DHCP & NAT

DHCP –
Dynamic Host Configuration Protocol

DHCP Motivation

- ❑ BOOTP
  - Support sending extra information beyond an IP address to a client to enable customized configuration
  - Effectively solve one of the major problems that administrators have with manual configuration

- ❑ Problems of BOOTP
  - BOOTP normally uses a static method of determining what IP address to assign to a device

- ❑ Dynamic Host Configuration Protocol (DHCP)
  - DHCP is an extension of the BOOTP. The first word describe the most important new capability added to BOOTP
    - ➢ Assign IP dynamically
    - ➢ Move away from static, permanent IP address assignment
  - Compatible with BOOTP

DHCP introduction

- ❑ DHCP
  - Dynamic address assignment
    - A pool of IP address is used to dynamically allocate addresses
    - Still support static mapping of addresses
  - Enable a DHCP client to “lease” a variety of network parameters
    - IP, netmask
    - Default router, DNS servers
    - A system can connect to a network and obtain the necessary information dynamically
- ❑ Client-Server architecture
  - DHCP client broadcasts request for configuration info.
    - UDP port 68
  - DHCP server reply on UDP port 67, including
    - IP, netmask, DNS, router, IP lease time, etc.
- ❑ RFC
  - RFC 2131 – Dynamic Host Configuration Protocol
  - RFC 2132 – DHCP Options
- ❑ Two main function of DHCP
  - Provide a mechanism for assigning addresses
  - A method by which clients can request addresses and other configurations

DHCP Address Assignment

- ❑ Address allocation mechanisms
  - Provide flexibility for configuring addresses on different types of clients
  - Three different address allocation mechanisms
    - ➢ Manual allocation
      - – IP address is pre-allocated to a single device
    - ➢ Automatic allocation
      - – Assign an IP address permanently to a device
    - ➢ Dynamic allocation
      - – Assign an IP address from a pool for a limited period of time
- ❑ Manual allocation
  - Equivalent to the method BOOTP used
  - For servers and routers
  - Administrative benefit

Dynamic allocation

❑ Benefits for dynamic allocation

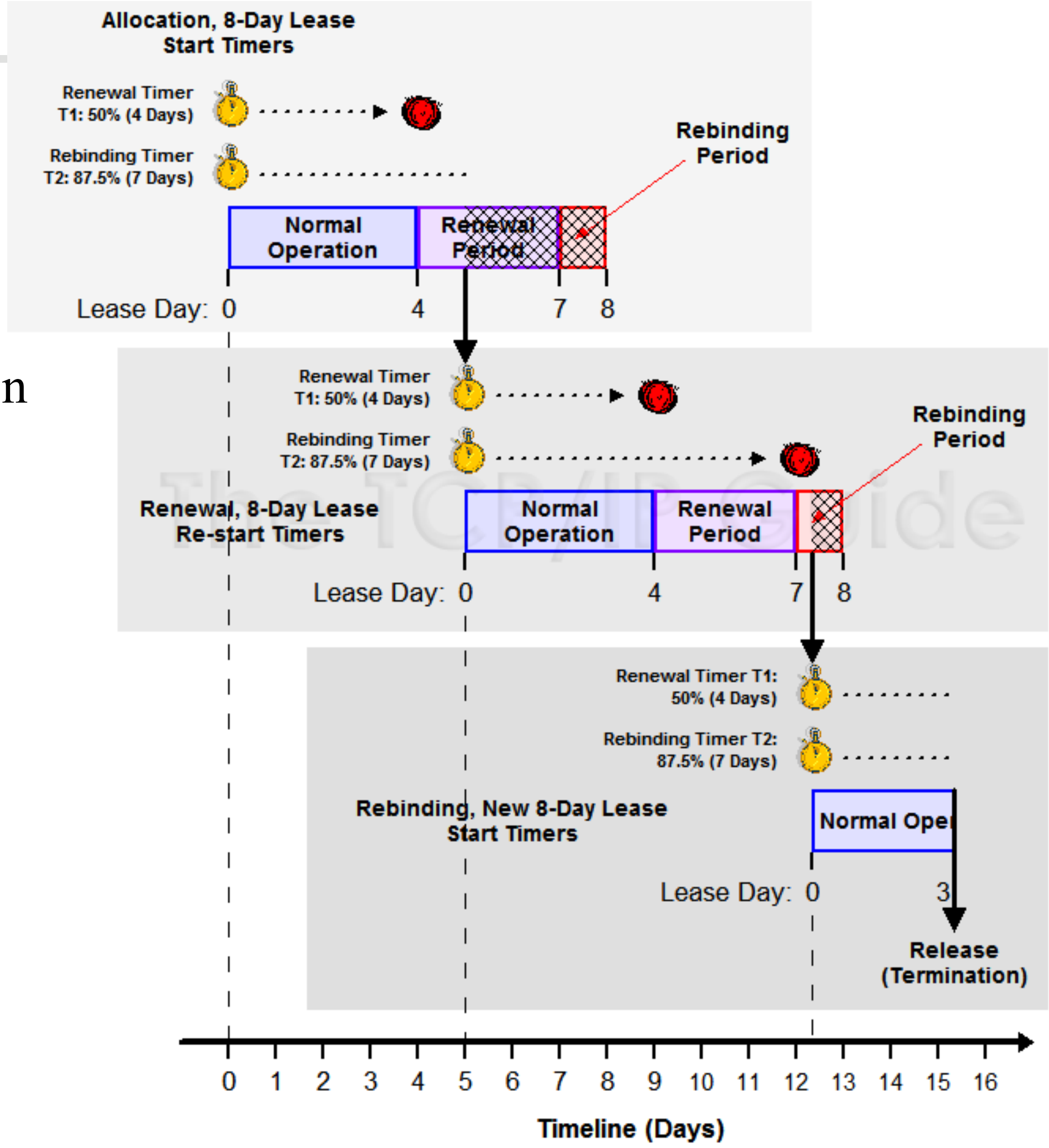
- Automation
  - ➢ No intervention for an administrator
- Centralized management
  - ➢ An administrator can easily look to see which devices are using which addresses
- Address reuse and sharing
- Portability and universality
  - ➢ Do NOT require DHCP server know the identify of each client
  - ➢ Support mobile devices
- Conflict avoidance

