

# COMP416: Computer Networks

## Project 3 Report

### Network Layer Analysis and Simulations with Cisco Tracer

Çisem Özden, 69707

## Part 1 Network Layer Analysis

### Part 1.1: ICMP Analysis

1. *Find the minimum TTL less than which the traceroute messages do not reach your particular URL destination. Provide a screenshot satisfying your answer.*

To find the minimum TTL less than which the traceroute messages do not reach my URL destination, we can look for the last TTL value where I receive a response. It is seen from the screenshot below that the last TTL with a response is at the 17th hop. After that, starting from 18th hop, we see only asterisks, indicating that the traceroute messages did not reach the destination. Therefore, the minimum TTL less than which the traceroute messages do not reach my URL destination is 18. (P.S. The asterisks continue till the 64th hop, then the traceroute completes.)

```
cisemozden@Cisems-MacBook-Air ~ % traceroute kuweb.ku.edu.kw
traceroute to kuweb.ku.edu.kw (139.141.103.49), 64 hops max, 52 byte packets
[ 1 172.20.96.2 (172.20.96.2) 6.994 ms 3.964 ms 6.469 ms
 2 10.20.30.2 (10.20.30.2) 4.696 ms 4.108 ms 6.629 ms
 3 212.174.167.209 (212.174.167.209) 9.457 ms 7.724 ms 5.366 ms
 4 * 00-gayrettepe-sr14s-t2-1---00-buyukdere-t3-1.statik.turktelekom.com.tr (212.156.121.72) 6.186 ms 5.697 ms
 5 * * *
 6 * * *
 7 302-ams-col-2---00-ebgp-gayrettepe-k.statik.turktelekom.com.tr (212.156.102.136) 66.546 ms 65.566 ms 65.336 ms
 8 ae56.edge7.amsterdam1.level3.net (213.19.198.193) 77.046 ms 65.195 ms 78.302 ms
[ 9 * * *
 10 be2814.ccr42.fra03.atlas.cogentco.com (130.117.0.142) 72.639 ms 68.600 ms 70.514 ms
 11 be2846.rcr22.fra06.atlas.cogentco.com (154.54.37.30) 65.949 ms 67.040 ms 66.847 ms
 12 be3277.nr51.b037206-0.fra06.atlas.cogentco.com (154.25.2.166) 66.618 ms 66.463 ms 66.022 ms
 13 149.14.211.66 (149.14.211.66) 66.866 ms 65.501 ms 66.377 ms
 14 185.100.209.159 (185.100.209.159) 202.403 ms 200.700 ms 200.739 ms
 15 185.100.209.159 (185.100.209.159) 200.820 ms 200.417 ms 200.982 ms
 16 185.100.209.145 (185.100.209.145) 180.370 ms 179.787 ms 179.582 ms
 17 62.215.229.210 (62.215.229.210) 181.089 ms 181.366 ms 181.492 ms
 18 * * *
 19 * * *
 20 * * *
 21 * * *
 22 * * *
 23 * * *
 24 * * *
 25 * * *
 26 * * *
 27 * * *
 28 * * *
 29 * * *
 30 * * *
 31 * * *
 32 * * *
 33 * * *
 34 * * *
 35 * * *
 36 * * *
 37 * * *
 38 * * *
 39 * * *
 40 * * *
 41 * * *
 42 * * *
 43 * * *
 44 * * *
```

2. What is the default number of probes used by the traceroute? Run multiple traceroutes, increasing the number of probes progressively. Explain your observation regarding the resolution of the route to your destination ip address.

The default number of probes used by the traceroute is 3. To run the traceroute with increasing number of probes, the following command can be used: `traceroute -q 6 kuweb.ku.edu.kw` (any number can be used in the place of 6).

Result of using 4 probes: As seen from the below, in terms of resolution, there is not much difference compared to the default one (3 probes).

```

64 * *
cisemozden@Cisems-MacBook-Air ~ % traceroute -q 4 www.kuweb.ku.edu.kw
traceroute: unknown host www.kuweb.ku.edu.kw
cisemozden@Cisems-MacBook-Air ~ % traceroute -q 4 kuweb.ku.edu.kw
traceroute to kuweb.ku.edu.kw (139.141.103.49), 64 hops max, 52 byte packets
 1  172.20.96.2 (172.20.96.2)  6.797 ms  3.028 ms  2.968 ms  3.015 ms
 2  10.20.30.2 (10.20.30.2)  4.440 ms  4.131 ms  3.967 ms  4.371 ms
 3  212.174.167.289 (212.174.167.209)  5.803 ms  5.823 ms  6.311 ms  6.137 ms
 4  00-gayrettepe-sr14s-t2-1---00-buyukdere-t3-1.statik.turktelekom.com.tr (212.156.121.72)  6.131 ms  5.561 ms  5.728 ms  5.417 ms
 5  * * *
 6  * * *
 7  302-ams-col-2---00-ebgp-gayrettepe-k.statik.turktelekom.com.tr (212.156.102.136)  66.646 ms  65.795 ms  65.273 ms  65.593 ms
 8  ae56.edge7.amsterdam1.level3.net (213.19.198.193)  65.521 ms  64.648 ms  69.582 ms  67.956 ms
 9  * * *
10  be2814.ccr42.fra03.atlas.cogentco.com (130.117.0.142)  69.493 ms  69.774 ms  68.346 ms  68.764 ms
11  be2846.rcr22.fra06.atlas.cogentco.com (154.54.37.30)  65.211 ms  65.859 ms  66.018 ms  66.509 ms
12  be3277.nr51.b037206-0.fra06.atlas.cogentco.com (154.25.2.166)  66.636 ms  70.395 ms  65.873 ms  66.962 ms
13  * * 149.14.211.66 (149.14.211.66)  69.394 ms  66.655 ms
14  185.100.209.159 (185.100.209.159)  201.778 ms  205.396 ms  201.231 ms  206.085 ms
15  185.100.209.159 (185.100.209.159)  201.920 ms  200.633 ms  200.422 ms  200.090 ms
16  * 185.100.209.145 (185.100.209.145)  181.950 ms  179.208 ms  180.382 ms
17  62.215.229.210 (62.215.229.210)  203.092 ms  180.284 ms  181.526 ms  180.624 ms
18  * * *
19  * * *
20  * * *
21  * * *
22  * * *
23  * * *
24  * * *
25  * * *
26  * * *
27  * * *
28  * * *

