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IP routing: static routes
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The current IP topology for the in-class workshop is as follows:

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                              {internet}
                                  |
                                  |
                                  | external IP
                               ------
                               | GW |
                               ------
                                  | 0.254
                                  |
                                  |
          +--------------------+-------------------------+
          |                    |                         |
          | 0.1                |0.2                       | 0.6
       ------               ------                     ------
       |rtr1|               |rtr2|        . . .        |rtr6| Cisco 7200's
       ------               ------                     ------
          | 1.254              | 2.254                    | 6.254
          |                    |                          |
          | 10.10.1.0/24       | 10.10.2.0/24             | 10.10.6.0/24
      --------------        --------------            ------------------
     |   |   |    |        |   |   |   |              |    |    |    |
     |   |   |    |        |   |   |   |              |    |    |    |
    pc1 pc3 pc5 pc7       pc2 pc4 pc6 pc8            pc18 pc20 pc22 pc24

    1.1 1.3 1.5 1.7       2.2 2.4 2.6 2.8            6.18 6.20 6.22 6.24
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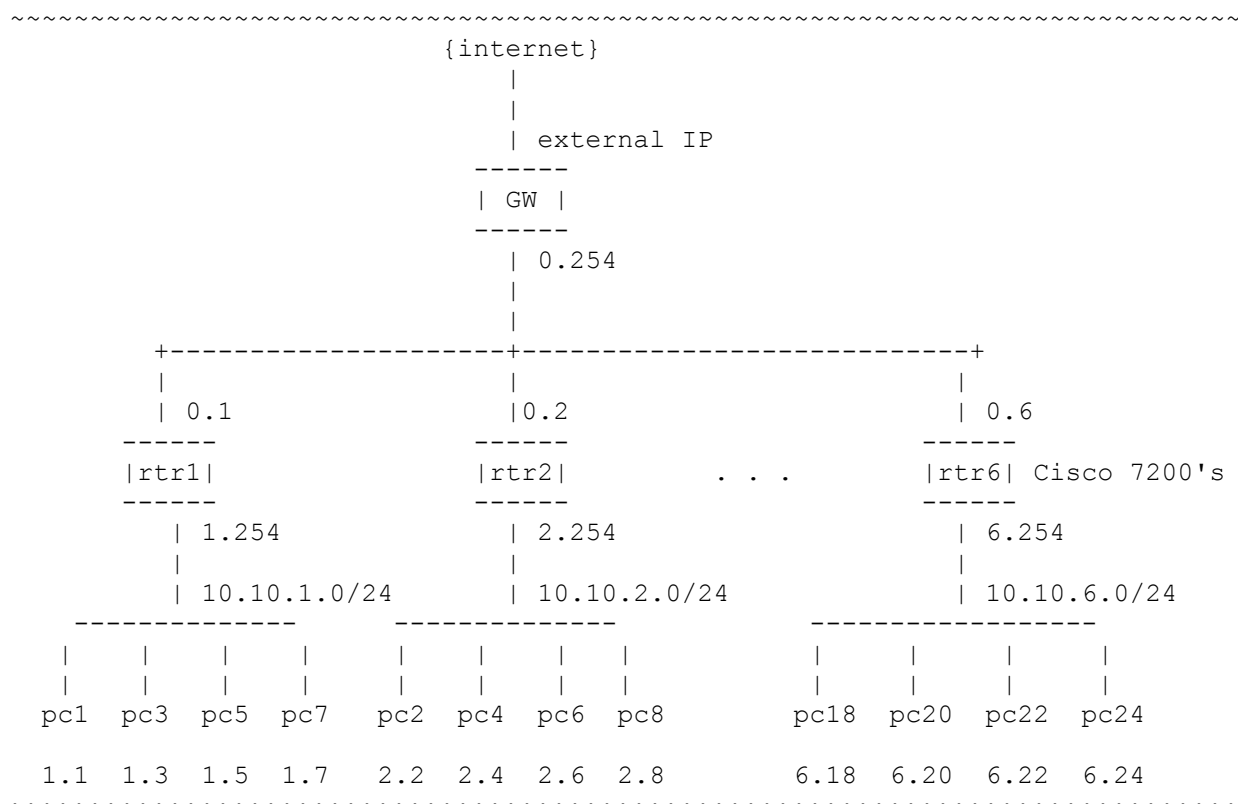
Part I: Static routes, default routes, and longest prefix

As you may have noticed earlier, from your PC, it is possible to ping other
PCs in the room. For example, from PC3, you can ping PC6, and vice-versa.

