# Chapter 11: Network Address Translation for IPv4

## Routing & Switching

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# Chapter 11

11.1 NAT Operation

11.2 Configuring NAT

11.3 Troubleshooting NAT

11.4 Summary

# Chapter 11: Objectives

- Describe NAT characteristics.
- Describe the benefits and drawbacks of NAT.
- Configure static NAT using the CLI.
- Configure dynamic NAT using the CLI.
- Configure PAT using the CLI.
- Configure port forwarding using the CLI.
- Configure NAT64.
- Use **`show`** commands to verify NAT operation.

# 11.1 NAT Operation

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# IPv4 Private Address Space

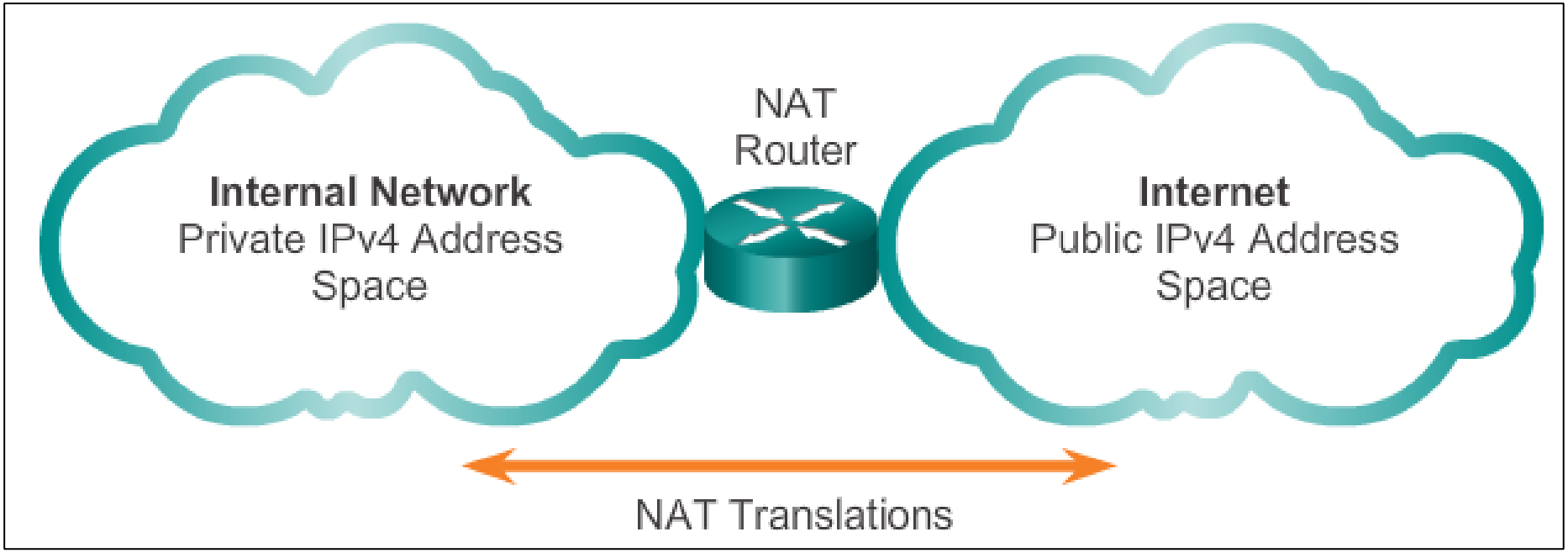
- IPv4 address space is not big enough to uniquely address all the devices that must be connected to the Internet.
- Network private addresses are described in RFC 1918 and are to designed to be used within an organization or site only.
- Private addresses are not routed by Internet routers while public addresses are.
- Private addresses can alleviate IPv4 scarcity, but because they aren't routed by Internet devices, they first need to be translated.
- NAT is process used to perform such translation.

## NAT Characteristics

# IPv4 Private Address Space

**Private Internet addresses are defined in RFC 1918:**

| Class | RFC 1918 Internal Address Range | CIDR Prefix |
|---|---|---|
| A | 10.0.0.0 - 10.255.255.255 | 10.0.0.0/8 |
| B | 172.16.0.0 - 172.31.255.255 | 172.16.0.0/12 |
| C | 192.168.0.0 - 192.168.255.255 | 192.168.0.0/16 |



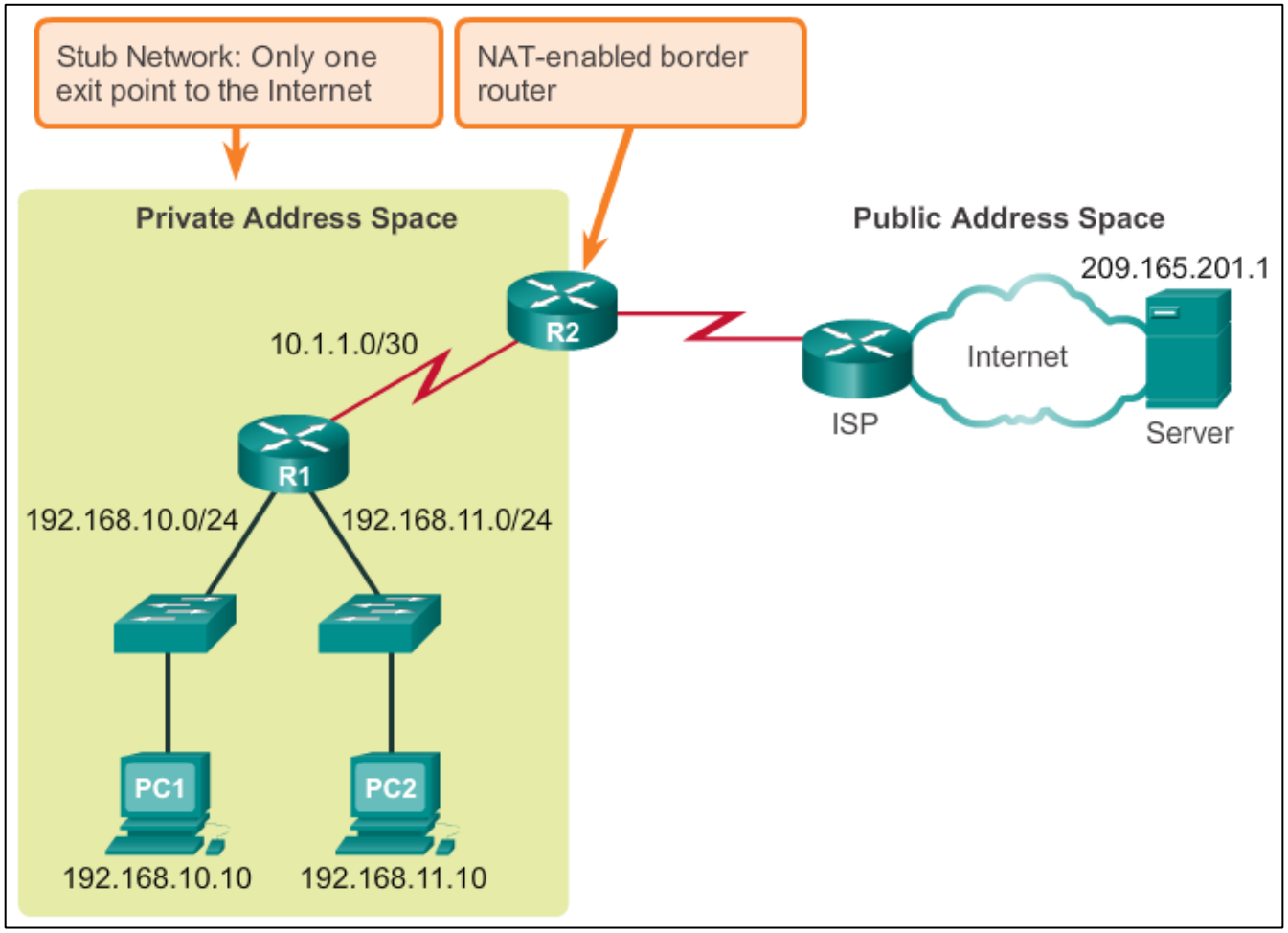
## NAT Characteristics

# What is NAT?

- NAT is a process used to translate network addresses.
- NAT's primary use is to conserve public IPv4 addresses.
- NAT is usually implemented at border network devices, such as firewalls or routers.
- NAT allows the networks to use private addresses internally, only translating to public addresses when needed.
- Devices within the organization can be assigned private addresses and operate with locally unique addresses.
- When traffic must be sent or received to or from other organizations or the Internet, the border router translates the addresses to a public and globally unique address.