```

Result of using 5 probes: Looking at the result below, we can say that the resolution of the traceroute increased a bit. At hops 5 and 6, now, we are able to see some responses. Moreover, Except the 9th hop, there are no unstable conditions at all till the 18th hop compared to previous traceroutes.

```

>Last login: Sun Jan 7 22:52:54 on ttys001
| cisemozden@Cisems-MacBook-Air ~ % traceroute -q 5 kuweb.ku.edu.kw
traceroute to kuweb.ku.edu.kw (139.141.103.49), 64 hops max, 52 byte packets
 1  172.20.96.2 (172.20.96.2)  6.144 ms  3.698 ms  3.388 ms  2.814 ms  3.257 ms
 2  10.20.30.2 (10.20.30.2)  4.058 ms  4.469 ms  3.972 ms  4.005 ms  4.332 ms
 3  212.174.167.209 (212.174.167.209)  5.944 ms  5.457 ms  8.115 ms  5.412 ms  5.746 ms
 4  * 00-gayrettepe-sr14s-t2-1---00-buyukdere-t3-1.statik.turktelekom.com.tr (212.156.121.72)  5.791 ms  7.655 ms  *  8.571 ms  5.608 ms
 5  41-gebze-t2-1---34-acibadem-xrs-t2-1.statik.turktelekom.com.tr (81.212.220.238)  5.821 ms  5.406 ms  5.464 ms  5.783 ms  5.669 ms
 6  10-balya-sr12-t4-1---10-balikesir-sr12e-t3-3.statik.turktelekom.com.tr (81.212.209.102)  6.843 ms  29.016 ms  7.143 ms  6.356 ms  6.309 ms
 7  302-ams-col-2---00-ebgp-gayrettepe-k.statik.turktelekom.com.tr (212.156.102.136)  65.247 ms  65.788 ms  65.750 ms  65.673 ms  65.996 ms
 8  ae56.edge7.amsterdam1.level3.net (213.19.198.193)  65.825 ms  64.195 ms  82.040 ms  67.360 ms  65.863 ms
 9  * * * * *
10  be2814.ccr42.fra03.atlas.cogentco.com (130.117.0.142)  73.774 ms  69.977 ms  68.977 ms  69.036 ms  68.148 ms
11  be2846.rcr22.fra06.atlas.cogentco.com (154.54.37.30)  66.654 ms  65.866 ms  66.102 ms  67.649 ms  65.896 ms
12  be3277.nr51.b037206-0.fra06.atlas.cogentco.com (154.25.2.166)  67.188 ms  66.073 ms  65.916 ms  66.635 ms  66.857 ms
13  149.14.211.66 (149.14.211.66)  67.214 ms  67.767 ms  66.311 ms  67.121 ms  66.722 ms
14  185.100.209.159 (185.100.209.159)  282.324 ms  201.109 ms  211.520 ms  201.321 ms  202.902 ms
15  185.100.209.159 (185.100.209.159)  200.765 ms  200.350 ms  200.292 ms  201.394 ms  199.799 ms
16  185.100.209.145 (185.100.209.145)  179.795 ms  179.073 ms  178.820 ms  180.564 ms  179.289 ms
17  62.215.229.210 (62.215.229.210)  181.757 ms  180.809 ms  317.843 ms  180.998 ms  181.008 ms
18  * * * * *
19  * * * * *
20  * * * * *
21  * * * * *
22  * * * * *
23  * * * * *
24  * * * * *
25  * * * * *
26  * * * * *
27  * * * * *
28  * * * * *
29  * * * * *
30  * * * * *
31  * * * * *
32  * * * * *
33  * * * * *

```

Result of using 6 probes: With 6 probes, the responses seem to be less stable compared to previous traceroutes.

```

Last login: Sun Jan 7 23:18:50 on ttys001
| cisemozden@Cisems-MacBook-Air ~ % traceroute -q 6 kuweb.ku.edu.kw
traceroute to kuweb.ku.edu.kw (139.141.103.49), 64 hops max, 52 byte packets
 1  172.20.96.2 (172.20.96.2)  6.709 ms  2.525 ms  3.420 ms  2.955 ms  3.370 ms  4.190 ms
 2  10.20.30.2 (10.20.30.2)  3.964 ms  4.076 ms  4.279 ms  4.939 ms  4.364 ms  3.989 ms
 3  212.174.167.209 (212.174.167.209)  5.239 ms  7.291 ms  4.723 ms  *  5.669 ms  5.823 ms
 4  * 00-gayrettepe-sr14s-t2-1---00-buyukdere-t3-1.statik.turktelekom.com.tr (212.156.121.72)  7.935 ms  6.602 ms  5.446 ms  6.364 ms  5.678 ms
 5  * * * * *
 6  * * * * *
 7  * 302-ams-col-2---00-ebgp-gayrettepe-k.statik.turktelekom.com.tr (212.156.102.136)  66.835 ms  66.092 ms  67.576 ms  66.424 ms  65.549 ms
 8  * ae56.edge7.amsterdam1.level3.net (213.19.198.193)  65.217 ms  *  66.486 ms  66.296 ms  64.878 ms
 9  * * * * *
10  be2814.ccr42.fra03.atlas.cogentco.com (130.117.0.142)  69.854 ms  69.792 ms  70.056 ms  68.971 ms  69.850 ms  71.540 ms
11  be2846.rcr22.fra06.atlas.cogentco.com (154.54.37.30)  66.118 ms  65.692 ms  66.102 ms  66.264 ms  67.815 ms  86.624 ms
12  be3277.nr51.b037206-0.fra06.atlas.cogentco.com (154.25.2.166)  66.313 ms  68.284 ms  66.297 ms  65.437 ms  75.848 ms  67.185 ms
13  149.14.211.66 (149.14.211.66)  66.616 ms  73.189 ms  66.013 ms  65.659 ms  66.400 ms  65.871 ms
14  185.100.209.159 (185.100.209.159)  201.826 ms  201.770 ms  201.532 ms  201.949 ms  201.211 ms  201.150 ms
15  185.100.209.159 (185.100.209.159)  210.208 ms  201.839 ms  204.378 ms  201.268 ms  200.749 ms  314.601 ms
16  185.100.209.145 (185.100.209.145)  180.215 ms  180.375 ms  182.651 ms  181.561 ms  189.237 ms  179.578 ms
17  62.215.229.210 (62.215.229.210)  190.807 ms  181.029 ms  *  184.501 ms  181.532 ms  183.224 ms
18  * * * * *
19  * * * * *
20  * * * * *
21  * * * * *

```

Result of using 7 probes: Using 7 probes doesn't seem to increase the resolution as well. The responses are similar to what was observed in the previous traceroutes.

```

Last login: Sun Jan 7 23:28:03 on ttys002
| cisemozden@Cisems-MacBook-Air ~ % traceroute -q 7 www.kuweb.ku.edu.kw
traceroute: unknown host www.kuweb.ku.edu.kw
| cisemozden@Cisems-MacBook-Air ~ % traceroute -q 7 kuweb.ku.edu.kw
traceroute to kuweb.ku.edu.kw (139.141.103.49), 64 hops max, 52 byte packets
 1  172.20.96.2 (172.20.96.2)  7.512 ms  3.434 ms  3.053 ms  5.856 ms  3.546 ms  2.868 ms *
 2  10.20.30.2 (10.20.30.2)  6.841 ms  3.958 ms  4.125 ms  3.988 ms  4.095 ms  4.089 ms *
 3  212.174.167.209 (212.174.167.209)  8.841 ms  6.018 ms  7.156 ms  5.113 ms  6.002 ms  5.906 ms  6.192 ms
 4  * 00-gayrettepe-sr14s-t2-1---00-buyukdere-t3-1.statik.turktelekom.com.tr (212.156.121.72)  5.818 ms  6.263 ms  5.637 ms  6.200 ms  6.018 ms  5.425 ms  7.317 ms
 5  * * * * *
 6  * * * * *
 7  302-ams-col-2---00-ebgp-gayrettepe-k.statik.turktelekom.com.tr (212.156.102.136)  66.972 ms  65.481 ms  65.558 ms  66.012 ms  65.715 ms  69.243 ms  65.957 ms
 8  * ae56.edge7.amsterdam1.level3.net (213.19.198.193)  67.875 ms  64.143 ms  69.839 ms  77.183 ms  66.254 ms  66.426 ms  82.739 ms
 9  * * * * *
10  be2814.ccr42.fra03.atlas.cogentco.com (130.117.0.142)  72.679 ms  69.636 ms  69.698 ms  68.915 ms  121.159 ms  68.540 ms  68.791 ms
11  be2846.rcr22.fra06.atlas.cogentco.com (154.54.37.30)  66.183 ms  65.505 ms  65.912 ms  65.803 ms  65.391 ms  66.653 ms  68.879 ms
12  be3277.nr51.b037206-0.fra06.atlas.cogentco.com (154.25.2.166)  69.018 ms  66.039 ms  67.200 ms  65.817 ms  66.511 ms  65.729 ms  65.790 ms
13  149.14.211.66 (149.14.211.66)  70.416 ms  66.557 ms  66.075 ms  67.719 ms  67.392 ms  65.431 ms  66.827 ms
14  185.100.209.159 (185.100.209.159)  201.834 ms  201.493 ms  201.137 ms  201.492 ms  201.499 ms  201.119 ms  200.927 ms
15  185.100.209.159 (185.100.209.159)  200.669 ms  203.104 ms  200.226 ms  200.677 ms  200.610 ms  204.110 ms  200.769 ms
16  185.100.209.145 (185.100.209.145)  179.380 ms  187.351 ms  179.034 ms  179.946 ms  188.023 ms  178.917 ms  187.609 ms
17  62.215.229.210 (62.215.229.210)  186.647 ms  180.598 ms  180.543 ms  *  183.919 ms  181.256 ms  181.127 ms
18  * * * * *
19  * * * * *
20  * * * * *

