Dynamic Host Configuration Protocol (DHCP)

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What is DHCP?

- It does name resolution
  - DNS resolves IP addresses and fully qualified domain name (FQDN)
  - WINS resolves NetBIOS names and IP addresses
  - ARP resolves IP addresses and MAC addresses (outgoing packets)
  - DHCP resolves IP addresses and MAC addresses dynamically
- BootP
  - BootP is a table of IP addresses and MAC addresses on a server
  - DHCP is a dynamic BootP

What is DHCP?

- Dynamic Host Configuration Protocol
  - Used for dynamic allocation of IP addresses
  - Allows for host-specific configuration parameters to be delivered from a DHCP server to a host
- DHCP can also be used to convey permanent IP address assignments to hosts
  - Server interfaces need permanent addresses because clients need to be able to reach them
  - Also, router interfaces should have permanent addresses for stability of routing data

Is dynamic address sufficient?

- End hosts, like user nodes, only make “outgoing calls”
  - When such an end host initiates a connection, the requested server receives an IP packet from the requesting host with the host’s new temporary address and hence it can, in turn, send back the requested data
- These hosts do not receive “incoming calls” i.e., no one calls them
  - Therefore, such end hosts do not need a permanent address that potentially clients will need to know

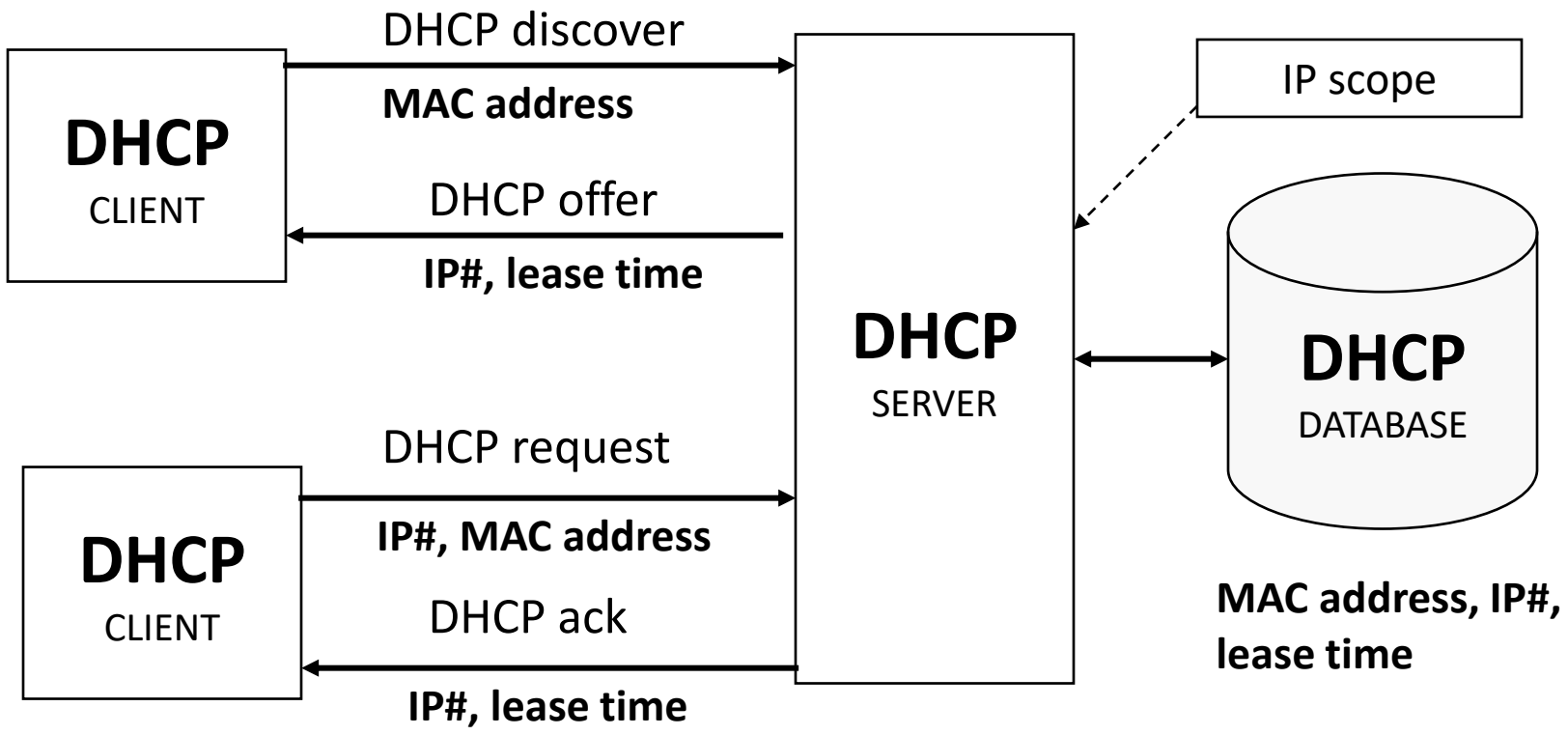
Where is DHCP used?

- Since class B and class C address spaces have been exhausted, service providers and enterprises use dynamically allocated IP addresses
  - e.g., a cable modem service provider who has many customers
  - e.g., used on the university wireless network, where many students, faculty and staff members use their wireless devices to access the campus network
- DHCP can be used whether link to endpoint is “wired” or “wireless”
  - Even with an Ethernet NIC, a host can use DHCP to dynamically obtain an IP address

DHCP Components

- DHCP client:
  - a host using DHCP to obtain an IP address and other configuration information
- DHCP server:
  - a host that returns IP addresses and other configuration information
- BOOTP relay agents:
  - host or router that passes DHCP messages between DHCP clients and DHCP servers

How does it work?

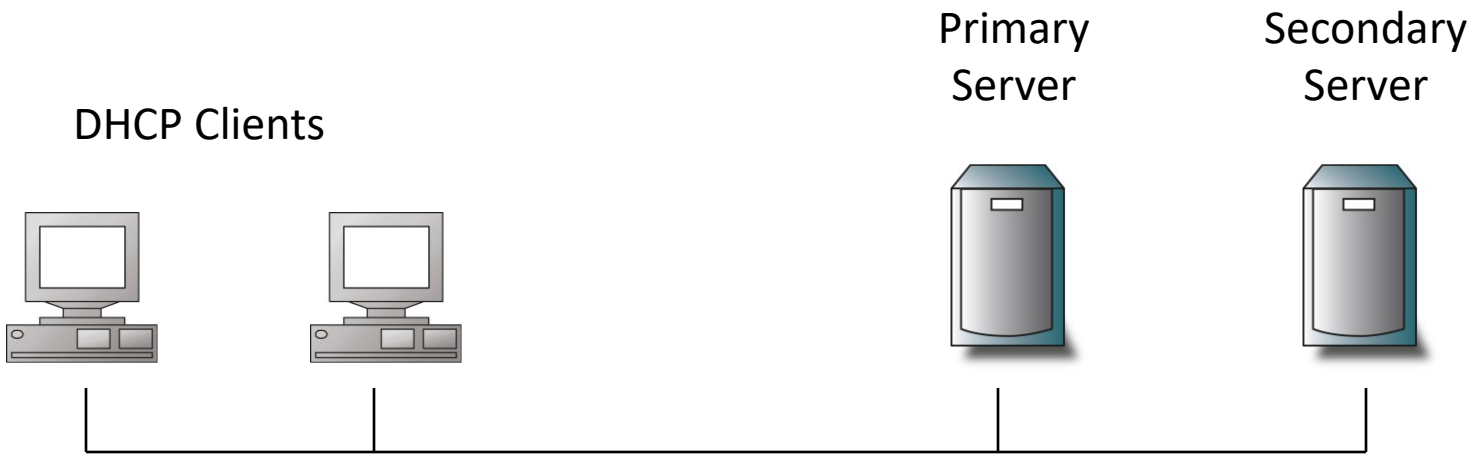


DHCP Lease Times

- Anywhere from 15 minutes – 1 year
- Common lease times & rationales
  - 15 minutes: Maximum number of addresses free
  - 3 days: Microsoft default
  - 4 months: Students can keep lease over summer
- Tradeoff

DHCP Reliability

- Two synchronized DHCP servers on the same network: Primary, Secondary
- Permanent storage constantly communicated
- Failure: Secondary server takes over



DHCP Security

- Potentially unauthorized clients
- Malicious client could exhaust address pool
- Malicious server (Rogue server)
  - Supply incorrect configuration parameters
  - Supply malicious configuration parameters