Question:

- What path do the packets take ? Do the packets follow the shortest path ?

    pc3 ----> [rtr1] ----> [rtr2] ----> pc6

... Or do they follow another route ? How can you find out ?

We're going to use the traceroute command.

* Connectivity test

Make sure can ping other PCs in the other groups (test a few)

Use the traceroute command to "see" the path from your PC to the other one.
For instance, if you want to see the path to pc6 (it must be a PC in another
group), you would run:

  $ traceroute -n pc6

Note: we use '-n' so we get IP addresses, and not DNS names when
showing the hosts in the path.

You should see something similar to the following:

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traceroute to pc6 (10.10.2.6), 30 hops max, 60 byte packets
 1   10.10.X.254   3.705 ms   5.819 ms   10.081 ms        <-- your group's router
 2   10.10.0.254   12.261 ms   14.341 ms   16.432 ms
 3   10.10.0.2   18.525 ms   20.760 ms   22.949 ms        <-- the router of group 2
 4   10.10.2.6   25.240 ms   27.354 ms   29.540 ms        <-- PC6
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First, you will notice that the first host in the path is the router of
your group nsrc.org) IP of 10.10.X.254.

Question:

- Now, look at the other hosts in the path - what do you observe ?

- Are the packets flowing directly from your group's router (10.10.X.254)
  to the router of the group of the PC you are pinging (10.10.0.2) ?
  Why not ?

* Static routes and default route

First, log in to the router for your group (using telnet or ssh) and run
the command:

rtrX> show ip route

You should get an output similar to the following:

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[...]

   Gateway of last resort is 10.10.0.254 to network 0.0.0.0

        10.0.0.0/24 is subnetted, 2 subnets
   C        10.10.0.0 is directly connected, FastEthernet0/0
   C        10.10.8.0 is directly connected, FastEthernet0/1
   S*   0.0.0.0/0 [1/0] via 10.10.0.254
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In the above output, it says our router is connected to two different
networks: 10.10.0.0/24 and 10.10.8.0/24 - that's what the 'C' means.

We are also told that there is a "Gateway of last resort", also called
a "default route" (0.0.0.0/0), which points to 10.10.0.254, also known as
"GW".

If your group router receives an IP packet that is NOT for either of these
two networks, for example 'pc6' on 10.10.2.0/24 , it will look to see if it
has explicit route (destination) information for the 10.10.2.6.

The router will perform a "longest match" search, looking for any

route information that matches the destination, 10.10.2.6. If it doesn't
find anything for the host (/32), it will look for a route matching
10.10.2.6/31, then /30, ... a route for 10.10.2.0/24, etc. It will
proceed like this from longest to shortest.

If it doesn't find anything matching, it will look for a "default gateway"
- marked with 'S' for 'static' (manually added).

We saw your group router has a default route: it is 10.10.0.254, and
therefore your group's router will send the packet to 10.10.0.254 (GW).

Question:

- What happens if a default route isn't found, and no other matching route
  information is found for the destination you want to forward packets to ?

- How does 10.10.0.254 know where to send the packet for 10.10.2.6 ?