```

Overall, I can say that the number of probes used in the traceroute may or may not change the resolution. It may provide more stable and reliable results as observed with 5 probes. Or, it may not affect it drastically as observed with other traceroutes.

3. *What is a Routing Blackhole? Provide a scenario where Routing Blackholes may be used beneficially. No screenshot is expected.*

A routing blackhole refers to a network route that goes nowhere. Matching packets are dropped (ignored) rather than forwarded, resulting in loss of data. Routing blackholes can be useful against DDoS attacks. When a routing blackhole is implemented, if a DDoS attack is happening, then all the malicious traffic can be routed to the blackhole rather than the targeted IP address. In this way, DDoS attacks can be avoided.

## **Part 1.2: Network Interface Analysis**

(P.S. Since the variations of *ipconfig* command is limited in Mac unlike Linux, I couldn't show the result for different objects in 2 of the commands. I am limited with en0 as interface\_name because others don't give an output.)

1. *Understand how to use the ip command and then execute three different variations (OBJECTs) of it while explaining their usefulness. Provide screenshots of each command executed. In each command, you are going to execute, use at least two OPTIONS you have not used before.*

*ipconfig getpacket interface\_name:* It prints the DHCP/BOOTP packet that the client accepted from the DHCP/BOOTP server. This command is useful to check what the server provided, and whether the values are sensible. An example usage can be seen below.

```
cisemozden@Cisems-MacBook-Air ~ % ipconfig getpacket en0
op = BOOTREPLY
htype = 1
flags = 0
hlen = 6
hops = 0
xid = 0xd9bbcf7f
secs = 0
ciaddr = 0.0.0.0
yiaddr = 172.20.104.143
siaddr = 0.0.0.0
giaddr = 0.0.0.0
chaddr = c4:35:d9:7f:dd:47
sname =
file =
options:
Options count is 10
dhcp_message_type (uint8): ACK 0x5
[renewal_t1_time_value (uint32): 0xe10
 rebinding_t2_time_value (uint32): 0x189c
lease_time (uint32): 0x1c20
server_identifier (ip): 172.20.21.23
subnet_mask (ip): 255.255.240.0
router (ip_mult): {172.20.96.1}
domain_name_server (ip_mult): {172.20.18.196, 172.20.18.2, 88.255.96.196}
domain_name (string): ku.edu.tr
end (none):
cisemozden@Cisems-MacBook-Air ~ %
```

*ipconfig getoptoption interface\_name (option-name | option-code)*: It prints the BOOTP/DHCP option with the given name or option code integer value. If an option has multiple values, only the first value is printed. Example usages can be seen below.

```
[cisemozden@Cisems-MacBook-Air ~ % ipconfig getoptoption en0 router
172.20.96.1
cisemozden@Cisems-MacBook-Air ~ %
```

```
Last login: Tue Jan  9 11:06:49 on ttys001
[cisemozden@Cisems-MacBook-Air ~ % ipconfig getoptoption en0 domain_name_server
172.20.18.196
cisemozden@Cisems-MacBook-Air ~ %
```

*ipconfig getsummary interface\_name*: It prints the summary of the current IPConfiguration state over the specific interface. An example usage can be seen below.

```
cisemozden@Cisems-MacBook-Air ~ % ipconfig getsummary en0
<dictionary> {
    BSSID : d8:84:66:0a:ed:b1
    IPv4 : <array> {
        0 : <dictionary> {
            Addresses : <array> {
                0 : 172.20.104.143
            }
            ChildServiceID : LINKLOCAL-en0
            ConfigMethod : DHCP
            DHCP : <dictionary> {
                LeaseExpirationTime : 01/08/2024 22:05:29
                LeaseStartTime : 01/08/2024 20:05:29
                Packet : op = BOOTREPLY
            }
            htype = 1
            flags = 0
            hlen = 6
            hops = 0
            xid = 0xd9bbcf7f
            secs = 0
            ciaddr = 0.0.0.0
            yiaddr = 172.20.104.143
            siaddr = 0.0.0.0
            giaddr = 0.0.0.0
            chaddr = c4:35:d9:7f:dd:47
            sname =
            file =
            options:
                Options count is 10
                dhcp_message_type (uint8): ACK 0x5
                renewal_t1_time_value (uint32): 0xe10
                rebinding_t2_time_value (uint32): 0x189c
                lease_time (uint32): 0x1c20
                server_identifier (ip): 172.20.21.23
                subnet_mask (ip): 255.255.240.0
                router (ip_mult): {172.20.96.1}
                domain_name_server (ip_mult): {172.20.18.196, 172.20.18.2, 88.255.96.196}
                domain_name (string): ku.edu.tr
            end (none):
                State : BOUND
            }
            IsPublished : TRUE
            Router : 172.20.96.1
            RouterARPVerified : TRUE
            ServiceID : A6287D00-137E-43FC-9A34-F23ABD2AAA85
            SubnetMasks : <array> {
                0 : 255.255.240.0
            }
        }
        1 : <dictionary> {
            ConfigMethod : LinkLocal
            IsPublished : TRUE
            ParentServiceID : A6287D00-137E-43FC-9A34-F23ABD2AAA85
            ServiceID : LINKLOCAL-en0
        }
    }
    IPv6 : <array> {
        0 : <dictionary> {
            ConfigMethod : Automatic
            DHCPv6 : <dictionary> {
                Mode : None
                State : Inactive
            }
            IsPublished : FALSE
            LastFailureStatus : network changed
            RTADV : <dictionary> {
                State : Solicit
            }
            ServiceID : A6287D00-137E-43FC-9A34-F23ABD2AAA85
        }
        1 : <dictionary> {
            InterfaceType : WiFi
            LinkStatusActive : TRUE
            NetworkID : 5CC4C6D7-98AE-47A2-AE54-F0C9285A9C95
            SSID : KU
            Security : WPA2
        }
    }
}
cisemozden@Cisems-MacBook-Air ~ %
```

## Part 2: Understanding IP and Subnetting

1. Using the command line on your computer, what is the IP address of the network you are currently connected to (choose the one that has a default gateway)? Attach a screenshot of the used command showing the IP address as well as the whole interface information.

