# CS-202 Exercises on Link Layer & Ethernet (L17)

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## Exercise 1: L2 forwarding

Consider an Ethernet IP subnet, where end-systems, labeled A through F, are star- connected to an Ethernet switch. Let's denote the link between A and the Switch as AS, between B and the Switch as BS, and so on. The switch's forwarding table is initially empty. Then:

1. E sends a packet to B.
2. B replies with a packet to E.
3. A sends a packet to B.
4. B replies with a packet to A.

Show for each of the four actions, how the state of the switch's forwarding table changes, and identify the link(s) on which the transmitted frame will be forwarded (+ briefly explain why).

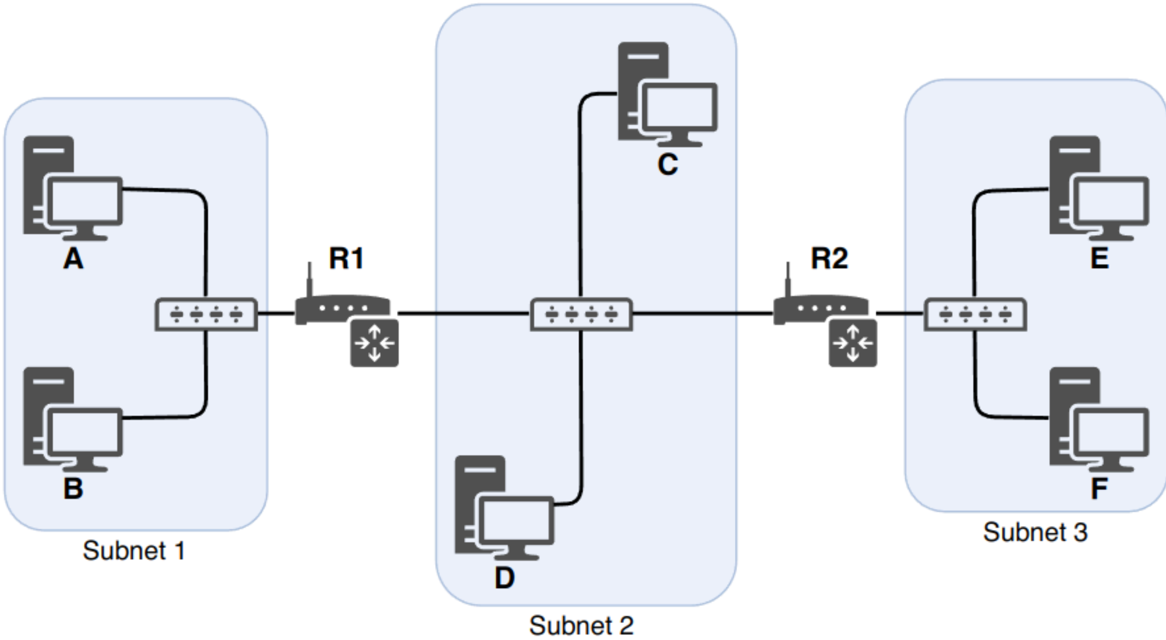
*Solution:*

| *Action* | *Switch Table State* | *Link(s) frame is forwarded to* | *Explanation* |
|---|---|---|---|
| *E sends a packet to B* | *Switch learns interface corresponding to MAC address of E* | *All except ES.* | *Switch table is empty, so it needs to forward to all.* |
| *B replies with a packet to E* | *Switch learns interface corresponding to MAC address of B* | *ES* | *Switch already knows the interface corresponding to MAC address of E* |
| *A sends a packet to B* | *Switch learns interface corresponding to MAC address of A* | *BS* | *Switch already knows the interface corresponding to MAC address of B* |

| | | | |
|---|---|---|---|
| *B replies with a packet to A* | *No change* | *AS* | *Switch already knows the interface corresponding to MAC address of A* |

## Exercise 2: Address allocation and ARP

Consider three IP subnets interconnected by two routers (R1 and R2) as shown in the Figure.

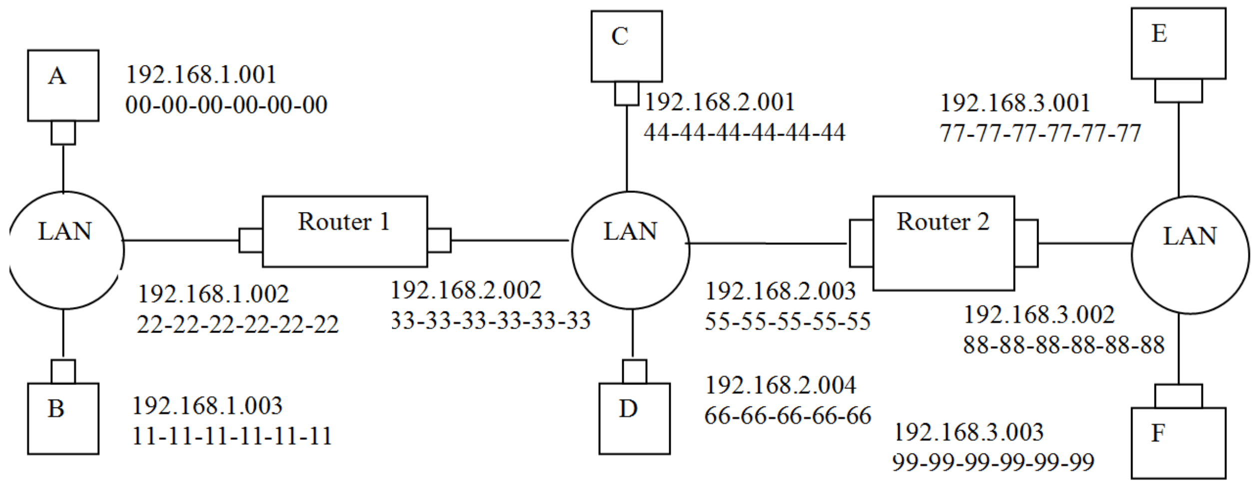



1. Assign an IP address to each network interface of an end-system and router. Allocate the addresses from IP prefix **192.168.1.0/24** for Subnet 1, **192.168.2.0/24** for Subnet 2, and **192.168.3.0/24** for Subnet 3. Reserve the first and last address of each range to the network and broadcast addresses, respectively.

*Solution:*

*The figure shows an example of an assignment of IP and MAC addresses.*

- *IPs are correctly allocated if they are inside the range and do not use the addresses reserved for network and broadcast.*
- *MACs addresses can have any value as long as they follow the correct format.*




2. Assign a MAC address to each network interface.

*Solution:*

*See previous figure.*

3. End-system E wants to send a packet to end-system B. List all the steps needed for the packet to be sent to B. Assume that the forwarding tables of all switches already have entries for all MAC addresses, and all end-systems and routers already know each other's MAC addresses.

*Solution:*

1. *The forwarding table in E determines that the datagram should be routed to interface R2-right (192.168.3.002 in the example solution).*
2. *E creates an Ethernet frame with Ethernet destination address MAC R2-right (88-88-88-88-88-88) and source address its own MAC (77-77-77-77-77-77).*
3. *Router 2 receives the frame and extracts the datagram. The forwarding table in this router indicates that the datagram has to be routed to R1-right (192.168.2.002).*
4. *Router 2 sends an Ethernet frame with the destination address R1-right (33-33-33-33-33-33) and source address its MAC (55-55-55-55-55-55) via its interface with IP address of 192.168.2.003.*
5. *The process continues until the packet has reached Host B.*

4. Now assume that end-systems and routers do NOT previously know each other's MAC addresses (but the forwarding tables of switches still have entries for all MAC addresses). What additional step do we need for the packet to be sent to B?