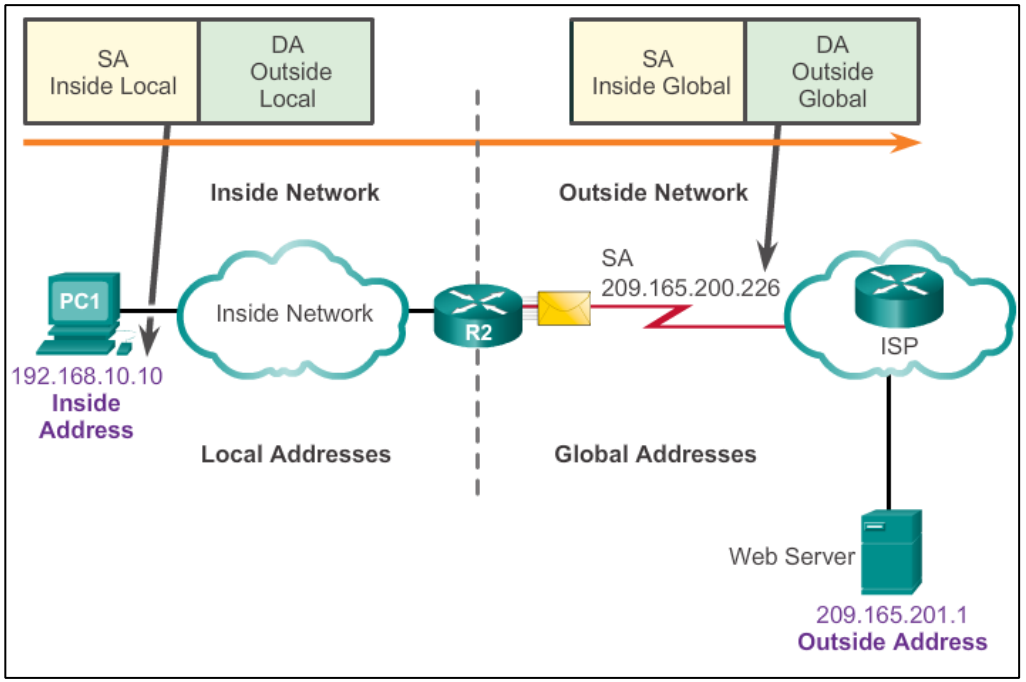
## NAT Characteristics

# What is NAT? (cont.)

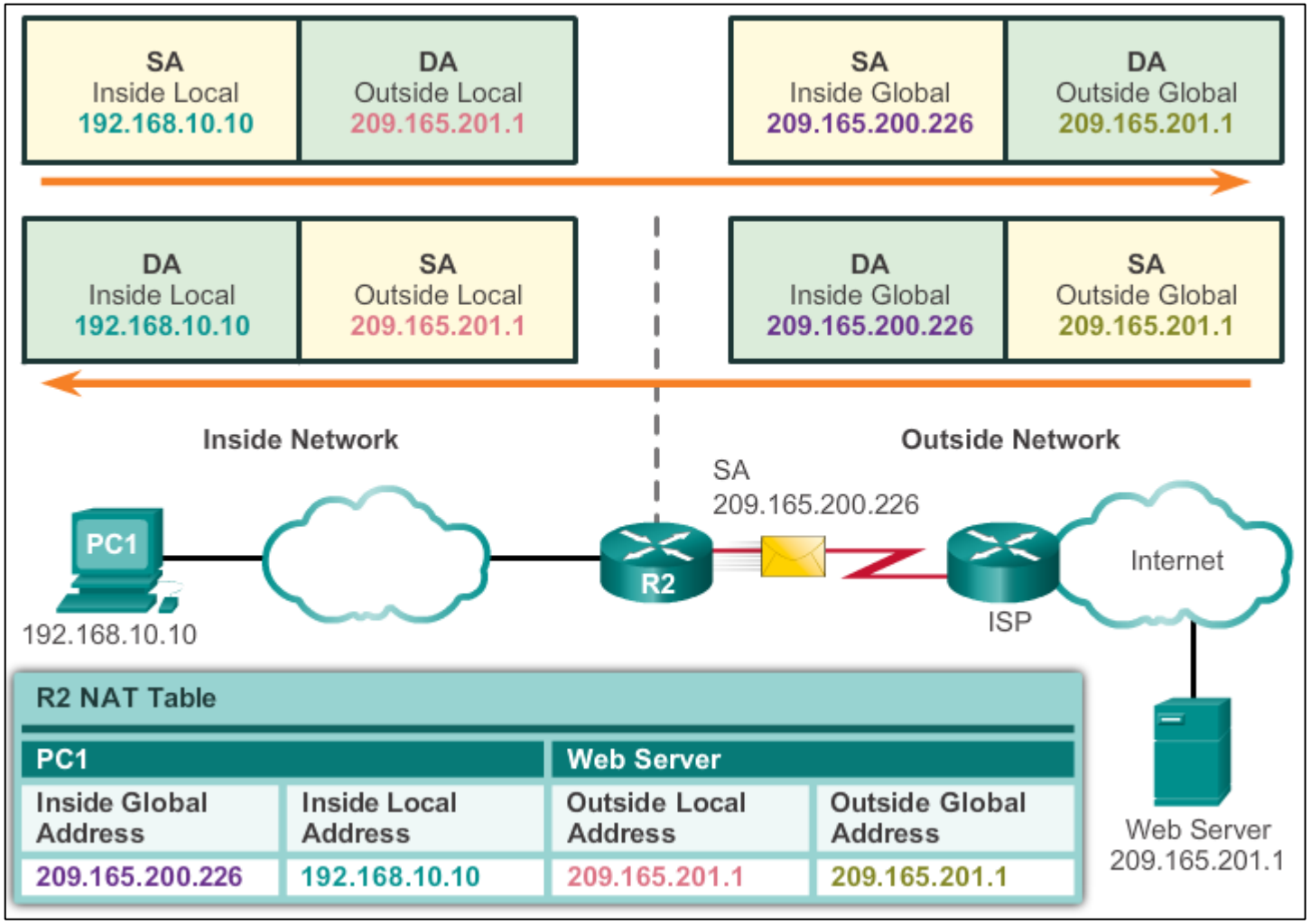


# NAT Terminology

- Inside network is the set of devices using private addresses
- Outside network refers to all other networks
- NAT includes four types of addresses:
  - Inside local address
  - Inside global address
  - Outside local address
  - Outside global address



# NAT Terminology (cont.)



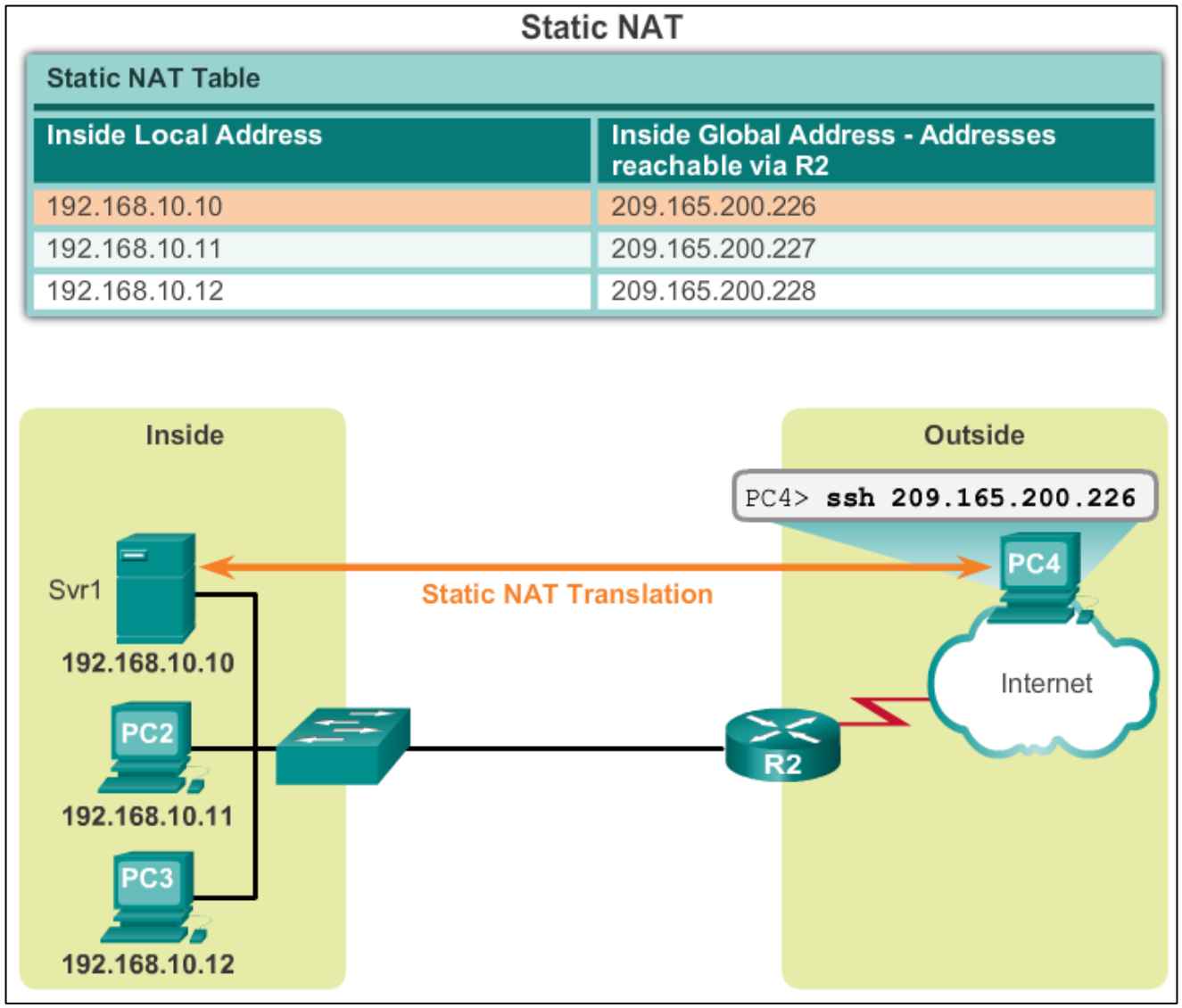
## Types of NAT

# Static NAT

- Static NAT uses a one-to-one mapping of local and global addresses.
- These mappings are configured by the network administrator and remain constant.
- Static NAT is particularly useful when servers hosted in the inside network must be accessible from the outside network.
- A network administrator can SSH to a server in the inside network by pointing the SSH client to the proper inside global address.

