $A1$ and $B1$ in question 4.)

   The keep-alive messages from $B1$ will stop coming and $A1$ will detect the failure; $A1$ deletes all routes with `NEXT-HOP = 22.22.33.2` from Loc-RIB and announces these changes to its IBGP neighbors. It would have done the same with the EBGP neighbors if it had any.

   The other routers now delete the affected routes from their Loc-RIBs and promote the alternative routes that they have in their RIB-INs. After the recalculation, $A1$-$A6$ will all replace the route to `33.33.33/24` that had `NEXT-HOP = 22.22.33.2` with the new route (`33.33.33/24, AS-PATH = D B, NEXT-HOP = 22.22.55.2`). Similarly, those routers that were using route `44.44.44/24, AS-PATH = B C, NEXT-HOP = 22.22.33.2` will replace it with the route announced by $D1$ at t_1 (`44.44.44/24, AS-PATH = D C, NEXT-HOP = 22.22.55.2`).

4. Assume, in this question only, that $A3, A4, A5$ and $A6$ do *not* run BGP (but all routers in AS A run RIP). Assume that $A1$ and $A2$ both advertise into RIP the prefix `*/0`. Assume that $A5$ has a packet to send to destination `33.33.33.1`. After all routing protocols have converged, what is the path followed by this packet until its exit point out of AS A ?

   Out of the two offered default gateways ($A1$ and $A2$), $A5$ will select $A2$ as its default gateway. The IGP is RIP and $A5$ has shorter distance to $A2$. The packet is thus routed to $A2$ (via $A6$), and from there to $A1$ where it leaves AS A (the second part is due to the fact that $A2$ had previously promoted `33.33.33/24, AS-PATH = B, NEXT-HOP = 22.22.33.2` as the best route to prefix `33.33.33/24` to its Loc-RIB, see question 2.).

   Assume now that the link between $A1$ and $A2$ crashes. Explain what will happen to BGP RIBs at $A1$ and $A2$; say in particular which routes to `22.22.22/24` and `33.33.33/24` will be selected at $A1$ and $A2$. Assume that $A5$ has a packet to send to destination `33.33.33.1`. After all routing protocols have converged after the failure, what is the path followed by this packet until its exit point out of AS A ?

   The failure of the link between $A1$ and $A2$ is soon detected, because of the absence of keep-alive messages. $A1$ and $A2$ will delete from their RIBs the routes they got from each other. In case of $A1$ these changes won't affect Loc-RIB. Only the route `44.44.44/24, AS-PATH = D C, NEXT-HOP = 22.22.55.2` will be deleted from RIB IN of $A1$. $A2$ on the other hand deletes route `33.33.33/24 AS-PATH = B, NEXT-HOP = 22.22.33.2` from Loc-RIB and promotes `33.33.33/24, AS-PATH = D B, NEXT-HOP = 22.22.55.2` instead.

   When $A5$ sends a packet to `33.33.33.1` it gets routed to $A2$ (via $A6$) as before. Here is where it now leaves AS A, since $A2$ promoted different route to `33.33.33/24`.

   Note: After some time the IBGP session between $A1$ and $A2$ can be reestablished, as BGP runs over TCP and these two routers are still connected via $A6, A5, A4, A3$. Once this happens $A2$ will again promote the route `33.33.33/24 AS-PATH = B, NEXT-HOP = 22.22.33.2` to the Loc-RIB. Now, when the packet from $A5$ arrives to $A2$ it will be sent to $A1$ via $A6, A5, A4, A3$ and from there to AS B. In order to eliminate this routing loop $A2$ might send an ICMP host redirect message to $A5$.