Here is the list of routes on the backbone GW (10.10.0.254):

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Destination	Gateway	Genmask	Flags	MSS Window	irtt Iface
0.0.0.0	202.144.146.145	0.0.0.0	UG	0 0	0 eth0
10.10.0.0	0.0.0.0	255.255.255.0	U	0 0	0 eth1
10.10.1.0	10.10.0.1	255.255.255.0	UG	0 0	0 eth1
10.10.2.0	10.10.0.2	255.255.255.0	UG	0 0	0 eth1
10.10.3.0	10.10.0.3	255.255.255.0	UG	0 0	0 eth1
10.10.4.0	10.10.0.4	255.255.255.0	UG	0 0	0 eth1
10.10.5.0	10.10.0.5	255.255.255.0	UG	0 0	0 eth1
10.10.6.0	10.10.0.6	255.255.255.0	UG	0 0	0 eth1
10.10.7.0	10.10.0.7	255.255.255.0	UG	0 0	0 eth1
10.10.8.0	10.10.0.8	255.255.255.0	UG	0 0	0 eth1
10.10.9.0	10.10.0.9	255.255.255.0	UG	0 0	0 eth1
202.144.146.144	0.0.0.0	255.255.255.248	U	0 0	0 eth0

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You will notice that two of the networks are "directly connected" on GW:

- the backbone (10.10.0.0/24)
- our internet connection (202.144.146.144/29)

Also, GW's default gateway is 202.144.146.145 (the first in the list, 0.0.0.0)

And you can see that there are 9 routes statically configured on GW.
What they say, simply, is:

"To reach network 10.10.3.0 with a netmask of /24, send packets to 10.10.0.3"
"To reach network 10.10.4.0 with a netmask of /24, send packets to 10.10.0.4"

etc.

If you remember your group router's configuration, there were no static
routes telling your router how to reach the network for pc6 (10.10.2.0/24): it
had to send all packets to the GW, and it, in turn, sends all packets
for pc6 to ...

So, even if rtr1 and rtr2 and rtr3 etc. are all on the same network (the
backbone), then they can talk to each other directly, but each router
doesn't have any knowledge of the networks *behind* their neighbors!

So each router for every group will always forward packets for networks
they do not know, to their default gateway, 10.10.0.254. This is why you
always see 10.10.0.254 in the path when you run the 'traceroute' command.

Question:

- What do you think happens if we "crash" the GW (10.10.0.254), or remove
  the static routes for all the networks configured on it (10.10.1.0,
  10.10.2.0, ...) ?

  Let's try! :)

Note: Your PC has a default route too, which you can see with the command

% netstat -r -n

This is how it knows to send everything that is not on the same network, to
your group's router.

Question:

- Is it a good idea to have all your routers be dependent on a single
  backbone router (GW) so they can exchange traffic ?

- How can we avoid it ?

Part II: Configuring static routes

In this part, we're going be doing the following:

- on each group's router, you will be setting up static routes for all
  of the other groups' networks, so that traffic does not have to flow
  through the GW

1. Log in to your router, and you should see the usual prompt

rtrX>

Once logged in, enter enable mode ("enable"):

rtrX> enable
Password:
rtrX#

You will be adding static routes for all the networks, except your own.

For example, if your group number is 2, then you will want to add static
routes for networks 1, 3, 4, 5, 6, 7, 8.

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To do this, enter configure mode:

rtrX# config terminal
Enter configuration commands, one per line.  End with CNTL/Z.
rtrX(config)#

Now, for each of the networks above - EXCEPT your own - add static routes
like this:

rtrX(config)# ip route 10.10.1.0 255.255.255.0 10.10.0.1
rtrX(config)# ip route 10.10.3.0 255.255.255.0 10.10.0.3
...

And do this for all networks (except your own)

When finished, type 'end', and save the configuration with 'write memory'

rtrX(config)# end
rtrX#
rtrX# write memory

Verify that the routes you created are there, with 'show ip route'

rtrX#show ip route

... you should see, in the output, the routes you created, prefixed with 'S'.

For example:

S       10.10.3.0 [1/0] via 10.10.0.3

Once everyone has done this in the class, we will, again disable the
routes on our backbone router, GW (10.10.0.254), and you will once again
test that you can ping other PCs in other groups.

Question:
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- Does pinging other PCs in other groups work ?

- If not, what could be the reason ? Explain.

- Do you find this complicated ? What happens when one router is removed,
  or another one is added ? How many configurations will need to be changed ?
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