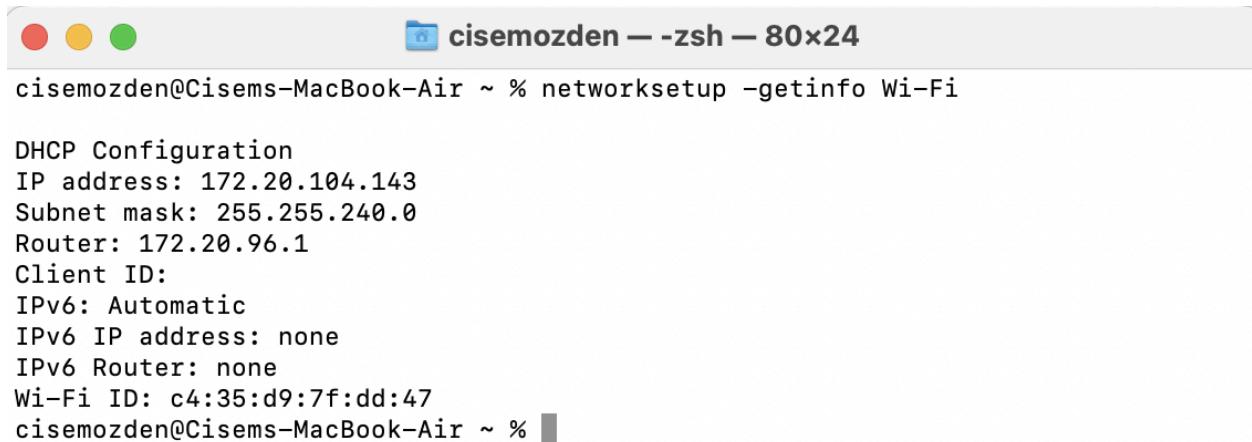
The IP address of the network I am connected to is 172.20.104.143 as shown below. To get that information I used the `ipconfig getifaddr en0` command.



```
[cisemozden@Cisems-MacBook-Air ~ % ipconfig getifaddr en0
172.20.104.143
cisemozden@Cisems-MacBook-Air ~ % ]
```

2. What is the subnet mask of the network?

To obtain the subnet mask information belonging to the ip address of the network I am connected to, `networksetup -getinfo Wi-Fi` command can be used as shown below. According to the output, the subnet mask of the network is 255.255.240.0.



```
cisemozden@Cisems-MacBook-Air ~ % networksetup -getinfo Wi-Fi

DHCP Configuration
IP address: 172.20.104.143
Subnet mask: 255.255.240.0
Router: 172.20.96.1
Client ID:
IPv6: Automatic
IPv6 IP address: none
IPv6 Router: none
Wi-Fi ID: c4:35:d9:7f:dd:47
cisemozden@Cisems-MacBook-Air ~ % ]
```

3. What is the network (subnet) address that you are connected to?

To calculate the network address, the following steps are pursued: first write the binary representation of the subnet mask, then write the binary representation of the IP address. Finally, performing a bitwise AND operation between them gives us the network address. The binary representation of the subnet mask is the following: 1111111.1111111.11110000.00000000. The binary representation of the IP address is 10101100.00010100.01101000.10001111. Performing AND operation between them gives us the network address:

10101100.00010100.01100000.00000000 which is equivalent to 172.20.96.0.

#### 4. What is the broadcast address?

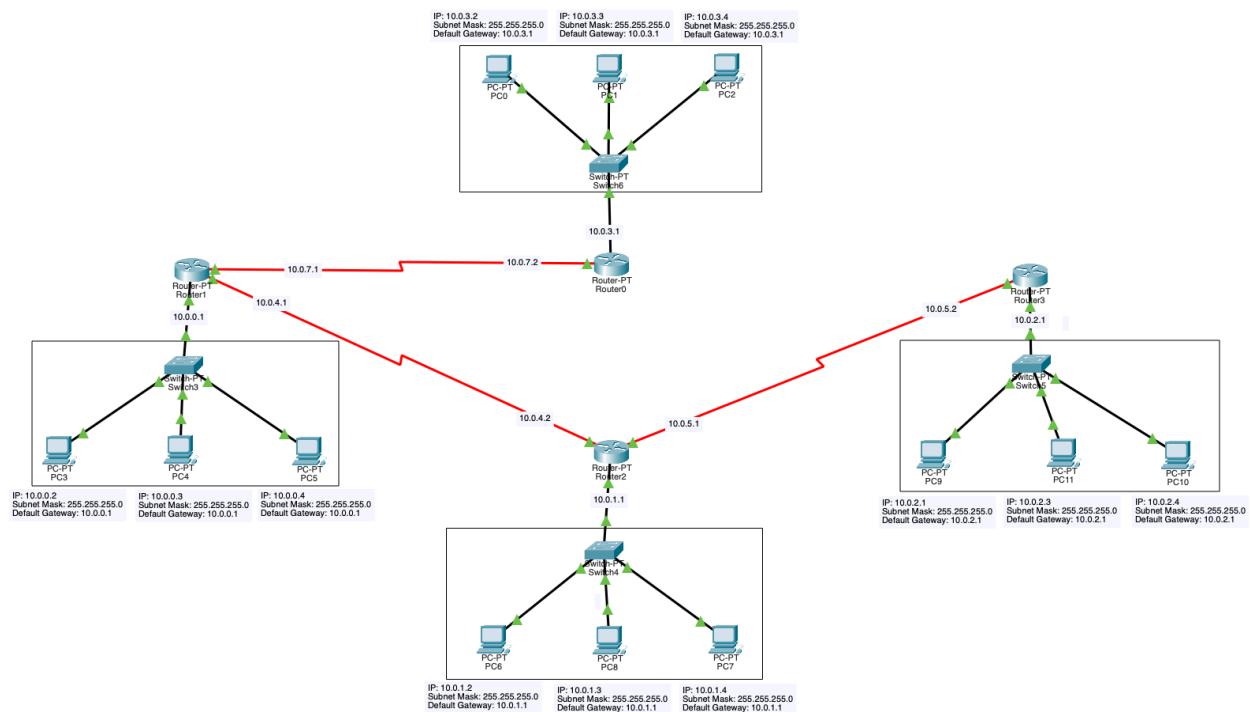
To calculate the broadcast address the following steps are pursued: first write the binary representation of the subnet mask, then calculate the wildcard mask by taking the inverse of the subnet mask. Finally, perform the bitwise OR operation between the wildcard mask and the binary representation of the network address. The binary representation of the subnet mask is the following: 11111111.11111111.11110000.00000000. Then, the Wildcard mask is 00000000.00000000.00001111.11111111. The binary representation of the network address (172.20.96.0) is 10101100.00010100.01100000.00000000. Performing OR operation between them gives us the broadcast address: 10101100.00010100.01101111.11111111 which is equivalent to 172.20.111.255.