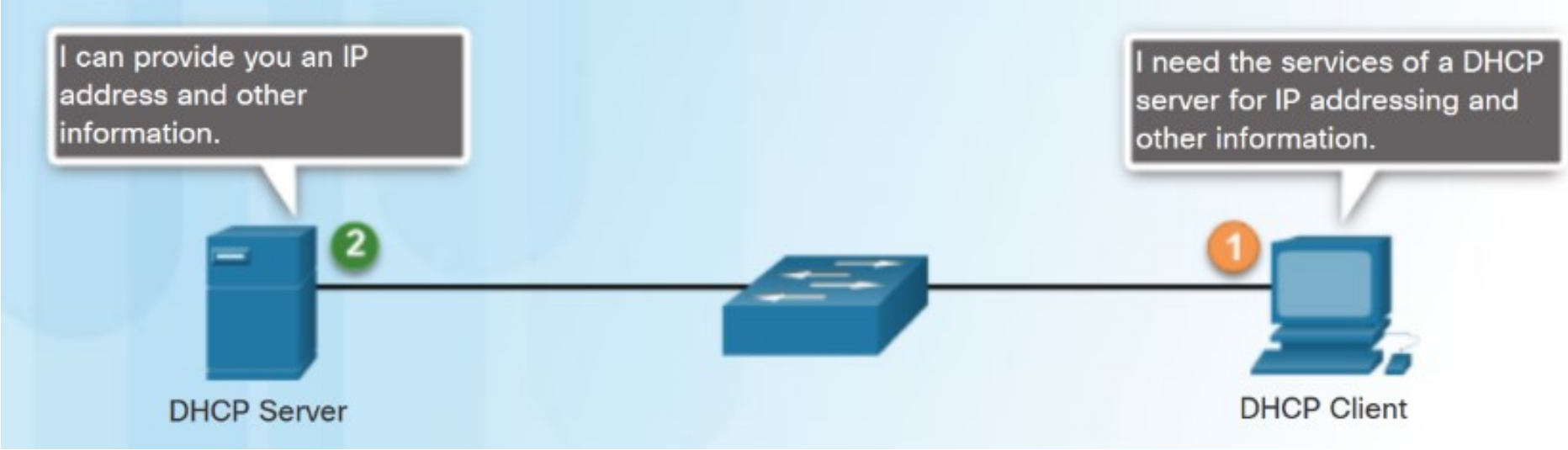
DHCP Pros and Cons

- Pros
  - simplifies the task of assigning IP addresses to each machine in the network
  - makes easy to add, remove or move a host
  - can assign defaults: default gateway, domain name, DNS server (if any)
  - ability to have fewer IP addresses than hosts
- Cons
  - if DHCP server is down, all hosts are down
  - hard to keep information on free and used IP addresses
  - Non-authenticated protocol, less secure

DHCPv4

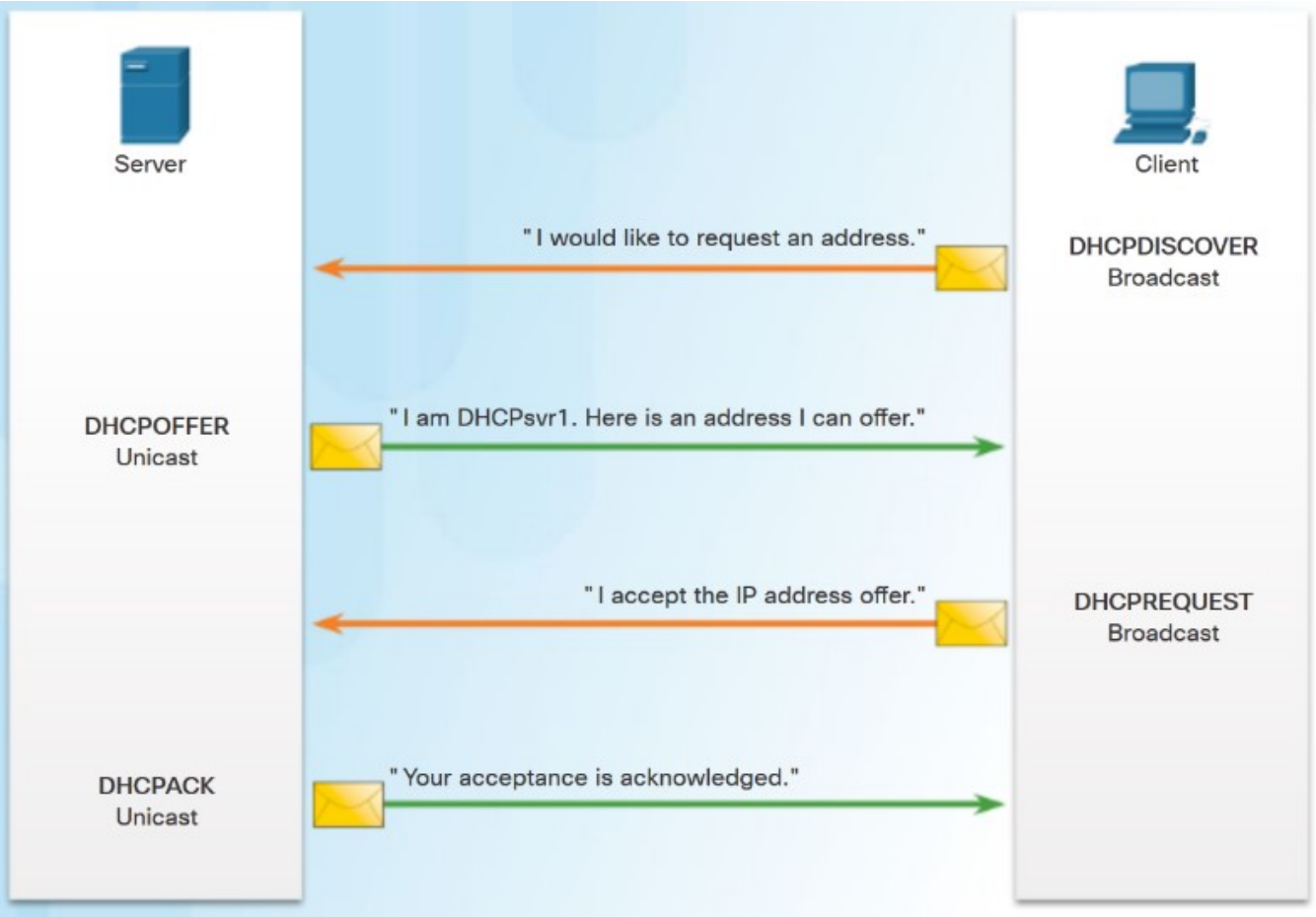
DHCPv4 Operation

- DHCPv4 assigns IPv4 addresses and other network configuration information dynamically.
  - A dedicated DHCPv4 server is scalable and relatively easy to manage.
  - A Cisco router can be configured to provide DHCPv4 services in a small network.



DHCPv4 Operation

- Four step process for a client to obtain a lease:
  - 1. DHCP Discover (DHCPDISCOVER) - client uses Layer 2 and Layer 3 broadcast addresses to find a DHCP server.
  - 2. DHCP Offer (DHCPOFFER) - DHCPv4 server sends the binding DHCPOFFER message to the requesting client as a unicast.
  - 3. DHCP Request (DHCPREQUEST) – the client sends back a broadcast DHCPREQUEST in response to the servers offer.
  - 4. DHCP Acknowledgment (DHCPACK) – the server replies with a unicast DHCPACK message.