DHCP Leases

- ❑ Dynamic address allocation is by far the most popular
  - Hosts are said to “lease” an address instead of “own” one
- ❑ DHCP lease length policy
  - A trade-off between stability and allocation efficiency
  - The primary benefit of using long lease is that the addresses of hosts are relatively stable
    - ➢ Servers
  - The main drawback of using long leases is to increase the amount of time that an IP can be reused
- ❑ Assigning lease length by client type
  - Use long lease for desktop computers
  - Use short lease for mobile devices
- ❑ Factoring lease renewal into lease length selection

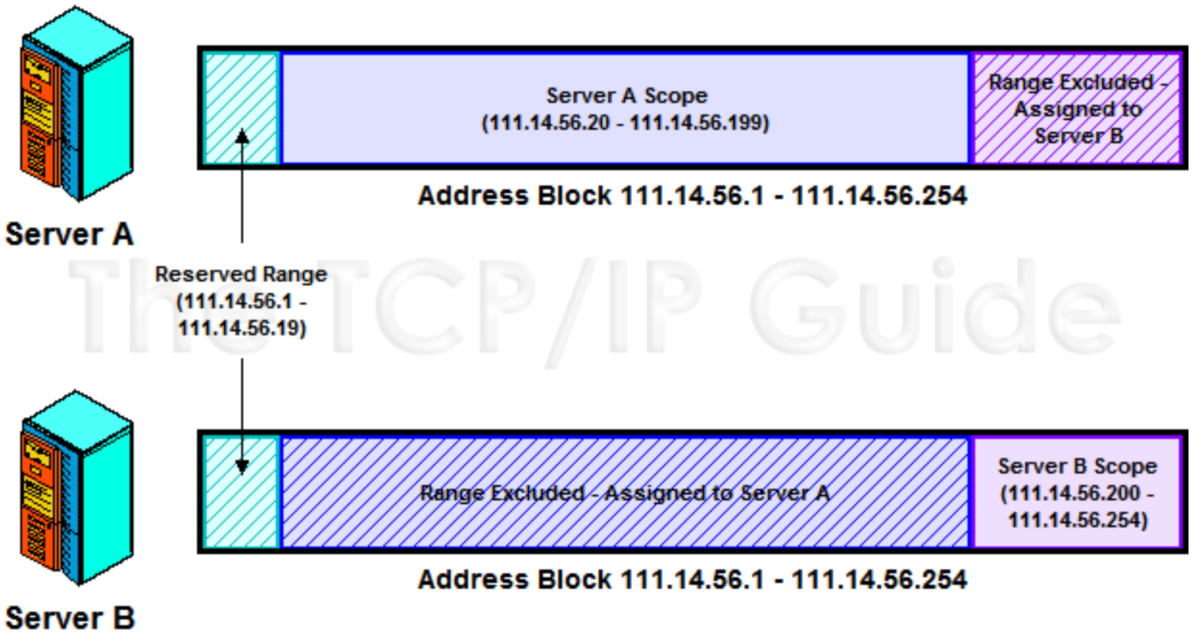
DHCP Lease “Life Cycle”

- ❑ Life cycle
  - Allocation
  - Reallocation
  - Normal operation
  - Renewal
  - Rebinding
  - Release



DHCP Lease Address Pools

- ❑ Each DHCP server maintains a set of IP addresses
  - Use to allocate leases to clients
    - ➢ Most of clients are equals
      - – A range of addresses is normally handled as a single group defined for a particular network

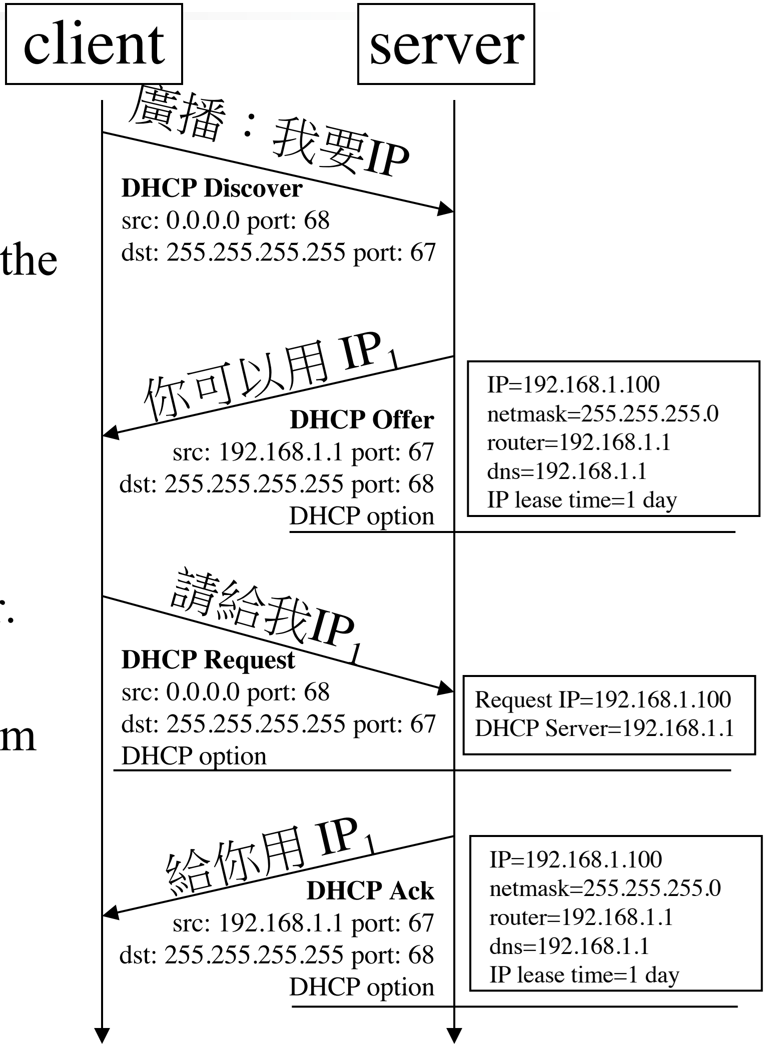


DHCP Protocol (1)

- ❑ DHCP Discover
  - Broadcasted by client to find available server.
  - Client can request its last-known IP, but the server can ignore it.
- ❑ DHCP Offer
  - Server find IP for client based on clients hardware address (MAC)
- ❑ DHCP Request
  - Client request the IP it want to the server.
- ❑ DHCP Acknowledge
  - Server acknowledges the client, admit him to use the requested IP.