#### 5. Calculate and write down the maximum number of devices that can connect to the identified network. Provide explanations.

The binary representation of the subnet mask 255.255.240.0 is the following: 11111111.11111111.11100000.00000000. The number of 1s in the representation is 20, and the number of 0s is 12. Total number of hosts can be calculated as follows:  $2^{12}=4096$ . However, the number of usable hosts is  $4096-2=4094$  since the first possible address of the subnet is the network address and the last possible address is the broadcast address.

## Part 3: Simulations with Cisco Packet Tracer

#### 1. Attach a screenshot of the designed network with a label beside each port indicating its IP address, subnet mask, and gateway (if exists).



I didn't write the subnet mask for all the ports so as not to make it too crowded. But it is the same for the serial and fast ethernet ports, as well. Subnet mask is 255.255.255.0 for all the ports.

*2. Which IP address you have selected from Options I, II, and III, and why?*

I chose Option 2. Although we are allowed to place 3 devices per subnet in the topology, the subnets should be configured so that they can accommodate 30, 20, 15, and 25 devices. Moreover, the topology should be scalable enough to add more branches and more devices in the future. When the calculations are made for all the options, the maximum number of hosts for Option 1, Option 2, and Option 3 are found as  $256(2^8)$ ,  $65536(2^{16})$ , and  $4096(2^{12})$ , respectively. Considering the requirements, it is best to choose Option 2 since it can accommodate the most IP addresses.

*3. How many branches does your network architecture support? What is the maximum number of devices that could be connected in each branch? Provide explanations. Include the calculations in your report (images of handwritten calculations are acceptable).*

I chose the IP address as 10.0.0.0/16. With this IP, my network can accommodate a maximum of 65536 IP addresses - 65534 of them are usable. Furthermore, I chose the mask for each subnet as 255.255.255.0. Thanks to this configuration, my network can accommodate 256 subnets, each of which can support  $254(2^8-2)$  IP addresses. However, in my network topology, I used 3 serial connections to connect 4 branches. For these connections, distinct subnets are used as well. Therefore, for my network to support n branches, n-1 serial connections would be needed, meaning  $2n-1$  subnets would be used in total. Since this network architecture allows a maximum of 256 subnets, the maximum number of branches my network architecture can support is 128, each of which can support 254 devices at most. The supporting calculations, and the table can be also seen below.

Chosen IP address: 10.0.0.0/16

Maximum number of hosts  $\Rightarrow 32-16=16$ .  $2^{16}-2 = 65534$ .

Chosen subnet mask: 255.255.255.0

Information on subnets:

Subnet Number	Host IP Range	Usable Host IP Range	# usable hosts
1	10.0.0.0 - 10.0.0.255	10.0.0.1 - 10.0.0.254	254
2	10.0.1.0 - 10.0.1.255	10.0.1.1 - 10.0.1.254	254
3	10.0.2.0 - 10.0.2.255	10.0.2.1 - 10.0.2.254	254
:	:	:	:
256	10.0.255.0 - 10.0.255.255	10.0.255.1 - 10.0.255.254	254

$n$  branches +  $(n-1)$  subnets for connecting routers  $\Rightarrow 2n-1$ .

$$2n-1 \leq 256.$$

$$2n \leq 257.$$

$$n \leq 128 \rightarrow n = 128 \text{ at most.}$$

4. While configuring your network, you probably configured the routers using the Graphical User Interface. However, in real life, a command line is probably used. Make a table having two columns. The first column is the process, and the second one is the command. You can notice the commands written automatically when selecting an option in the GUI.

Router 1:

Process	Command
Selecting and configuring FastEthernet0/0 with ip address 10.0.0.1 and subnet mask 255.255.255.0	<i>interface FastEthernet0/0 ip address 10.0.0.1 255.255.255.0</i>
Selecting and configuring Serial2/0	<i>interface Serial2/0 ip address 10.0.7.1 255.255.255.0</i>
Selecting and configuring Serial3/0	<i>interface Serial3/0 ip address 10.0.4.1 255.255.255.0</i>
Static routing for network 10.0.1.0	<i>ip route 10.0.1.0 255.255.255.0 10.0.4.2</i>
Static routing for network 10.0.2.0	<i>ip route 10.0.2.0 255.255.255.0 10.0.4.2</i>
Static routing for network 10.0.5.0	<i>ip route 10.0.5.0 255.255.255.0 10.0.4.2</i>
Static routing for network 10.0.3.0	<i>ip route 10.0.3.0 255.255.255.0 10.0.7.2</i>

Router 2:

<b>Process</b>	<b>Command</b>
Selecting and configuring FastEthernet0/0 with ip address 10.0.1.1 and subnet mask 255.255.255.0	<i>interface FastEthernet0/0 ip address 10.0.1.1 255.255.255.0</i>
Selecting and configuring Serial2/0	<i>interface Serial2/0 ip address 10.0.4.2 255.255.255.0</i>
Selecting and configuring Serial3/0	<i>interface Serial3/0 ip address 10.0.5.1 255.255.255.0</i>
Static routing for network 10.0.0.0	<i>ip route 10.0.0.0 255.255.255.0 10.0.4.1</i>
Static routing for network 10.0.2.0	<i>ip route 10.0.2.0 255.255.255.0 10.0.5.2</i>
Static routing for network 10.0.3.0	<i>ip route 10.0.3.0 255.255.255.0 10.0.4.1</i>
Static routing for network 10.0.7.0	<i>ip route 10.0.7.0 255.255.255.0 10.0.4.1</i>

Router 3:

<b>Process</b>	<b>Command</b>
Selecting and configuring FastEthernet0/0 with ip address 10.0.2.1 and subnet mask 255.255.255.0	<i>interface FastEthernet0/0 ip address 10.0.2.1 255.255.255.0</i>
Selecting and configuring Serial3/0	<i>interface Serial3/0 ip address 10.0.5.2 255.255.255.0</i>
Static routing for network 10.0.1.0	<i>ip route 10.0.1.0 255.255.255.0 10.0.5.1</i>
Static routing for network 10.0.0.0	<i>ip route 10.0.0.0 255.255.255.0 10.0.5.1</i>
Static routing for network 10.0.4.0	<i>ip route 10.0.4.0 255.255.255.0 10.0.5.1</i>
Static routing for network 10.0.3.0	<i>ip route 10.0.3.0 255.255.255.0 10.0.5.1</i>
Static routing for network 10.0.7.0	<i>ip route 10.0.7.0 255.255.255.0 10.0.5.1</i>

Router 0:

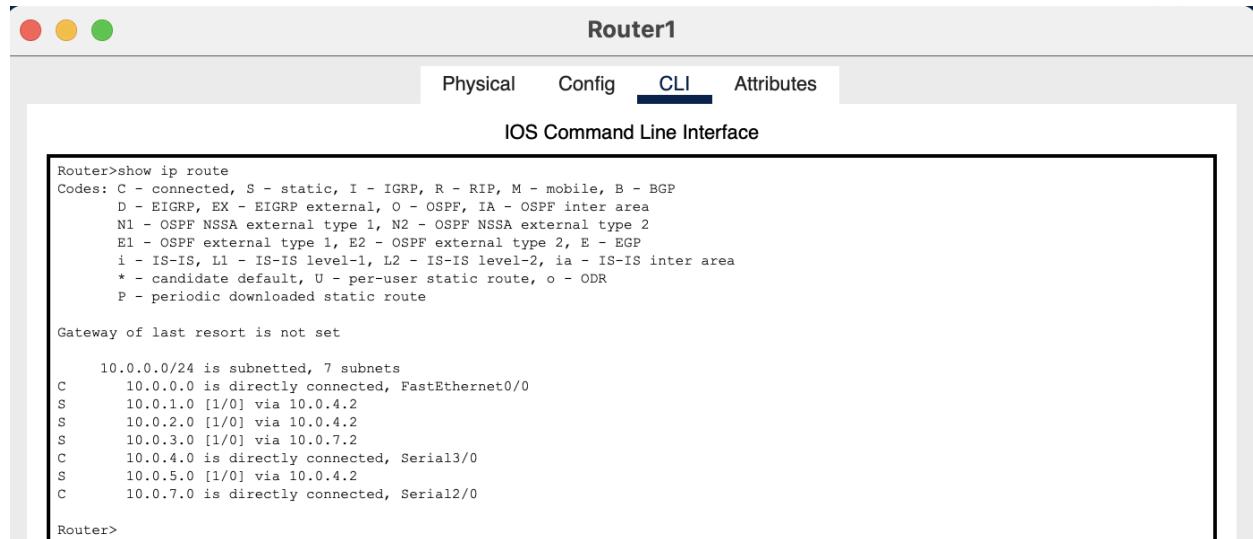
<b>Process</b>	<b>Command</b>
Selecting and configuring FastEthernet0/0 with ip address 10.0.3.1 and subnet mask 255.255.255.0	<i>interface FastEthernet0/0 ip address 10.0.3.1 255.255.255.0</i>
Selecting and configuring Serial2/0	<i>interface Serial2/0 ip address 10.0.7.2 255.255.255.0</i>
Static routing for network 10.0.0.0	<i>ip route 10.0.0.0 255.255.255.0 10.0.7.1</i>

Static routing for network 10.0.1.0	<i>ip route 10.0.1.0 255.255.255.0 10.0.7.1</i>
Static routing for network 10.0.2.0	<i>ip route 10.0.2.0 255.255.255.0 10.0.7.1</i>
Static routing for network 10.0.4.0	<i>ip route 10.0.4.0 255.255.255.0 10.0.7.1</i>
Static routing for network 10.0.5.0	<i>ip route 10.0.5.0 255.255.255.0 10.0.7.1</i>

5. You can display the routing table using the command line at each router. Search for the command that displays the routing table and attach a screenshot for the routing table at each router.

To display the routing table, *show ip route* command can be used in the CLI of the selected router. There is only one router in my network topology and the following figure shows the corresponding routing table.

Routing table of Router 1:



The screenshot shows the Router1 interface. At the top, there are three colored dots (red, yellow, green) followed by the text "Router1". Below this is a navigation bar with tabs: "Physical", "Config", "CLI" (which is highlighted in blue), and "Attributes". The main area is titled "IOS Command Line Interface". Inside, the command "Router>show ip route" is entered, followed by its output. The output shows a summary of subnetting and then a list of routes with their source type (C, S) and destination/mask/prefix-list/via information. The output ends with "Router>".

```

Router>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 area
      * - candidate default, U - per-user static route, o - ODR
      P - periodic downloaded static route

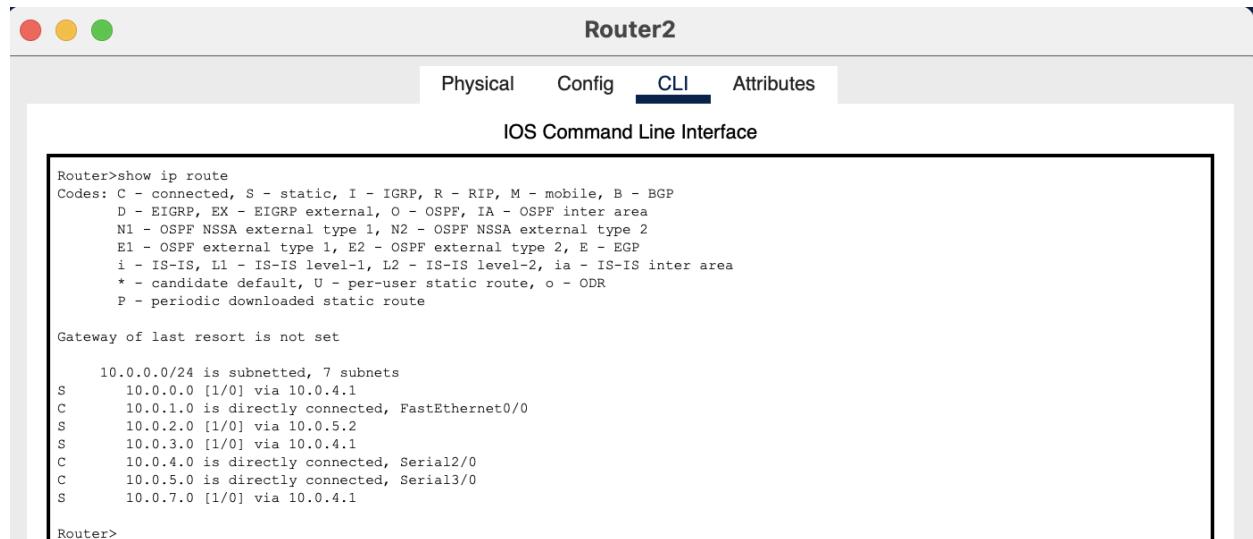
Gateway of last resort is not set

  10.0.0/24 is subnetted, 7 subnets
C    10.0.0.0 is directly connected, FastEthernet0/0
S    10.0.1.0 [1/0] via 10.0.4.2
S    10.0.2.0 [1/0] via 10.0.4.2
S    10.0.3.0 [1/0] via 10.0.7.2
C    10.0.4.0 is directly connected, Serial3/0
S    10.0.5.0 [1/0] via 10.0.4.2
C    10.0.7.0 is directly connected, Serial2/0

Router>

```

Routing table of Router 2:



The screenshot shows the Router2 interface. At the top, there are three colored dots (red, yellow, green) followed by the text "Router2". Below this is a navigation bar with tabs: "Physical", "Config", "CLI" (which is highlighted in blue), and "Attributes". The main area is titled "IOS Command Line Interface". Inside, the command "Router>show ip route" is entered, followed by its output. The output shows a summary of subnetting and then a list of routes with their source type (S) and destination/mask/prefix-list/via information. The output ends with "Router>".

```

Router>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 area
      * - candidate default, U - per-user static route, o - ODR
      P - periodic downloaded static route

Gateway of last resort is not set

  10.0.0/24 is subnetted, 7 subnets
S    10.0.0.0 [1/0] via 10.0.4.1
C    10.0.1.0 is directly connected, FastEthernet0/0
S    10.0.2.0 [1/0] via 10.0.5.2
S    10.0.3.0 [1/0] via 10.0.4.1
C    10.0.4.0 is directly connected, Serial2/0
C    10.0.5.0 is directly connected, Serial3/0
S    10.0.7.0 [1/0] via 10.0.4.1

Router>