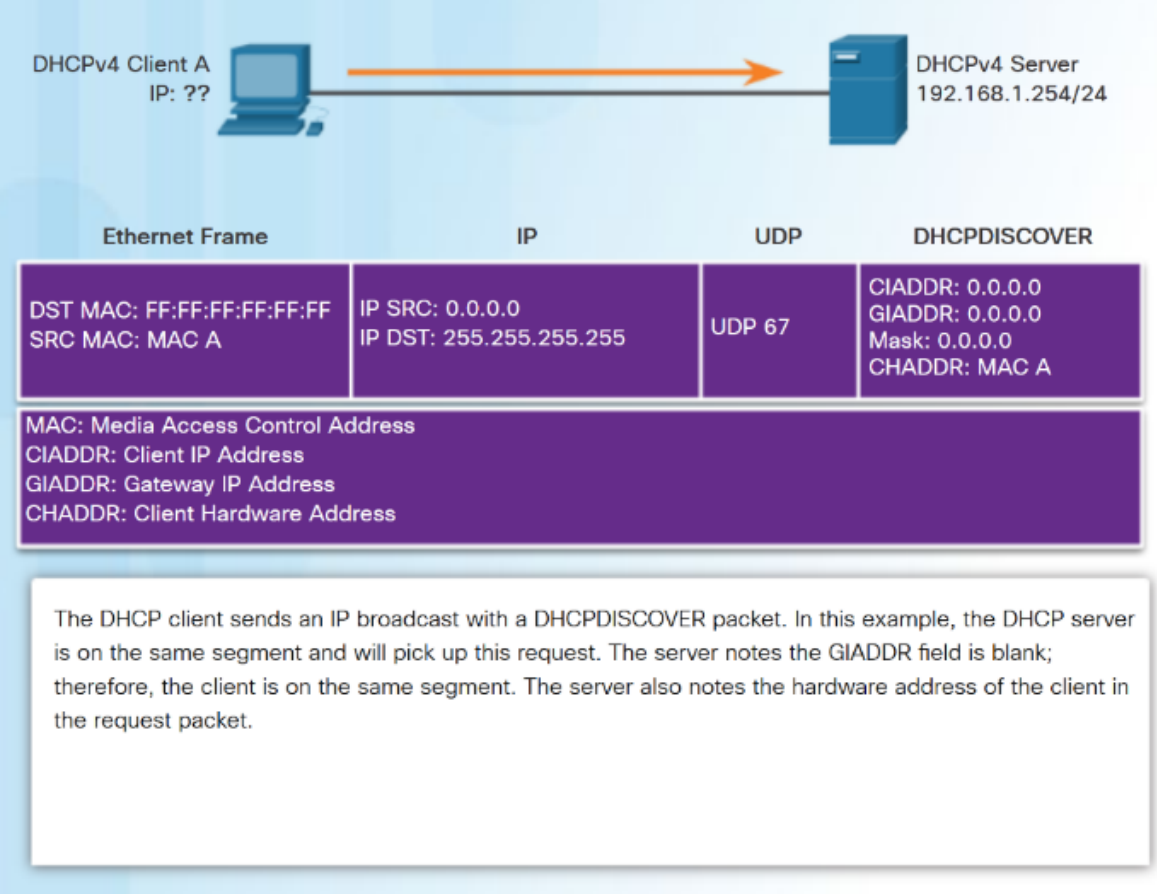


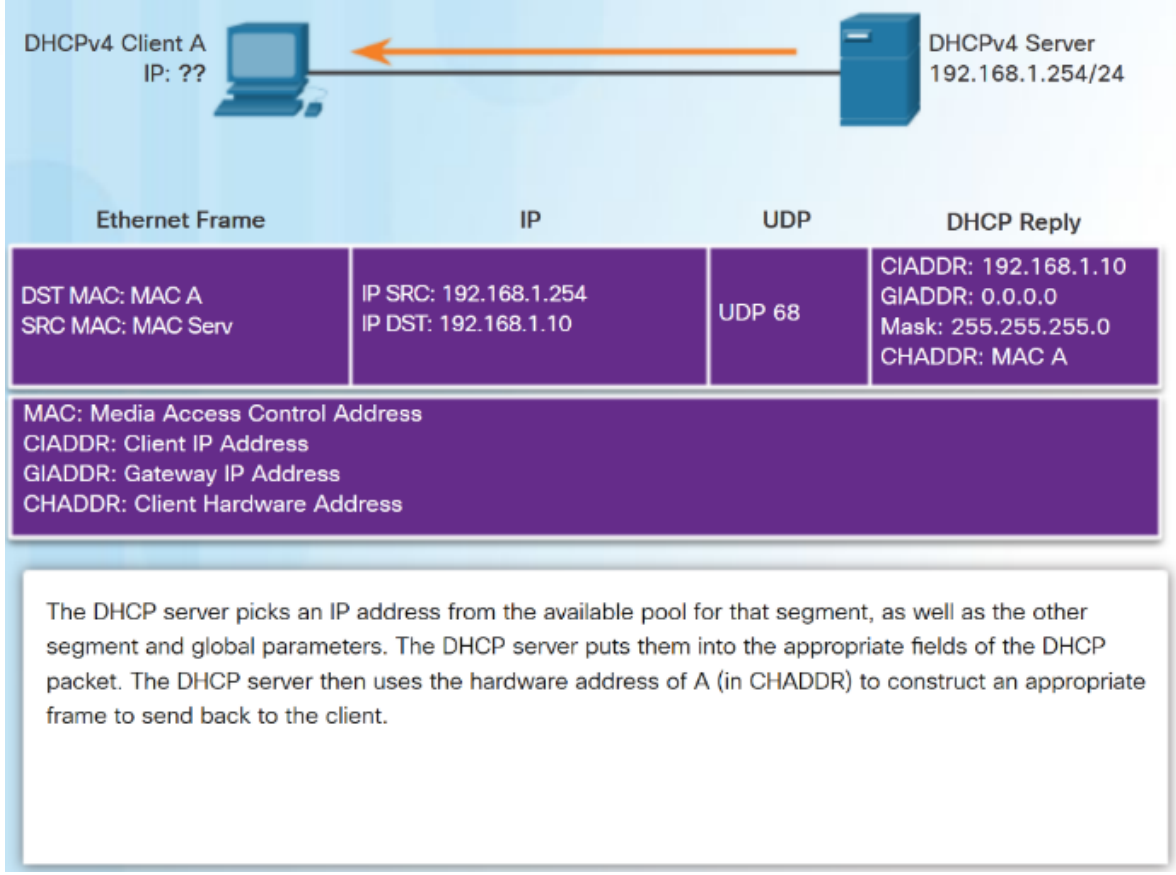
DHCPv4 Message Format

- DHCPv4 messages:
  - If sent from the client, use UDP source port 68 and destination port 67.
  - If sent from the server, use UDP source port 67 and destination port 68.

8	16	24	32
OP Code (1)	Hardware Type (1)	Hardware Address Length (1)	Hops (1)
Transaction Identifier			
Seconds - 2 bytes		Flags - 2 bytes	
Client IP Address (CIADDR) - 4 bytes			
Your IP Address (YIADDR) - 4 bytes			
Server IP Address (SIADDR) - 4 bytes			
Gateway IP Address (GIADDR) - 4 bytes			
Client Hardware Address (CHADDR) - 16 bytes			
Server Name (SNAME) - 64 bytes			
Boot Filename - 128 bytes			
DHCP Options - variable			

DHCPv4 Discover and Offer Messages





Configuring a Basic DHCPv4 Server

- Configuring a Cisco router as a DHCPv4 server:
  - Excluding IPv4 Addresses – **ip dhcp excluded-address** can exclude a single address or a range of addresses from being assigned.
  - Configuring a DHCPv4 Pool – **ip dhcp pool pool-name** command creates a pool with the specified name and puts the router in DHCPv4 configuration mode.
  - Address pool assigned using network command.
  - Default gateway assigned using default-router command.
  - Other commands are optional.

```
R1(config)# ip dhcp excluded-address 192.168.10.1 192.168.10.9
R1(config)# ip dhcp excluded-address 192.168.10.254
R1(config)# ip dhcp pool LAN-POOL-1
R1(dhcp-config)# network 192.168.10.0 255.255.255.0
R1(dhcp-config)# default-router 192.168.10.1
R1(dhcp-config)# dns-server 192.168.11.5
R1(dhcp-config)# domain-name example.com
R1(dhcp-config)# end
R1#
```

Verifying DHCPv4

- Verify DHCPv4 configuration using the **show running-config |section dhcp** command.
- Verify the operation of DHCPv4 using the **show ip dhcp binding** command.
- Verify that messages are being received or sent by the router using the **show ip dhcp server statistics** command.

```
R1# show running-config | section dhcp
ip dhcp excluded-address 192.168.10.1 192.168.10.9
ip dhcp excluded-address 192.168.10.254
ip dhcp excluded-address 192.168.11.1 192.168.11.9
ip dhcp excluded-address 192.168.11.254
ip dhcp pool LAN-POOL-1
 network 192.168.10.0 255.255.255.0
 default-router 192.168.10.1
 dns-server 192.168.11.5
 domain-name example.com
ip dhcp pool LAN-POOL-2
 network 192.168.11.0 255.255.255.0
 default-router 192.168.11.1
 dns-server 192.168.11.5
 domain-name example.com
R1#
```

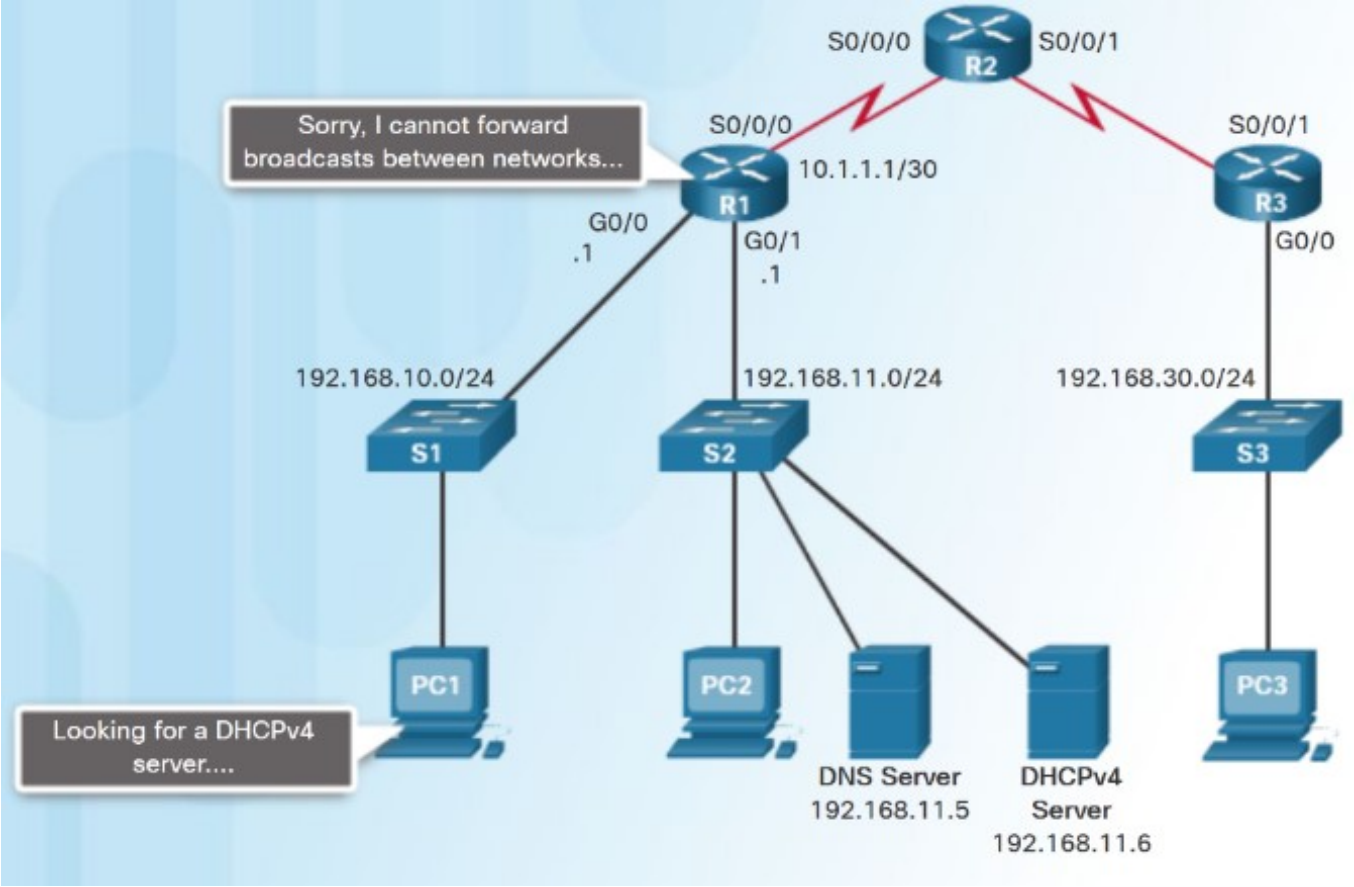
```
R1# show ip dhcp binding
Bindings from all pools not associated with VRF:
IP address      Client-ID/          Lease expiration      Type
                Hardware address/
                User name
192.168.10.10   0100.e018.5bdd.35   May 28 2013 01:06 PM Automatic
192.168.11.10   0100.b0d0.d817.e6   May 28 2013 01:10 PM Automatic
```

```
R1# show ip dhcp server statistics
Memory usage         25307
Address pools        2
Database agents      0
Automatic bindings   2
Manual bindings      0
Expired bindings     0
Malformed messages   0
Secure arp entries   0
```

