Communication Protocols
2021-2022

**Lab Assignment 3 – Routing introduction**

## Objectives and organisation

The objective of this lab assignment is to explore basic topics concerning static and dynamic routing. Although Cisco routers are used in the lab, the assignment will explore vendor-independent routing aspects as much as possible. Routing is one of the main functions of the network layer (layer 3 in ISO's OSI model), whose purpose is to determine the routes that should be followed by IP packets in their way from origin to destination. Thus, it is essential for the operation of any network or group of networks and, in general, to the operation of the Internet.

<u>The assignment can be prepared using the GNS3 router emulator before executing it in the lab</u>. There are guided exercises, for which the commands/actions to execute are presented and explained, and proposed exercises that should be done autonomously by the students.

The following topics are addressed in the lab assignment:

- Static routing
- Dynamic routing
- Types of routing protocols
- RIP

Throughout the execution of the lab assignment, commands output and configuration files should be kept for inspection by the teacher. Special attention should be given to their interpretation and explanation.

The current lab assignment may require cooperation between groups in order to setup the scenarios under study. More than the sheer configuration of individual routers, it is important to interpret, explain and understand the behaviour in the overall network scenario. This is a key element for evaluation.

The following aspects will be taken into account when evaluating the work:

- Preparation of the lab assignment – 10%
- Knowledge of the aspects under consideration – 30%
- Exercises execution – 50%
- Group autonomy – 10%

## 1. IP routing overview

Communication between hosts belonging to different sub-networks requires the use of routing devices named routers. Figure 1 illustrates a routing scenario.

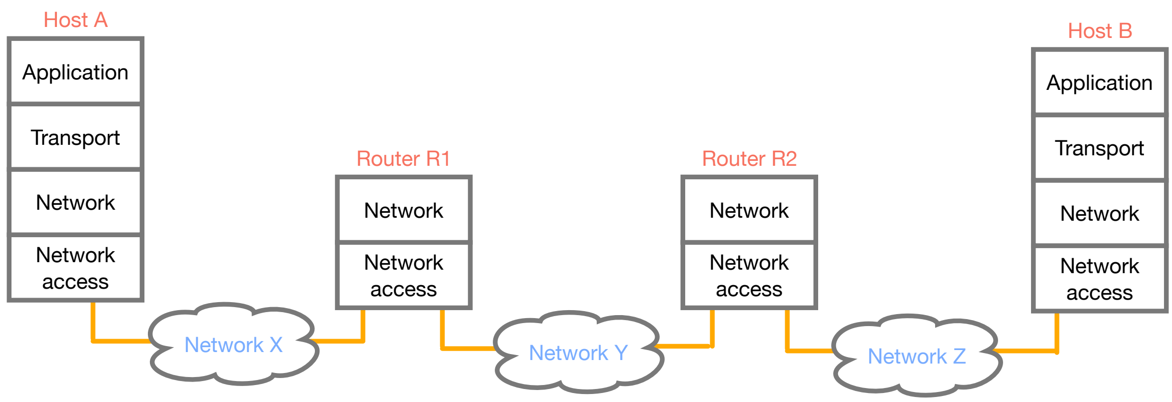


**Figure 1** – Routing scenario

Whenever a router receives a packet from a host in one network, destined to a host in another network, it checks its routing table in order to determine how to route the packet, that is, to determine the next hop for the packet. This is known as the basic routing mechanism. Routing tables keep information on the next hop to use in order to reach all known destinations.

The addition of entries to routing tables is made according to routing policies, which may use statically defined routes (i.e., routes that were calculated off-line and manually inserted in the routing table) or, on the other hand, dynamic routes calculated on the basis of routing information exchanged between routers. Thus, routing policies determined the origin and type of information to use in route calculation. The calculated routes will then be added to the routing table. The relation between the various routing components is illustrated in Figure 2.