## Types of NAT

# Static NAT (cont.)



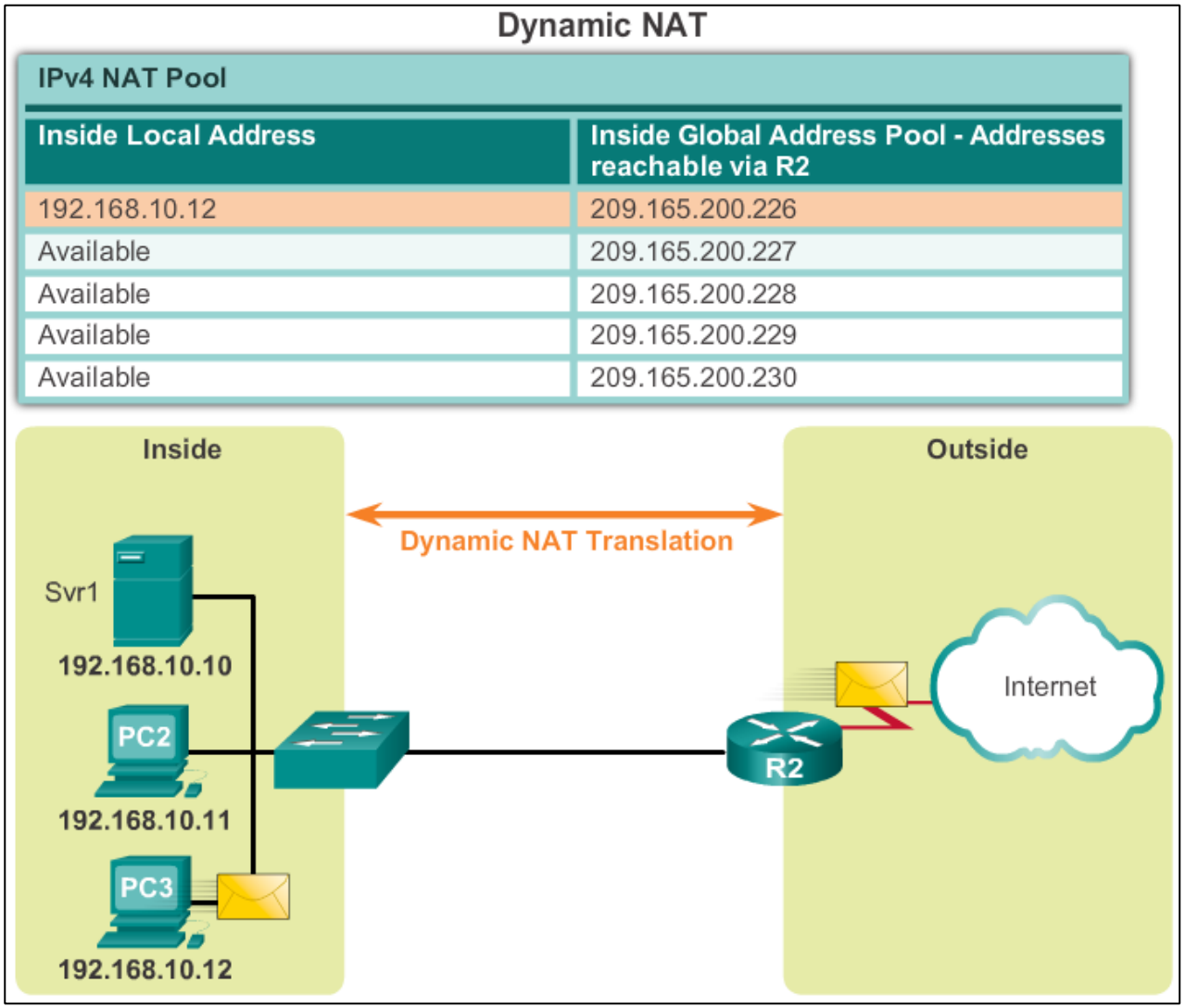
## Types of NAT

# Dynamic NAT

- Dynamic NAT uses a pool of public addresses and assigns them on a first-come, first-served basis.
- When an inside device requests access to an outside network, dynamic NAT assigns an available public IPv4 address from the pool.
- Dynamic NAT requires that enough public addresses are available to satisfy the total number of simultaneous user sessions.

## Types of NAT

# Dynamic NAT (cont.)



## Types of NAT

# Port Address Translation

- Port Address Translation (PAT) maps multiple private IPv4 addresses to a single public IPv4 address or a few addresses.
- PAT uses the pair source port and source IP address to keep track of what traffic belongs to what internal client.
- PAT is also known as NAT overload.
- By also using the port number, PAT forwards the response packets to the correct internal device.
- The PAT process also validates that the incoming packets were requested, thus adding a degree of security to the session.

# Comparing NAT and PAT

- NAT translates IPv4 addresses on a 1:1 basis between private IPv4 addresses and public IPv4 addresses.
- PAT modifies both the address and the port number.
- NAT forwards incoming packets to their inside destination by referring to the incoming source IPv4 address provided by the host on the public network.
- With PAT, there is generally only one or a very few publicly exposed IPv4 addresses.
- PAT is able to translate protocols that do not use port numbers, such as ICMP; each one of these protocols is supported differently by PAT.

# Benefits of NAT

- Conserves the legally registered addressing scheme
- Increases the flexibility of connections to the public network
- Provides consistency for internal network addressing schemes
- Provides network security

# Disadvantages of NAT

- Performance is degraded
- End-to-end functionality is degraded
- End-to-end IP traceability is lost
- Tunneling is more complicated
- Initiating TCP connections can be disrupted

# 11.2 Configuring NAT

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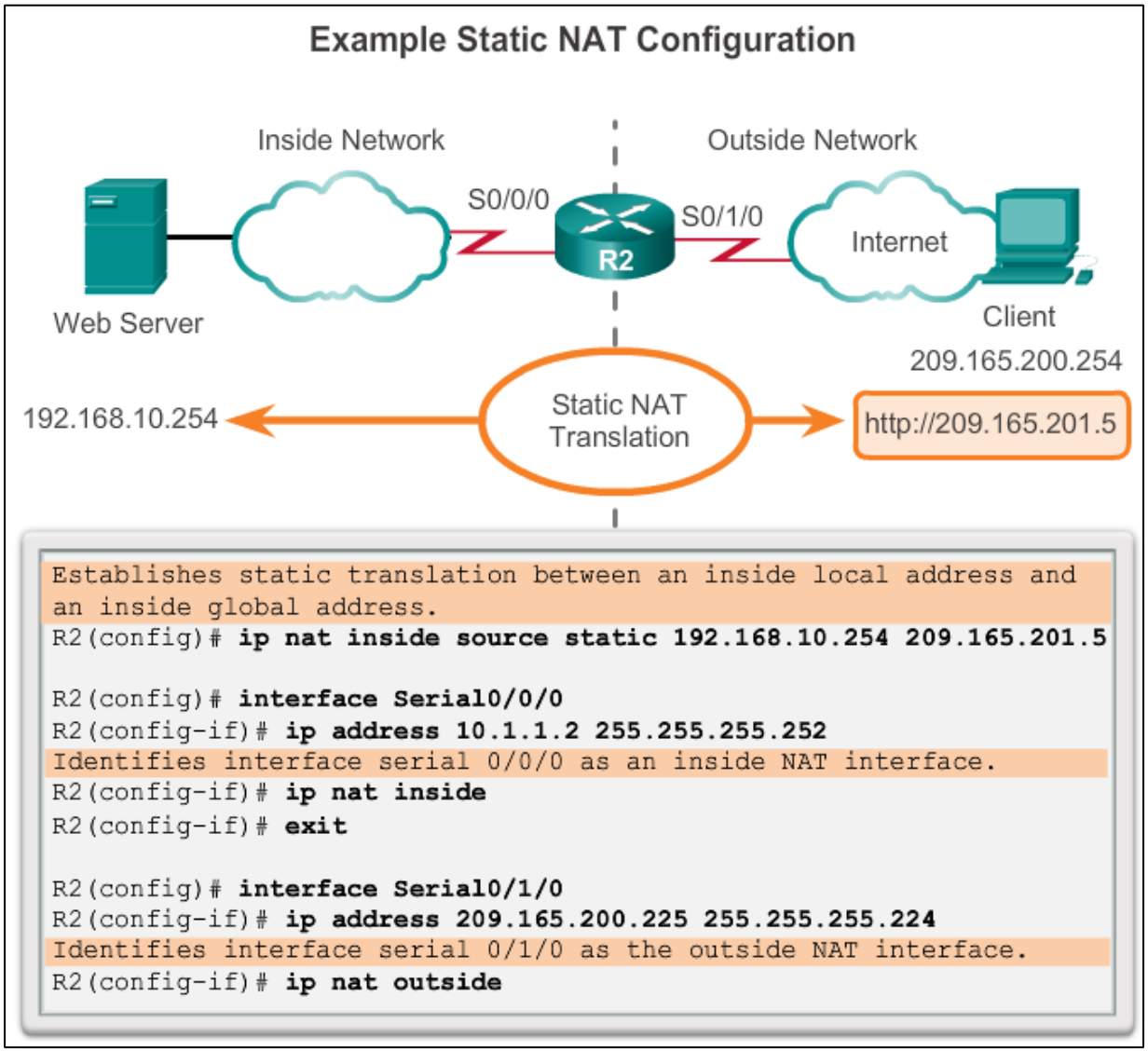
# Configuring Static NAT

There are two basic tasks to perform when configuring static NAT translations:

- Create the mapping between the inside local and outside local addresses.
- Define which interfaces belong to the inside network and which belong to the outside network.