DHCPv4 Relay

- DHCPDISCOVER messages are sent as broadcast messages.
- Routers do not forward broadcasts.
- A Cisco IOS helper address is configured so that the router acts as a relay agent forwarding the message to the DHCPv4 server.

```
R1(config)# interface g0/0
R1(config-if)# ip helper-address 192.168.11.6
R1(config-if)# end
R1# show ip interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet address is 192.168.10.1/24
  Broadcast address is 255.255.255.255
  Address determined by setup command
  MTU is 1500 bytes
  Helper address is 192.168.11.6
<output omitted>
```



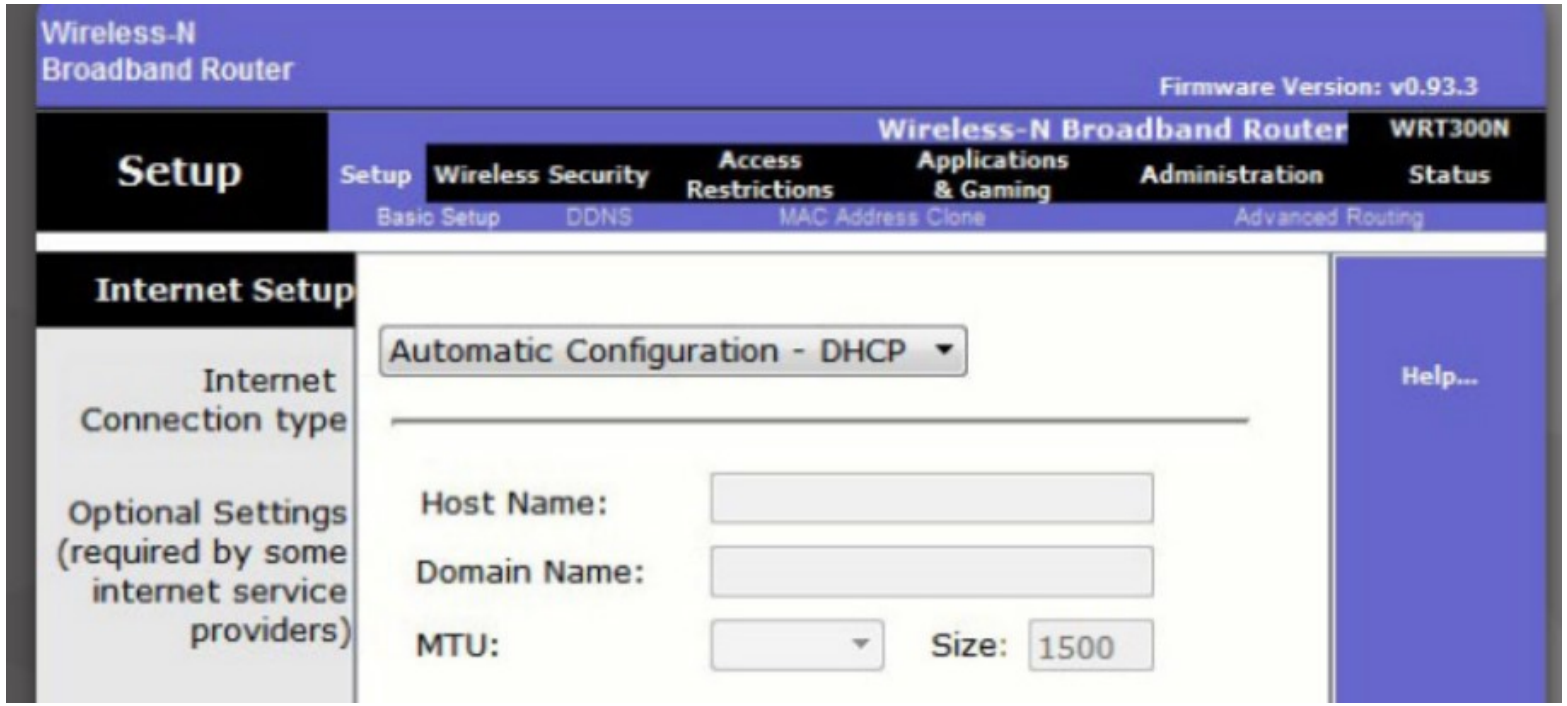
Configuring a Router as DHCPv4 Client

- Small office/home office (SOHO) and branch sites often have to be configured as DHCPv4 clients.
- Use the **ip address dhcp** command in the interface configuration mode.


```
SOHO(config)# interface g0/1
SOHO(config-if)# ip address dhcp
SOHO(config-if)# no shutdown
SOHO(config-if)#
*Jan 31 17:31:11.507: %DHCP-6-ADDRESS_ASSIGN: Interface
GigabitEthernet0/1 assigned DHCP address 209.165.201.12, mask
255.255.255.224, hostname SOHO
SOHO(config-if)# end
SOHO# show ip interface g0/1
GigabitEthernet0/1 is up, line protocol is up
  Internet address is 209.165.201.12/27
  Broadcast address is 255.255.255.255
  Address determined by DHCP
<output ommitted>
```

Configuring a Wireless Router as a DHCPv4 Client

- Wireless routers are set to receive IPv4 addressing information automatically from the ISP.



Troubleshoot DHCPv4

- Verify DHCPv4 Relay
  - use **show running-config** command to verify that the ip helper address is configured.
- Verify DHCPv4 configuration
  - use the **show running-config | include no service dhcp** command to verify dhcp is enabled, because there is no match for the **no service dhcp**.

```
R1# show running-config | section interface GigabitEthernet0/0
interface GigabitEthernet0/0
 ip address 192.168.10.1 255.255.255.0
 ip helper-address 192.168.11.6
 duplex auto
 speed auto
R1#

R1# show running-config | include no service dhcp
R1#
```

Debugging DHCPv4

- The extended ACL is used with the **debug ip packet** command to display only DHCPv4 messages.
- Another troubleshooting command is the **debug ip dhcp server events**.

```
R1(config)# access-list 100 permit udp any any eq 67
R1(config)# access-list 100 permit udp any any eq 68
R1(config)# end
R1# debug ip packet 100
IP packet debugging is on for access list 100
*IP: s=0.0.0.0 (GigabitEthernet0/1), d=255.255.255.255,
len 333, rcvd 2
*IP: s=0.0.0.0 (GigabitEthernet0/1), d=255.255.255.255,
len 333, stop process pak for forus packet
*IP: s=192.168.11.1 (local), d=255.255.255.255
(GigabitEthernet0/1), len 328, sending broad/multicast
```