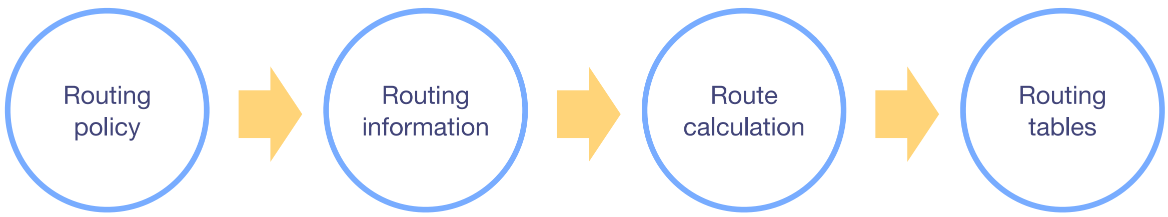


**Figure 2** – Relation between routing components

## 2. Static routing

In this section, we will explore static routing, using the scenario presented in Figure 3, which comprises three routers, four networks, and two hosts. The setting up of the scenario requires cooperation between groups, according to the teacher's instructions. The various groups should make sure that no conflicting configurations are in place.

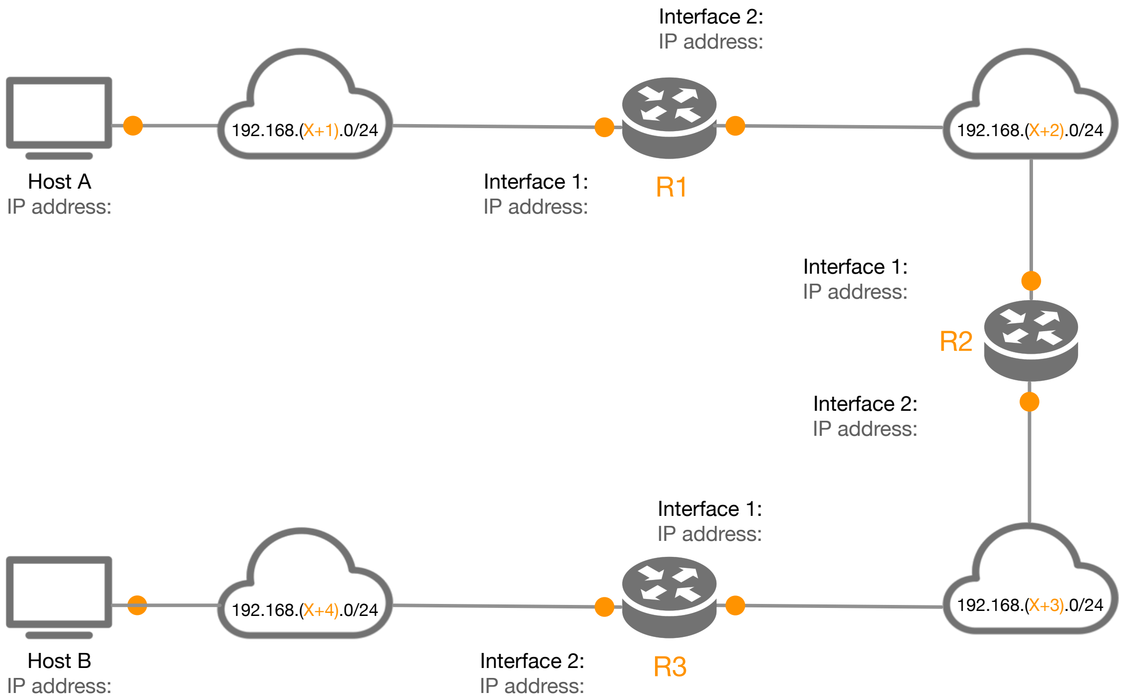


**Figure 3** – Routing scenario

## 2.1 Connections and addressing plan

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**Exercise 1** – In the last page of the current document you can find a reproduction of the scenario presented in Figure 3. Use this page to define the connections and addressing plan. Use the private address spaces identified in the figure. Ask the teacher the value to use for X.

This plan should comprise:

- The identification of the specific interfaces of each router
- The IP address of each router interface
- The IP addresses of hostas A and B

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## 2.2 Setting up of the basic scenario

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**Exercise 2** –Set up the scenario presented in Figure 3, establishing the connections and defining the addresses of the various interfaces according to the plan defined in Exercise 1. To do so, use the IOS commands that you have explored in Lab Assignment 1, namely the 'enable', 'config t' and 'interface' commands. At this stage do not configure any route.

