• Simplifying IPv4 routeing tables. • Practical exercises (IPv4 networks dimensioning and static routeing) • Project 1 – dimensioning and design of IPv4 networks.	

1. Simplifying IPv4 routeing tables

Routers' routeing tables can often be simplified, this means **reducing the number of lines, yet keeping the same behaviour**.

In routeing terms, the same behaviour expresses the same next-hops are used in the same cases as before. Moreover, a shorter routeing table improves the router performance.

The generic methodology for simplifying a routeing table is searching for a pair of lines that could be replaced by a single line, with have the same effect of the original two lines.

There's one first fundamental condition for such a simplification to be possible:

Both original lines need to have the same next-hop.

Once we notice two routeing table lines have the **same next-hop, only then**, we should check if they could be reduced to a single line.

1.1. Aggregation to default-route

If there's a default-route in the routeing table (0.0.0.0/0 line), it means any IP address not matching previous lines will match it, and thus the corresponding next-hop will be used. Typically this next-hop points toward the internet connection.

In most cases, if there's a routeing table line with a next-hop that is the same next-hop of the default-route, then the line can simply be removed, leaving only the default-route.

This is true if we assume that, in the absence of the removed line, the default-route is going be reached, and thus, the same next-hop will be used.

However, we must be aware that there are exceptions to this assumption, the following routeing table is one of those cases:

Destination	Next-hop
190.200.30.0/24	170.10.10.1
190.200.0.0/16	170.10.10.5
0.0.0.0/0	170.10.10.1

We would assume the first rule could be removed because the next-hop is the same as the default-route next-hop. However, in this case that's not true.

The issue is, the second line includes the first line addresses, therefore, the assumption that removing the first line will make the corresponding addresses match the default-route is, in this case false.

This routeing table can't be simplified.

Nevertheless, **aggregation to default-route** is pretty simple and it should always be the first strategy to be used. Only after getting rid of all removable lines through **aggregation to default-route**, then **addresses block aggregation** ought to be tried.

1.2. Addresses block aggregation

From IPv4 classless addressing study, we already know two same size addresses blocks **can, in some cases,** be aggregated into a single block with the double size. Formally, viewing addresses blocks as sets of addresses, the aggregation result block is the **union** between the two original blocks.

If the routeing table contains two lines with equal sizes addresses blocks (same prefix) and the same next-hop, there is the chance these two lines can be replaced by a single line with an address block that is the union of the first two.

Criteria's that must be checked for address block aggregation of two routeing table lines:

1st – Same next-hop
2nd – Same block size (same prefix/network mask)
3rd – The two original blocks can be aggregated into a single block

Once the first two rules are verified, we must test the third rule. The test is rather simple:

Two blocks can be aggregated if, by reducing one bit to the prefix length on both blocks, we end up with the same resulting block.

By reducing one bit to the prefix, one bit is transferred from the network area to the node area of the address, thus depending on the transferred bit being zero or one, the resulting network address remains the same or changes.

Of course that, for the resulting network address to be the same, **the two original networks addresses have to be very similar**, they can only differ on the value of one bit around the prefix position.

Example: simplify the following routeing table.

Destination	*Next-hop*
195.20.80.0/20	178.10.10.1
195.20.64.0/20	178.10.10.1
195.30.64.0/20	178.10.10.1
195.20.96.0/19	178.10.10.1
0.0.0.0/0	178.10.10.80

We can see no aggregation to default-route is possible, this is because no line has the same next-hop as the default-route (178.10.10.80).

Though, the remaining lines all share the same next-hop (178.10.10.1), so we can study aggregations between them. Aggregation can be possible between same mask networks only, so we have three candidates with 20 bits prefix length.

Nevertheless, the third candidate (195.30.64.0/20) can be immediately excluded. Because the value of the second octet is different and the prefix-length is on the middle of the third octet. There is no way changing some bits on the third octet will change the second octet value.

For now, we are left with **195.20.80.0/20** and **195.20.64.0/20**, the first two criteria's are met: same next-hop and same prefix, also addresses are similar and differ only on the octet where the prefix is located.

Let's test one bit prefix reduction to a 19 bits network mask on both networks:

195.20.80.0/20 = 195.20.(01010000)$_2$.0/20

By reducing one bit, the 20th-bit having value **one** will no longer be part of the network address, thus the address becomes **195.20.64.0/19**

195.20.64.0/20 = 195.20.(01000000)$_2$.0/20

By reducing one bit, the 20th-bit having value **zero** will no longer be part of the network address, thus the address remains the same: **195.20.64.0/19**

We can, therefore, conclude: **195.20.64.0/19 is the union of 195.20.80.0/20 and 195.20.64.0/20**

For now the simplified table becomes:

Destination	*Next-hop*
195.20.64.0/19	**178.10.10.1**
195.30.0.0/20	178.10.10.1
195.20.96.0/19	178.10.10.1
0.0.0.0/0	178.10.10.80

We can now restart the procedure because, again, two lines meet the requirements for aggregation: 195.20.64.0/19 and 195.20.96.0/19

(Same next-hop, same prefix, and similar addresses differ only on the octet where the prefix is located)

Let's test one bit prefix reduction to 18 bits network mask on both networks:

195.20.64.0/19 – 195.20.(01000000)$_2$.0/19

By reducing one bit, the 19th-bit having value **zero** will no longer be part of the network address, thus the address remains the same: **195.20.64.0/18**

195.20.96.0/20 – 195.20.(01100000)$_2$.0/19

By reducing one bit, the 19th-bit having value **one** will no longer be part of the network address, thus the address becomes **195.20.64.0/18**

We can, therefore, conclude: **195.20.64.0/18 is the union of 195.20.64.0/19 and 195.20.96.0/19**

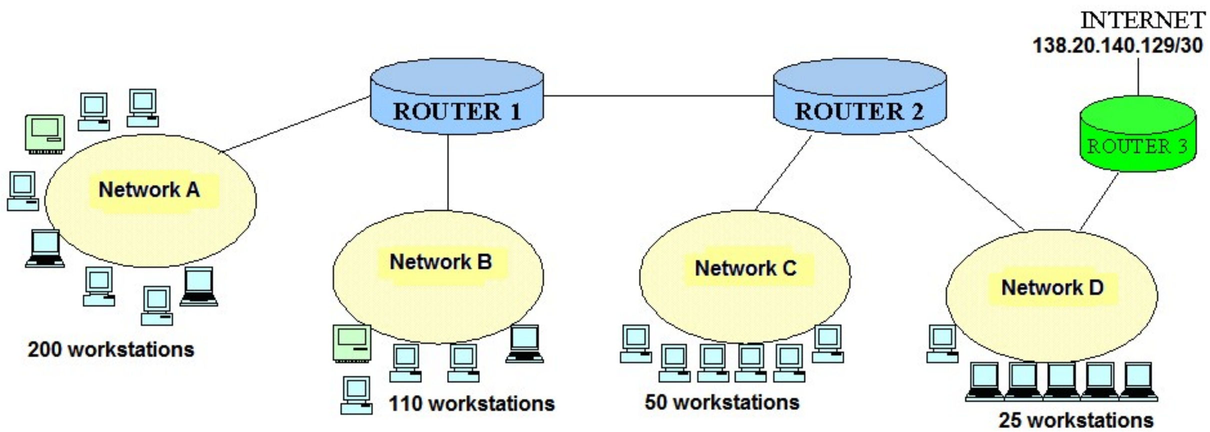
The simplified table becomes:

Destination	*Next-hop*
195.20.64.0/18	178.10.10.1
195.30.0.0/20	178.10.10.1
0.0.0.0/0	178.10.10.80

No further simplifications are possible.

2. Practical exercises (IPv4 networks dimensioning and static routeing)

2.1. The following diagram represents some IPv4 networks interconnected by routers



The image shows the maximum number of workstations to be supported in each network.

a) Use the 194.56.224.0/23 addresses block to assign an address to each network.

b) Define routers IPv4 addresses in each network.

c) Define each router routeing table.

d) Simplify to the extent possible each routeing table defined in c).

Warnings:

- Be aware that some networks may exist, and yet not explicitly identified. On the present case, there's a network connecting ROUTER 1 to ROUTER 2.

- Regarding the number of nodes each network must support. Routers shouldn't be forgotten, in this exercise, provided date refers the number of workstation and not the number of nodes. For instance Network D must support 27 valid nodes: 25 workstations, and in addition, two connected routers.

2.2. Use the 170.5.96.0/20 addresses block to complete the following table

	Number of IPv4 valid nodes to support	Network address	Prefix (network mask bits)	Network broadcast address	First valid node address	Last valid node address
Network 1	100					
Network 2	50					
Network 3	2000					
Network 4	500					
Network 5	200					
Network 6	5	170.5.98.64	29	170.5.98.71	170.5.98.65	170.5.98.70
Network 7	1000					

When compared with previous exercises, this problem is one step above in difficulty level. The increased difficulty results from the provided addresses block not being entirely available. Namely, Network 6 is using addresses within the given block, addresses assigned to other networks can't overlap these addresses.

Guidelines:

- The sequential addresses assignment method can, nevertheless, be used. However, when placing a network at an address it must be checked if overlaps already used addresses. In such a case we must jump to the next **same-size block** starting point, **often not immediately after the last already in use address**.

- Due to these jumps in sequential addresses assignment, unassigned blocks may be left behind. If ultimately the provided addresses block is exhausted, recalling these blocks is necessary.

3. Project 1 – IPv4 networks dimensioning and configuration

The layer two infrastructure, made of interconnected switches, has now a set of flexible VLANs that can be extended anywhere. Over each VLAN, an IPv4 network is supposed to be running and supporting a requested maximum number of nodes.

- Use the available addresses block to assign IPv4 addressed to each IPv4 network, meeting the project requirements.

- Routers' role is forwarding layer three packets from one network to another, to do that they must be connected to more than one network (VLAN). For each router, define IPv4 addresses in each network that router is supposed to be connected to.

- Without accurate routeing tables, neither routers nor end-nodes will be able to reach other networks. As requested in this project, establish the routeing table for each router (static routeing).

- The Packet Tracer simulation has several workstations connected to different networks, they are supposed to receive their configuration information through DHCP. So, the DHCP service must be available in all networks holding workstations, including wireless networks. One solution is using the already deployed routers to provide de DHCP service, in fact, every network is connected to a router.

All this configuration data is to be included in sprint three submission, both in the report and the Packet Tracer simulation.