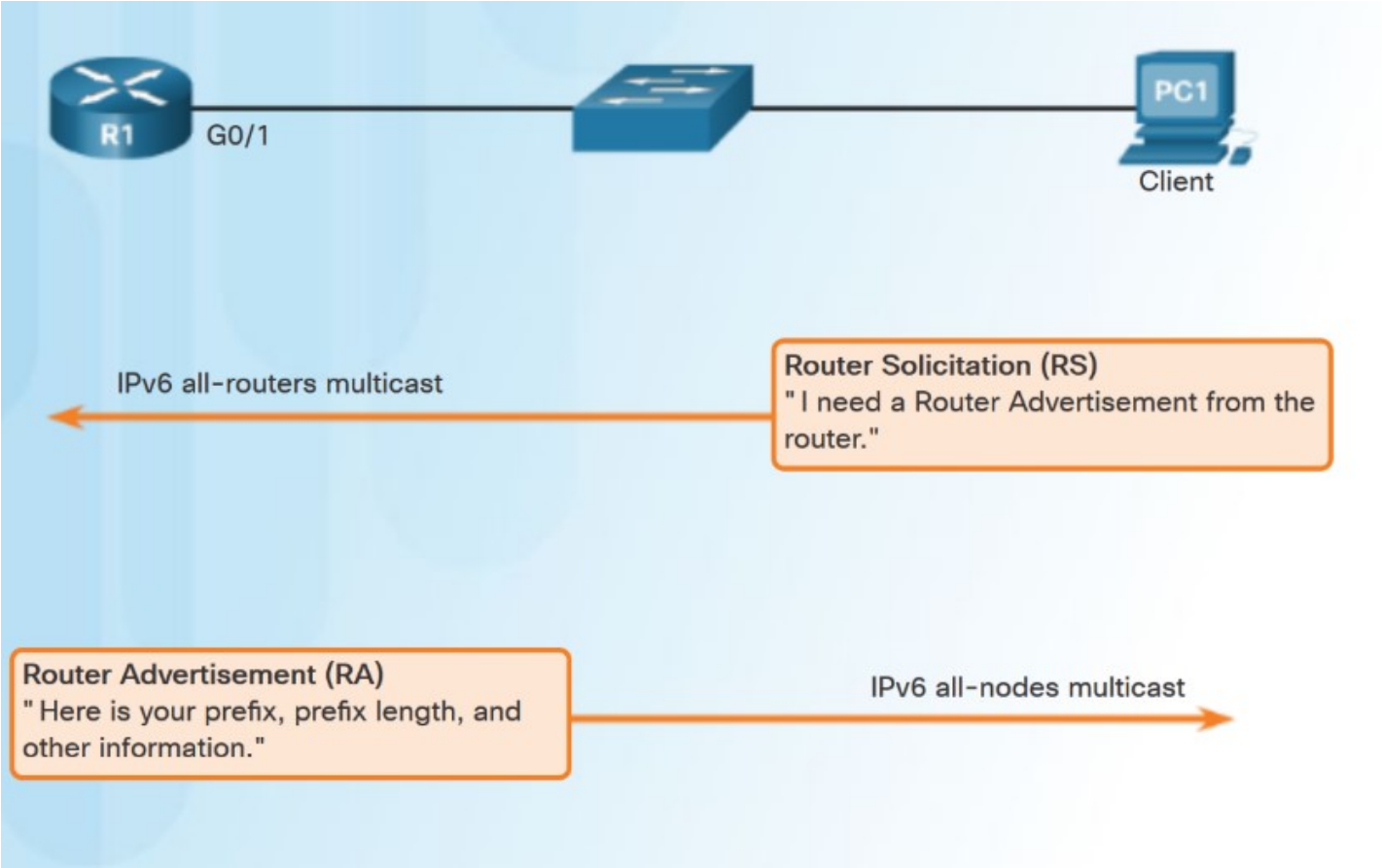
<output omitted>

```
R1# debug ip dhcp server events
DHCPD: returned 192.168.10.11 to address pool LAN-POOL-1
DHCPD: assigned IP address 192.168.10.12 to client
0100.0103.85e9.87.
DHCPD: checking for expired leases.
DHCPD: the lease for address 192.168.10.10 has expired.
DHCPD: returned 192.168.10.10 to address pool LAN-POOL-1
```

DHCPv6

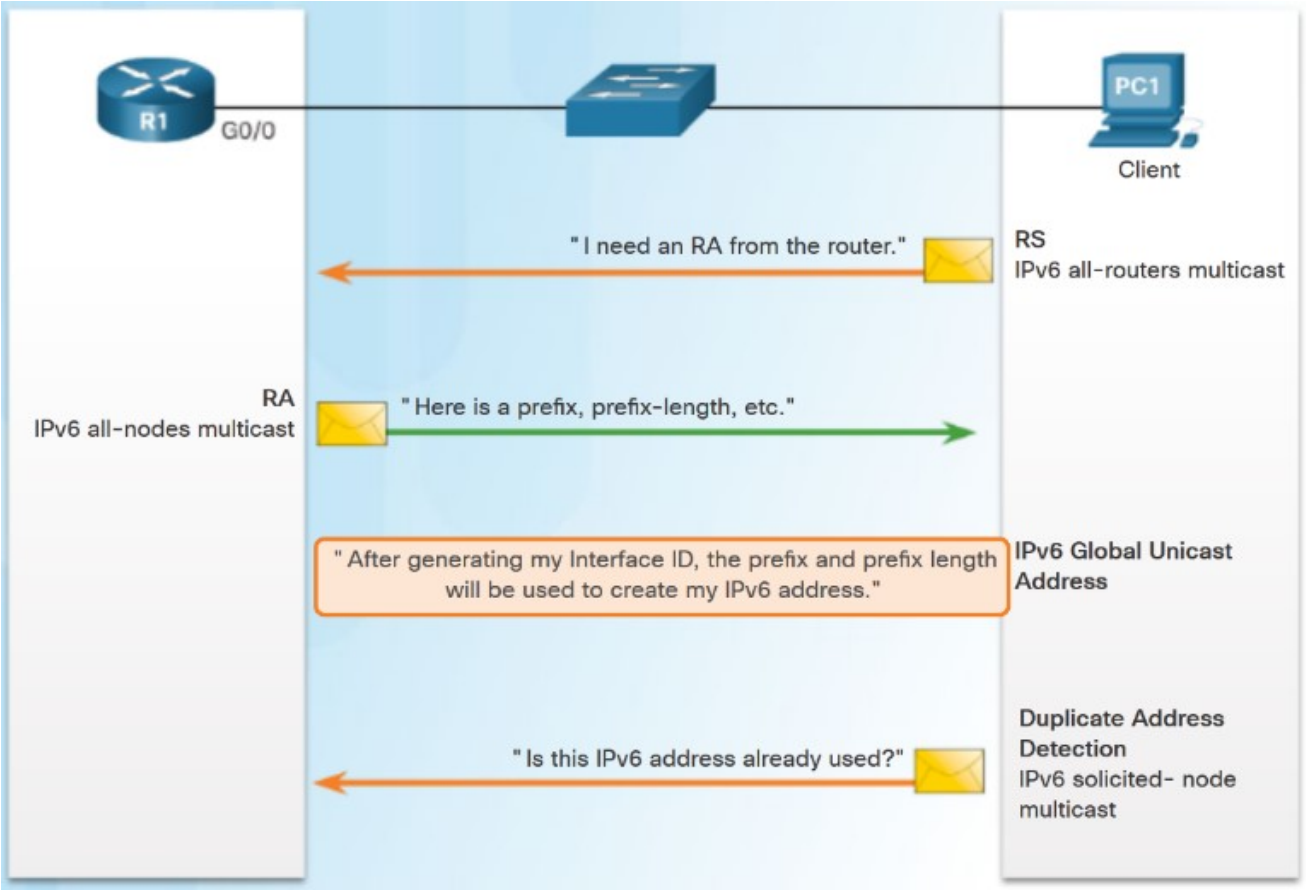
Dynamic assignment with IPv6

- Two methods to dynamically assign IPv6 global unicast addresses:
  - Stateless Address Autoconfiguration (SLAAC).
  - Dynamic Host Configuration Protocol for IPv6 (Stateful DHCPv6).
- SLAAC uses ICMPv6 Router Solicitation and Router Advertisement messages to provide addressing and other configuration information.



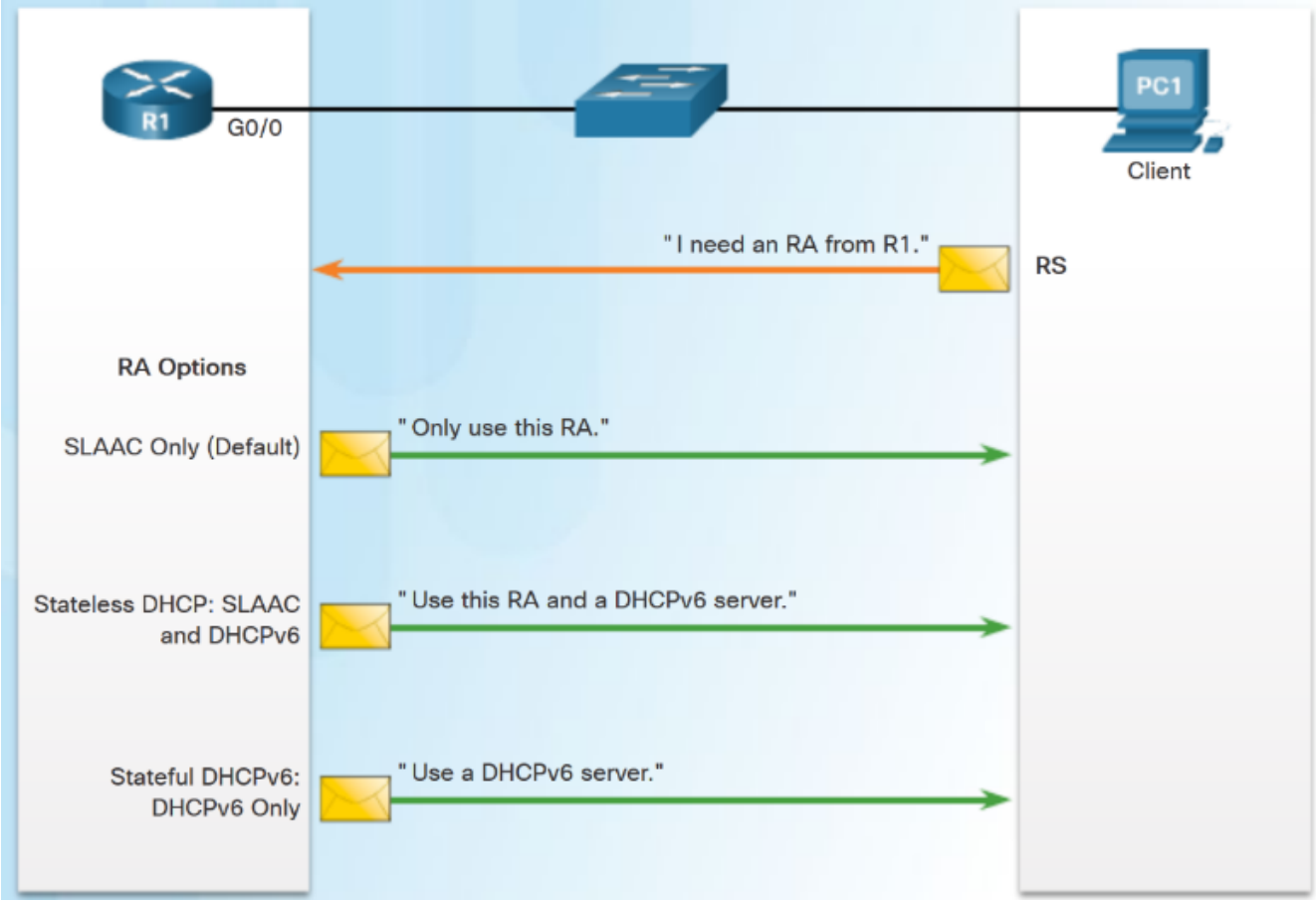
Stateless Address Autoconfiguration (SLAAC)

- The router must have IPv6 routing enabled – **ipv6 unicast-routing**
- PC1 sends an RS message to the all-routers multicast address that it needs an RA.
- R1 responds with an RA message that has the prefix and prefix length of the network.
- PC1 uses this information to create its IPv6 global unicast address. It creates its interface id using EUI-64 or randomly generates it.
- PC1 must verify that the address is unique by sending an ICMPv6 Neighbor Solicitation message.



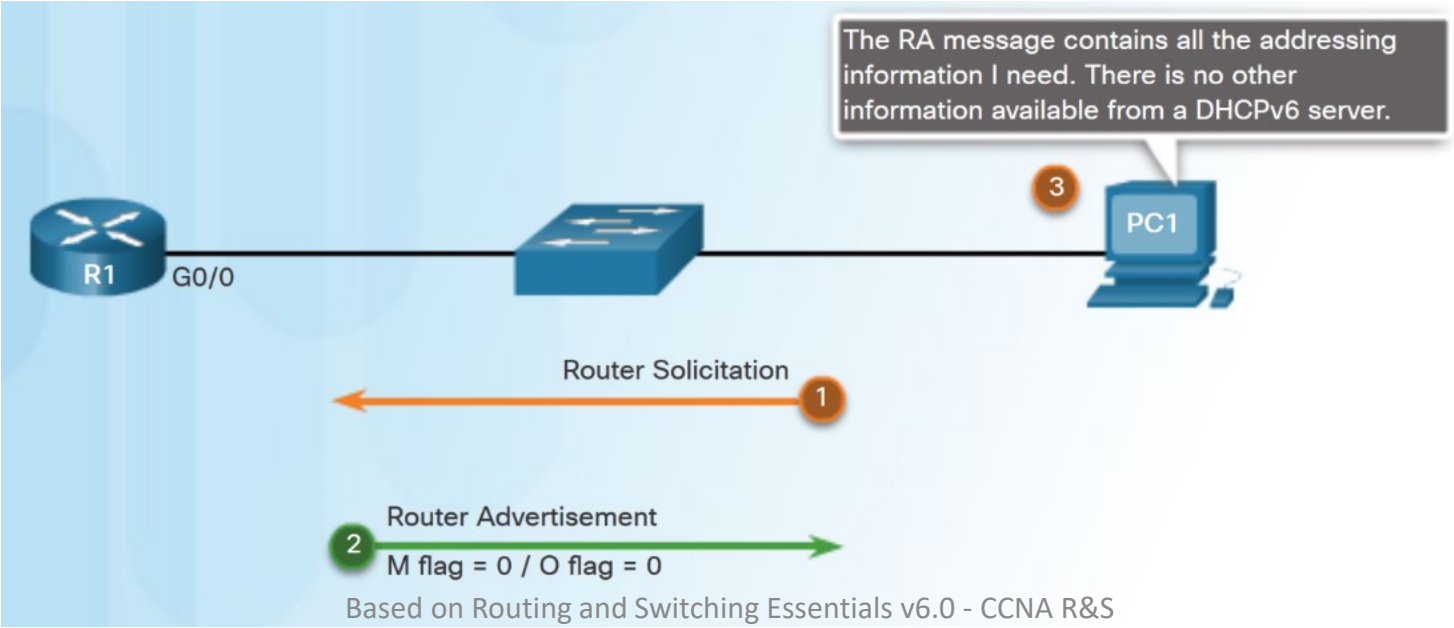
SLAAC and DHCPv6

- Different combinations of the Managed Address Configuration flag (M flag) and the Other Configuration flag (O flag) in the RA determine how the IPv6 address is assigned:
  - SLAAC (Router Advertisement only)
  - Stateless DHCPv6 (Router Advertisement and DHCPv6)
  - Stateful DHCPv6 (DHCPv6 only)



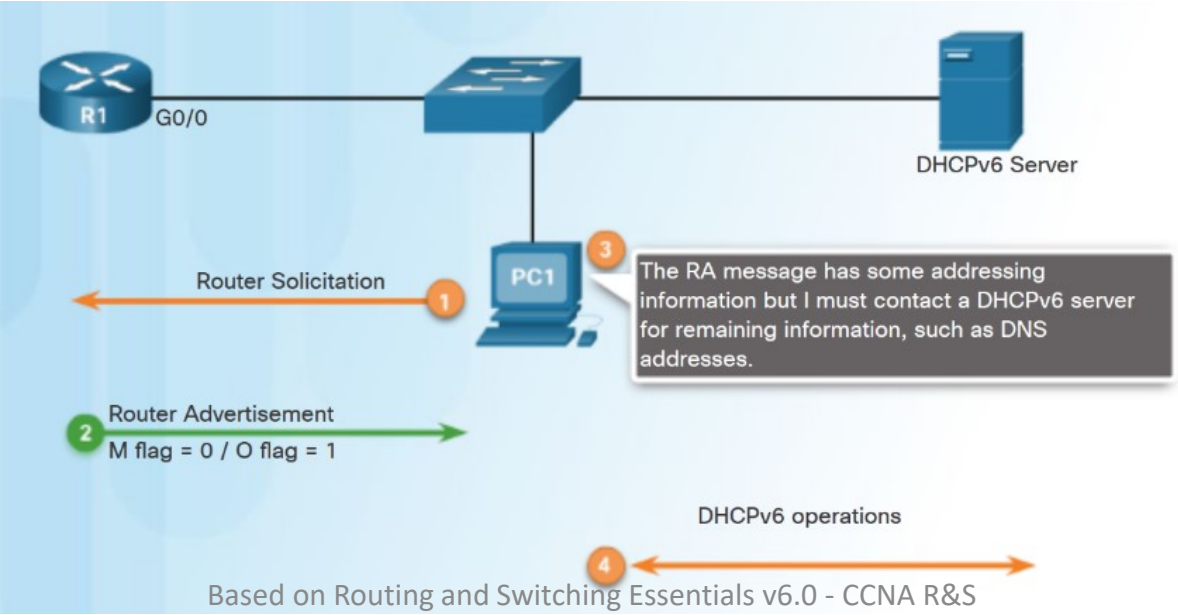
SLAAC (Router Advertisement only) Option

- SLAAC is the default on Cisco routers. Both the M flag and the O flag are set to 0 in the RA.
- This option instructs the client to use the information in the RA message only.