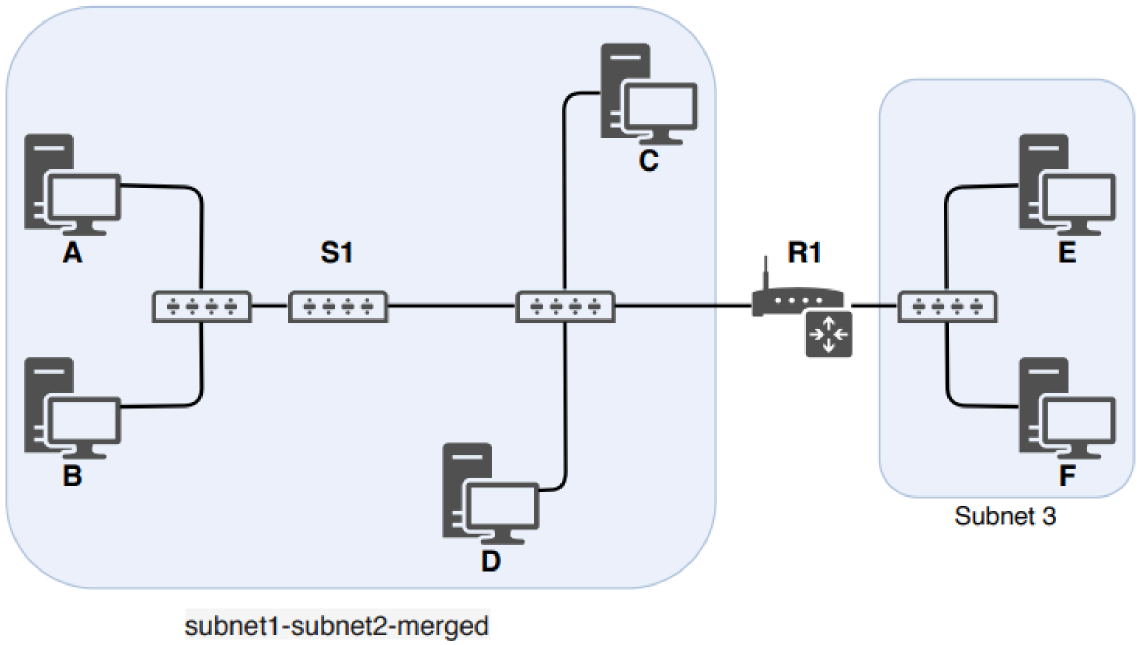
*Solution:*

*E must now determine the MAC address of 192.168.3.002 using ARP. To do this:*

1. *Host E sends out an ARP request within a broadcast Ethernet frame.*
2. *Router 2 receives the ARP request and sends an ARP response with its MAC address to Host E. This ARP response is carried by an Ethernet frame with Ethernet destination address 77-77-77-77-77-77.*
3. *Then, when Router 2 receives the datagram, it will broadcast an ARP request to determine the MAC address of 192.168.2.002 before it can route it to Router 1 (before step 4 in the previous question).*
4. *Router 1 will do the same and send an ARP request to get the MAC address of B.*

## Exercise 3: Address allocation and ARP - Part 2

Assume we changed the topology from the previous exercise to the one shown below. We replace the router between Subnets 1 and 2 with a switch S1, so now these subnets will become one subnet “subnet1-subnet2-merged”. We also label the router between the subnets as R1.




1. End-system C wants to send a packet to end-system B. Is router R1 involved in forwarding the datagram? What are the source/destination MAC/IP addresses in the packet’s Ethernet and IP headers?

*Solution:*
*No, router R1 is not involved. C can check the subnet prefix of Host B’s IP address, and then learn that B is on the same IP subnet. Thus, C will not send the packet to the default router R1.*
*Ethernet frame from C to B:*

- *Source IP = C’s IP address*
- *Destination IP = B’s IP address*
- *Source MAC = C’s MAC address*
- *Destination MAC = B’s MAC address*

2. End-system C wants to send a packet to end-system F. C does not know F's MAC address. Will C send out an ARP request (before sending the actual packet) to learn F's MAC address? What are the source/destination MAC/IP addresses in the actual packet's Ethernet and IP headers?

*Solution:*

*No, C does not send an ARP request because C and F are not on the same IP subnet. C can figure this out by checking F's IP address. However, C will still send an ARP request but to learn R1's MAC address (and not that of F).*

*Ethernet frame from C to R1:*

- *Source IP = C's IP address*
- *Destination IP = F's IP address*
- *Source MAC = C's MAC address*
- *Destination MAC = The MAC address of R1's interface connecting to Subnet1-Subnet2-Merged.*

3. End-system A wants to send a packet to end-system B. Switch S1's forwarding table contains entries with B's and R1's MAC addresses only. Neither A nor B know each other's MAC address. Hence, A sends out an ARP request message before sending the actual packet.

    a. What will the switch S1 do when it receives A's ARP request?

*Solution:*

*Switch S1 will forward the frame containing the ARP request (MAC destination 0xFF:FF:FF:FF:FF, broadcast) on the port on the right side. At the same time S1 will update its forwarding table to include an entry for Host A: associate MAC A with the port on the left side.*

    b. Will router R1 also receive this ARP request? If so, will R1 forward the ARP request to Subnet 3?

*Solution:*

*Router R1 also receives this ARP request message, but R1 won't forward the message to Subnet 3.*

When end-system B receives this ARP request, it will send back an ARP response.

c. Before sending this ARP response, does B need to send its own ARP request to learn A's MAC address?

*Solution:*

*When B receives the ARP request, it won't send an ARP request asking for A's MAC address, as this address can be obtained from A's ARP.*

d. What will S1 do when it receives B's ARP response?

*Solution:*

*Switch S1 will not receive the ARP response from B, because the switch connecting A and B (left-most switch on the figure) already knows that it has to forward the packet to the link towards A and not towards S1 (remember that its forwarding table already includes an entry for A).*

## Exercise 4: Reliable Internet

If all links in the Internet each link guaranteed that an IP datagram sent over the link will be received at the other end of the link without error (meaning, all links would provide reliable data delivery), would TCP still be necessary? Why or why not?

*Solution:*

*Although each datagram will be received at the other end of the link without errors, it is not guaranteed that IP datagrams will arrive at the* ***final destination*** *in the proper order because of two main reasons:*

1. *With IP, datagrams in the same TCP connection can take different routes in the network, and therefore arrive out of order. TCP is still needed to provide the receiving end of the application the byte stream in the correct order.*
2. *IP can lose packets in one of the intermediate hops due to routing loops or equipment failures. TCP is needed to assure that all the packets have been received at the final destination.*

## Exercise 5: Step-by-step

You walk into a room, connect your laptop to an Ethernet outlet, and type in your web browser a URL of a web page located outside the local network. List all the packets that you expect your laptop to send or receive until you download the web page. Assume that:

- Your laptop is configured with the IP address of a local DNS server located in the local network.
- Your laptop is configured with the IP address of a default gateway (a router through which traffic from your laptop will exit the local IP subnet).
- Your laptop's ARP cache starts empty.

*Solution:*

1. *Since your laptop's ARP cache is initially empty, your laptop will use ARP protocol to get the MAC addresses of the first-hop router and the local DNS server.*
2. *Your laptop will query the local DNS server to find the IP address of the Web page you would like to download.*
3. *Once your laptop has the IP address of the Web page, it will establish a TCP connection and send out a HTTP request message via the first-hop router. The HTTP request message will be segmented and encapsulated into TCP packets, and then further encapsulated into IP packets, and finally encapsulated into Ethernet frames.*
4. *Your laptop sends the Ethernet frames to the first-hop router.*
5. *Once the router receives the frames, it checks its routing table, and then sends the packets to the interface corresponding to the next-hop in the routing table.*
6. *Your IP packets will be routed through the Internet until they reach the Web server.*
7. *The Web server will send back the Web page to your computer via HTTP response messages. Those messages will be encapsulated into TCP packets and then further into IP packets.*
8. *The IP packets follow IP routes and finally reach your first-hop router.*
9. *Finally, the router will forward those IP packets to your laptop.*