# Configuring Static NAT



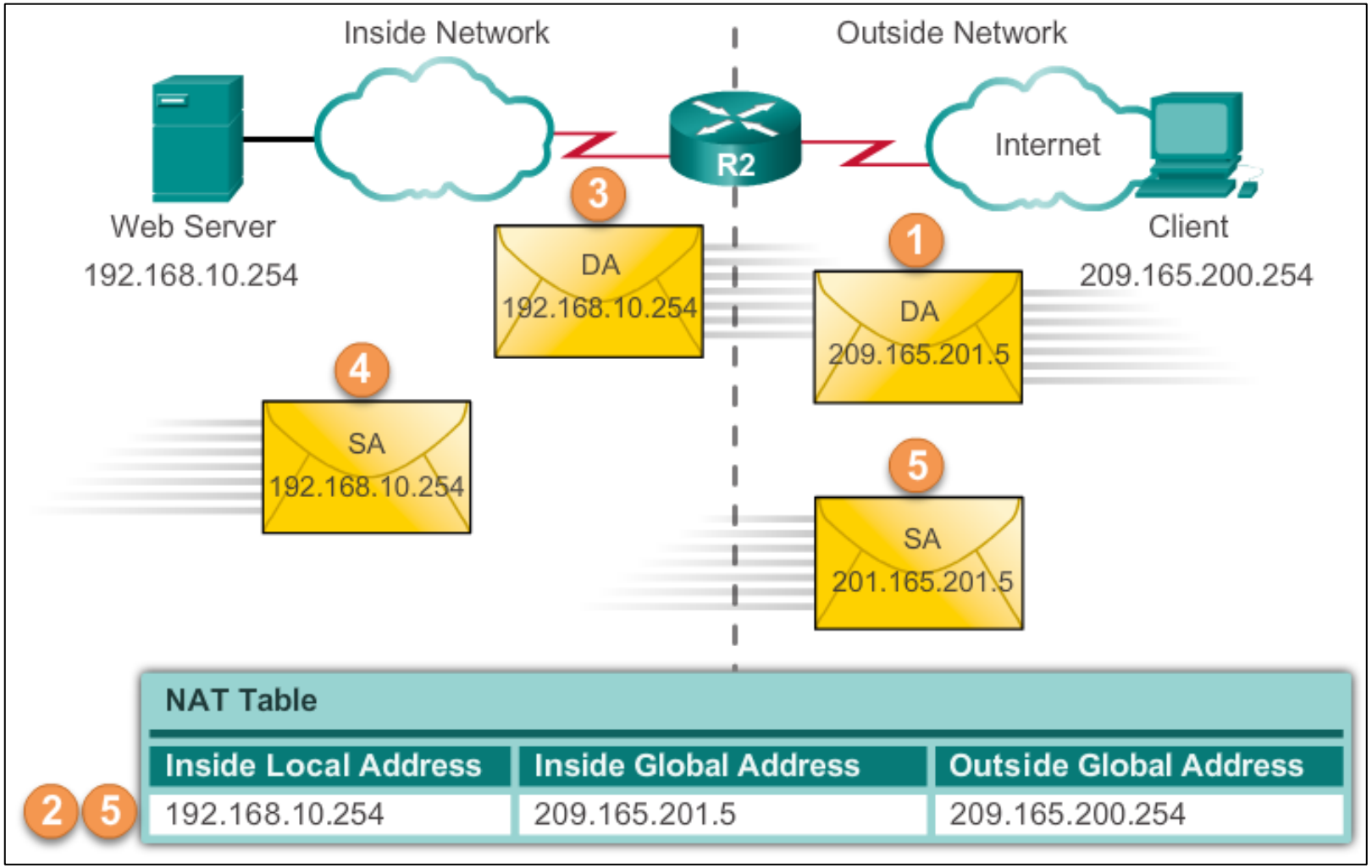

```
Establishes static translation between an inside local address and
an inside global address.
R2(config)# ip nat inside source static 192.168.10.254 209.165.201.5

R2(config)# interface Serial0/0/0
R2(config-if)# ip address 10.1.1.2 255.255.255.252
Identifies interface serial 0/0/0 as an inside NAT interface.
R2(config-if)# ip nat inside
R2(config-if)# exit

R2(config)# interface Serial0/1/0
R2(config-if)# ip address 209.165.200.225 255.255.255.224
Identifies interface serial 0/1/0 as the outside NAT interface.
R2(config-if)# ip nat outside
```

## Configuring Static NAT

# Analyzing Static NAT



## Configuring Static NAT

# Verifying Static NAT

**The static translation is always present in the NAT table.**

```
R2# show ip nat translations
Pro Inside global  Inside local   Outside local  Outside global
--- 209.165.201.5  192.168.10.254  ---            ---
R2#
```

**The static translation during an active session.**

```
R2# show ip nat translations
Pro Inside global Inside local   Outside local    Outside global
--- 209.165.201.5 192.168.10.254 209.165.200.254  209.165.200.254
R2#
```

## Configuring Static NAT

# Verifying Static NAT (cont.)

```
R2# clear ip nat statistics

R2# show ip nat statistics
Total active translations: 1 (1 static, 0 dynamic; 0 extended)
Peak translations: 0
Outside interfaces:
  Serial0/0/1
Inside interfaces:
  Serial0/0/0
Hits: 0  Misses: 0
<output omitted>
```

**Client PC establishes a session with the web server**

```
R2# show ip nat statistics
Total active translations: 1 (1 static, 0 dynamic; 0 extended)
Peak translations: 2, occurred 00:00:14 ago
Outside interfaces:
  Serial0/1/0
Inside interfaces:
  Serial0/0/0
Hits: 5  Misses: 0
<output omitted>
```

# Dynamic NAT Operation

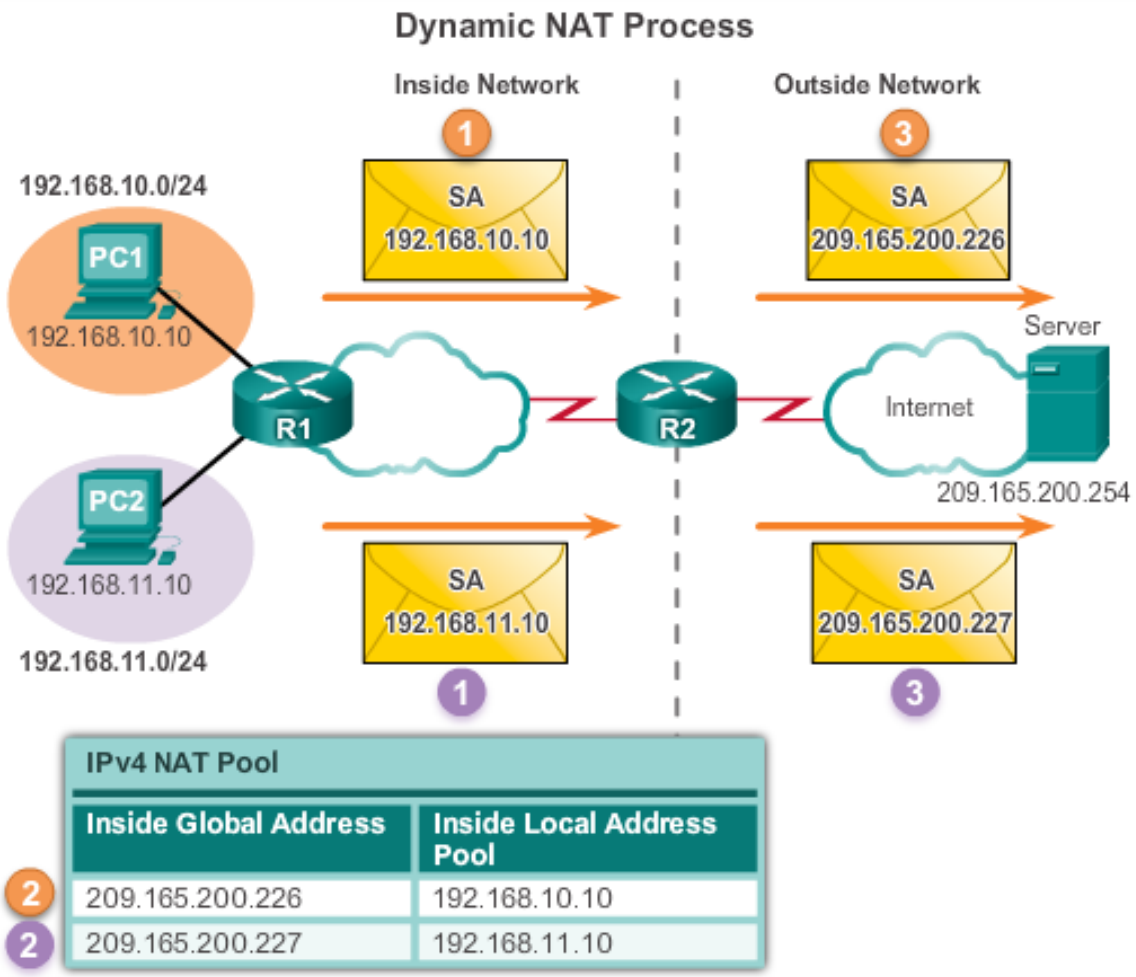
- The pool of public IPv4 addresses (inside global address pool) is available to any device on the inside network on a first-come, first-served basis.
- With dynamic NAT, a single inside address is translated to a single outside address.
- The pool must be large enough to accommodate all inside devices.
- A device is unable to communicate to any external networks if no addresses are available in the pool.