After configuring the various router and host interfaces, check the connectivity from Host A and progressing one step at a time through the topology (i.e., first try to reach R1's interface 1, then R1's interface 2, then R2's interface 1, and so on). To do so, use the ping command.

Can you reach Host B from Host A? What is the most distant interface that you are able to reach? Why? Perform a similar experiment starting with Host B.

Check the routing table at each of the routers, by using the following command:

```
R1#show ip route
```

This command generates a listing similar to the one presented in Figure 4 (note that the output in this figure is merely illustrative and does not correspond to the scenario that you have implemented).

Interpret the results that you obtained when you execute the indicated command at each of the routers. Formulate some hypotheses that may explain why the ping command fails in some cases. Why does the ping command from host A to R2's interface 1 leads to a timeout while the same command targeting R2's interface 2 generates a 'host unreachable'?

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```
gta#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M – mobile
       B – BGP, D - EIGRP, EX - EIGRP external, O – OSPF
       IA - OSPF inter area, N1 - OSPF NSSA external type 1
       N2 - OSPF NSSA external type 2, E1 - OSPF external type 1
       E2 - OSPF external type 2, E – EGP, i - IS-IS
       L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter a
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route
Gateway of last resort is 192.168.094.1 to network 0.0.0.0
C    192.168.201.0/24 is directly connected, Ethernet0
R    192.168.200.0/24 [120/1] via 192.168.201.2, 00:00:17, Ethernet0
R    192.168.202.0/24 [120/1] via 192.168.204.2, 00:00:53, Serial0
_    ________________ _______     _____________   ________   _______
|            |            |              |             |          |
|            |            |              |             |          |
1            2            3              4             5          6
```

KEY:

1: Indicates the source of the routing information, according to the codes presented in the upper part of the table
2: Destination network IP address and respective number of address mask bits
3: Administrative distance and metric associated to the route; the administrative distance is a Cisco-specific parameter that reflects the confidence level on how the route was created; the metric depends on the source of the routing information
4: IP address of the router to which the packets destined to the address indicated in field 2 should be sent
5: Time since the last route update
6: Interface to be used in order to route the packets

**Figure 4** – Typical output of the 'show ip route' command and respective interpretation

## 2.3 Setting up static routes in the basic scenario

In order to overcome the observed connectivity problems, we can configure static routes at R1, R2 and R3 so that each router knows how to reach any of the involved networks, whether or not they are directly connected.

Static route configuration is done through the 'ip route' command, whose syntax is the following:

```
ip route [remote_network] [address_mask] [next_hop] [distance]
```

The distance field is the 'administrative distance' parameter that was mentioned earlier. The smaller its value the higher the confidence level on the route. This Cisco-specific parameter can be used to define backup routes, which will be set up with a higher administrative distance. The value of this parameter also depends on the protocol or mechanism used to create the route, according to Table 1.

**Table 1** – Administrative distance

| Source of routing information | Administrative distance |
|---|---|
| Directly connected | 0 |
| Static route | 1 |
| External BGP | 20 |
| Internal EIGRP | 90 |
| IGRP | 100 |
| OSPF | 110 |
| IS-IS | 115 |
| RIP | 120 |
| EGP | 140 |
| External EIGRP | 170 |
| Internal BGP | 200 |
| Unknown | 255 |

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**Exercise 3** – In the case of the R1 router, set up static routes to networks 192.168.(X+3).0 and 192.168.(X+4).0, in the following way:

```
R1#config t
R1(config)#ip route 192.168.(X+3).0 255.255.255.0 < R2_if1_IP_addr>
R1(config)#ip route 192.168.(X+4).0 255.255.255.0 < R2_if1_IP_addr>
```

Define static routes at R2 and R3 in a similar way.

After setting up the static routes check the routing tables of each of the routers, using the 'show ip route' command. Analyse and interpret these tables.

You can now check the connectivity between hosts A and B, using the 'ping' command.

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Instead of explicitly configuring routes for the 192.168.(X+3).0 and 192.168.(X+4).0 networks in the R1 router, another alternative would be to specify a route to use in order to reach any network besides the ones to which the router is directly connected. This can be done by setting up a default route, which will be used to route packets for any destination not explicitly in the routing table.

In the case of R1, the default route would be specified through the use of the 'ip route' command, in the following way:

```
R1#config t
R1(config)#ip route 0.0.0.0 0.0.0.0 <R2_if1_IP_addr>
```

**Exercise 4** – Replace the static routes configured in the previous exercise by default route in R1 and R3 (Note: to eliminate a route use 'no ip route <IP_address>'). Now view the routing tables and check the connectivity between the various networks.

## 3. Dynamic routing

Static routing is only viable in small networks, typically with only one connection to the Internet and/or subject to infrequent topology changes.

In large networks with complex topologies there may be redundant paths and/or frequent topology changes. The paths characteristics may change over time (e.g., cost, performance, availability). As it is not viable to constantly monitor these changes and manually introduce the needed modifications in routing tables, dynamic routing must be used.

Dynamic routing relies on routing protocols for exchanging topology and state information. This information is used by routers in order to determine (calculate) the routes that will be stored in routing tables.

As it would not be feasible for all the routers on the Internet to exchange routing information among them, the Internet is organised into autonomous systems. This organisation is presented in Figure 5.

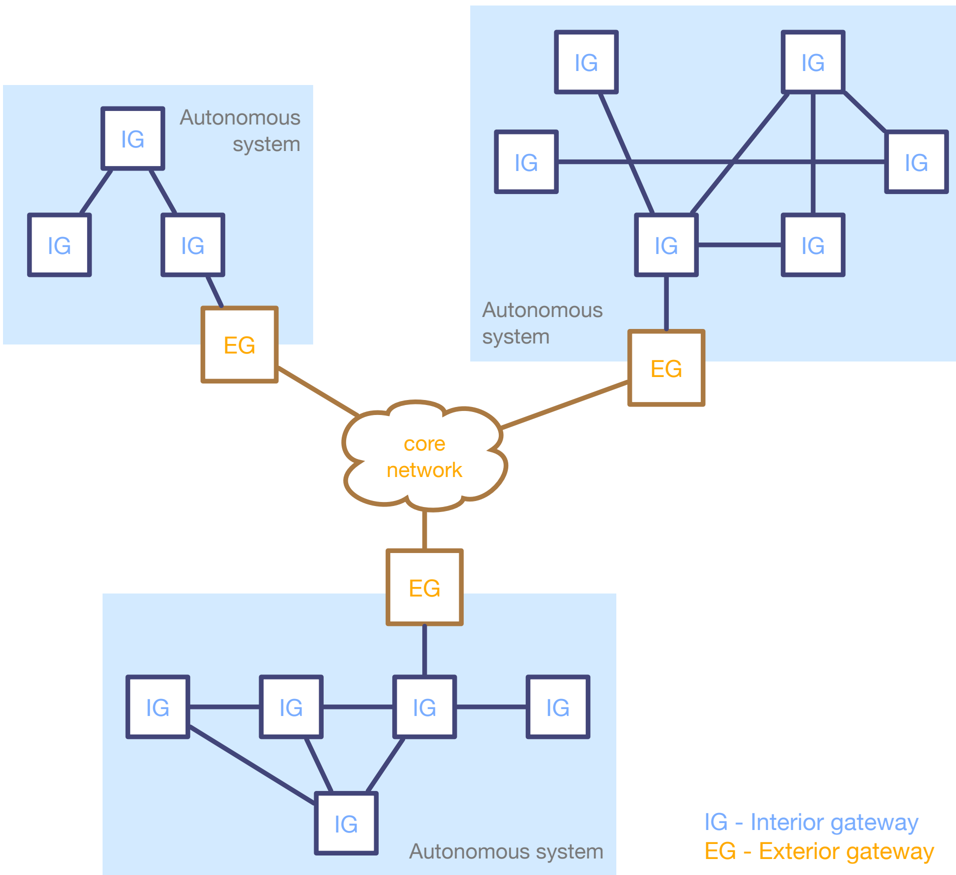


**Figure 5** – Internet routing architecture

Routers belonging to the same autonomous system exchange routing information using interior routing protocols. Information exchanged between routers belonging to different autonomous system is carried by exterior routing protocols.

In this lab assignment, we will only cover interior routing and, more specifically, the RIP-2 protocol (Routing Information Protocol version 2). This is an extremely simple protocol, available in most routers. Despite its simplicity and limitations – mostly inherent to distance-vector protocols – it is extensively used, mainly in simple topology networks.

## 3.1 Basic RIP characteristics

As already mentioned, RIP is a quite simple protocol, with some limitations. RIP packets (version 1 or 2) basically carry distance information (recall that RIP is a distance-vector protocol). Each information element carried by RIP has the following fields:

- Destination – this is the network address of one of networks reachable through this router
- Distance – the number of hops in order to reach the announced network from the advertising router
- Next router – IP address of the router that provides access to this destination. If the destination is directly connected this field is left blank.

RIP packets are periodically sent by a router to all its neighbours. The latter use the information contained in the packets to calculate/update the routes in their routing table.

RIP has several limitations. On one hand, it uses a simplistic metric: the number of hops. This does not provide other important information, such as bandwidth, error rate or cost. On the other hand, it is limited to networks with 15 hops or less, as the maximum value for the distance field is 16 and this value is used to signal unreachable destinations (NOTE: the distance field should not be confused with the administrative distance parameter mentioned in the previous section). In addition, RIP version 1 does not support address masks. RIP-2 already supports this feature, as well as a simple authentication mechanism.

## 3.2 Dynamic routing using RIP

Configuring RIP in Cisco routers is quite simple. To do so, the 'router rip' command is used.

In the scenario of Figure 3, the R1 router can easily be configured to announce the networks it connects to in the following way:

```
R1#config t
R1(config)#router rip
R1(config-router)#version 2
R1(config-router)#network 192.168.(X+1).0
R1(config-router)#network 192.168.(X+2).0
R1(config-router)#passive-interface interface1
R1(config-router)#^Z
R1#
```

The 'version 2' command instructs the router to use RIP-2 instead of RIP-1. By default, Cisco routers can receive and process packets from any of these two versions, although they only send RIP-1 packets if this command is not given.

The ‘network’ command is used to indicate the networks that should initially be announced by the router in the RIP packets that it sends to its neighbours. NOTE: as routes are dynamically added to the routing table, the router will also announce them.

The ‘passive-interface’ command is used to configure the router not to send RIP packets through the Ethernet0 interface. In fact, announcing routes through this interface is unnecessary, as there are no routers connected to the network attached to the interface. Thus, any RIP packets send through it would only be consuming bandwidth. As a result of the ‘passive interface’ command, the router will only send RIP advertisements through the Ethernet1 interface.

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**Exercise 5** – Based on the previous example, set up the routing scenario under consideration in this lab assignment, by configuring the RIP-2 protocol in all routers. Again, the setting up of the scenario requires cooperation between groups, as each group will be responsible for a limited number of routers. The various groups should make sure that no conflicting configurations are in place.

After setting up the scenario, do the following:

- Check the connectivity between the various networks, using the ‘ping’ and ‘traceroute’ commands;
- View the routing table in each of the routers, using the ‘show ip route’ command;
- Check each of the routes, using the ‘show ip route <destination_address>’ command;
- Analyse and interpret the results.

You can also use the ‘show ip protocols’ command in order to obtain detailed information on the routing protocols running in the router (in this case, this is only the RIP protocol).

You can observe the RIP operation in real-time, using the ‘debug ip rip’ command. This command can be cancelled issuing the ‘no debug ip rip’ command.

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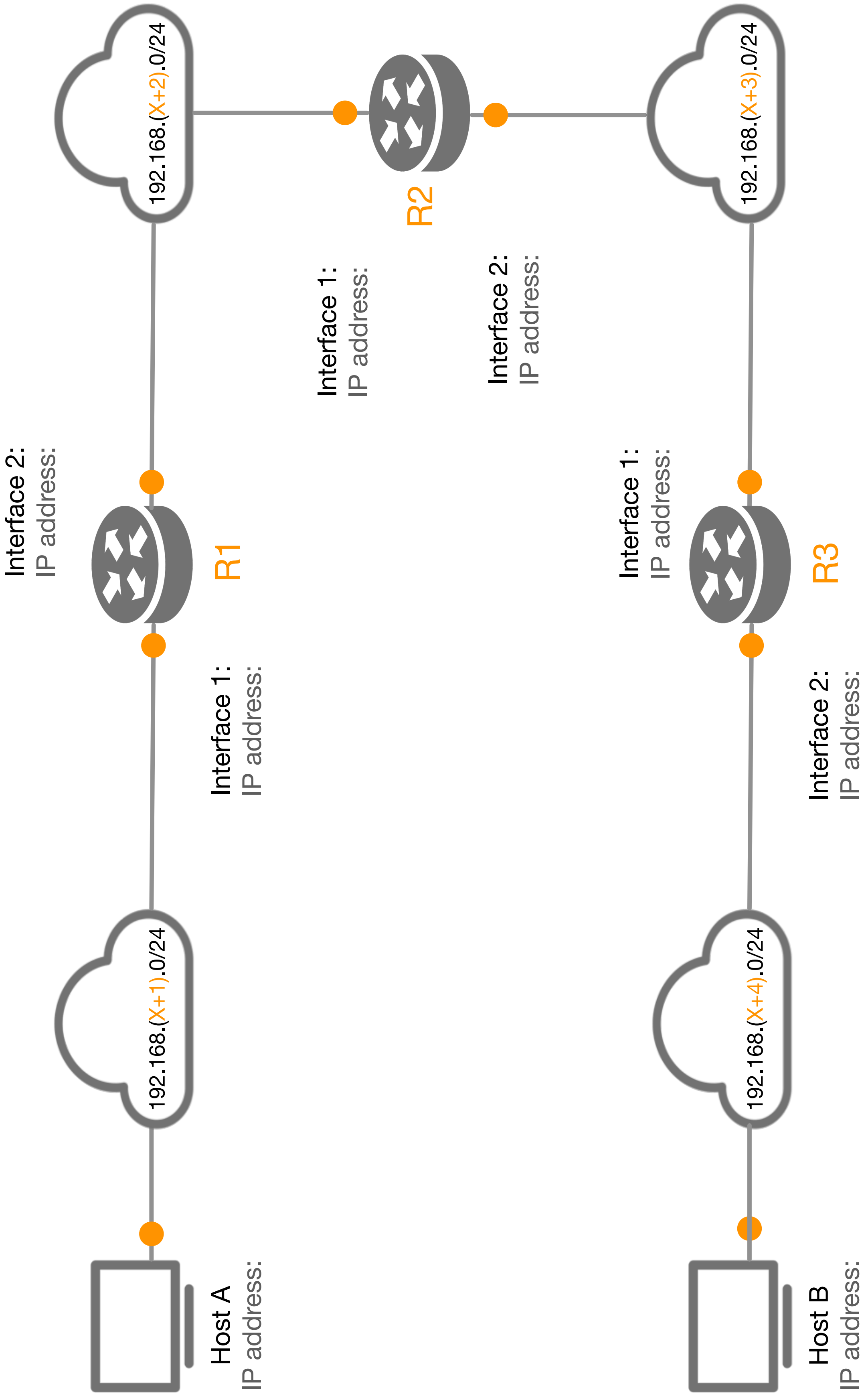
192.168.(X+2).0/24
192.168.(X+3).0/24
R2
Interface 1:
IP address:
Interface 2:
IP address:
Interface 2:
IP address:
R1
Interface 1:
IP address:
Interface 1:
IP address:
R3
Interface 2:
IP address:
192.168.(X+1).0/24
192.168.(X+4).0/24
Host A
IP address:
Host B
IP address: