



## CNE – Tutorial Guide

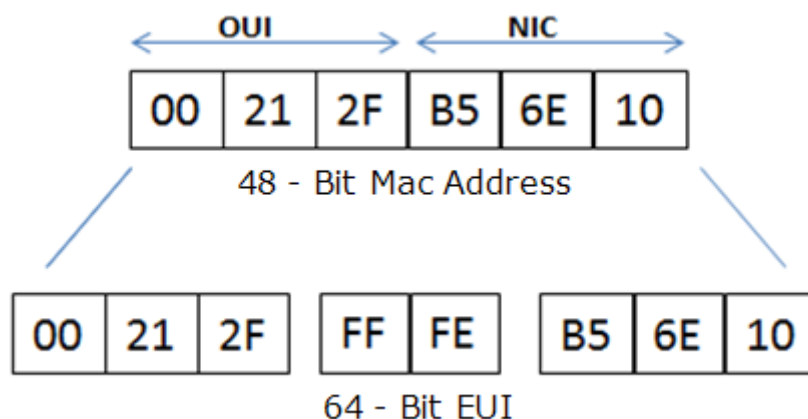
### Week 10

# IPv6 address configuration and IPv6 static routing

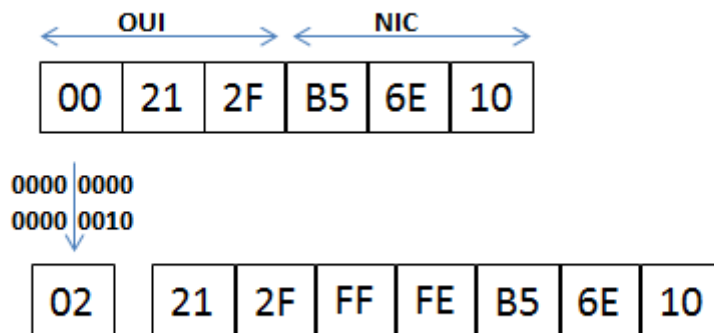
## I. Understanding IPv6 EUI-64 Bit Address

Extended Unique Identifier (EUI), as per RFC2373, allows a host to assign itself a unique 64-Bit IP Version 6 interface identifier (EUI-64). This feature is a key benefit over IPv4 as it eliminates the need of manual configuration or DHCP as in the world of IPv4. The IPv6 EUI-64 format address is obtained through the 48-bit MAC address. The MAC address is first separated into two 24-bits, with one being OUI (Organizationally Unique Identifier) and the other being NIC specific. The 16-bit 0xFFFE is then inserted between these two 24-bits for the 64-bit EUI address. IEEE has chosen FFFE as a reserved value which can only appear in EUI-64 generated from the an EUI-48 MAC address.

Here is an example showing how a the MAC Address is used to generate EUI.



Next, the seventh bit from the left, or the universal/local (U/L) bit, needs to be inverted. This bit identifies whether this interface identifier is universally or locally administered. If 0, the address is locally administered and if 1, the address is globally unique. It is worth noticing that in the OUI portion, the globally unique addresses assigned by the IEEE has always been set to 0 whereas the locally created addresses has 1 configured. Therefore, when the bit is inverted, it maintains its original scope (global unique address is still global unique and vice versa). The reason for inverting can be found in RFC4291 section 2.5.1.



Once the above is done, we have a fully functional EUI-64 format address.

## II. IPv6 address configuration

There are 3 ways to do IPv6 address configuration: Static configuration, Auto-configuration by DHCPv6 and Auto-configuration.

### 1. Static IPv6 configuration:

In Pack Tracer you can use the following command to assign a static IPv6 address in the Global configuration mode at a router:

```
Router(config)#int fa0/0
Router(config-if)#ipv6 address <IPv6 address>/prefix_length
```

### 2. Stateful Auto-configuration by DHCPv6:

This type of configuration requires a certain level of human intervention because it needs a Dynamic Host Configuration Protocol for IPv6 (DHCPv6) server for the installation and administration of the nodes. The DHCPv6 server keeps a list of nodes to which it supplies configuration information. It also maintains state information so the server knows how long each address is in use, and when it might be available for reassignment.

### 3. Stateless Auto-configuration

One important goal for IPv6 is to support node Plug and Play. That is, it should be possible to plug a node into an IPv6 network and have it automatically configured without any human intervention.

Auto configuration is the ability for a node to auto-configure a global unique IPv6 address without the need of an IPv6 DHCP server is very appealing to businesses looking to save some time. This type of configuration is suitable for small organizations and individuals.

In this case, each host determines its addresses from the contents of received router advertisements. Using the IEEE EUI-64 standard to define the network ID portion of the address, it is reasonable to assume the uniqueness of the host address on the link.

There are some types of Unicast address:

Type	Binary	Hex
Aggregatable Global Unicast Address	001	2 or 3
Unique Local Unicast Address	1111 1100 1111 1101	FC00::/7 FC00::/8(Registry) FD00::/8 (No Registry)
Link-Local Unicast Address	1111 1110 10	FE80::/10
Multicast Address	1111 1111	FF00::/8

### Link-Local Unicast Address auto-configuration

A link-local address is an IPv6 unicast address that can be automatically configured on any interface using the link-local prefix FE80::/10 (1111 1110 10) and the interface identifier in the modified EUI-64 format. Link-local addresses are not necessarily bound to the MAC address (configured in a EUI-64 format). Link-local addresses can also be manually configured in the FE80::/10 format using the `ipv6 address link-local` command:

```
ipv6 address ipv6-address/prefix-length link-local
```

```
Example: ipv6 address FE80::260:3EFF:FE11:6770 link-local
```

These addresses refer only to a particular physical link and are used for addressing on a single link for purposes such as automatic address configuration and neighbor discovery protocol. Link-local addresses can be used to reach the neighboring nodes attached to the same link. The nodes do not need a globally unique address to communicate. Routers will not forward datagram using link-local addresses. IPv6 routers must not forward packets that have link-local source or destination addresses to other links. All IPv6 enabled interfaces have a link-local unicast address.

### Aggregatable Global Unicast Address auto-configuration

Before you dive into configuring Aggregatable Global Unicast IPv6 Address autoconfig first let's dive more into depth with how it works. IPv6 uses a mechanism called Neighbor Discovery Protocol (NDP),

which gives IPv6 its unique plug-and-play features. NDP performs several functions which are listed below;

- Router Discovery – The ability for a node to discover local routers on a network segment without the aid of a DHCP server.
- Parameter Discovery – The ability for a node to discover link parameters such as MTU and hop limits for its links.
- Prefix Discovery – The ability for a node to discover the prefix or prefixes assigned to a specific IPv6 link.
- Address Autoconfiguration – The ability for a node to determine its full unique address without the aid of a DHCP server.
- Duplicated Address Detection (DAD) – The ability for a node to determine rather or not an IPv6 address it attempts to use already exist.
- Address Resolution – The ability for a node to discover the link-layer addresses of other node(s) on a link without the use of Address Resolution Protocol (ARP).
- Next-Hop Determination – The ability for a node to determine the next link-layer hop on a network link; a local node or router destination.
- Neighbor Unreachability Detection – The ability for a node to determine when a neighboring device on the network link is no longer reachable.
- Redirect – The ability for a router to notify a host that a better path exist to reach a given destination.

Network Discovery Protocol messages should always be link-local originating. To add further security to NDP messages, the hop limit (IPv6 TTL) of the IPv6 packet carrying all NDP traffic is set to 255. (TTL) to ensure it does not traverse routers.

The Network Discovery Protocol is defined in RFC2461 which uses ICMPv6 to exchange messages required for its functions. Specifically, five new ICMPv6 messages are defined in RFC2461 which you be aware. These messages which are listed below are responsible for the operation of NDP;

- Router Advertisement (RA) – An RA is a message that originates from a Router, (Cisco or non-Cisco) to advertise their existence on a network link. These RA's also include link parameters and are sent automatically periodically and in response of a Router Solicitation (RS) message.
- Router Solicitation (RS) – These messages originate from host nodes to request that any router on the link respond with a RA.
- Neighbor Solicitation (NS) – These messages are sent from a node requesting the link layer address of another node and also used by the duplicate address detection and neighbor unreachability detection mechanisms.
- Neighbor Advertisement (NA) – These messages are sent in response to a NS message. If a node changes its link-layer address then a NA can be used to send an unsolicited advertisement to advertise its new address.
- Redirect – These messages are used in the same fashion as IPv4 ICMP redirects however they have been migrated from ICMP in IPv4 to native operation NDP which uses ICMPv6 to function.

To configure IPv6 stateless auto configuration on an interface you first must configure the router to advertise its connected prefix on the link using the NDP Router Advertisement (RA) message(s). Without this advertisement the host on the network link will not know what address to autoconfig to.

There are several commands that have been ported over to suit the needs of IPv6 on a Cisco router such as `show ip interface brief` for ipv6 is `show ipv6 interface brief`. Also `show ip route` for IPv6 is now `show ipv6 route`.

To configure a Cisco router to advertise an IPv6 prefix out an Ethernet interface for neighbor IPv6 auto configuration you must first to enable IPv6 unicast routing on that router by executing the `ipv6 unicast-routing` command in global configuration. After IPv6 unicast routing is enabled you can then continue to configure the advertised prefix by using the `ipv6 nd prefix x:x:x:x::x` command in interface configuration mode. Once the prefix is configured the router will advertised the interface prefix specified in the Network Discovery Protocol (NDP) Router Advertisements (RA)'s periodically and upon receipt of a Router Solicitation (RS).

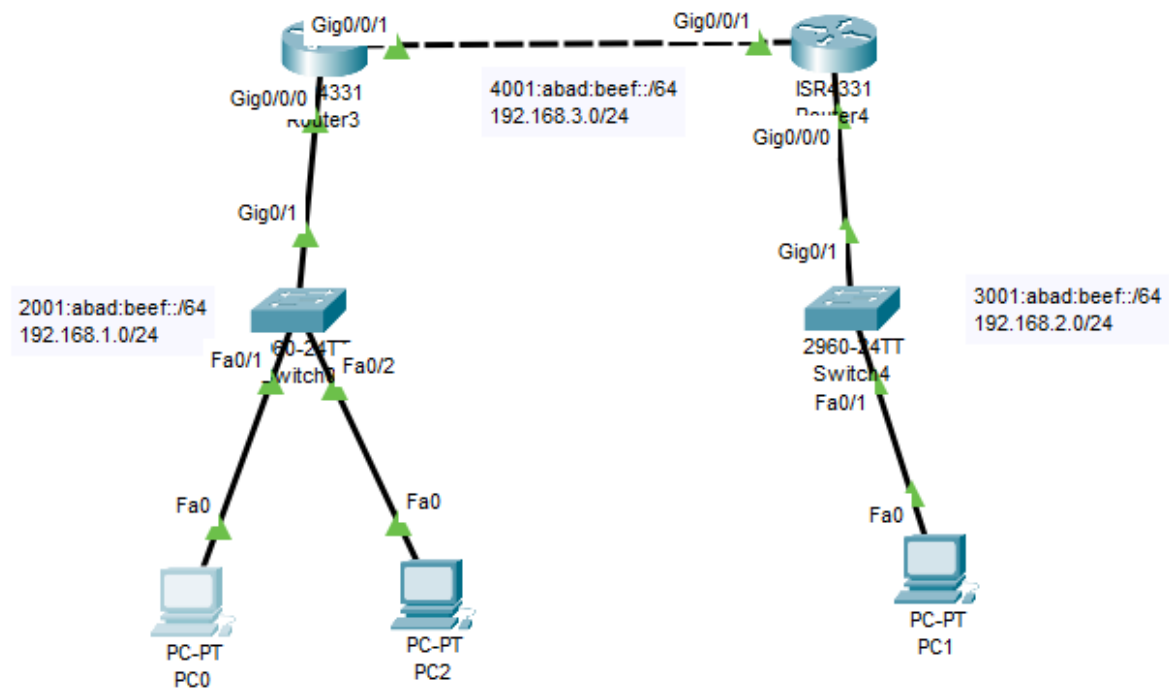
Command	Description
<code>ipv6 unicast-routing</code>	This command when executed in global configuration mode to enable IPv6 Unicast routing on a Cisco router and/or Switch.
<code>ipv6 nd prefix X:X:X:X::/n</code>	This command when executed in interface configuration mode configures which prefix or prefixes to advertise in its IPv6 NDP router advertisements (RA's) which is used by neighboring nodes to auto configure an IPv6 address.
<code>ipv6 address X:X:X:X::X/n</code>	This command when executed in interface configuration mode sets an IPv6 address on the specified interface.
<code>ipv6 address autoconfig</code>	This command when executed in interface configuration mode configures that specific interface to autoconfig its IPv6 address based on prefix advertisements from routers on that network segment.
<code>ipv6 address ipv6-prefix/prefix-length eui-64</code>  <code>ipv6 address X:X:X:X::/n eui-64</code>	The IPv6 network assigned to the interface and The length of the IPv6 prefix where the <code>ipv6-prefix</code> is specified in hexadecimal using 16-bit values between colons, <code>prefix-length</code> is a decimal value that indicates how many of the high-order contiguous bits of the address comprise the prefix (the network portion of the address). A slash mark must precede the decimal value

### III. IPv6 Static routing - Practice with Packet Tracer

To establish static IPv6 routes, use the `ipv6 route` command in global configuration mode:

`ipv6 route ipv6-prefix/prefix-length [administrative-distance] [next-hop-address]`

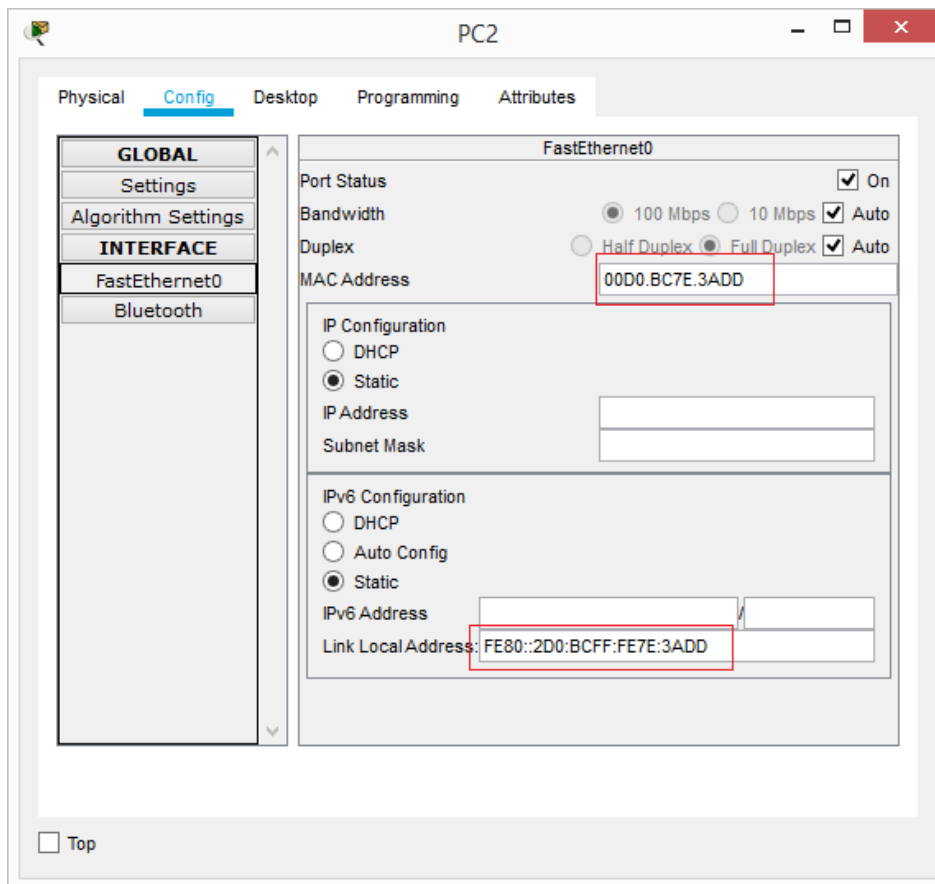
In this example, we will set both IPv4 and IPv6 address on the same interface and we will do both IPv4 routing and IPv6 routing configuration on the same router.



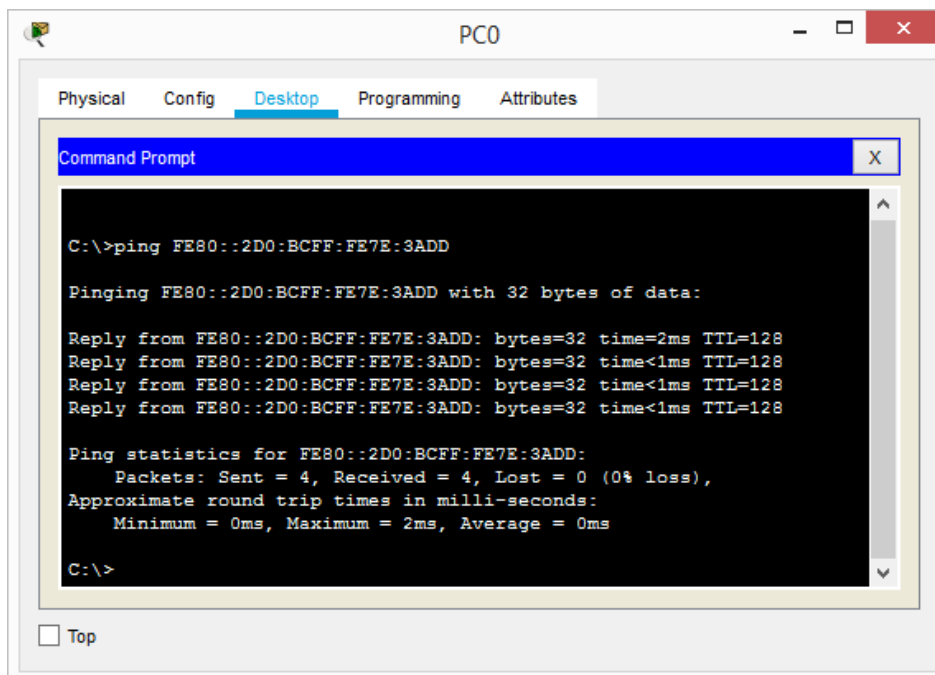
## 1. Check link-local address

When we do nothing, you can check link-local IPv6 address of PC0 and PC2:

Link-local IPv6 address = FE80:: + EUI-64 (from MAC address)



We can use immediately these link-local addresses to ping between PC0 and PC2:



## 2. IPv6 global unicast address configuration and static routing configuration

PC0:

The screenshot shows the 'PC0' configuration window with the 'Desktop' tab selected. The 'IP Configuration' section is expanded, showing 'FastEthernet0' as the interface. Under 'IP Configuration', 'Static' is selected, with IP Address '192.168.1.2', Subnet Mask '255.255.255.0', Default Gateway '192.168.1.1', and DNS Server '0.0.0.0'. The 'IPv6 Configuration' section is also expanded, showing 'Static' selected, with IPv6 Address '2001:ABAD:BEEF::2/64', Link Local Address 'FE80::200:CFF:FE69:A911', IPv6 Gateway '2001:ABAD:BEEF::1', and IPv6 DNS Server left empty. The '802.1X' section is collapsed, and the 'Top' button is at the bottom.

Port	Link	IP Address	IPv6 Address	MAC Address
FastEthernet0	Up	192.168.1.2/24	2001:ABAD:BEEF::2/64	0000.0C69.A911
Bluetooth	Down	<not set>	<not set>	0060.3E52.67C8

Gateway: 192.168.1.1  
DNS Server: <not set>  
Line Number: <not set>

PC1:

Port	Link	IP Address	IPv6 Address	MAC Address
FastEthernet0	Up	192.168.2.2/24	3001:ABAD:BEEF::2/64	00D0.BAB2.753A
Bluetooth	Down	<not set>	<not set>	000C.85B4.B8C9

Gateway: 192.168.2.1  
DNS Server: <not set>  
Line Number: <not set>

Router 3:

```
Router(config)#ipv6 unicast-routing
Router(config)#int Gig0/0/0
Router(config-if)# no shut
Router(config-if)#ip address 192.168.1.1 255.255.255.0
Router(config-if)#ipv6 address 2001:abad:beef::1/64
Router(config-if)#exit
Router(config)#int Gig0/0/1
Router(config-if)# no shut
Router(config-if)# ip address 192.168.3.1 255.255.255.0
Router(config-if)# ipv6 address 4001:abad:beef::1/64
```



Port	Link	VLAN	IP Address	IPv6 Address	MAC Address
GigabitEthernet0/0/0	Up	--	192.168.1.1/24	2001:ABAD:BEEF::1/64	0002.4AD3.1101
GigabitEthernet0/0/1	Up	--	192.168.3.1/24	4001:ABAD:BEEF::1/64	0002.4AD3.1102
GigabitEthernet0/0/2	Down	--	<not set>	<not set>	0002.4AD3.1103
Vlan1	Down	1	<not set>	<not set>	0004.9ABB.B7AD

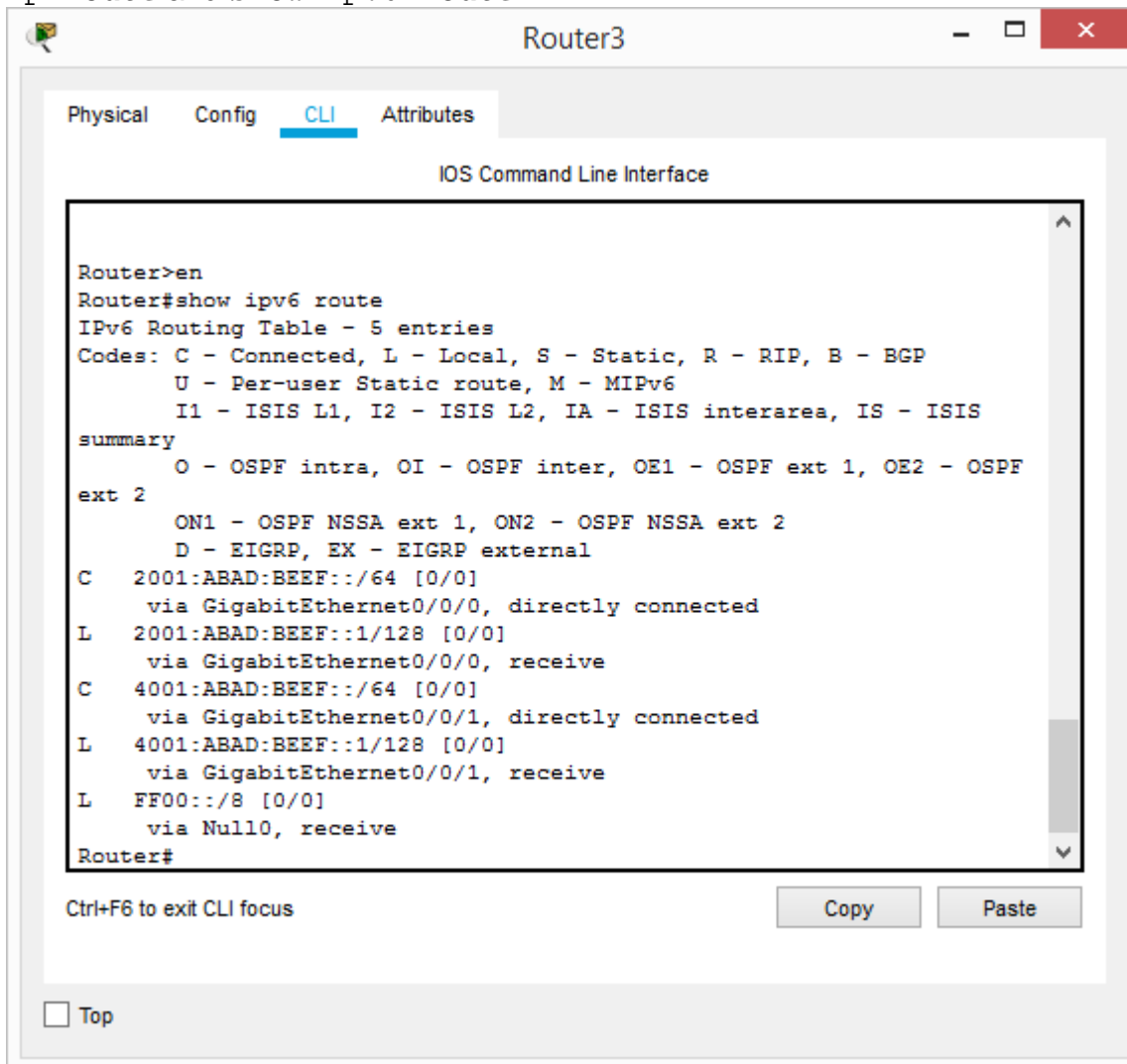
Hostname: Router

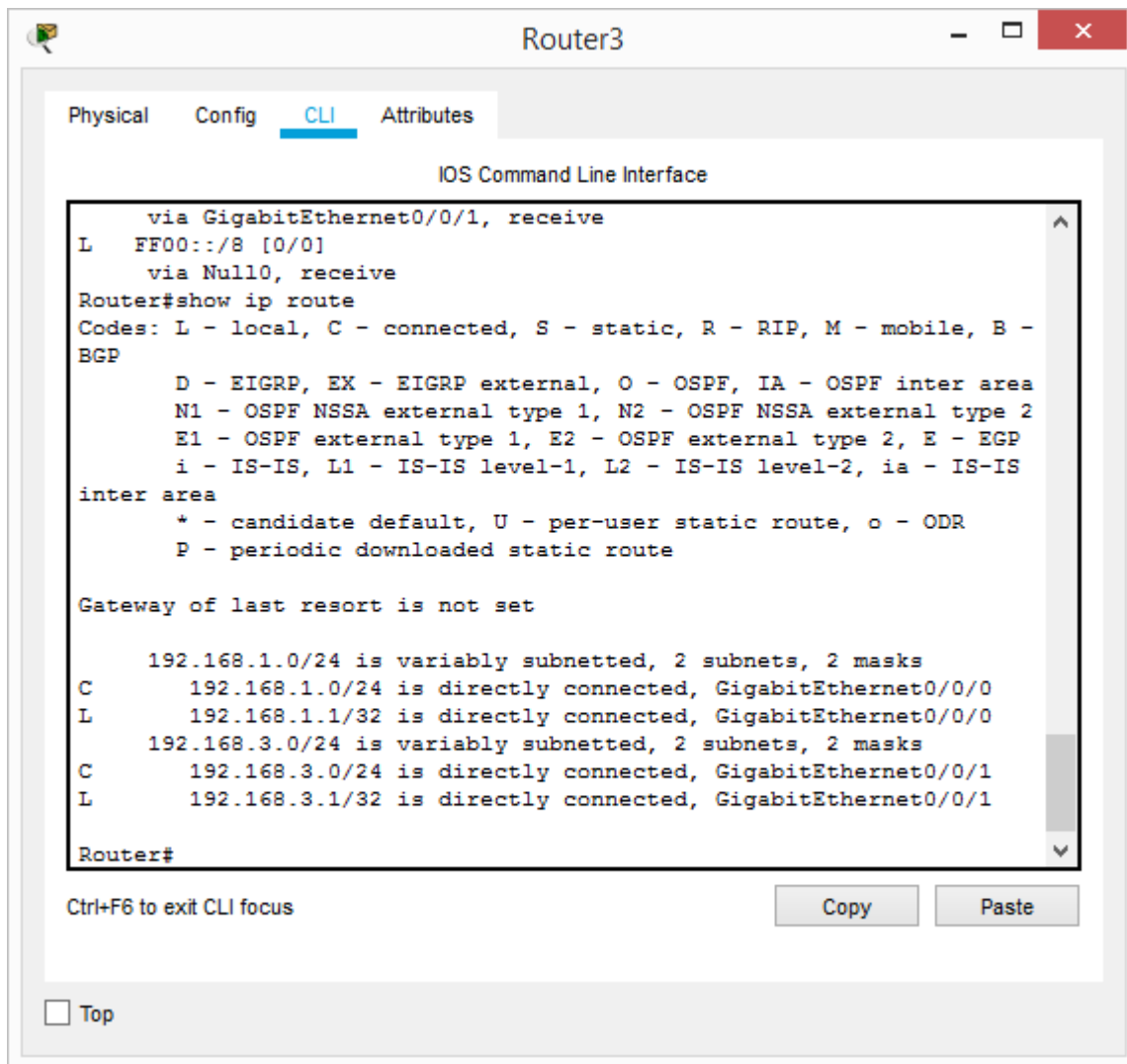
#### Router 4:

Port	Link	VLAN	IP Address	IPv6 Address	MAC Address
GigabitEthernet0/0/0	Up	--	192.168.2.1/24	3001:ABAD:BEEF::1/64	000A.4140.EB01
GigabitEthernet0/0/1	Up	--	192.168.3.2/24	4001:ABAD:BEEF::2/64	000A.4140.EB02
GigabitEthernet0/0/2	Down	--	<not set>	<not set>	000A.4140.EB03
Vlan1	Down	1	<not set>	<not set>	0040.0B56.37E1

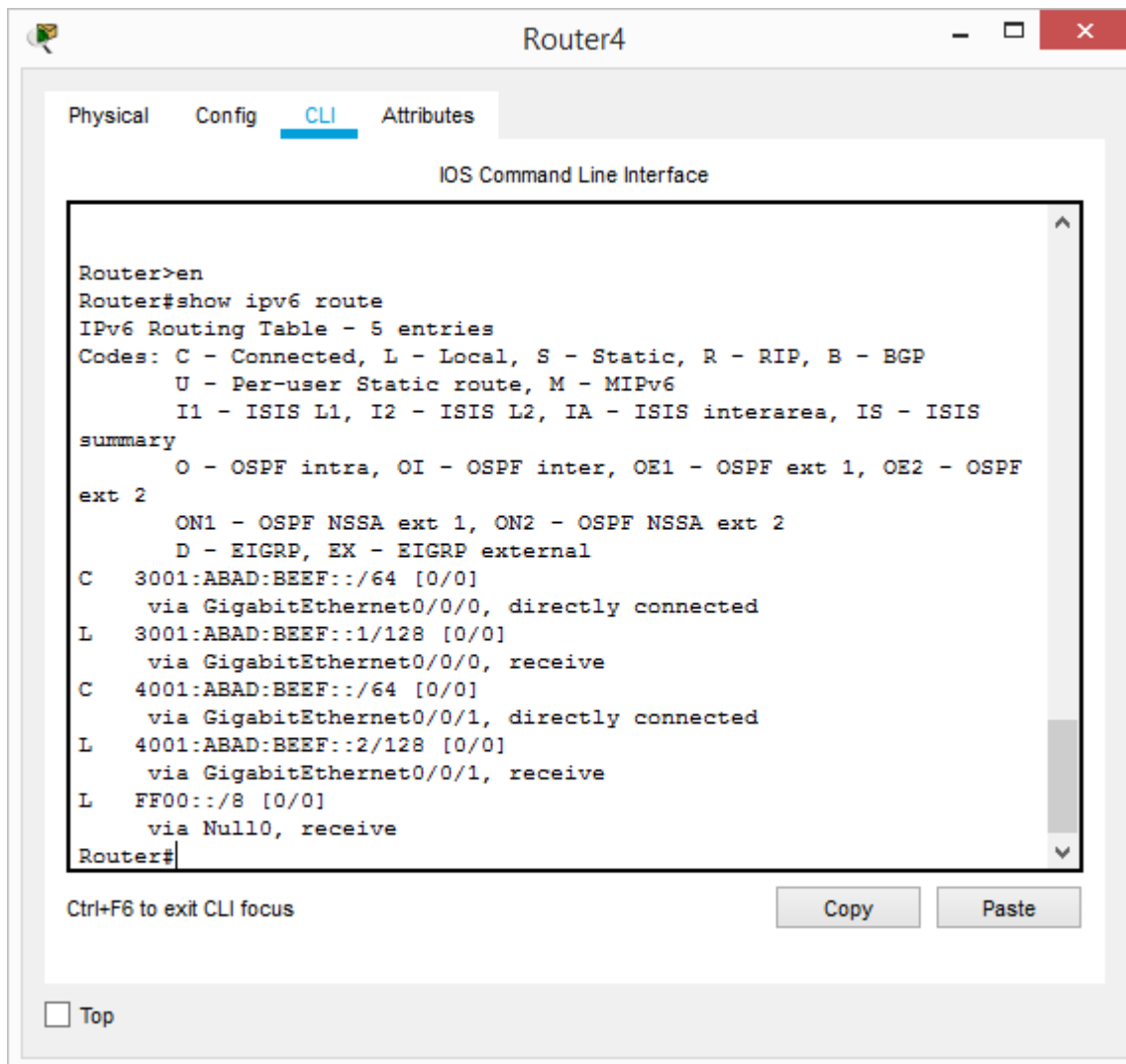
Hostname: Router

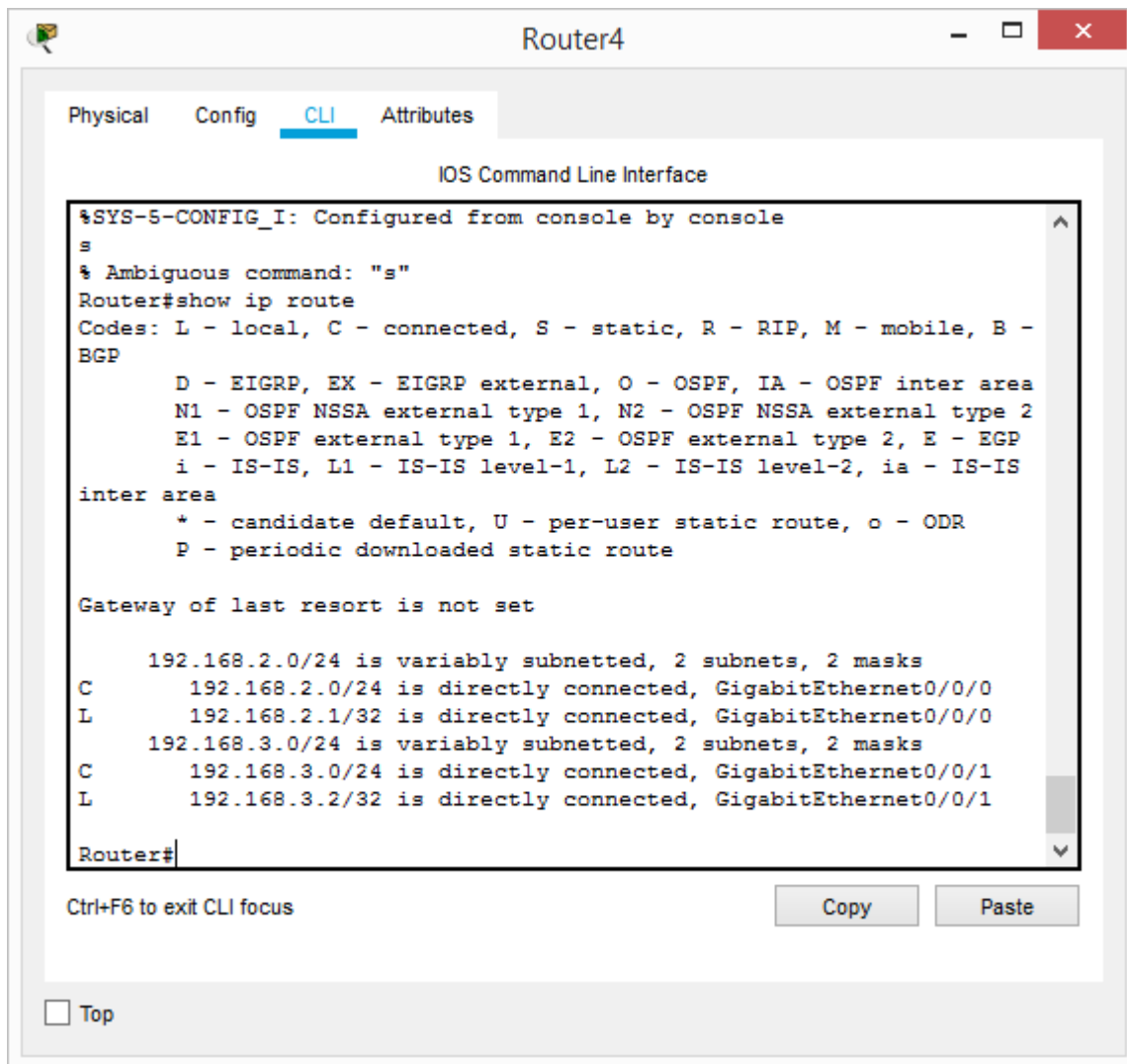
At router 3, you can check ipv4 and ipv6 configuration by typing the commands `show ip route` and `show ipv6 route`





At router 4, you can type `show ip route` and `show ipv6 route`:





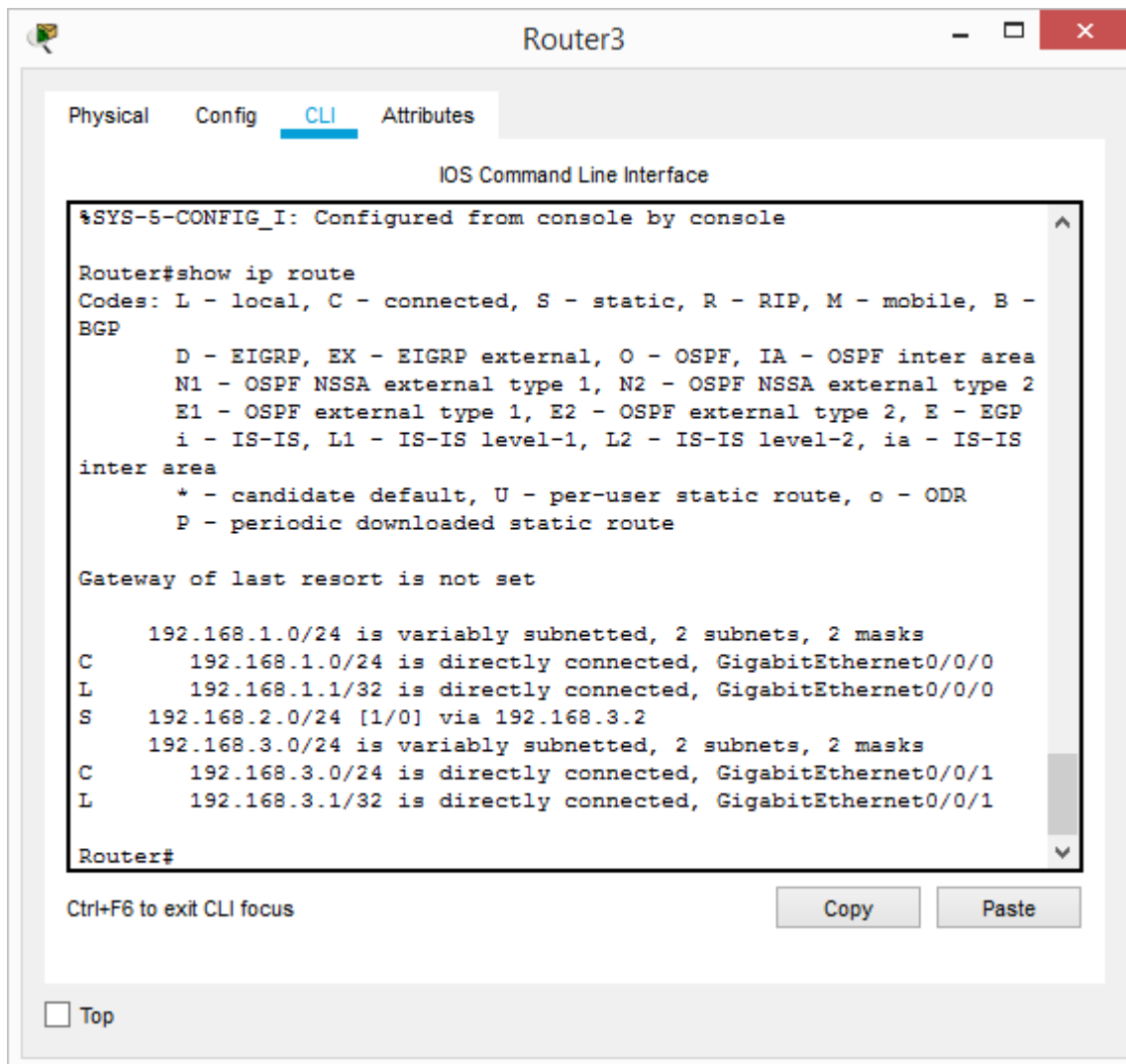
**Now we setup static routing configuration on router 3 and 4:**

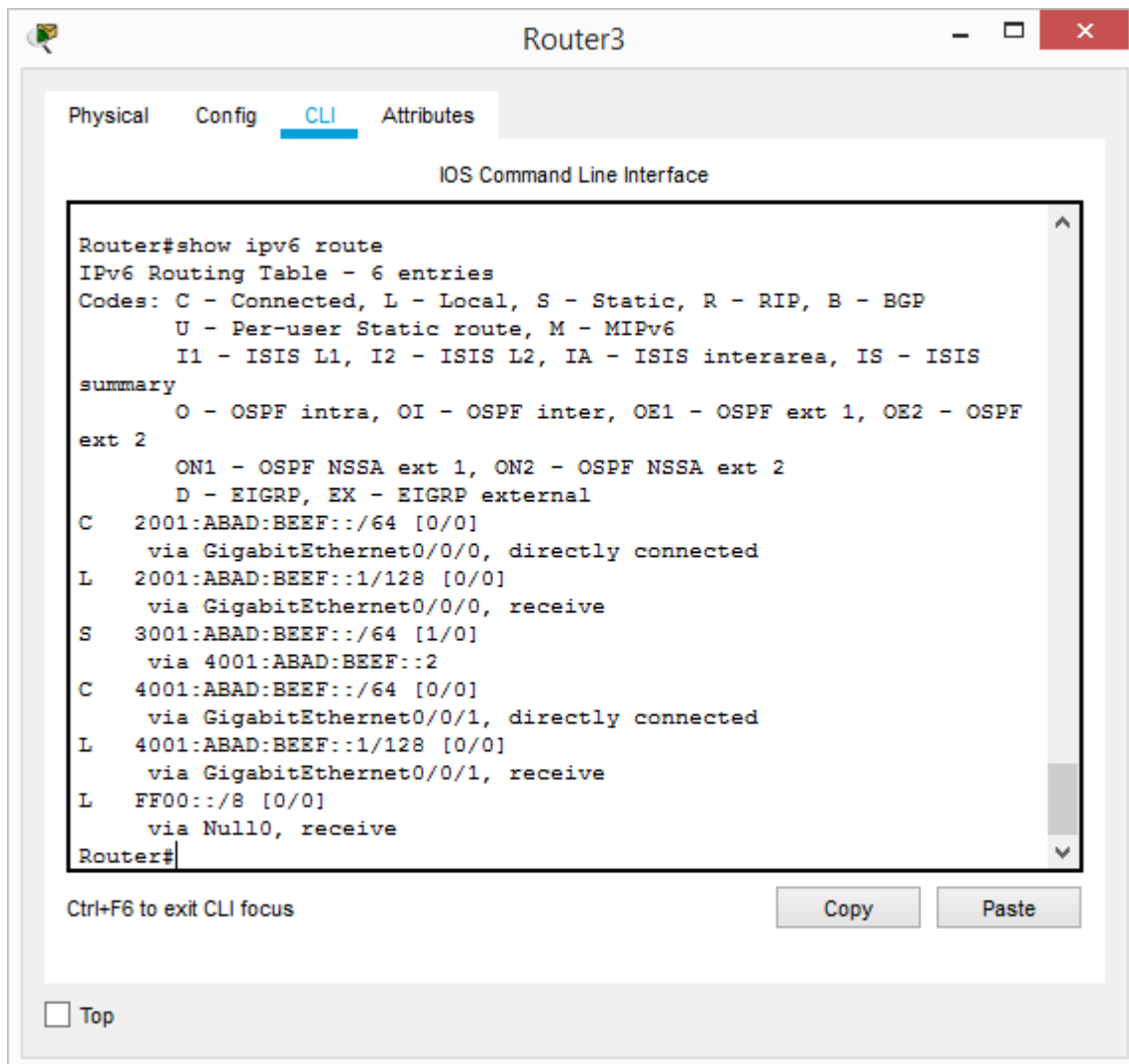
**Router 3:**

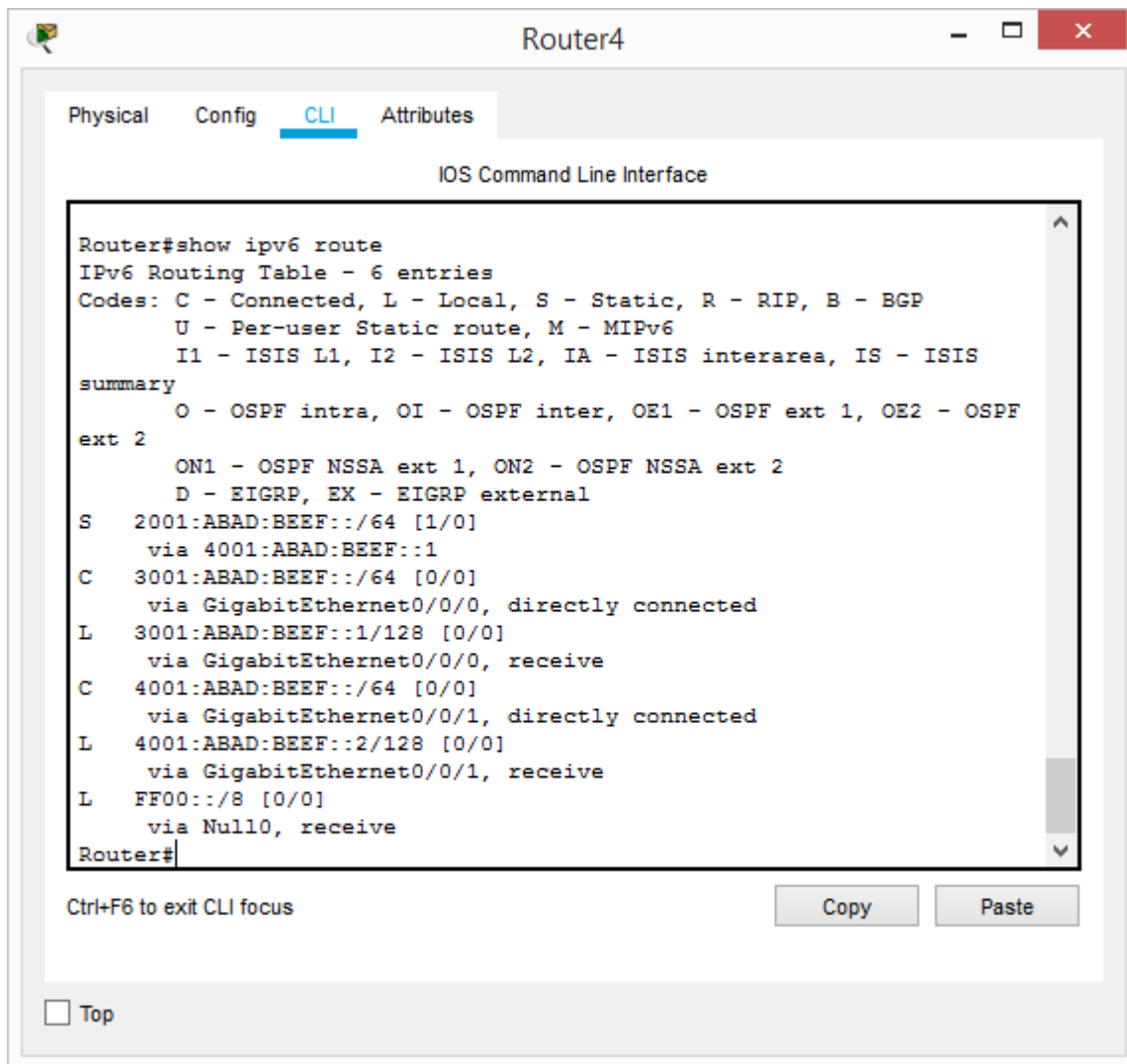
```
Router(config)# ipv6 route 3001:abad:beef::/64 4001:abad:beef::2
Router(config)# ip route 192.168.2.0 255.255.255.0 192.168.3.2
```

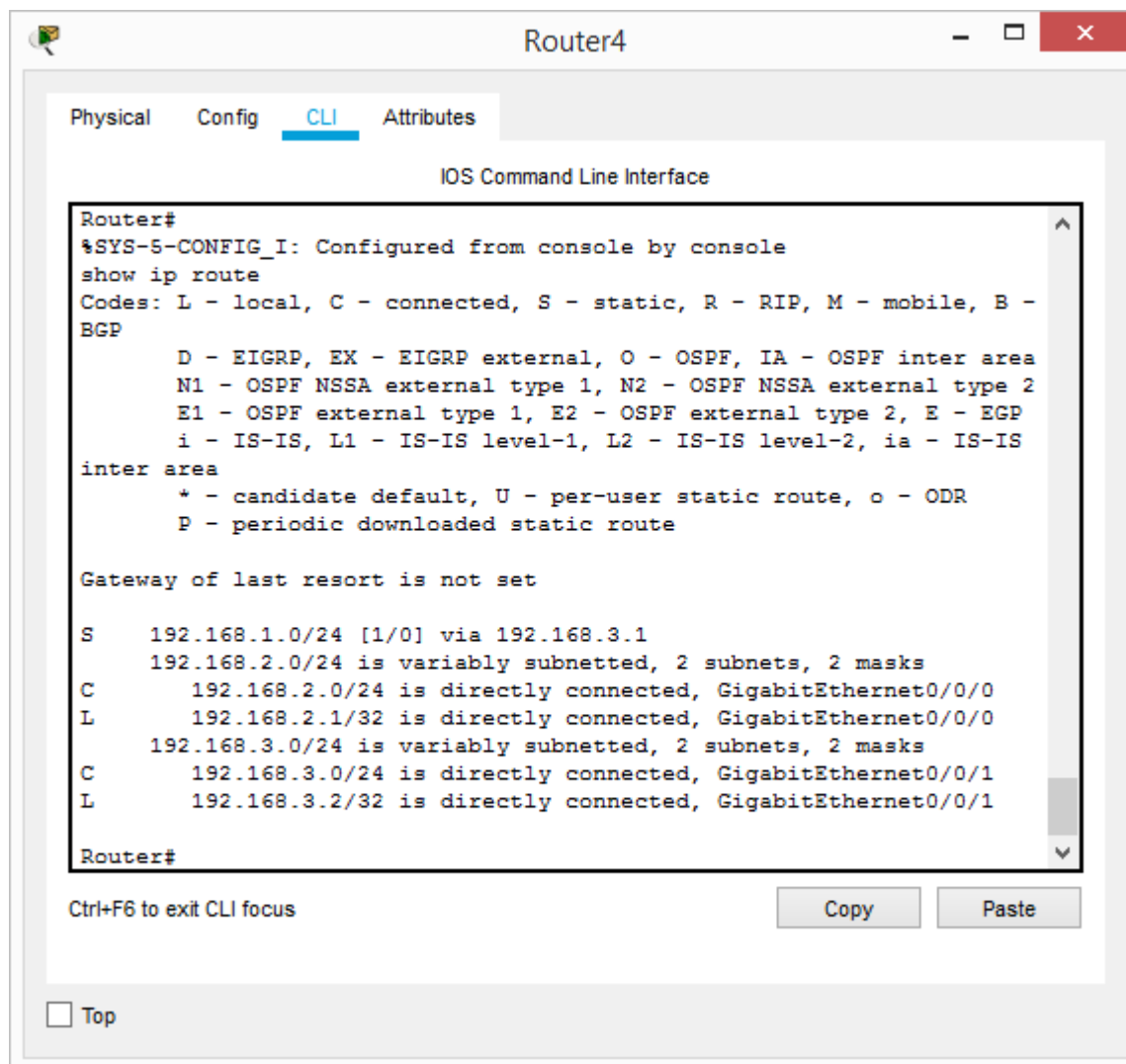
**Router 4:**

```
Router(config)# ipv6 route 2001:abad:beef::/64 4001:abad:beef::1
Router(config)# ip route 192.168.1.0 255.255.255.0 192.168.3.1
```



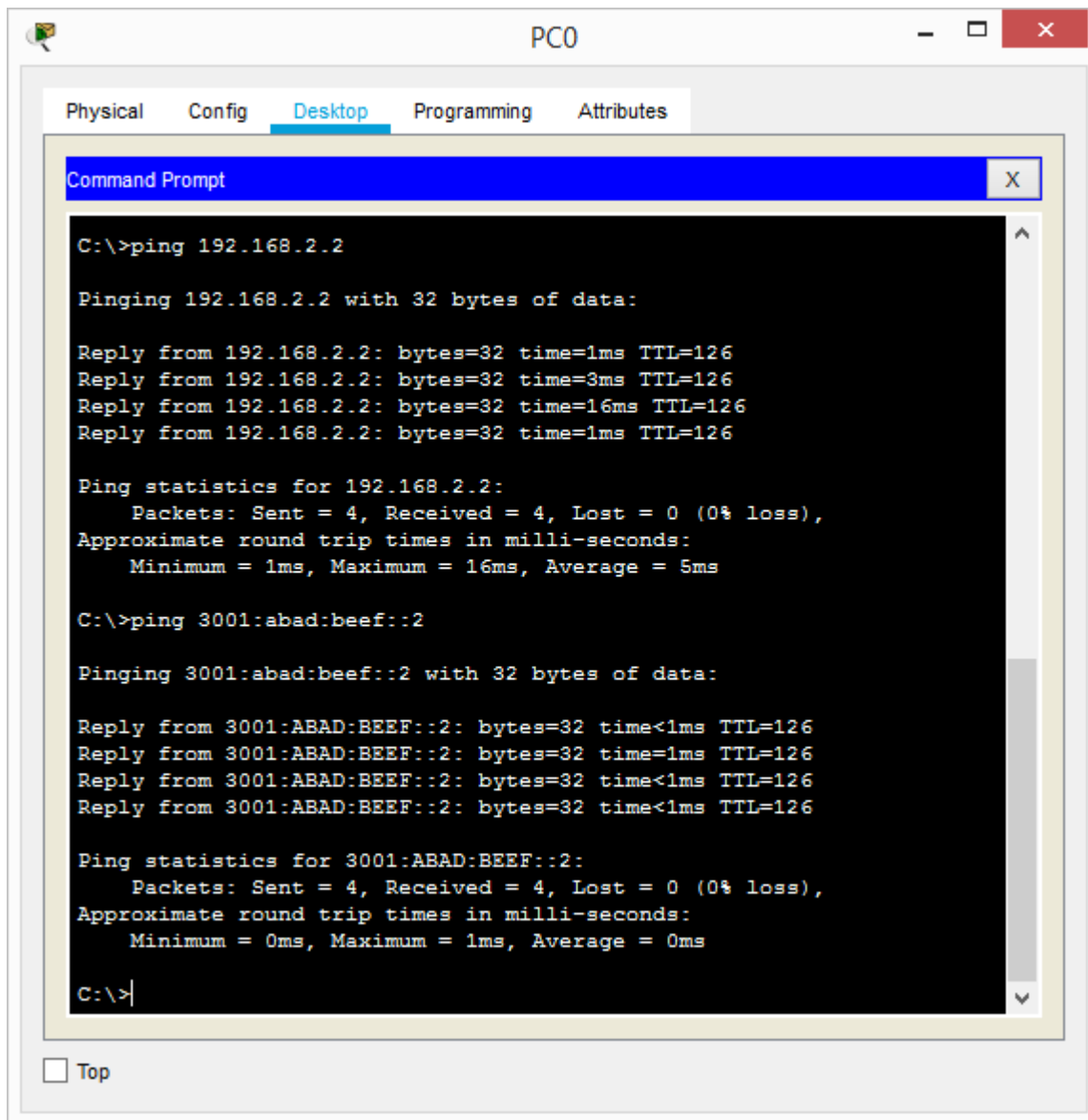


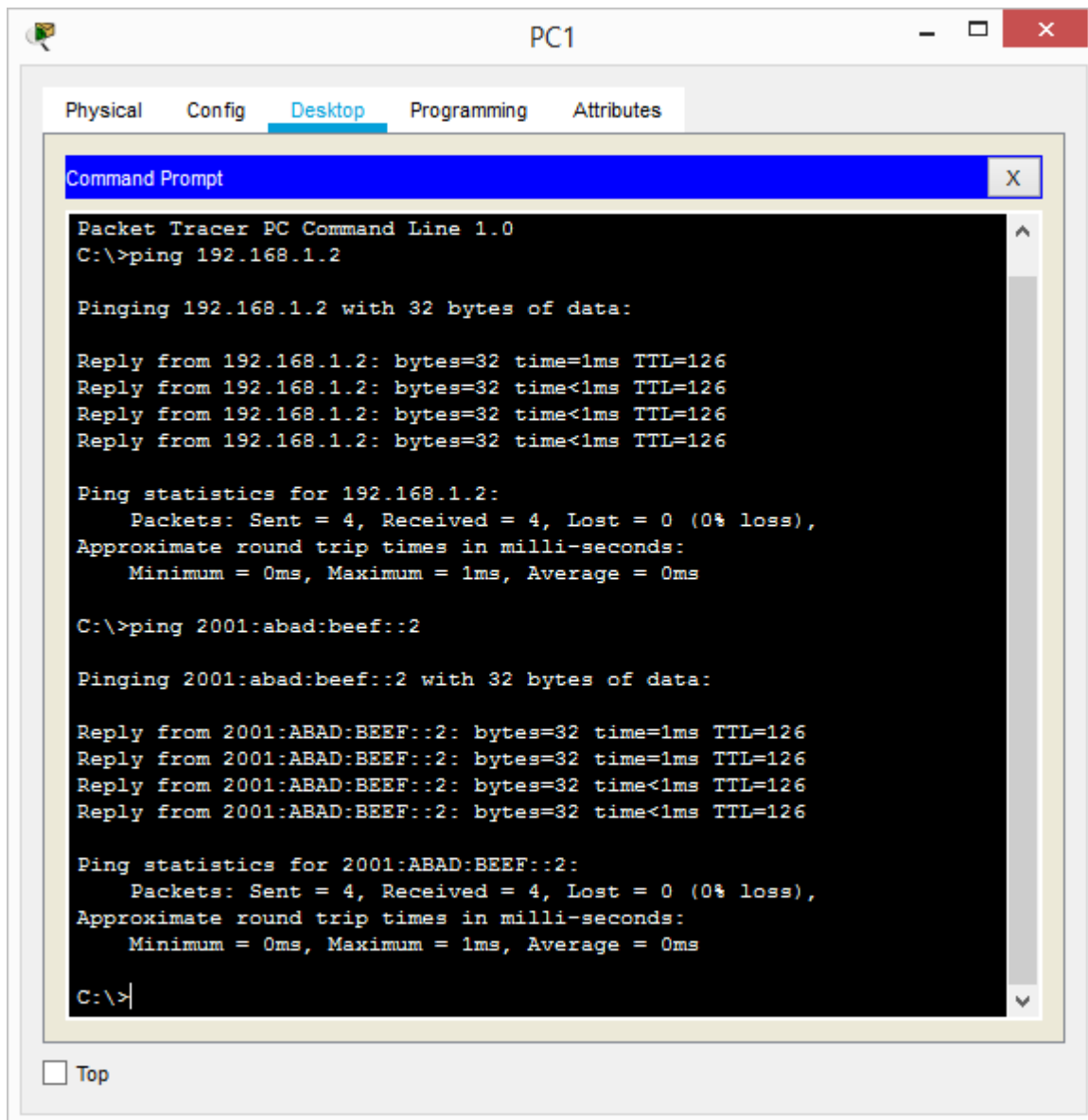




Now you can ping from PC0 to PC1 by both ipv4 and ipv6 address:







### Reference:

Cisco IOS IPv6 Command Reference

<https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/ipv6/command/ipv6-cr-book.html>