# Configuring Dynamic NAT

| Dynamic NAT Configuration Steps | |
|---|---|
| **Step 1** | Define a pool of global addresses to be used for translation.<br>**ip nat pool** *name start-ip end-ip*<br>{**netmask** *netmask* \| **prefix-length** *prefix-length*} |
| **Step 2** | Configure a standard access list permitting the addresses that should be translated.<br>**access-list** *access-list-number* **permit** *source*[*source-wildcard*] |
| **Step 3** | Establish dynamic source translation, specifying the access list and pool defined in prior steps.<br>**ip nat inside source list** *access-list-number* **pool** *name* |
| **Step 4** | Identify the inside interface.<br>**interface** *type number*<br>**ip nat inside** |
| **Step 5** | Identify the outside interface.<br>**interface** *type number*<br>**ip nat outside** |

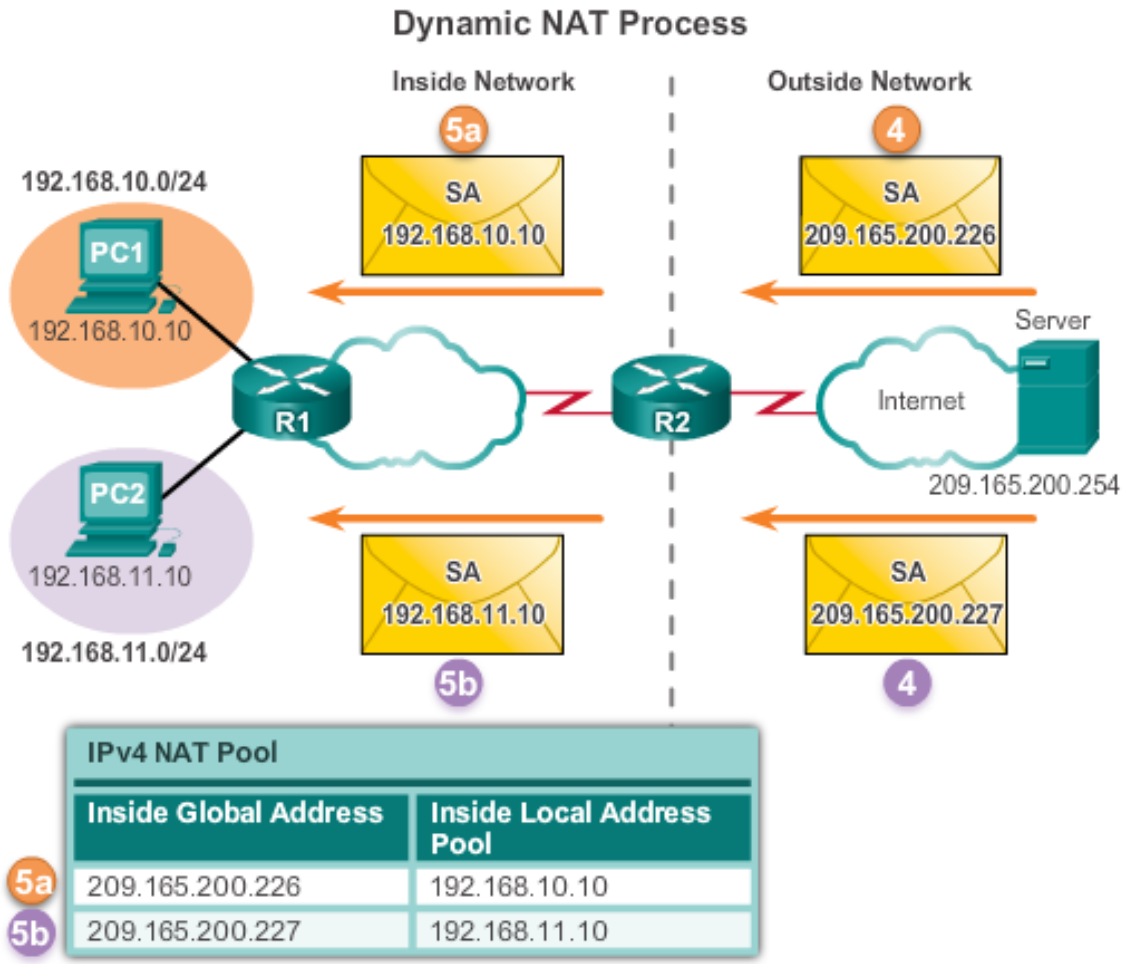
## Configuring Dynamic NAT

# Analyzing Dynamic NAT



## Configuring Dynamic NAT

# Analyzing Dynamic NAT



## Configuring Dynamic NAT

# Verifying Dynamic NAT

### Verifying Dynamic NAT with show ip nat translations

```
R2# show ip nat translations
Pro Inside global     Inside local  Outside local Outside global
--- 209.165.200.226   192.168.10.10 ---           ---
--- 209.165.200.227   192.168.11.10 ---           ---
R2#
R2# show ip nat translations verbose
Pro Inside global     Inside local  Outside local Outside global
--- 209.165.200.226   192.168.10.10 ---           ---
    create 00:17:25, use 00:01:54 timeout:86400000, left
23:58:05, Map-Id(In): 1,
    flags:
none, use_count: 0, entry-id: 32, lc_entries: 0
--- 209.165.200.227    192.168.11.10      ---     ---
    create 00:17:22, use 00:01:51 timeout:86400000, left
23:58:08, Map-Id(In): 1,
    flags:
none, use_count: 0, entry-id: 34, lc_entries: 0
R2#
```

## Configuring Dynamic NAT

# Verifying Dynamic NAT

### Verifying Dynamic NAT with show ip nat statistics

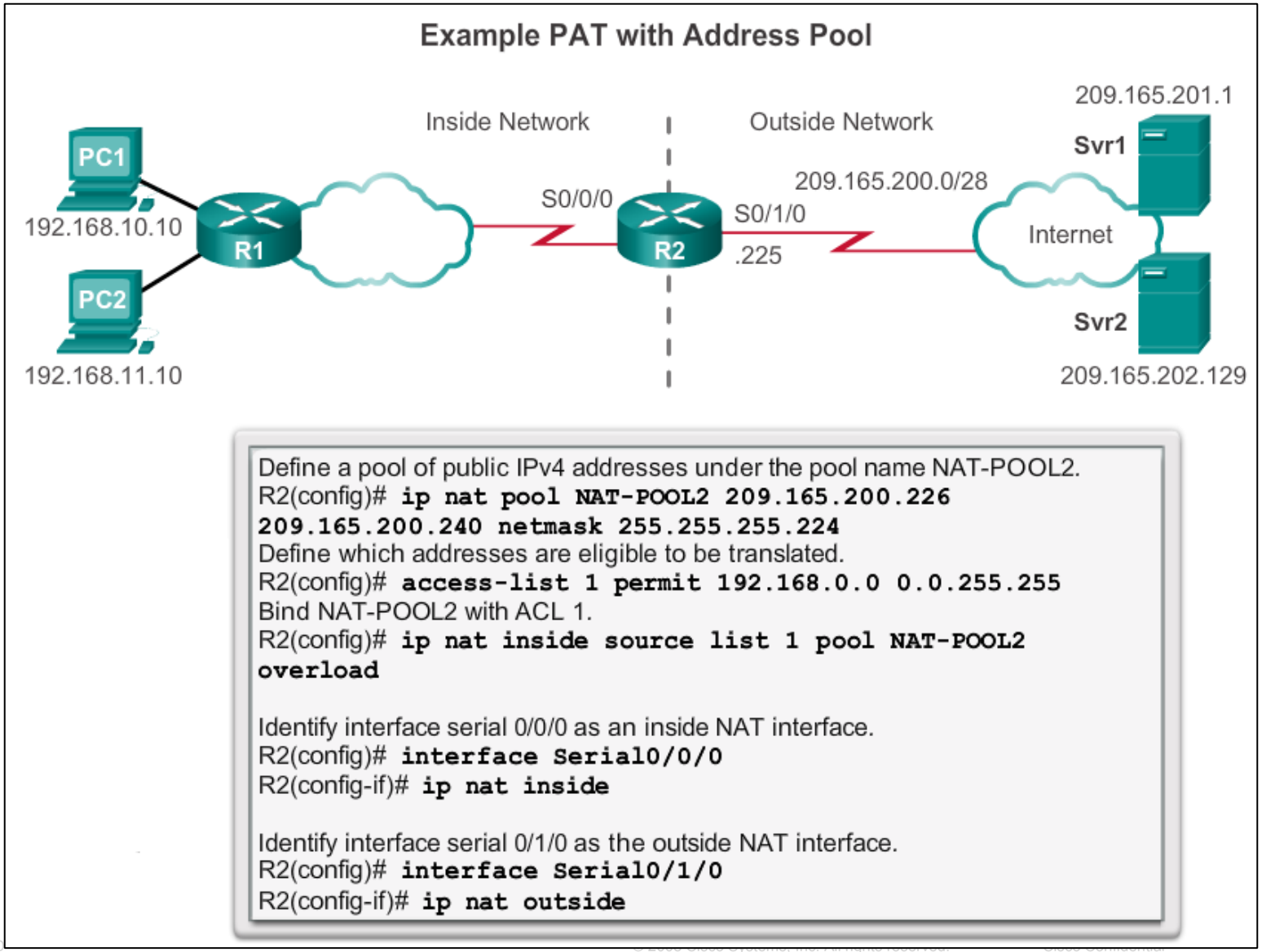
```
R2# clear ip nat statistics

PC1 and PC2 establish sessions with the server

R2# show ip nat statistics
Total active translations: 2 (0 static, 2 dynamic; 0 extended)
Peak translations: 6, occurred 00:27:07 ago
Outside interfaces:
  Serial0/0/1
Inside interfaces:
  Serial0/1/0
Hits: 24  Misses: 0
CEF Translated packets: 24, CEF Punted packets: 0
Expired translations: 4
Dynamic mappings:
-- Inside Source
[Id: 1] access-list 1 pool NAT-POOL1 refcount 2
 pool NAT-POOL1: netmask 255.255.255.224
start 209.165.200.226 end 209.165.200.240
type generic, total addresses 15, allocated 2 (13%), misses 0

Total doors: 0
Appl doors: 0
Normal doors: 0
Queued Packets: 0
R2#
```

# Configuring PAT: Address Pool




Define a pool of public IPv4 addresses under the pool name NAT-POOL2.

```
R2(config)# ip nat pool NAT-POOL2 209.165.200.226
209.165.200.240 netmask 255.255.255.224
```

Define which addresses are eligible to be translated.

```
R2(config)# access-list 1 permit 192.168.0.0 0.0.255.255
```

Bind NAT-POOL2 with ACL 1.

```
R2(config)# ip nat inside source list 1 pool NAT-POOL2
overload
```

Identify interface serial 0/0/0 as an inside NAT interface.

```
R2(config)# interface Serial0/0/0
R2(config-if)# ip nat inside
```

Identify interface serial 0/1/0 as the outside NAT interface.

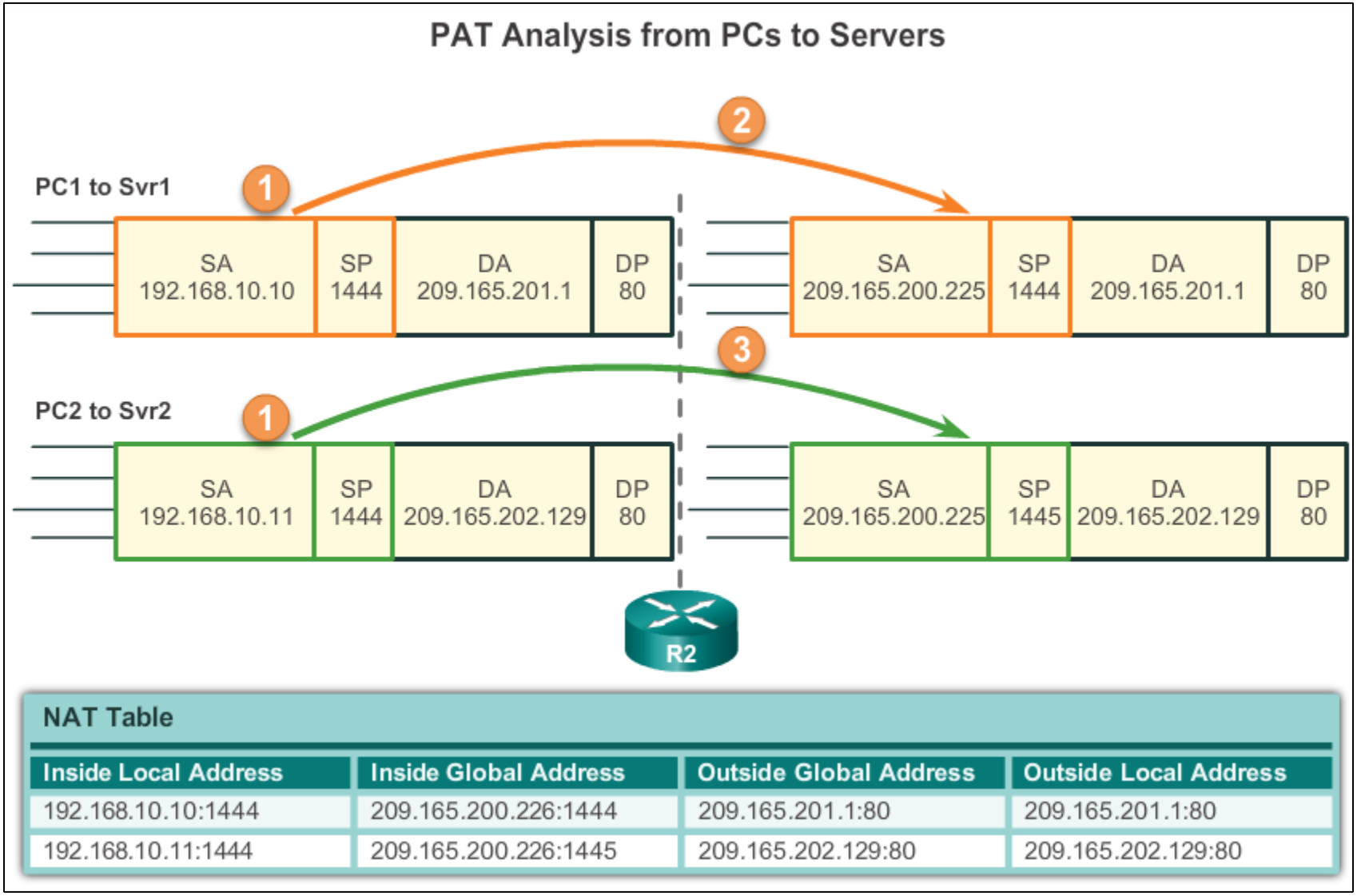
```
R2(config)# interface Serial0/1/0
R2(config-if)# ip nat outside
```

# Configuring PAT: Single Address

| | |
|---|---|
| **Step 1** | Define a standard access list permitting the addresses that should be translated.<br><br>**access-list** *access-list-number* **permit** *source* [*source-wildcard*] |
| **Step 2** | Establish dynamic source translation, specifying the ACL, exit interface and overload options.<br><br>**ip nat inside source list** *access-list-number* **interface** *type number* **overload** |
| **Step 3** | Identify the inside interface.<br><br>**interface** *type number*<br>**ip nat inside** |
| **Step 4** | Identify the outside interface.<br><br>**interface** *type number*<br>**ip nat outside** |

## Configuring PAT

# Analyzing PAT

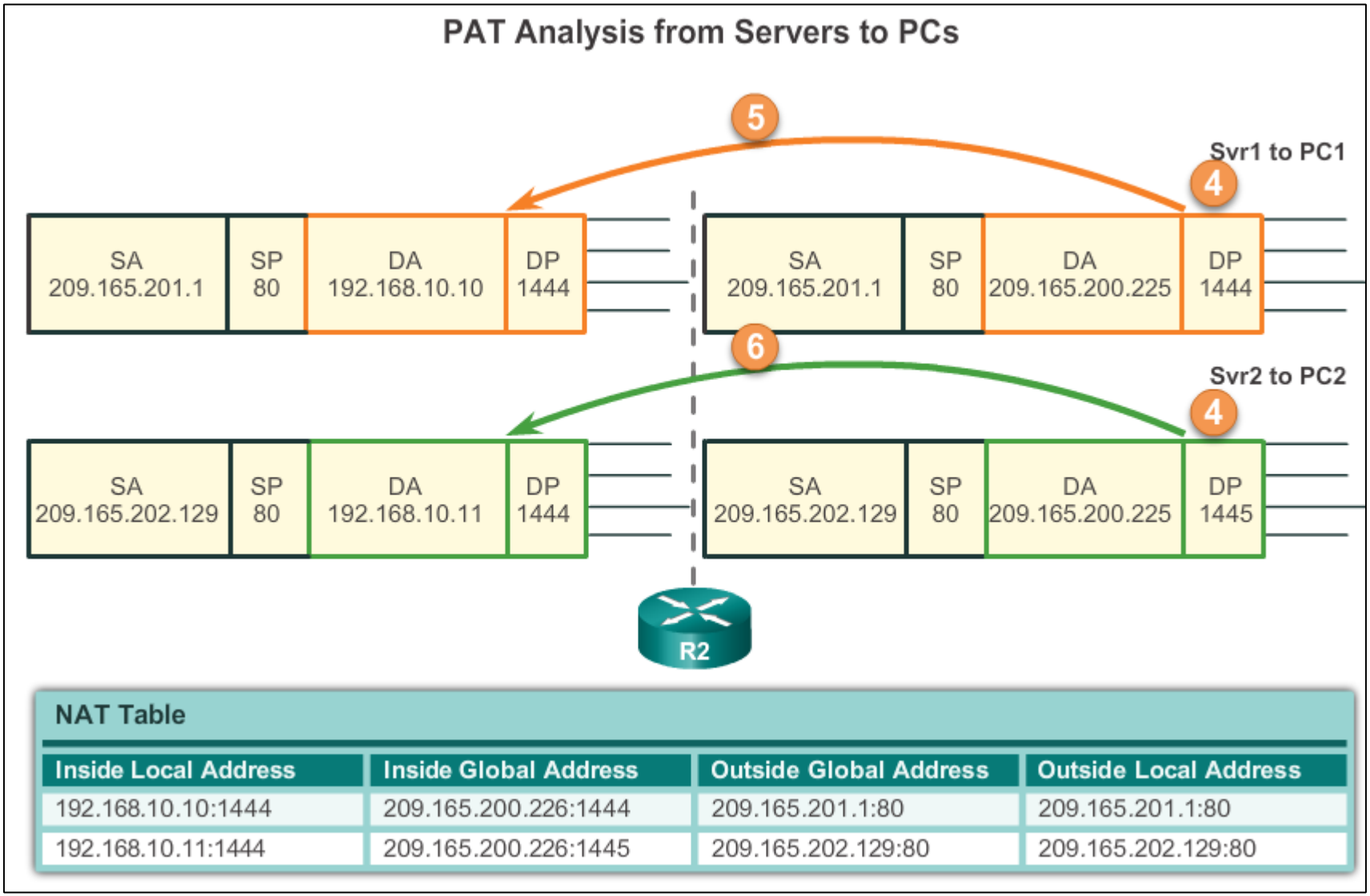



**NAT Table**

| Inside Local Address | Inside Global Address | Outside Global Address | Outside Local Address |
|---|---|---|---|
| 192.168.10.10:1444 | 209.165.200.226:1444 | 209.165.201.1:80 | 209.165.201.1:80 |
| 192.168.10.11:1444 | 209.165.200.226:1445 | 209.165.202.129:80 | 209.165.202.129:80 |

## Configuring PAT

# Analyzing PAT




**NAT Table**

| Inside Local Address | Inside Global Address | Outside Global Address | Outside Local Address |
|---|---|---|---|
| 192.168.10.10:1444 | 209.165.200.226:1444 | 209.165.201.1:80 | 209.165.201.1:80 |
| 192.168.10.11:1444 | 209.165.200.226:1445 | 209.165.202.129:80 | 209.165.202.129:80 |