※ Question

- Why not use the IP after DHCP offer?



client

server

廣播：我要IP

DHCP Discover
src: 0.0.0.0 port: 68
dst: 255.255.255.255 port: 67

你可以用 IP$_1$

DHCP Offer
src: 192.168.1.1 port: 67
dst: 255.255.255.255 port: 68
DHCP option

IP=192.168.1.100
netmask=255.255.255.0
router=192.168.1.1
dns=192.168.1.1
IP lease time=1 day

請給我IP$_1$

DHCP Request
src: 0.0.0.0 port: 68
dst: 255.255.255.255 port: 67
DHCP option

Request IP=192.168.1.100
DHCP Server=192.168.1.1

給你用 IP$_1$

DHCP Ack
src: 192.168.1.1 port: 67
dst: 255.255.255.255 port: 68
DHCP option

IP=192.168.1.100
netmask=255.255.255.0
router=192.168.1.1
dns=192.168.1.1
IP lease time=1 day

DHCP Protocol (2)

- ❑ DHCP Inform
  - Request more information than the server sent.
  - Repeat data for a particular application.
    - ➢ ex. browsers request web proxy settings from server.
  - It does not refresh the IP expiry time in server’s database.
- ❑ DHCP Release
  - Client send this request to server to releases the IP, and the client will un-configure this IP.
  - Not mandatory.

DHCP server on FreeBSD (1)

❑ Kernel support

device bpf	(FreeBSD 5.x↑)
pseudo-device bpf	(FreeBSD 4.x↓)

❑ Install DHCP server

- /usr/ports/net/isc-dhcp44-server/
- pkg install isc-dhcp44-server

❑ Enable DHCP server in /etc/rc.conf

```
dhcpd_enable="YES"
dhcpd_flags="-q"
dhcpd_conf="/usr/local/etc/dhcpd.conf"
dhcpd_ifaces=""
dhcpd_withumask="022"
```

DHCP server on FreeBSD (2)

- ❑ Option definitions

```
option domain-name "cs.nctu.edu.tw";
option domain-name-servers 140.113.235.107, 140.113.1.1;

default-lease-time 600;
max-lease-time 7200;
ddns-update-style none;
log-facility local7;
```

/etc/syslogd.conf
/etc/newsyslog.conf

DHCP server on FreeBSD (3)

- Subnet definition

```
subnet 192.168.1.0 netmask 255.255.255.0 {
    range 192.168.1.101 192.168.1.200;
    option domain-name "cs.nctu.edu.tw";
    option routers 192.168.1.254;
    option broadcast-address 192.168.1.255;
    option domain-name-servers 140.113.17.5, 140.113.1.1;
    default-lease-time 3600;
    max-lease-time 21600;
}
```

- Host definition

```
host fantasia {
    hardware ethernet 08:00:07:26:c0:a5;
    fixed-address 192.168.1.30;
}
host denyClient {
    hardware ethernet 00:07:95:fd:12:13;
    deny booting;
}
```

DHCP server on FreeBSD (4)

❑ Important files

- /usr/local/sbin/dhcpd
- /usr/local/etc/dhcpd.conf
- /var/db/dhcpd.leases (leases issued)
- /usr/local/etc/rc.d/isc-dhcpd

NAT –
Network Address Translation

IP address crisis

- ❑ IP address crisis
  - Run out of class B address
    - ➢ The most desirable ones for moderately large organizations
  - IP address were being allocated on a FCFS
    - ➢ With no locality of reference

- ❑ Solutions
  - Short term
    - ➢ Subnetting and CIDR (classless inter-domain routing)
    - ➢ NAT (network address translation)
  - Long term
    - ➢ IPv6

Network Address Translation (NAT)

❑ Some important characteristics of how most organizations use the internet

- Most hosts are client
- Few hosts access the internet simultaneously
- Internet communications are routed

❑ Network Address Translation

- RFC 1631, in May 1994
- A basic implementation of NAT involves
  - ➢ Using one of the private addresses for local networks
  - ➢ Assigned one or more public IP addresses
- The word ‘translator’ refers to the device that implements NAT

Private Address Space

- ❑ Private addresses space defined by RFC1918
  - 24-bit block (Class A)
    - ➢ 10.0.0.0/8
  - 20-bit block (16 contiguous Class B)
    - ➢ 172.16.0.0/12 ~ 172.31.0.0/12
  - 16-bit block (256 contiguous Class C)
    - ➢ 192.168.0.0/16 ~ 192.168.255.0/16

- ❑ Operation consideration
  - Router should set up filters for both inbound and outbound private network traffic

Network Address Translation (NAT)