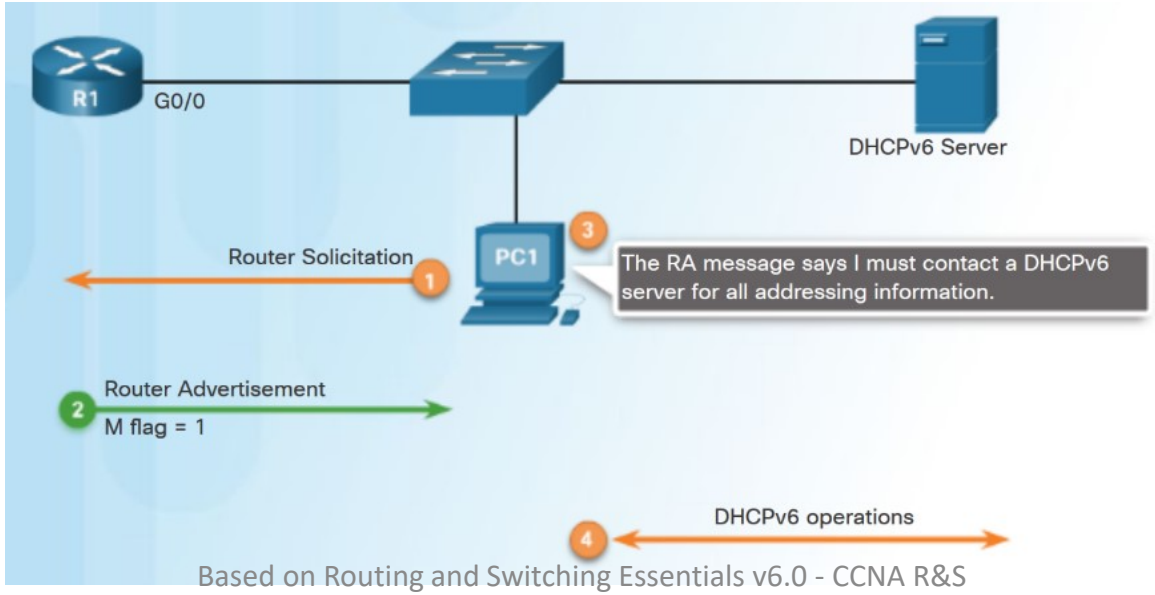
Stateless DHCPv6 Option

- Stateless DHCPv6 option – client uses the RA message for addressing, additional parameters are obtained from DHCPv6 server.
- O flag is set to 1 and the M flag is left at the default setting of 0. Use command **ipv6 nd other-config-flag**.



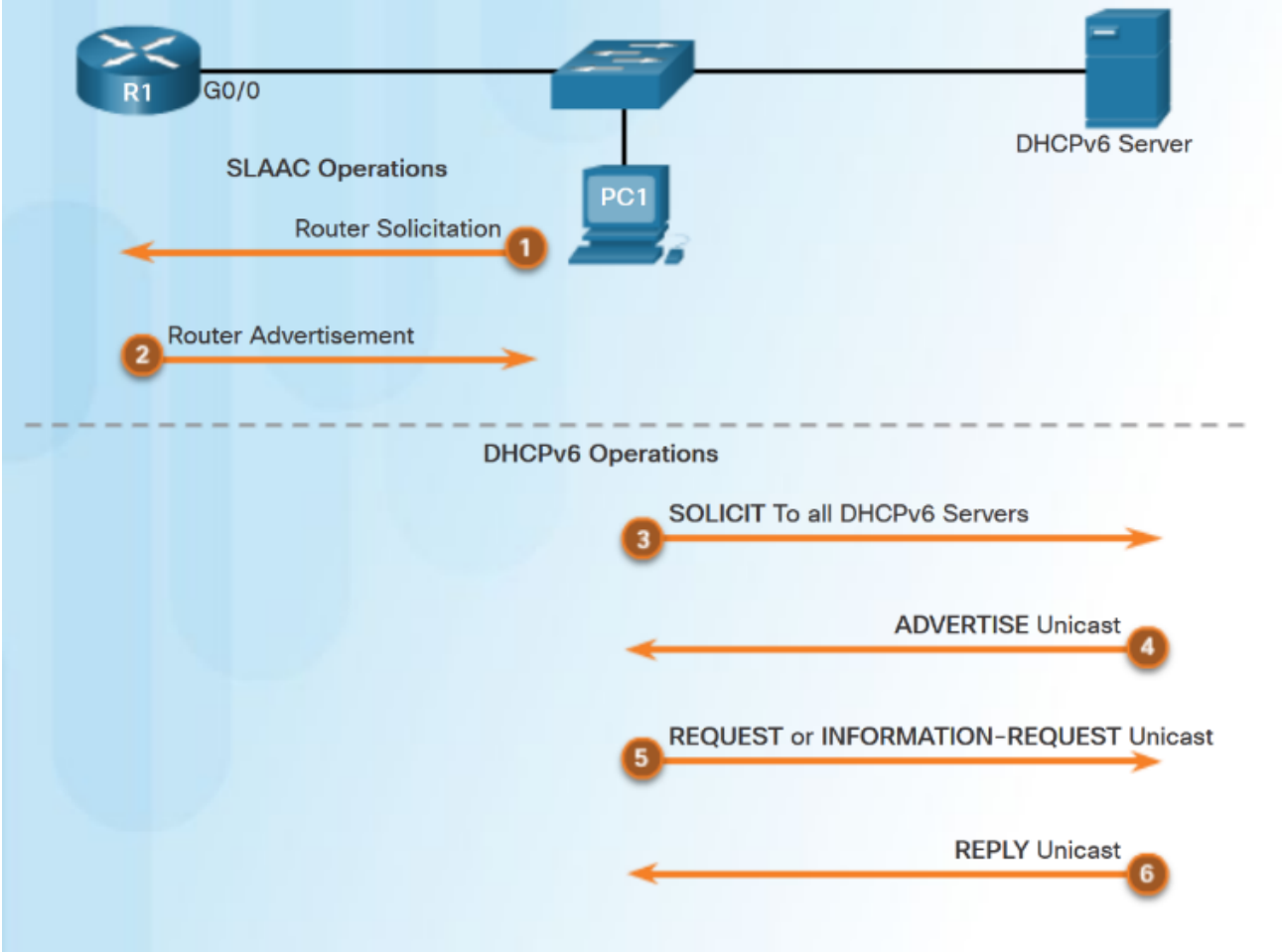
Stateful DHCPv6 Option

- RA message informs the client not to use the information in it.
- All addressing and configuration information must be obtained from a stateful DHCPv6 server.
- M flag is set to 1. Use the command **ipv6 nd managed-config-flag**.



DHCPv6 Operations

- DHCPv6 messages from server to client use UDP port 546. Client to server use UDP port 547.
- Client sends a DHCPv6 SOLICIT message using FF02::1:2.
- DHCPv6 server responds with a DHCPv6 ADVERTISE unicast message.
- Stateless DHCPv6 client - Generates its own address. Sends a DHCPv6 INFORMATION-REQUEST to the DHCPv6 server requesting only configuration parameters.
- Stateful DHCPv6 client - Sends a DHCPv6 REQUEST message to server for an IPv6 address and all other configuration parameters.



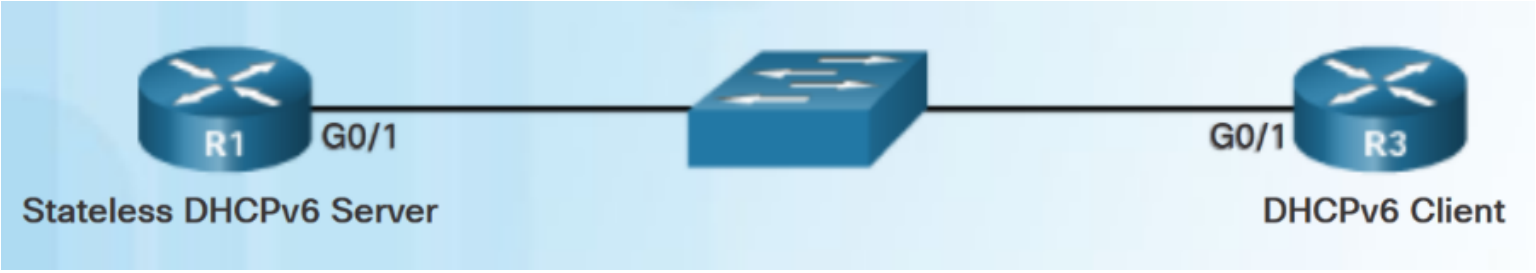
Configuring a Router as a Stateless DHCPv6 Server

1. Enable IPv6 routing. **ipv6 unicast-routing**
2. Configure a DHCPv6 pool. **ipv6 dhcp pool** *pool-name*
3. Configure pool parameters**.** **dns-server** *server-address*
4. Configure the DHCPv6 interface **ipv6 dhcp server** *pool-name*

```
R1(config)# ipv6 unicast-routing
R1(config)# ipv6 dhcp pool IPV6-STATELESS
R1(config-dhcpv6)# dns-server 2001:db8:cafe:aaaa::5
R1(config-dhcpv6)# domain-name example.com
R1(config-dhcpv6)# exit
R1(config)# interface g0/1
R1(config-if)# ipv6 address 2001:db8:cafe:1::1/64
R1(config-if)# ipv6 dhcp server IPV6-STATELESS
R1(config-if)# ipv6 nd other-config-flag
```

Configuring a Router as a Stateless DHCPv6 Client

1. IPv6 enabled on interface **ipv6 enable**
2. Enable automatic configuration of IPv6 addressing **ipv6 address autoconfig**




```
R3(config)# interface g0/1
R3(config-if)# ipv6 enable
R3(config-if)# ipv6 address autoconfig
R3(config-if)#
```