## Configuring PAT

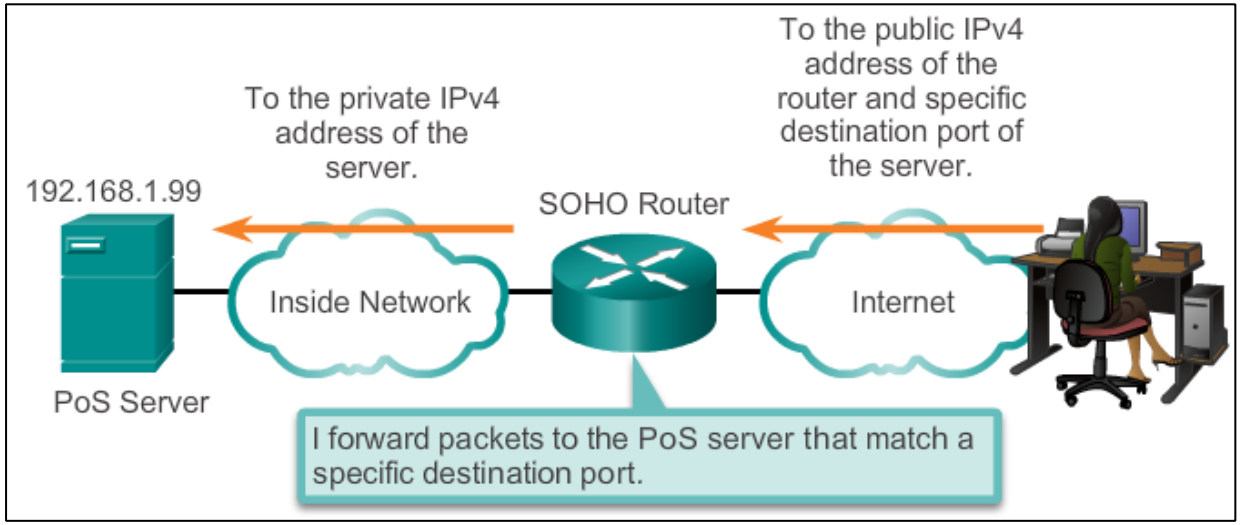
# Verifying PAT Translations

### Verifying PAT Translations

```
R2# show ip nat translations
Pro  Inside global          Inside local       Outside local      Outside global
tcp  209.165.200.226:51839  192.168.10.10:51839  209.165.201.1:80   209.165.201.1:80
tcp  209.165.200.226:42558  192.168.11.10:42558  209.165.202.129:80  209.165.202.129:80
R2#
```

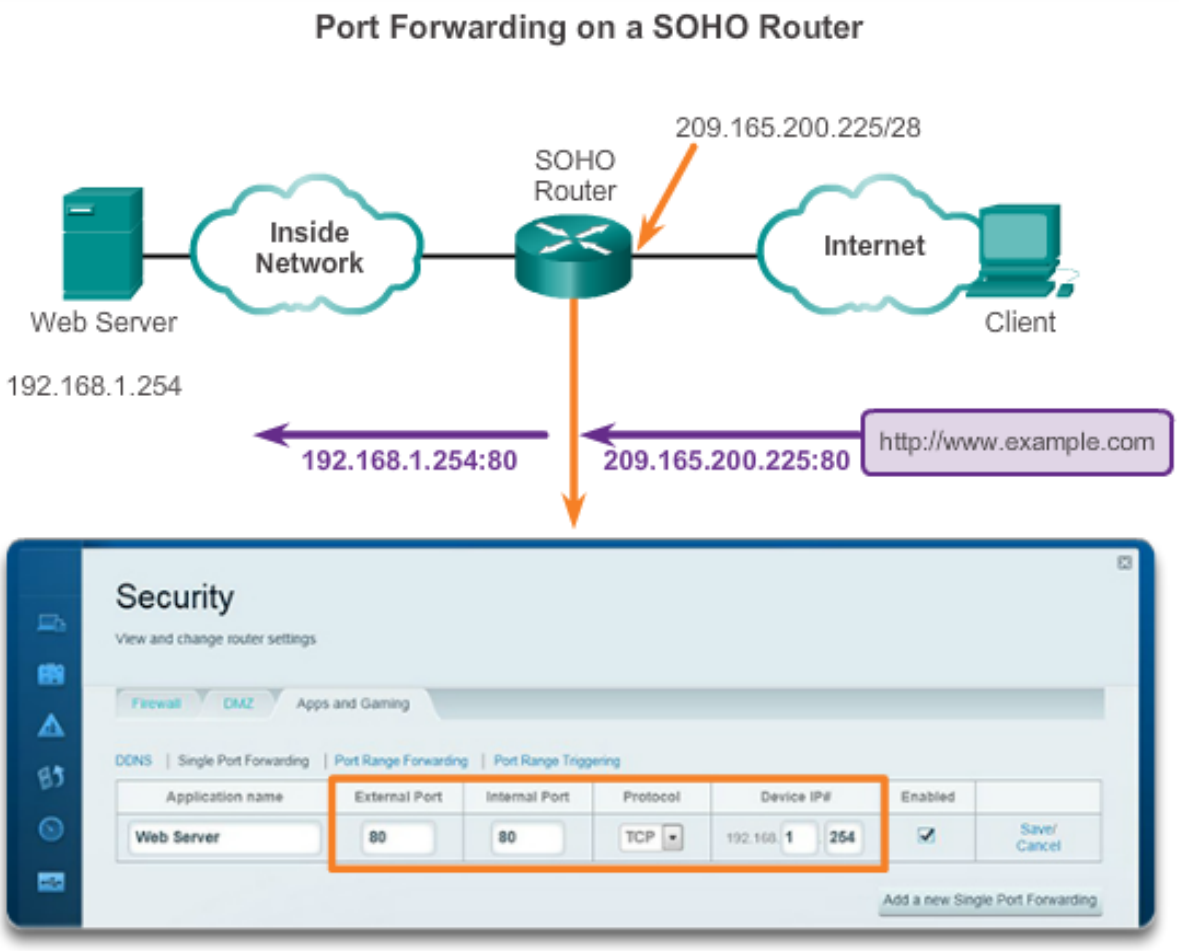
# Port Forwarding

- Port forwarding is the act of forwarding a network port from one network node to another.
- A packet sent to the public IP address and port of a router can be forwarded to a private IP address and port in inside network.
- Port forwarding is helpful in situations where servers have private addresses, not reachable from the outside networks.



## Port Forwarding

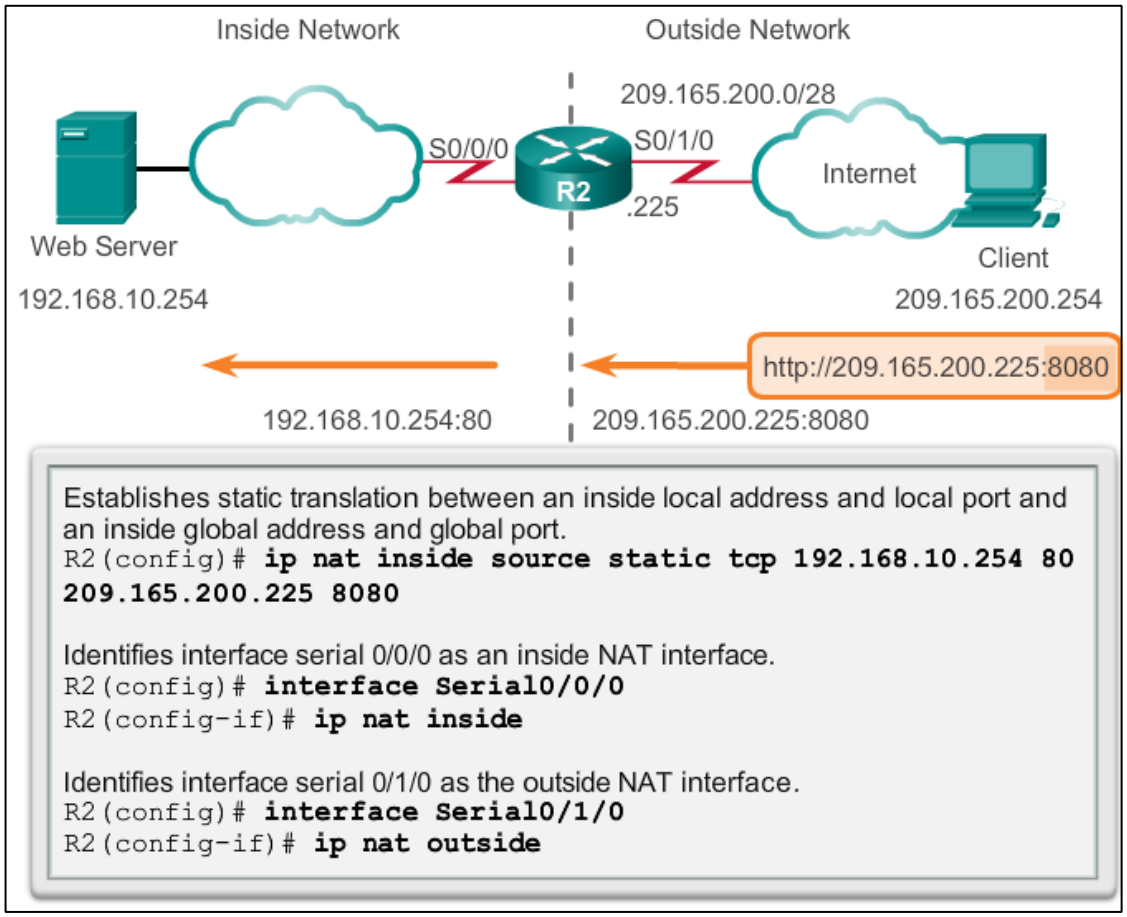
# SOHO Example



## Port Forwarding

# Configuring Port Forwarding with IOS

In IOS, Port forwarding is essentially a static NAT translation with a specified TCP or UDP port number.

