

Types of IPv6 addresses in Windows 10

- DHCP: DHCP is the DHCPv6 address assigned to the machine.
 - DHCP can run at the same time as SLAAC or independently.
 - Does not provide default gateway information unless a router is connected to the network for Router Solicitation and Router advertisement (RS and RA.)
- Temporary: If SLAAC is enabled on the network a host may elect to use a SLACC address for communications with the outside world
 - There can be multiple temporary SLAAC address on a machine, and individual programs can grab ones
 - Buggy programs or process stuck in loops can open hundreds of temporary addresses.
 - A good short read on temporary addresses
 - <https://rakhesh.com/networks/why-multiple-temporary-ipv6-addresses-when-using-slaac/>
- Public: SLAAC IPV6 address
 - Can coexist with DHCPv6 address
- Other: The other address is the Link local address
 - All IPv6 nodes will always have a link local address for neighbor discovery
 - Uses EUI-64
 - This is why the host portion of the Public and Other address are identical

```
PS C:\Users\IEUser> netsh
netsh>int ipv6
netsh interface ipv6>show addre

Interface 1: Loopback Pseudo-Interface 1

Addr Type  DAD State  Valid Life Pref. Life Address
-----
Other      Preferred  infinite   infinite  ::1

Interface 5: Ethernet

Addr Type  DAD State  Valid Life Pref. Life Address
-----
Dhcp       Preferred  11d23h51m5s 7d23h51m5s 2001:db8::686:f210:8e3:f3bb
Temporary Preferred  6d23h59m40s 23h51m49s 2001:db8::3405:e84e:e980:17e9
Public     Preferred  29d23h59m56s 6d23h59m56s 2001:db8::9167:2883:3c9:bd2b
Other      Preferred  infinite    infinite  fe80::9167:2883:3c9:bd2b%5

netsh interface ipv6>
```

The process of addressing an IPv6 node:

- 1) Once connected, a new node creates a Link Local address for neighbor discovery
- 2) The node will send a Neighbor Solicitation (NS) messages to verify the address is not in use
 - a) NOTE: If an address is in use, then the link local address will need to be manually configured, autoconfiguration will stop at this point. Because Link local uses EUI-64, which is based off the mac address of the NIC it can only create one link local address

- 3) The node will now send out Router Solicitation messages (RS) to the All routers multicast address FF02::2 from the link local address (in the fe80::/64 network)
 - a) If a Router Advertisement is not received the new node will begin soliciting for a DHCP server via the All-devices address FF02::1
 - i) If this happens the node will not have a default gateway, DHCP does not create a default gateway with IPv6
- 4) The node will receive back a Router Advertisement (RA) with instructions on how to connect
 - a) The RA will contain the following information:
 - i) Subnet prefix of the network in use
 - ii) Inform the node to use SLAAC or Stateful DHCPv6
- 5) From this point the node will finish autoconfiguring using either SLAAC or DHCPv6

Types of Stateless Address Autoconfiguration (SLAAC)

- EUI-64: Converts MAC address into the host address of an IPv6 address
 - A great video on EUI-64
 - <https://www.youtube.com/watch?v=eMe88FqiPso>
- Random: Some nodes can elect to use privacy extensions and create random addresses for the host portion of their address (the last 64 bits)
 - This is supported by windows and is called Privacy Extensions
 - Is based on RFC 4941

IPv6 solicited-node multicast addresses

- A node will take the last 24 bits (last 6 hex characters) and append them to ff02::1:ff to create their solicited-node multicast address.
 - This is how all IPv6 nodes can be in a multicast message without broadcast.
 - A great video on multicast addresses
 - <https://www.youtube.com/watch?v=nTsD9BxmjaQ>
- Every node also has a “solicited node multicast address” as explained above. Each node also adopts one of these addresses.

Multicast address	Address purpose
FF02::1	All-devices
FF02::2	All-routers
FF02::5	OSPF routers
FF02::6	OSPF DRs
FF02::9	RIP routers
FF02::A	EIGRP routers
FF02::1:2	DHCP server/relay

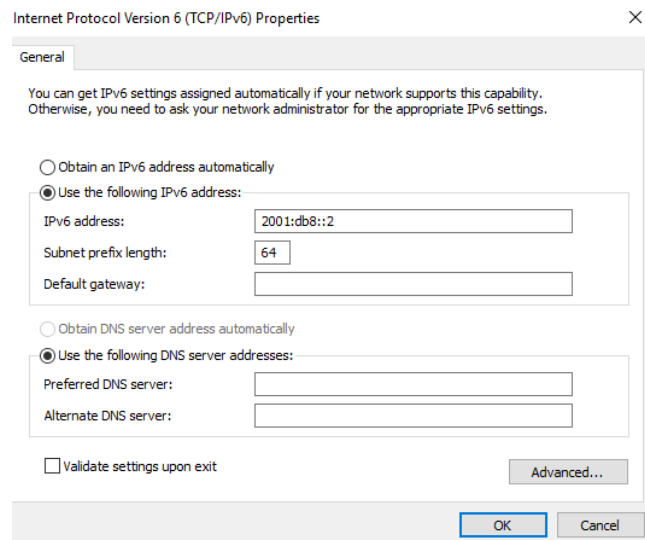
Router Advertisement

- A Router Advertisement (RA) is sent from a router to a node every 200 seconds, or in response to a received Router Solicitation (RS). The RA can contain the following information:
 - IPv6 subnet in use on the network.
 - The On-Link flag (L) state
 - Tells the node that the advertised prefix is also the local prefix
 - The Autonomous address-autoconfiguration flag (A) state
 - Tells the node that SLAAC is being used
 - The Managed address flag (M) state
 - Tells the node to use use stateful DHCPv6
 - Not in image below
 - Other config flat (O) state
 - Tells the node there is further information
 - Not in image below
- A good article on Router Advertisements
 - <https://blogs.infoblox.com/ipv6-coe/why-you-must-use-icmpv6-router-advertisements-ras/>

```
> Frame 10: 110 bytes on wire (880 bits), 110 bytes captured (880 bits) on interface -, id 0
▼ Ethernet II, Src: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03), Dst: IPv6mcast_01 (33:33:00:00:00:01)
  > Destination: IPv6mcast_01 (33:33:00:00:00:01)
  > Source: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)
  Type: IPv6 (0x86dd)
▼ Internet Protocol Version 6, Src: fe80::e3c:79ff:fefe:3, Dst: ff02::1
  0110 .... = Version: 6
  > ... 0000 0000 .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
  .... 0000 0000 0000 0000 = Flow Label: 0x000000
  Payload Length: 56
  Next Header: ICMPv6 (58)
  Hop Limit: 255
  Source Address: fe80::e3c:79ff:fefe:3
  Destination Address: ff02::1
  [Source SA MAC: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)]
▼ Internet Control Message Protocol v6
  Type: Router Advertisement (134)
  Code: 0
  Checksum: 0xed55 [correct]
  [Checksum Status: Good]
  Cur hop limit: 64
  > Flags: 0x00, Prf (Default Router Preference): Medium
  Router lifetime (s): 1800
  Reachable time (ms): 0
  Retrans timer (ms): 0
  ▼ ICMPv6 Option (Source link-layer address : 0c:3c:79:fe:00:03)
    Type: Source link-layer address (1)
    Length: 1 (8 bytes)
    Link-layer address: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)
  ▼ ICMPv6 Option (Prefix information : 2001:db8::/64)
    Type: Prefix information (3)
    Length: 4 (32 bytes)
    Prefix Length: 64
  ▼ Flag: 0xc0, On-link flag(L), Autonomous address-configuration flag(A)
    1... .... = On-link flag(L): Set
    .1... .... = Autonomous address-configuration flag(A): Set
    ..0. .... = Router address flag(R): Not set
    ...0 0000 = Reserved: 0
    Valid Lifetime: 2592000
    Preferred Lifetime: 604800
    Reserved
    Prefix: 2001:db8::
```

Configuring static IPv6 addresses

- We can configure static IP address in IPv6 just like in IPv4, the only consideration is the top 128 addresses in a /64 subnet are reserved anycast addresses.
- If router advertisements have been setup on the router we can configure a static IP (and DNS) on a node without defining the default gateway.
 - The RA will define the gateway for our machine.



```
PS C:\Users\Administrator> ipconfig /all

Windows IP Configuration

Host Name . . . . . : WIN-LCF7K13U2LS
Primary Dns Suffix . . . . . :
Node Type . . . . . : Hybrid
IP Routing Enabled. . . . . : No
WINS Proxy Enabled. . . . . : No

Ethernet adapter Ethernet:

Connection-specific DNS Suffix . :
Description . . . . . : Intel(R) PRO/1000 MT Network Connection
Physical Address. . . . . : 0C-F1-DD-C2-00-00
DHCP Enabled. . . . . : No
Autoconfiguration Enabled . . . : Yes
IPv6 Address. . . . . : 2001:db8::2(Preferred)
IPv6 Address. . . . . : 2001:db8::364f:e90c:2541:b448(Preferred)
Lease Obtained. . . . . : Wednesday, January 5, 2022 4:30:55 PM
Lease Expires . . . . . : Monday, January 17, 2022 4:30:55 PM
IPv6 Address. . . . . : 2001:db8::9cea:db75:e17a:fce1(Preferred)
Link-local IPv6 Address . . . . : fe80::9cea:db75:e17a:fce1%3(Preferred)
IPv4 Address. . . . . : 10.0.0.2(Preferred)
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . : fe80::e3c:79ff:fefe:3%3
                             10.0.0.1
DHCPv6 IAID . . . . . : 51179997
DHCPv6 Client DUID. . . . . : 00-01-00-01-29-65-30-49-0C-F1-DD-C2-00-00
DNS Servers . . . . . : 127.0.0.1
NetBIOS over Tcpip. . . . . : Enabled

Tunnel adapter isatap.{FD08F84D-F086-4DFD-A987-1CA3ADC91B41}:

Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . :
Description . . . . . : Microsoft ISATAP Adapter
Physical Address. . . . . : 00-00-00-00-00-00-E0
DHCP Enabled. . . . . : No
Autoconfiguration Enabled . . . : Yes
PS C:\Users\Administrator>
```

Configure Stateless addressing (SLAAC) in Juniper

This setup is fairly straightforward, you will need to

- Create an interface with an IPv6 address
- Enable route-advertisements with the appropriate prefix

Juniper config Example:

```
set interfaces ge-0/0/1 unit 0 family inet6 address 2001:db8::1/64
```

```
set protocols router-advertisement interface ge-0/0/1.0 prefix 2001:db8::/64
```

```
interfaces {
  ge-0/0/1 {
    unit 0 {
      family inet {
        address 10.0.0.1/24;
      }
      family inet6 {
        address 2001:db8::1/64;
      }
    }
  }
}
protocols {
  router-advertisement {
    interface ge-0/0/1.0 {
      prefix 2001:db8::/64
    }
  }
}
```

Configure stateful autoconfiguration with Windows DHCPv6 in Juniper

- This setup is like the stateless setup, plus one more command
 - Under router-advertisement, interface, prefix we need to specify no-autonomous
 - This changes the A flag in the Router Advertisement message to unset, and hosts will not use SLAAC
- This setup also works with in Dual stacked environments
- You can verify these changes on a DHCPv6 node by
 - Verify any assigned IPv6 addresses are in the DHCP lease database
 - Verify there are no IPv6 address with address type "public"

```

PS C:\Users\IEUser> ipconfig /all

Windows IP Configuration

Host Name . . . . . : MSEDGEWIN10
Primary Dns Suffix . . . . . :
Node Type . . . . . : Hybrid
IP Routing Enabled. . . . . : No
WINS Proxy Enabled. . . . . : No

Ethernet adapter Ethernet:

Connection-specific DNS Suffix . :
Description . . . . . : Intel(R) PRO/1000 MT Network Connection #2
Physical Address. . . . . : 0C-8A-62-C8-00-00
DHCP Enabled. . . . . : Yes
Autoconfiguration Enabled . . . . : Yes
IPv6 Address. . . . . : 2001:db8::9158:6bf7:7dbf:41b8(Preferred)
Lease Obtained. . . . . : Wednesday, January 5, 2022 6:04:34 PM
Lease Expires . . . . . : Monday, January 17, 2022 4:35:46 PM
Link-local IPv6 Address . . . . . : fe80::9167:2883:3c9:bd2b%5(Preferred)
IPv4 Address. . . . . : 10.0.0.10(Preferred)
Subnet Mask . . . . . : 255.255.255.0
Lease Obtained. . . . . : Wednesday, January 5, 2022 6:32:57 PM
Lease Expires . . . . . : Thursday, January 13, 2022 6:32:57 PM
Default Gateway . . . . . : fe80::e3c:79ff:fefe:3%5
                             10.0.0.1
DHCP Server . . . . . : 10.0.0.2
DHCPv6 IAID . . . . . : 118262370
DHCPv6 Client DUID. . . . . : 00-01-00-01-24-23-10-85-00-0C-29-7B-A4-A5
DNS Servers . . . . . : 10.0.0.2
NetBIOS over Tcpip. . . . . : Enabled

PS C:\Users\IEUser> netsh int ipv6 show addr

Interface 1: Loopback Pseudo-Interface 1

Addr Type  DAD State  Valid Life Pref. Life Address
-----
Other      Preferred  infinite  infinite ::1

Interface 5: Ethernet

Addr Type  DAD State  Valid Life Pref. Life Address
-----
Dhcp       Preferred  11d21h47m51s 7d21h47m51s 2001:db8::9158:6bf7:7dbf:41b8
Other      Preferred  infinite  infinite fe80::9167:2883:3c9:bd2b%5

PS C:\Users\IEUser>

```

DHCP			
File Action View Help			
<div> DHCP <ul style="list-style-type: none"> win-lcf7k13u2ls <ul style="list-style-type: none"> IPv4 <ul style="list-style-type: none"> IPv6 <ul style="list-style-type: none"> Scope [2001:db8::] lab_ipv6 <ul style="list-style-type: none"> Address Leases Exclusions Reservations Scope Options Server Options </div>			
Client IPv6 Address	Name	Lease Expiration	
2001:db8::9158:6bf7:7dbf:41b8	MSEDGEWIN10	1/17/2022 6:15:33 PM	

- As you can see in the above image, the IPv6 default gateway is a link local address. This is normal and expected behavior.
 - Nodes can also use the network address (in this example 2001:db8::1) as the default gateway, however link local is default
 - A useful thread on this
 - <https://learningnetwork.cisco.com/s/question/0D53i00000Slspi/could-someone-please-explain-me-the-sentence-bellow-a-linklocal-unicast-ipv6-address-is-used-as-the-default-gateway-by-hosts-in-a-local-network-is-the-above-sentence-correct-can-anyone-give-an-example-to-help-me-understand-it-tks>

Juniper config Example:

set interfaces ge-0/0/1 unit 0 family inet6 address 2001:db8::1/64

set protocols router-advertisement interface ge-0/0/1.0 prefix 2001:db8::/64 no-autonomous

```

interfaces {
  ge-0/0/1 {
    unit 0 {
      family inet6 {
        address 2001:db8::1/64;
      }
    }
  }
}
protocols {
  router-advertisement {
    interface ge-0/0/1.0 {
      prefix 2001:db8::/64 {
        no-autonomous;
      }
    }
  }
}

```

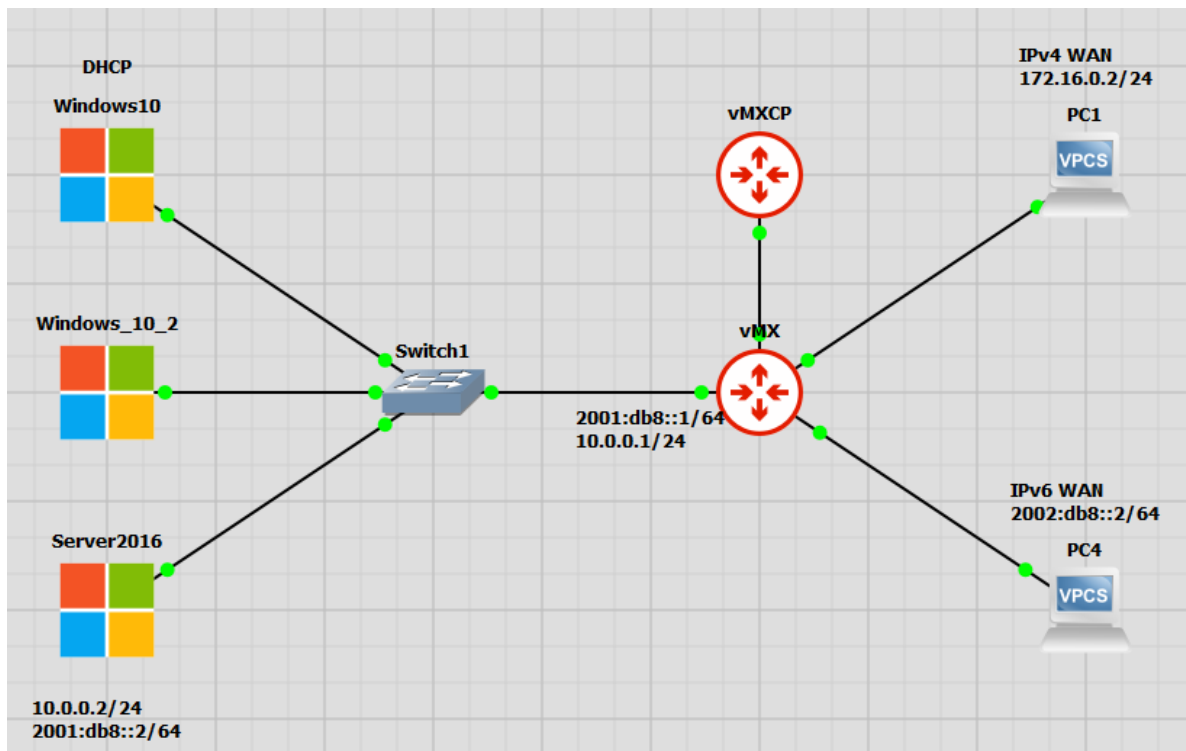
- Useful articles
 - https://www.juniper.net/documentation/en_US/junos/topics/topic-map/ipv6-interfaces-neighbor-discovery.html
 - <https://www.juniper.net/documentation/us/en/software/junos/neighbor-discovery/topics/ref/statement/autonomous-edit-protocols-router-advertisement.html>

Lab setup

Everything in this document was tested and verified working in a GNS3 environment.

- There are 4 networks in this environment:
 - IPv4 wan 172.16.0.0/24
 - IPv6 wan 2002:db8::/64
 - IPv4 lan 10.0.0.0/24
 - Ipv6 lan 2001:db8::/64
- 1 Juniper vMX with 3 interfaces
 - One for the IPv4 simulated wan
 - One for the IPv6 simulated wan
 - One dual stacked interface for the lan running both
 - One IPv4 address
 - One IPv6 address
- 1 unmanaged switch
- 2 nodes on WAN links that we can ping
- 1 Windows server 2016, running DHCP and DNS
- 2 windows 10 clients on the lan

After setup we are able to verify that, as we add and remove nodes from the lan network they are able to acquire IPv4 and IPv6 addresses from the Windows server via DHCP and are able to have two way communication with the IPv4 and IPv6 WAN networks.



DHCP

File

Action

View

Help

←

→

DHCP

▼

win-lcf7k13u2ls

▼

IPv4

>

Scope [10.0.0.0] Lab_ipv4

Server Options

Policies

>

Filters

▼

IPv6

▼

Scope [2001:db8::] lab_ipv6

Address Leases

Exclusions

Reservations

Scope Options

Server Options

Name

IPv4

IPv6

Actions

win-lcf7k13u2ls

More Actions

Juniper config:

```
set interfaces ge-0/0/1 unit 0 family inet address 10.0.0.1/24
set interfaces ge-0/0/1 unit 0 family inet6 address 2001:db8::1/64
set interfaces ge-0/0/2 unit 0 family inet6 address 2002:db8::1/64
set interfaces ge-0/0/3 unit 0 family inet address 172.16.0.1/24
set protocols router-advertisement interface ge-0/0/1.0 prefix 2001:db8::/64 no-autonomous
```

```
interfaces {
  ge-0/0/1 {
    unit 0 {
      family inet {
        address 10.0.0.1/24;
      }
      family inet6 {
        address 2001:db8::1/64;
      }
    }
  }
  ge-0/0/2 {
    unit 0 {
      family inet6 {
        address 2002:db8::1/64;
      }
    }
  }
  ge-0/0/3 {
    unit 0 {
      family inet {
        address 172.16.0.1/24;
      }
    }
  }
}
protocols {
  router-advertisement {
    interface ge-0/0/1.0 {
      prefix 2001:db8::/64 {
        no-autonomous;
      }
    }
  }
}
```

Examples of packets discussed in this article

Neighbor Solicitation message

```
> Frame 503: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface -, id 0
▼ Ethernet II, Src: 0c:f1:dd:c2:00:00 (0c:f1:dd:c2:00:00), Dst: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)
  > Destination: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)
  > Source: 0c:f1:dd:c2:00:00 (0c:f1:dd:c2:00:00)
  Type: IPv6 (0x86dd)
▼ Internet Protocol Version 6, Src: fe80::9cea:db75:e17a:fce1, Dst: fe80::e3c:79ff:fefe:3
  0110 .... = Version: 6
  > .... 0000 0000 .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
  .... 0000 0000 0000 0000 0000 0000 = Flow Label: 0x000000
  Payload Length: 32
  Next Header: ICMPv6 (58)
  Hop Limit: 255
  Source Address: fe80::9cea:db75:e17a:fce1
  Destination Address: fe80::e3c:79ff:fefe:3
  [Destination SA MAC: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)]
▼ Internet Control Message Protocol v6
  Type: Neighbor Solicitation (135)
  Code: 0
  Checksum: 0x2c35 [correct]
  [Checksum Status: Good]
  Reserved: 00000000
  Target Address: fe80::e3c:79ff:fefe:3
▼ ICMPv6 Option (Source link-layer address : 0c:f1:dd:c2:00:00)
  Type: Source link-layer address (1)
  Length: 1 (8 bytes)
  Link-layer address: 0c:f1:dd:c2:00:00 (0c:f1:dd:c2:00:00)
```

Neighbor Advertisement message

```
> Frame 504: 78 bytes on wire (624 bits), 78 bytes captured (624 bits) on interface -, id 0
▼ Ethernet II, Src: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03), Dst: 0c:f1:dd:c2:00:00 (0c:f1:dd:c2:00:00)
  > Destination: 0c:f1:dd:c2:00:00 (0c:f1:dd:c2:00:00)
  > Source: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)
  Type: IPv6 (0x86dd)
▼ Internet Protocol Version 6, Src: fe80::e3c:79ff:fefe:3, Dst: fe80::9cea:db75:e17a:fce1
  0110 .... = Version: 6
  > .... 1100 0000 .... = Traffic Class: 0xc0 (DSCP: CS6, ECN: Not-ECT)
  .... 0000 0000 0000 0000 0000 0000 = Flow Label: 0x000000
  Payload Length: 24
  Next Header: ICMPv6 (58)
  Hop Limit: 255
  Source Address: fe80::e3c:79ff:fefe:3
  Destination Address: fe80::9cea:db75:e17a:fce1
  [Source SA MAC: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)]
▼ Internet Control Message Protocol v6
  Type: Neighbor Advertisement (136)
  Code: 0
  Checksum: 0x56f1 [correct]
  [Checksum Status: Good]
▼ Flags: 0xc0000000, Router, Solicited
  1... .. = Router: Set
  .1.. .. = Solicited: Set
  ..0. .. = Override: Not set
  ...0 0000 0000 0000 0000 0000 0000 0000 = Reserved: 0
  Target Address: fe80::e3c:79ff:fefe:3
```

Router solicitation

```
> Frame 18: 62 bytes on wire (496 bits), 62 bytes captured (496 bits) on interface -, id 0
▼ Ethernet II, Src: 0c:8a:62:c8:00:00 (0c:8a:62:c8:00:00), Dst: IPv6mcast_02 (33:33:00:00:00:02)
  > Destination: IPv6mcast_02 (33:33:00:00:00:02)
  > Source: 0c:8a:62:c8:00:00 (0c:8a:62:c8:00:00)
  Type: IPv6 (0x86dd)
▼ Internet Protocol Version 6, Src: fe80::9167:2883:3c9:bd2b, Dst: ff02::2
  0110 .... = Version: 6
  > .... 0000 0000 .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
  .... 0000 0000 0000 0000 0000 0000 = Flow Label: 0x000000
  Payload Length: 8
  Next Header: ICMPv6 (58)
  Hop Limit: 255
  Source Address: fe80::9167:2883:3c9:bd2b
  Destination Address: ff02::2
▼ Internet Control Message Protocol v6
  Type: Router Solicitation (133)
  Code: 0
  Checksum: 0x0258 [correct]
  [Checksum Status: Good]
  Reserved: 00000000
```

Router advertisement

```
> Frame 10: 110 bytes on wire (880 bits), 110 bytes captured (880 bits) on interface -, id 0
▼ Ethernet II, Src: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03), Dst: IPv6mcast_01 (33:33:00:00:00:01)
  > Destination: IPv6mcast_01 (33:33:00:00:00:01)
  > Source: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)
  Type: IPv6 (0x86dd)
▼ Internet Protocol Version 6, Src: fe80::e3c:79ff:fefe:3, Dst: ff02::1
  0110 .... = Version: 6
  > .... 0000 0000 .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
  .... 0000 0000 0000 0000 0000 0000 = Flow Label: 0x000000
  Payload Length: 56
  Next Header: ICMPv6 (58)
  Hop Limit: 255
  Source Address: fe80::e3c:79ff:fefe:3
  Destination Address: ff02::1
  [Source SA MAC: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)]
▼ Internet Control Message Protocol v6
  Type: Router Advertisement (134)
  Code: 0
  Checksum: 0xed55 [correct]
  [Checksum Status: Good]
  Cur hop limit: 64
  > Flags: 0x00, Prf (Default Router Preference): Medium
  Router lifetime (s): 1800
  Reachable time (ms): 0
  Retrans timer (ms): 0
▼ ICMPv6 Option (Source link-layer address : 0c:3c:79:fe:00:03)
  Type: Source link-layer address (1)
  Length: 1 (8 bytes)
  Link-layer address: 0c:3c:79:fe:00:03 (0c:3c:79:fe:00:03)
▼ ICMPv6 Option (Prefix information : 2001:db8::/64)
  Type: Prefix information (3)
  Length: 4 (32 bytes)
  Prefix Length: 64
▼ Flag: 0xc0, On-link flag(L), Autonomous address-configuration flag(A)
  1... .... = On-link flag(L): Set
  .1.. .... = Autonomous address-configuration flag(A): Set
  ..0. .... = Router address flag(R): Not set
  ...0 0000 = Reserved: 0
  Valid Lifetime: 2592000
  Preferred Lifetime: 604800
  Reserved
  Prefix: 2001:db8::
```