```

### Routing table of Router 3:

The screenshot shows a window titled "Router3" with a tab bar at the top. The "CLI" tab is selected. Below the tab bar is a section titled "IOS Command Line Interface". Inside this section, the output of the command "Router#show ip route" is displayed. The output shows the routing table with routes for various subnets (10.0.0.0/24, 10.0.1.0/24, etc.) and their respective metrics and interfaces.

```
Router#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 area
      * - candidate default, U - per-user static route, o - ODR
      P - periodic downloaded static route

Gateway of last resort is not set

  10.0.0.0/24 is subnetted, 7 subnets
S        10.0.0.0 [1/0] via 10.0.5.1
S        10.0.1.0 [1/0] via 10.0.5.1
C        10.0.2.0 is directly connected, FastEthernet0/0
S        10.0.3.0 [1/0] via 10.0.5.1
S        10.0.4.0 [1/0] via 10.0.5.1
C        10.0.5.0 is directly connected, Serial3/0
S        10.0.7.0 [1/0] via 10.0.5.1

Router#
```

### Routing table of Router 0:

The screenshot shows a window titled "Router0" with a tab bar at the top. The "CLI" tab is selected. Below the tab bar is a section titled "IOS Command Line Interface". Inside this section, the output of the command "Router#show ip route" is displayed. The output shows the routing table with routes for various subnets (10.0.0.0/24, 10.0.1.0/24, etc.) and their respective metrics and interfaces.

```
Router#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 area
      * - candidate default, U - per-user static route, o - ODR
      P - periodic downloaded static route

Gateway of last resort is not set

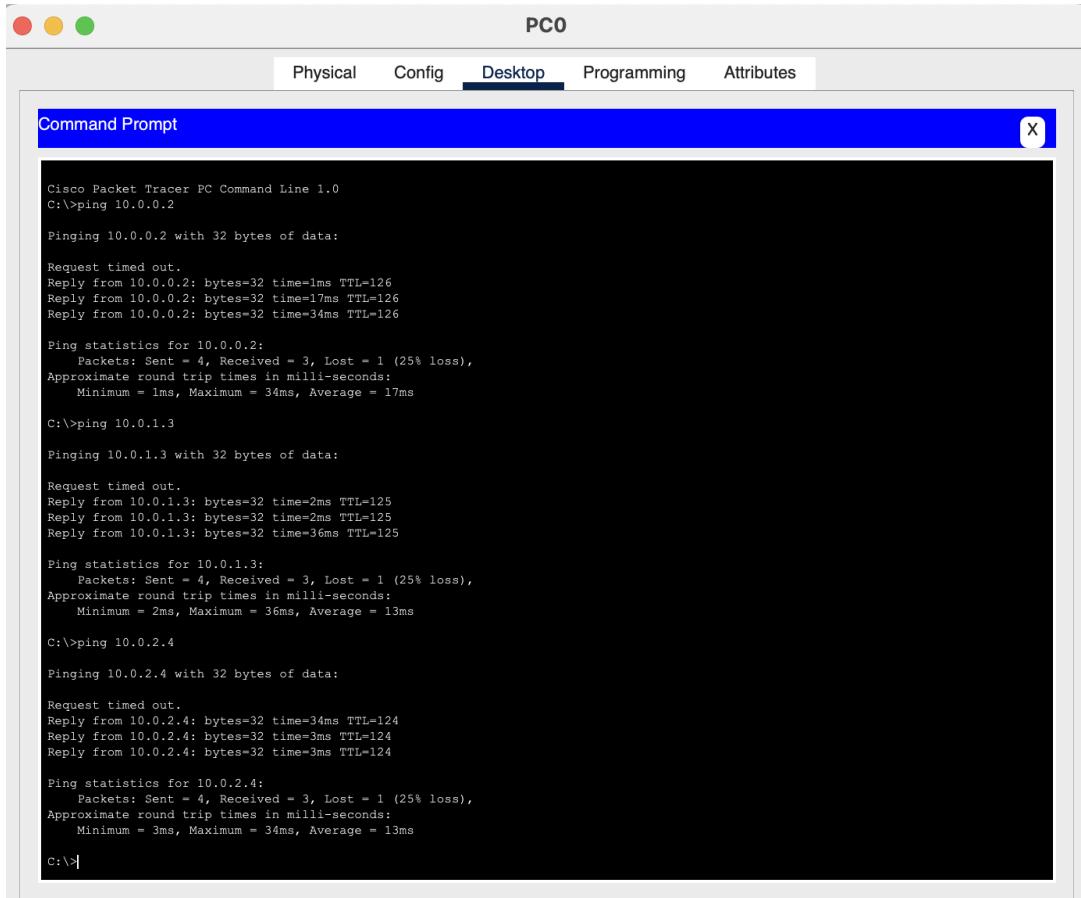
  10.0.0.0/24 is subnetted, 7 subnets
S        10.0.0.0 [1/0] via 10.0.7.1
S        10.0.1.0 [1/0] via 10.0.7.1
S        10.0.2.0 [1/0] via 10.0.7.1
C        10.0.3.0 is directly connected, FastEthernet0/0
S        10.0.4.0 [1/0] via 10.0.7.1
S        10.0.5.0 [1/0] via 10.0.7.1
C        10.0.7.0 is directly connected, Serial2/0

Router#
```

6. Your network should be working, it means any two devices can communicate. Attach screenshots of using the ping command to test connectivity between a device from each branch with a device from other branches.

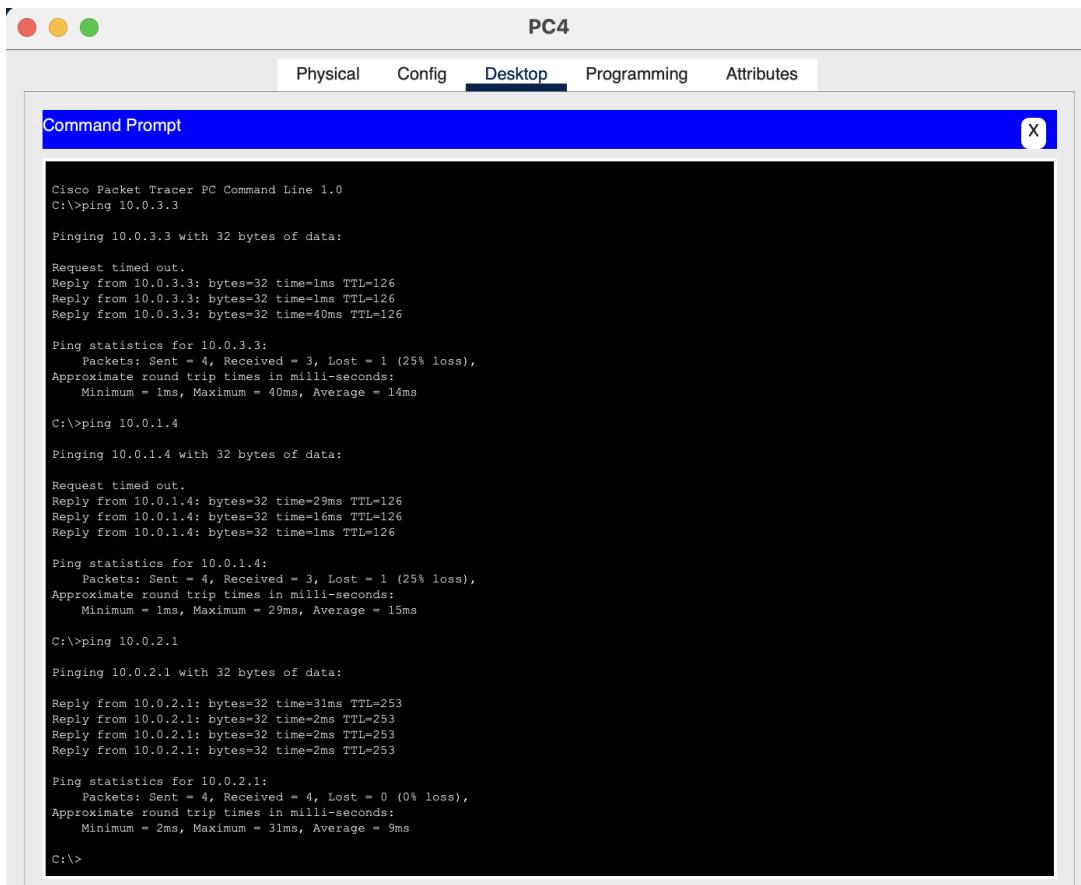
From the screenshots below, communication between a device from each branch with a device from all other branches can be seen.