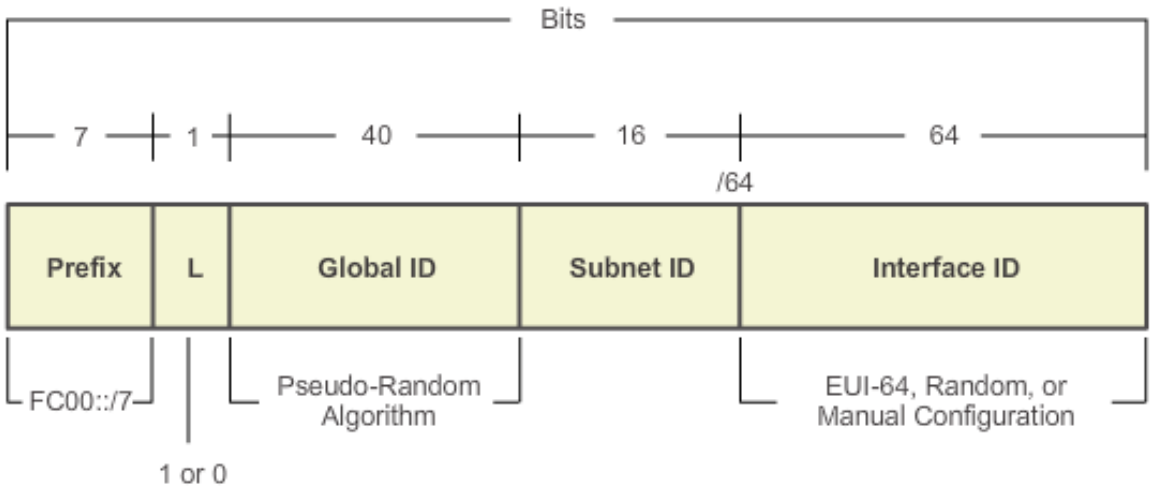


# NAT for IPv6?

- NAT is a workaround for IPv4 address scarcity.
- IPv6 with a 128-bit address provides 340 undecillion addresses.
- Address space is not an issue for IPv6.
- IPv6 makes IPv4 public-private NAT unnecessary by design; however, IPv6 does implement a form of private addresses, and it is implemented differently than they are for IPv4.

# IPv6 Unique Local Addresses

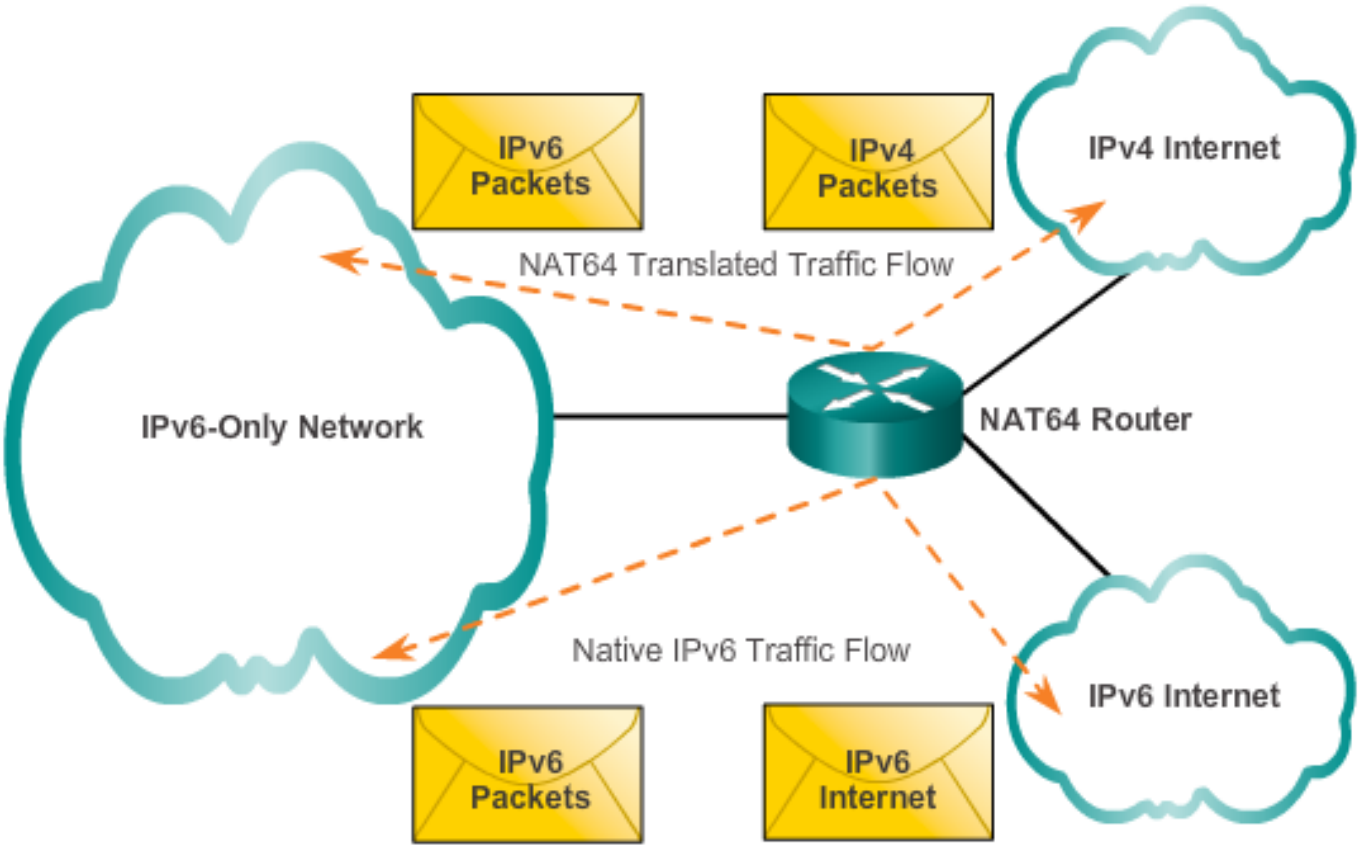
- IPv6 unique local addresses (ULAs) are designed to allow IPv6 communications within a local site.
- ULAs are not meant to provide additional IPv6 address space.
- ULAs have the prefix FC00::/7, which results in a first hextet range of FC00 to FDFF.
- ULAs are also known as local IPv6 addresses (not to be confused with IPv6 link-local addresses).



# NAT for IPv6

- IPv6 also uses NAT, but in a much different context.
- In IPv6, NAT is used to provide transparent communication between IPv6 and IPv4.
- NAT64 is not intended to be a permanent solution; it is meant to be a transition mechanism.
- Network Address Translation-Protocol Translation (NAT-PT) was another NAT-based transition mechanism for IPv6, but is now deprecated by IETF.
- NAT64 is now recommended.

# NAT for IPv6



# 11.3 Troubleshooting NAT

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# Troubleshooting NAT: show commands

```
R2# clear ip nat statistics
R2# clear ip nat translation *
R2#
```

Host 192.168.10.10 telnets to server at 209.165.201.1

```
R2# show ip nat statistics
Total active translations: 1 (0 static, 1 dynamic; 1 extended)
Peak translations: 1, occurred 00:00:09 ago
Outside interfaces:
  Serial0/0/1
Inside interfaces:
  Serial0/0/0
Hits: 31  Misses: 0
CEF Translated packets: 31, CEF Punted packets: 0
Expired translations: 0
Dynamic mappings:
-- Inside Source
[Id: 5] access-list 1 pool NAT-POOL2 refcount 1
 pool NAT-POOL2: netmask 255.255.255.224
start 209.165.200.226 end 209.165.200.240
type generic, total addresses 15, allocated 1 (6%), misses 0
<output omitted>
R2# show ip nat translations
Pro Inside global         Inside local         Outside local      Out
tcp 209.165.200.226:19005 192.168.10.10:19005  209.165.201.1:23   209
R2#
```

# Troubleshooting NAT: debug command

```
R2# debug ip nat
IP NAT debugging is on
R2#
*Feb 15 20:01:311.670: NAT*: s=192.168.10.10->209.165.200.226, d=209.165.201.1 [2817]
*Feb 15 20:01:311.682: NAT*: s=209.165.201.1, d=209.165.200.226->192.168.10.10 [4180]
*Feb 15 20:01:311.698: NAT*: s=192.168.10.10->209.165.200.226, d=209.165.201.1 [2818]
*Feb 15 20:01:311.702: NAT*: s=192.168.10.10->209.165.200.226, d=209.165.201.1 [2819]
*Feb 15 20:01:311.710: NAT*: s=192.168.10.10->209.165.200.226, d=209.165.201.1 [2820]
*Feb 15 20:01:311.710: NAT*: s=209.165.201.1, d=209.165.200.226->192.168.10.10 [4181]
*Feb 15 20:01:311.722: NAT*: s=209.165.201.1, d=209.165.200.226->192.168.10.10 [4182]
*Feb 15 20:01:311.726: NAT*: s=192.168.10.10->209.165.200.226, d=209.165.201.1 [2821]
*Feb 15 20:01:311.730: NAT*: s=209.165.201.1, d=209.165.200.226->192.168.10.10 [4183]
*Feb 15 20:01:311.734: NAT*: s=192.168.10.10->209.165.200.226, d=209.165.201.1 [2822]
*Feb 15 20:01:311.734: NAT*: s=209.165.201.1, d=209.165.200.226->192.168.10.10 [4184]
output omitted
```

# Chapter 11: Summary

This chapter has outlined:

- How NAT is used to help alleviate the depletion of the IPv4 address space.
- NAT conserves public address space and saves considerable administrative overhead in managing adds, moves, and changes.
- NAT for IPv4, including:
  - NAT characteristics, terminology, and general operations
  - Different types of NAT, including static NAT, dynamic NAT, and NAT with overloading
  - Benefits and disadvantages of NAT
- The configuration, verification, and analysis of static NAT, dynamic NAT, and NAT with overloading.

# Chapter 11: Summary (cont.)

- How port forwarding can be used to access an internal devices from the Internet.
- Troubleshooting NAT using **`show`** and **`debug`** commands.
- How NAT for IPv6 is used to translate between IPv6 addresses and IPv4 addresses.