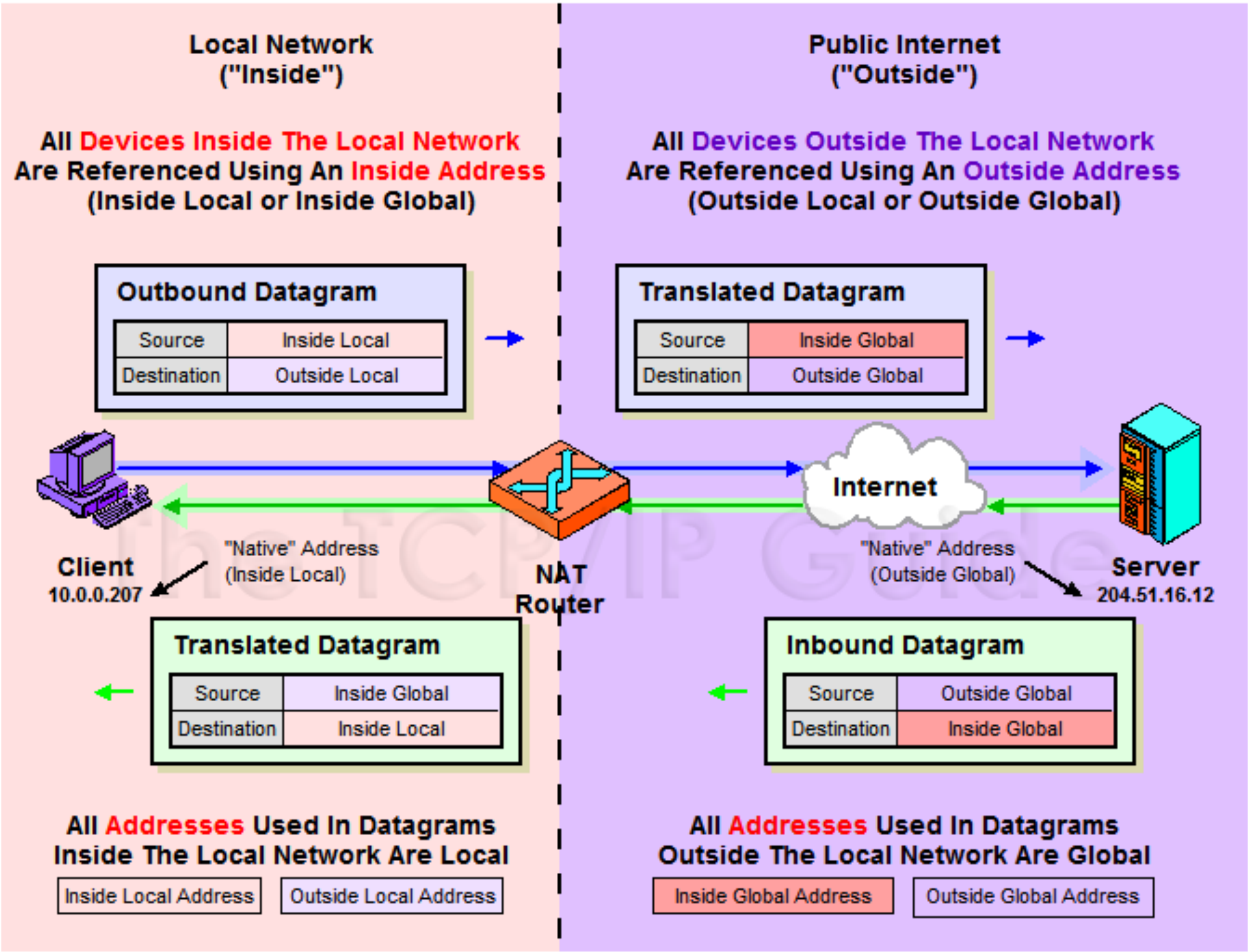
❑ What is NAT?

- Network Address Translation
- Re-write the source and/or destination addresses of IP packets when they pass through a router or firewall.
- What can be re-written?
  - ➢ Source/destination IPs
  - ➢ Source/destination ports

❑ What can NAT do?

- Solve the IPv4 address shortage. (the most common purpose)
- Kind of firewall (security)
- Load balancing
- Fail over (for service requiring high availability)

NAT Terminology



Local Network ("Inside")

All Devices Inside The Local Network Are Referenced Using An Inside Address (Inside Local or Inside Global)

Public Internet ("Outside")

All Devices Outside The Local Network Are Referenced Using An Outside Address (Outside Local or Outside Global)

Outbound Datagram

Source	Inside Local
Destination	Outside Local

Translated Datagram

Source	Inside Global
Destination	Outside Global

Translated Datagram

Source	Inside Global
Destination	Inside Local

Inbound Datagram

Source	Outside Global
Destination	Inside Global

All Addresses Used In Datagrams Inside The Local Network Are Local

Inside Local Address | Outside Local Address

All Addresses Used In Datagrams Outside The Local Network Are Global

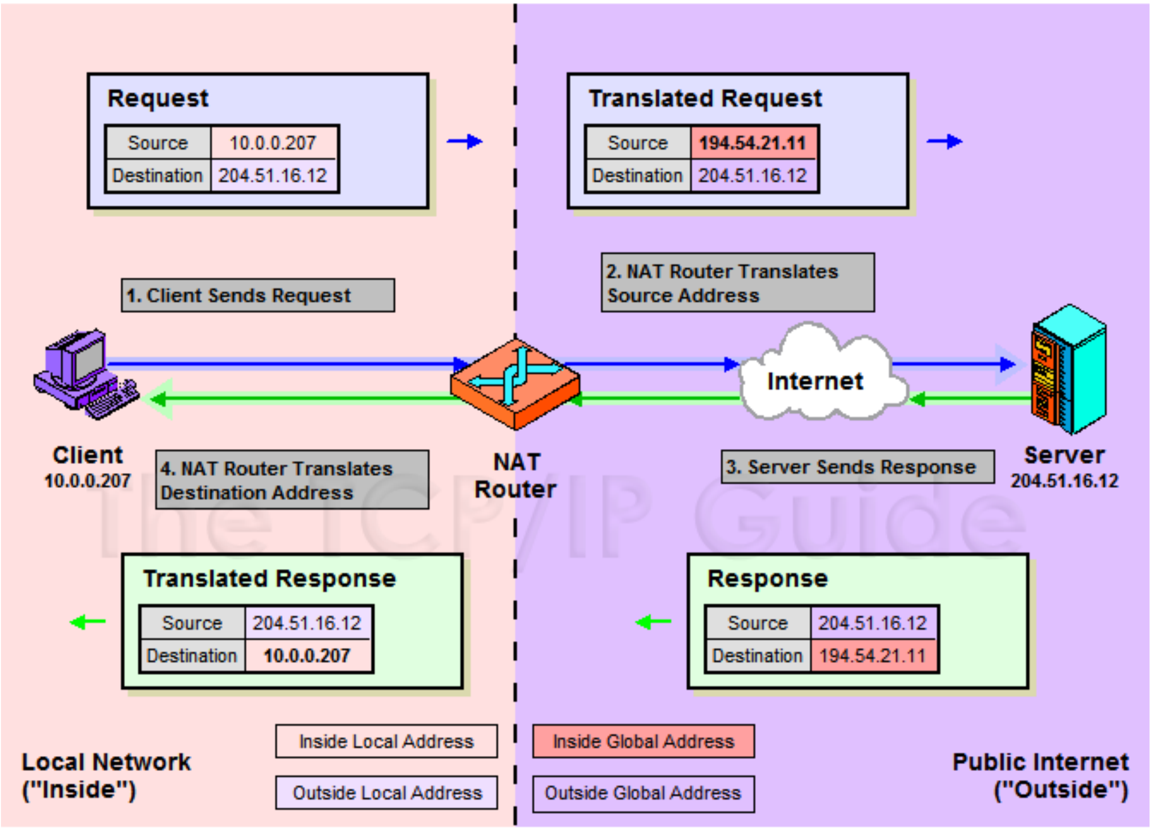
Inside Global Address | Outside Global Address