Ping from PC0 (belonging to subnet 10.0.3.0):



Cisco Packet Tracer PC Command Line 1.0  
C:>ping 10.0.0.2  
  
Pinging 10.0.0.2 with 32 bytes of data:  
  
Request timed out.  
Reply from 10.0.0.2: bytes=32 time=1ms TTL=126  
Reply from 10.0.0.2: bytes=32 time=17ms TTL=126  
Reply from 10.0.0.2: bytes=32 time=34ms TTL=126  
  
Ping statistics for 10.0.0.2:  
Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 1ms, Maximum = 34ms, Average = 17ms  
  
C:>ping 10.0.1.3  
  
Pinging 10.0.1.3 with 32 bytes of data:  
  
Request timed out.  
Reply from 10.0.1.3: bytes=32 time=2ms TTL=125  
Reply from 10.0.1.3: bytes=32 time=2ms TTL=125  
Reply from 10.0.1.3: bytes=32 time=36ms TTL=125  
  
Ping statistics for 10.0.1.3:  
Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 2ms, Maximum = 36ms, Average = 13ms  
  
C:>ping 10.0.2.4  
  
Pinging 10.0.2.4 with 32 bytes of data:  
  
Request timed out.  
Reply from 10.0.2.4: bytes=32 time=34ms TTL=124  
Reply from 10.0.2.4: bytes=32 time=3ms TTL=124  
Reply from 10.0.2.4: bytes=32 time=3ms TTL=124  
  
Ping statistics for 10.0.2.4:  
Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 3ms, Maximum = 34ms, Average = 13ms  
  
C:>

Ping from PC4 (belonging to subnet 10.0.0.0):



Cisco Packet Tracer PC Command Line 1.0  
C:>ping 10.0.3.3  
  
Pinging 10.0.3.3 with 32 bytes of data:  
  
Request timed out.  
Reply from 10.0.3.3: bytes=32 time=1ms TTL=126  
Reply from 10.0.3.3: bytes=32 time=1ms TTL=126  
Reply from 10.0.3.3: bytes=32 time=40ms TTL=126  
  
Ping statistics for 10.0.3.3:  
Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 1ms, Maximum = 40ms, Average = 14ms  
  
C:>ping 10.0.1.4  
  
Pinging 10.0.1.4 with 32 bytes of data:  
  
Request timed out.  
Reply from 10.0.1.4: bytes=32 time=29ms TTL=126  
Reply from 10.0.1.4: bytes=32 time=16ms TTL=126  
Reply from 10.0.1.4: bytes=32 time=1ms TTL=126  
  
Ping statistics for 10.0.1.4:  
Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 1ms, Maximum = 29ms, Average = 15ms  
  
C:>ping 10.0.2.1  
  
Pinging 10.0.2.1 with 32 bytes of data:  
  
Reply from 10.0.2.1: bytes=32 time=31ms TTL=253  
Reply from 10.0.2.1: bytes=32 time=2ms TTL=253  
Reply from 10.0.2.1: bytes=32 time=2ms TTL=253  
Reply from 10.0.2.1: bytes=32 time=2ms TTL=253  
  
Ping statistics for 10.0.2.1:  
Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),  
Approximate round trip times in milli-seconds:  
Minimum = 2ms, Maximum = 31ms, Average = 9ms  
  
C:>

Ping from PC7 (belonging to subnet 10.0.1.0):

```
Cisco Packet Tracer PC Command Line 1.0
C:\>ping 10.0.3.4

Pinging 10.0.3.4 with 32 bytes of data:

Request timed out.
Reply from 10.0.3.4: bytes=32 time=2ms TTL=125
Reply from 10.0.3.4: bytes=32 time=2ms TTL=125
Reply from 10.0.3.4: bytes=32 time=3ms TTL=125

Ping statistics for 10.0.3.4:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 2ms, Maximum = 3ms, Average = 2ms

C:\>ping 10.0.0.2

Pinging 10.0.0.2 with 32 bytes of data:

Reply from 10.0.0.2: bytes=32 time=23ms TTL=126
Reply from 10.0.0.2: bytes=32 time=24ms TTL=126
Reply from 10.0.0.2: bytes=32 time=1ms TTL=126
Reply from 10.0.0.2: bytes=32 time=1ms TTL=126

Ping statistics for 10.0.0.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 1ms, Maximum = 24ms, Average = 12ms

C:\>ping 10.0.2.3

Pinging 10.0.2.3 with 32 bytes of data:

Request timed out.
Reply from 10.0.2.3: bytes=32 time=24ms TTL=126
Reply from 10.0.2.3: bytes=32 time=17ms TTL=126
Reply from 10.0.2.3: bytes=32 time=23ms TTL=126

Ping statistics for 10.0.2.3:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 17ms, Maximum = 24ms, Average = 21ms

C:\>
```

Ping from PC9 (belonging to subnet 10.0.2.0):

```
Cisco Packet Tracer PC Command Line 1.0
C:\>ping 10.0.3.2

Pinging 10.0.3.2 with 32 bytes of data:

Reply from 10.0.3.2: bytes=32 time=3ms TTL=124

Ping statistics for 10.0.3.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 3ms, Maximum = 3ms, Average = 3ms

C:\>ping 10.0.0.3

Pinging 10.0.0.3 with 32 bytes of data:

Reply from 10.0.0.3: bytes=32 time=25ms TTL=125
Reply from 10.0.0.3: bytes=32 time=32ms TTL=125
Reply from 10.0.0.3: bytes=32 time=1ms TTL=125
Reply from 10.0.0.3: bytes=32 time=2ms TTL=125

Ping statistics for 10.0.0.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 2ms, Maximum = 32ms, Average = 15ms

C:\>ping 10.0.1.4

Pinging 10.0.1.4 with 32 bytes of data:

Reply from 10.0.1.4: bytes=32 time=16ms TTL=126
Reply from 10.0.1.4: bytes=32 time=10ms TTL=126
Reply from 10.0.1.4: bytes=32 time=1ms TTL=126
Reply from 10.0.1.4: bytes=32 time=22ms TTL=126

Ping statistics for 10.0.1.4:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 1ms, Maximum = 22ms, Average = 12ms

C:\>
```