Verifying Stateless DHCPv6

- Commands to verify Stateless DHCPv6:
  - **show ipv6 dhcp pool**
  - **show running-config**
  - **show ipv6 interface**
  - **debug ipv6 dhcp detail**

```
R1# show ipv6 dhcp pool
DHCPv6 pool: IPV6-STATELESS
 DNS server: 2001:DB8:CAFE:AAAA::5
 Domain name: example.com
 Active clients: 0
R1#
```

```
R3# show ipv6 interface g0/1
GigabitEthernet0/1 is up, line protocol is up
 IPv6 is enabled, link-local address is FE80::32F7:DFF:FE25:2DE1
No Virtual link-local address(es):
Stateless address autoconfig enabled
Global unicast address(es):
  2001:DB8:CAFE:1:32F7:DFF:FE25:2DE1,subnet is 2001:DB8:CAFE:1::/64 [EUI/CAL/PRE]
   valid lifetime 2591935 preferred lifetime 604735
Joined group address(es):
  FF02::1
  FF02::1:FF25:2DE1
MTU is 1500 bytes
ICMP error messages limited to one every 100 milliseconds
ICMP redirects are enabled
ICMP unreachables are sent
ND DAD is enabled, number of DAD attempts: 1
ND reachable time is 30000 milliseconds (using 30000)
ND NS retransmit interval is 1000 milliseconds
Default router is FE80::D68C:B5FF:FECE:A0C1 on
 GigabitEthernet0/1
R3#
```

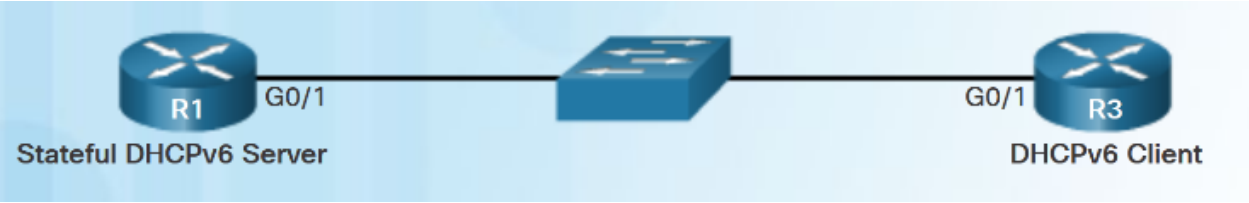
Configuring a Router as a Stateful DHCPv6 Server

1. Enable IPv6 Routing.
   - **ipv6 unicast routing**
2. Configure a DHCPv6 pool.
   - **ipv6 dhcp pool** *pool-name*
3. Configure pool parameters:
   - **address prefix** *prefix/length*
   - **dns-server** *dns-server-address*
   - **domain-name** *domain-name*
4. Configure DHCPv6 interface:
   - **ipv6 dhcp server** *pool-name*
   - **ipv6 nd managed-config-flag**

```
R1(config)# ipv6 unicast-routing
R1(config)# ipv6 dhcp pool IPV6-STATEFUL
R1(config-dhcpv6)# address prefix 2001:DB8:CAFE:1::/64 lifetime infinite
R1(config-dhcpv6)# dns-server 2001:db8:cafe:aaaa::5
R1(config-dhcpv6)# domain-name example.com
R1(config-dhcpv6)# exit
R1(config)# interface g0/1
R1(config-if)# ipv6 address 2001:db8:cafe:1::1/64
R1(config-if)# ipv6 dhcp server IPV6-STATEFUL
R1(config-if)# ipv6 nd managed-config-flag
```

Configuring a Router as a Stateful DHCPv6 Client

1. Allow the router to send RS messages and participate in DHCPv6.
   - **ipv6 enable**
2. Make the router a DHCPv6 client.
   - **ipv6 address dhcp**




```
R3(config)# interface g0/1
R3(config-if)# ipv6 enable
R3(config-if)# ipv6 address dhcp
R3(config-if)#
```

Verifying Stateful DHCPv6

- Use the following commands to verify Stateful DHCPv6:
  - **show ipv6 dhcp pool**
  - **show ipv6 dhcp binding**
  - **show ipv6 interface**

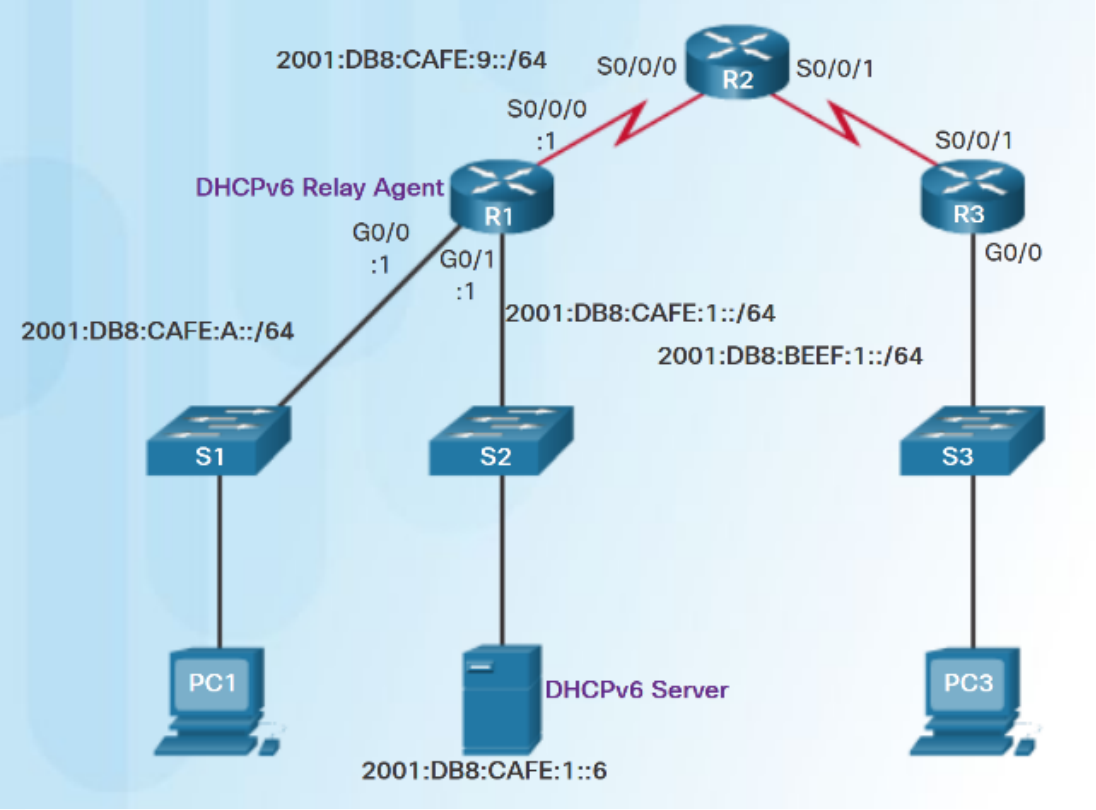
```
R1# show ipv6 dhcp binding
Client: FE80::32F7:DFF:FE25:2DE1
  DUID: 0003000130F70D252DE0
  Username : unassigned
  IA NA: IA ID 0x00040001, T1 43200, T2 69120
    Address: 2001:DB8:CAFE:1:5844:47B2:2603:C171
            preferred lifetime INFINITY, , valid lifetime INFINITY,
R1#
```

```
R3# show ipv6 interface g0/1
GigabitEthernet0/1 is up, line protocol is up
  IPv6 is enabled, link-local address is
FE80::32F7:DFF:FE25:2DE1
  No Virtual link-local address(es):
  Global unicast address(es):
    2001:DB8:CAFE:1:5844:47B2:2603:C171, subnet is
2001:DB8:CAFE:1:5844:47B2:2603:C171/128
  Joined group address(es):
    FF02::1
    FF02::1:FF03:C171
    FF02::1:FF25:2DE1
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ICMP unreachables are sent
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds (using 30000)
  ND NS retransmit interval is 1000 milliseconds
  Default router is FE80::D68C:B5FF:FECE:A0C1 on
  GigabitEthernet0/1
R3#
```

Configuring a Router as a DHCPv6 Relay Agent

- If the DHCPv6 server is located on a different network than the client, the router can be configured as a DHCPv6 relay agent.
  - **ipv6 dhcp relay destination** *destination-address*

```
R1(config)# interface g0/0
R1(config-if)# ipv6 dhcp relay destination 2001:db8:cafe:1::6
R1(config-if)# end
R1# show ipv6 dhcp interface g0/0
GigabitEthernet0/0 is in relay mode
  Relay destinations:
    2001:DB8:CAFE:1::6
R1#
```



Troubleshoot DHCPv6

- Use the **show ipv6 interface** command to verify DHCPv6 configuration.

SLAAC

```
R1# show ipv6 interface g0/1
GigabitEthernet0/1 is up, line protocol is up
 IPv6 is enabled, link-local address is
FE80::D68C:B5FF:FECE:A0C1
<output omitted>

Hosts use stateless autoconfig for addresses.
```

Stateless DHCPv6

```
R1# show ipv6 interface g0/1
GigabitEthernet0/1 is up, line protocol is up
 IPv6 is enabled, link-local address is FE80::D68C:B5FF:FECE:A0C1
<output omitted>

Hosts use DHCP to obtain other configuration.
```

Stateful DHCPv6

```
R1# show ipv6 interface g0/1
GigabitEthernet0/1 is up, line protocol is up
IPv6 is enabled, link-local address is FE80::D68C:B5FF:FECE:A0C1
<output omitted>

Hosts use DHCP to obtain routable addresses.
```

Summary

- DHCP
  - What is DHCP and why is it used?
- DHCPv4
  - Implement DHCPv4 to operate across multiple LANs in a small to medium-sized business network.
- DHCPv6
  - Implement DHCPv6 to operate across multiple LANs in a small to medium-sized business network.