NAT Address Mappings

- ❑ Each time a NAT router encounters an IP datagram
  - It must translate addresses
  - BUT, how does it know what to translate, and what to use for the translated addresses
- ❑ Translation table
  - Maps the inside local address to the inside global address
  - Also contains mappings between outside global address and outside local address for inbound translations
- ❑ Two address mappings
  - Static mappings
    - ➢ Allow the inside host with an inside local address to always use a inside global address
  - Dynamic mappings
    - ➢ Allow a pool of inside global addresses to be shared by a large number of inside hosts

NAT Unidirectional Operation

- ❑ NAT Unidirectional Operation
  - Traditional/Outbound operation
  - The original variety of NAT in RFC 1631
    - The simplest NAT
    - The client/server request/response communication would sent from the inside to outside network



Request

Source	10.0.0.207
Destination	204.51.16.12

Translated Request

Source	194.54.21.11
Destination	204.51.16.12

Translated Response

Source	204.51.16.12
Destination	10.0.0.207

Response

Source	204.51.16.12
Destination	194.54.21.11

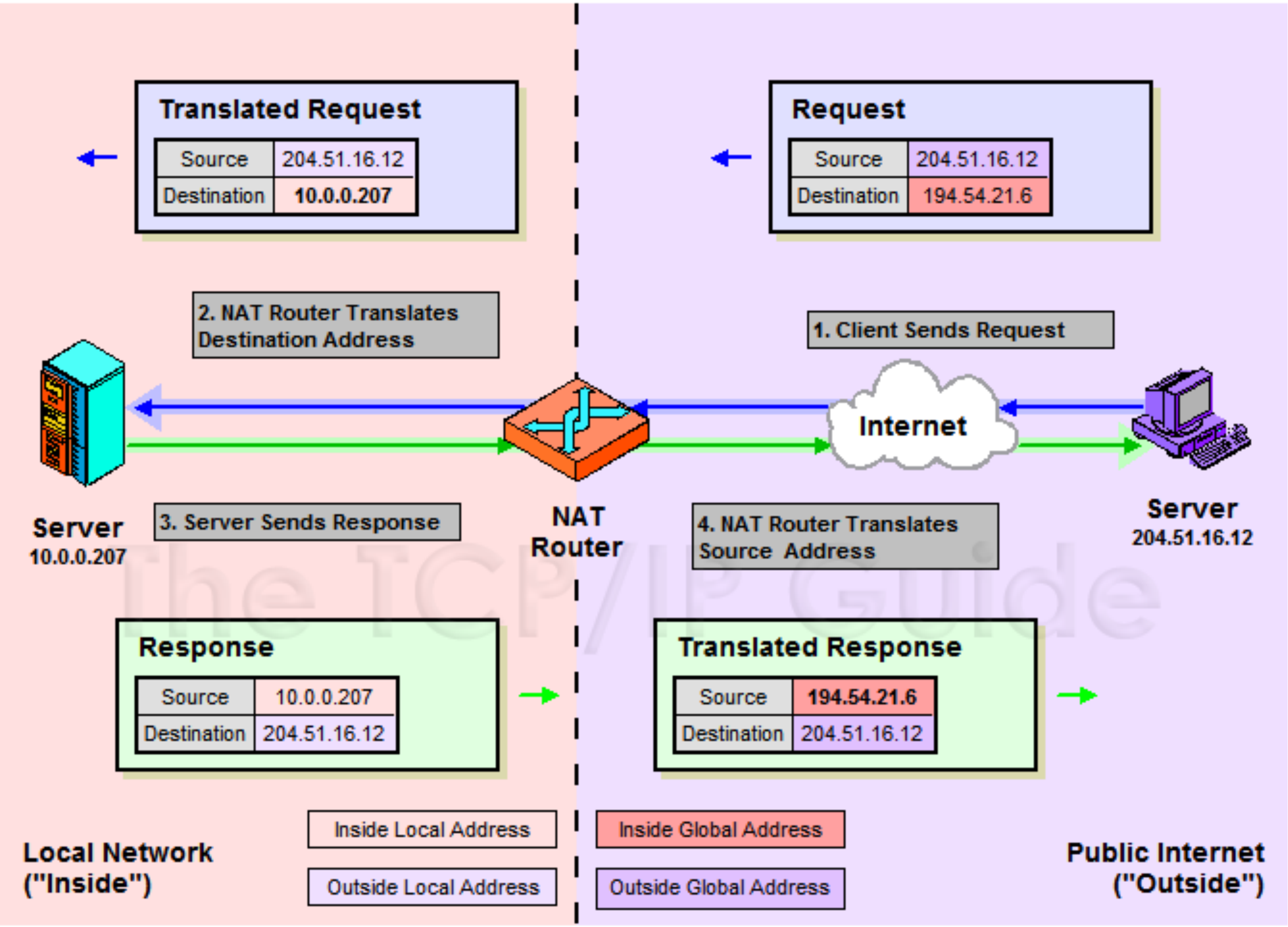
NAT Bidirectional Operation

- ❑ NAT Bidirectional Operation
  - Two-Way/Inbound operation
  - A host on the outside network initiate a transaction with one on the inside
- ❑ The problem with inbound NAT
  - NAT is inherently asymmetric
    - ➢ The outside network does not know the private addresses of the inside network
    - ➢ Hidden addresses are not routable
    - ➢ The outbound hosts DO NOT know the identity of the NAT router
    - ➢ NAT mapping table

NAT Bidirectional Operation

- Two methods to resolve the hidden address problem
  - Static mapping
  - DNS
    - RFC 2694, DNS extensions to NAT
- The basic process is as follows
  - The outside host sends a DNS request using the name of the private host
  - The DNS server for the internal network resolves the name into an inside local address
  - The inside local address is passed to NAT and used to create a dynamic mapping
  - DNS server sends back the name resolution with the inside global address

NAT Bidirectional Operation



Translated Request

Source	204.51.16.12
Destination	10.0.0.207

Request

Source	204.51.16.12
Destination	194.54.21.6

2. NAT Router Translates Destination Address

1. Client Sends Request

3. Server Sends Response

4. NAT Router Translates Source Address

Response

Source	10.0.0.207
Destination	204.51.16.12

Translated Response

Source	194.54.21.6
Destination	204.51.16.12

Inside Local Address

Outside Local Address

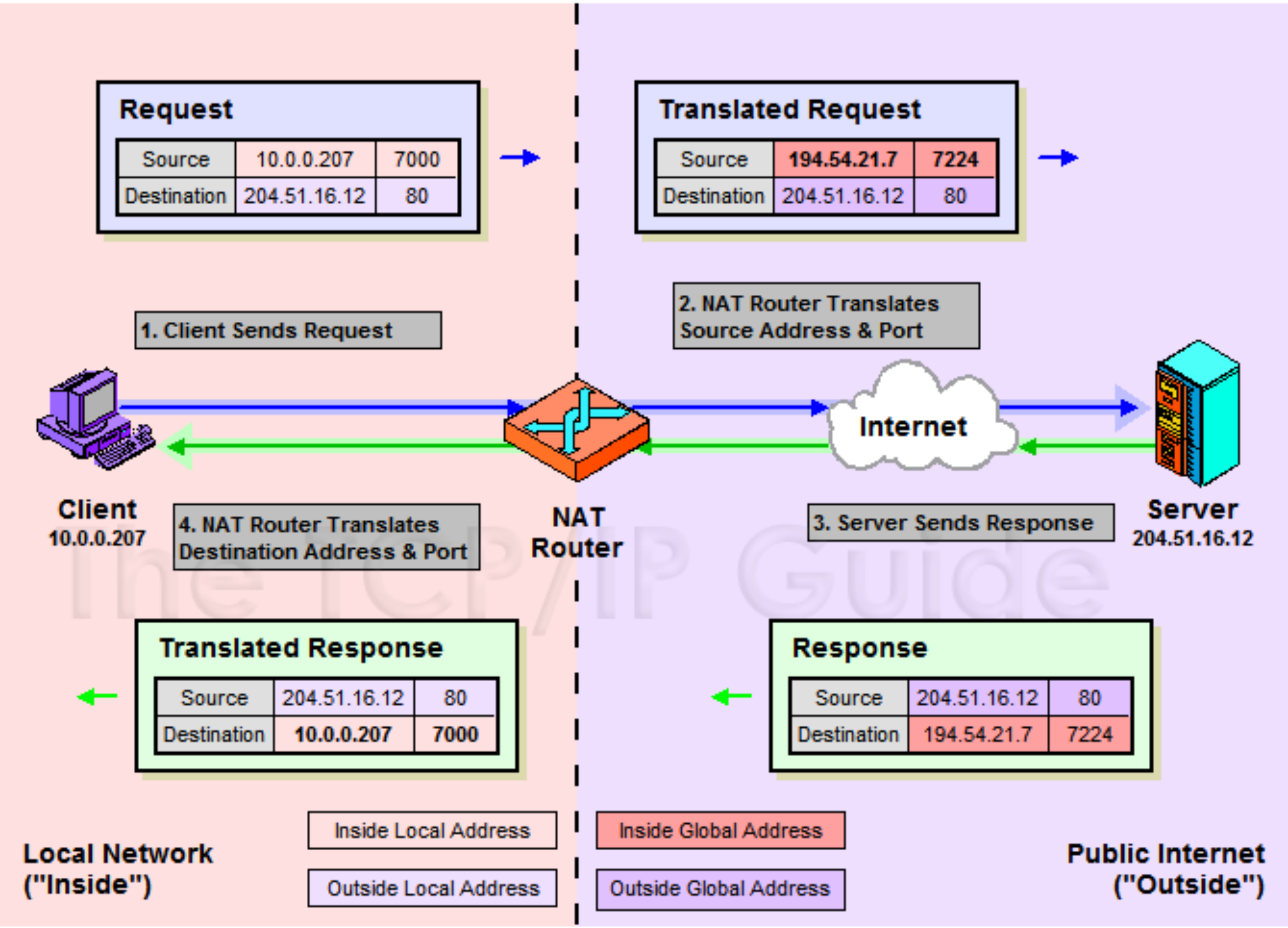
Inside Global Address

Outside Global Address

NAT Port-Based Operation

- ❑ NAT Port-Based Operation
  - Overloaded operation
  - Network Address Port Translation (NAPT)/Port Address Translation (PAT)
  - Both traditional NAT and bidirectional NAT work by swapping inside network and outside network addresses
    - ➢ One-to-one mapping between inside local address and inside global address
    - ➢ Use dynamic address assignment to allow a large number of private hosts to share a small number of registered public addresses
- ❑ Using ports to multiplex private addresses
  - Also translate port addresses
  - Allow 250 hosts on the private network to use only 20 IP address
  - Overloading of an inside global address

NAT Port-Based Operation



Request

Source	10.0.0.207	7000
Destination	204.51.16.12	80

Translated Request

Source	**194.54.21.7**	**7224**
Destination	204.51.16.12	80

1. Client Sends Request

2. NAT Router Translates Source Address & Port

3. Server Sends Response

4. NAT Router Translates Destination Address & Port

Response

Source	204.51.16.12	80
Destination	194.54.21.7	7224

Translated Response

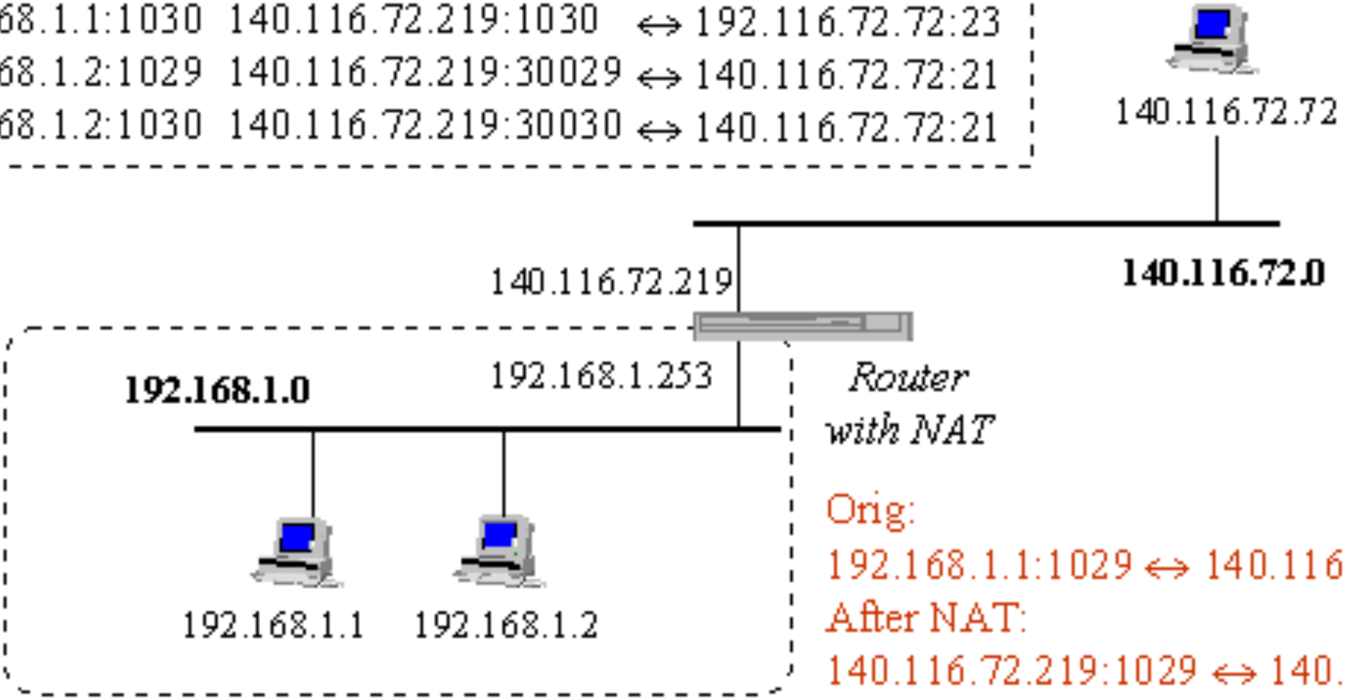
Source	204.51.16.12	80
Destination	**10.0.0.207**	**7000**

NAT Port-Based Operation

- ❑ NAT example:

NAT mapping table

Orig	Alias		Remote
192.168.1.1:1029	140.116.72.219:1029	↔	140.116.72.72:23
192.168.1.1:1030	140.116.72.219:1030	↔	192.116.72.72:23
192.168.1.2:1029	140.116.72.219:30029	↔	140.116.72.72:21
192.168.1.2:1030	140.116.72.219:30030	↔	140.116.72.72:21



Orig:
192.168.1.1:1029 ↔ 140.116.72.72:23
After NAT:
140.116.72.219:1029 ↔ 140.116.72.72:23

NAT Overlapping Operation

❑ NAT Overlapping Operation

- Twice NAT Operation
- The previous three versions of NAT are normally used to connect a network using private, non-routable addresses to the public internet
  - ➢ No overlap between the address spaces of the inside and outside network

❑ Cases with overlapping private and public address blocks

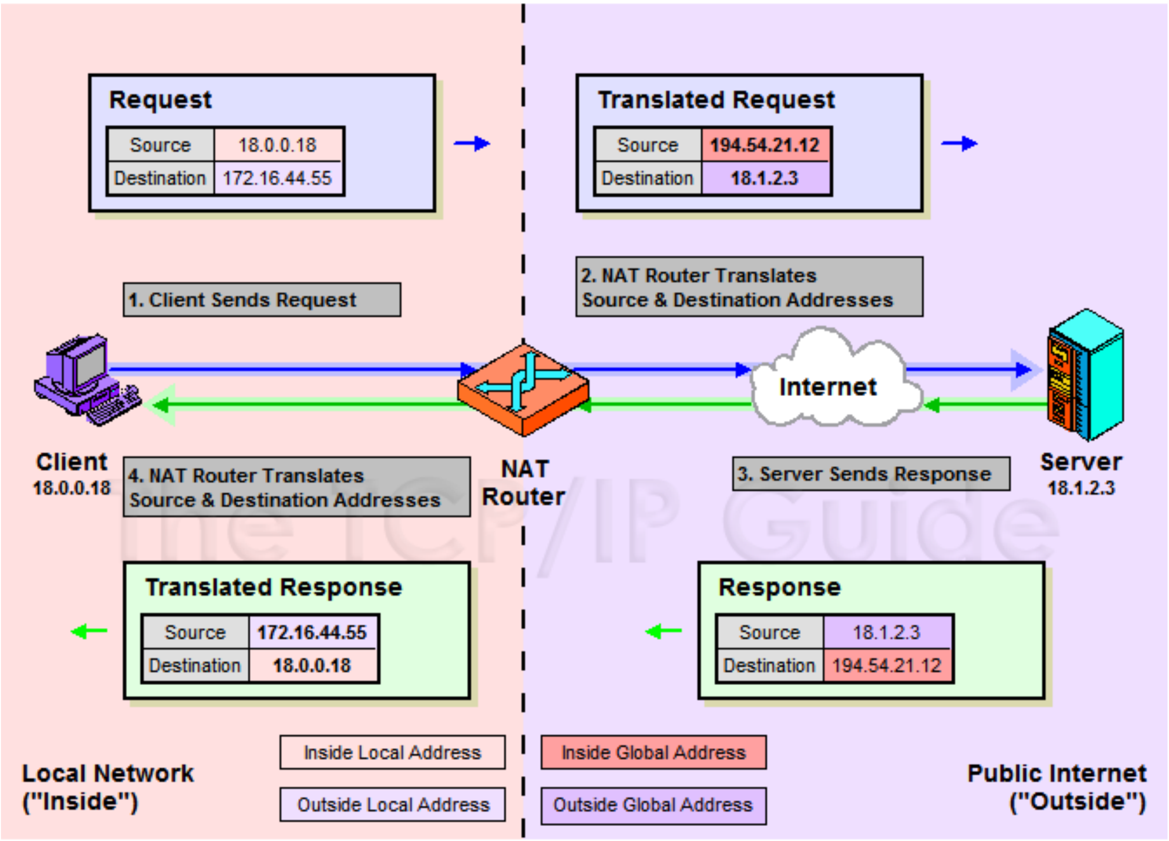
- Private network to private network connections
- Invalid assignment of public address space to private network

❑ Dealing with overlapping blocks by using NAT twice

- Translate both the source and destination address on each transition
- Rely on use of the DNS
  - ➢ Let the inside network send requests to the overlapping network in a way that can be uniquely identified

NAT Overlapping Operation

- A client, 18.0.0.18, wants to send a request to the server www.twicenat.mit.edu, 18.1.2.3.
  - 18.0.0.18 sends a DNS request
  - NAT router intercepts this DNS request
    - Consult its tables to find a special mapping for this outside host
  - NAT router returns 172.16.44.55 to the source client



Request

Source	18.0.0.18
Destination	172.16.44.55

Translated Request

Source	194.54.21.12
Destination	18.1.2.3

Translated Response

Source	172.16.44.55
Destination	18.0.0.18

Response

Source	18.1.2.3
Destination	194.54.21.12

1. Client Sends Request

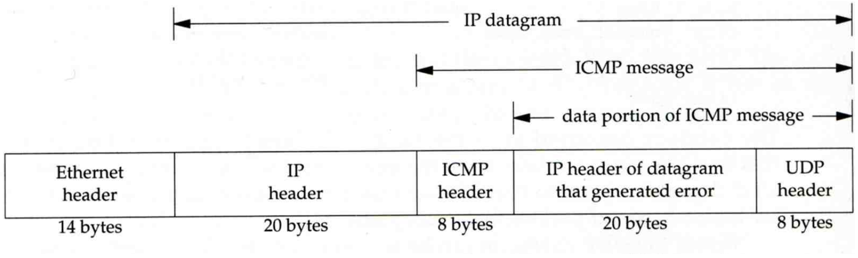
2. NAT Router Translates Source & Destination Addresses

3. Server Sends Response

4. NAT Router Translates Source & Destination Addresses

NAT Compatibility Issues

- ❑ It is NOT possible for NAT to be completely transparent to the hosts that use it
  - ICMP Manipulations

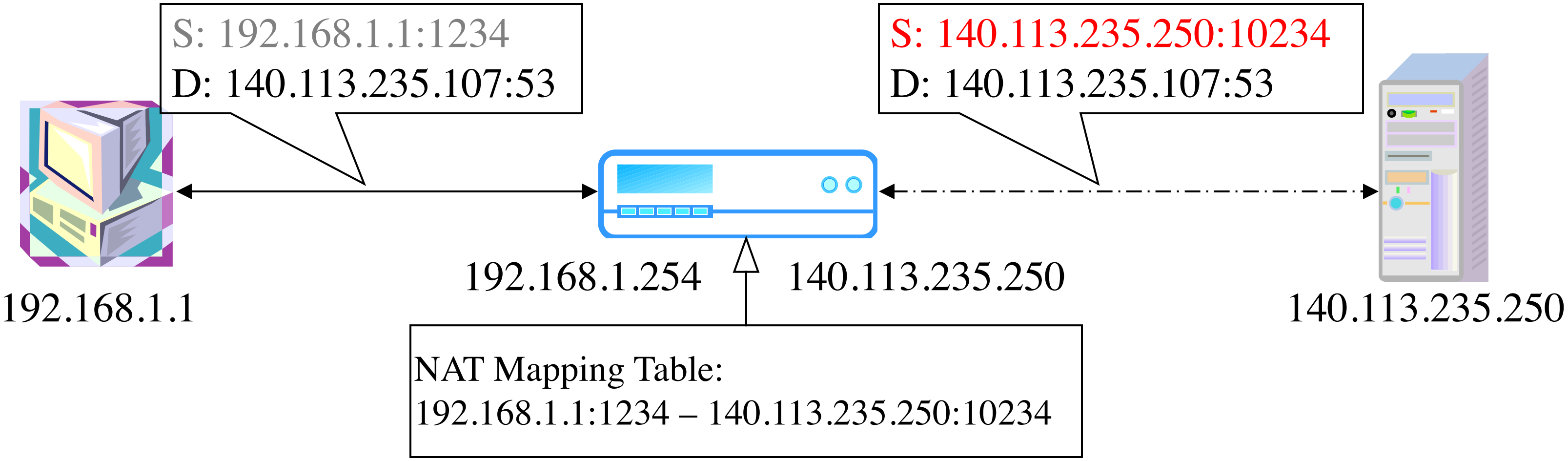


  - Applications that embed IP address
    - FTP
  - Additional issues with port translation
    - The issues applying to addresses now apply to ports as well
  - Problems with IPSec

SNAT

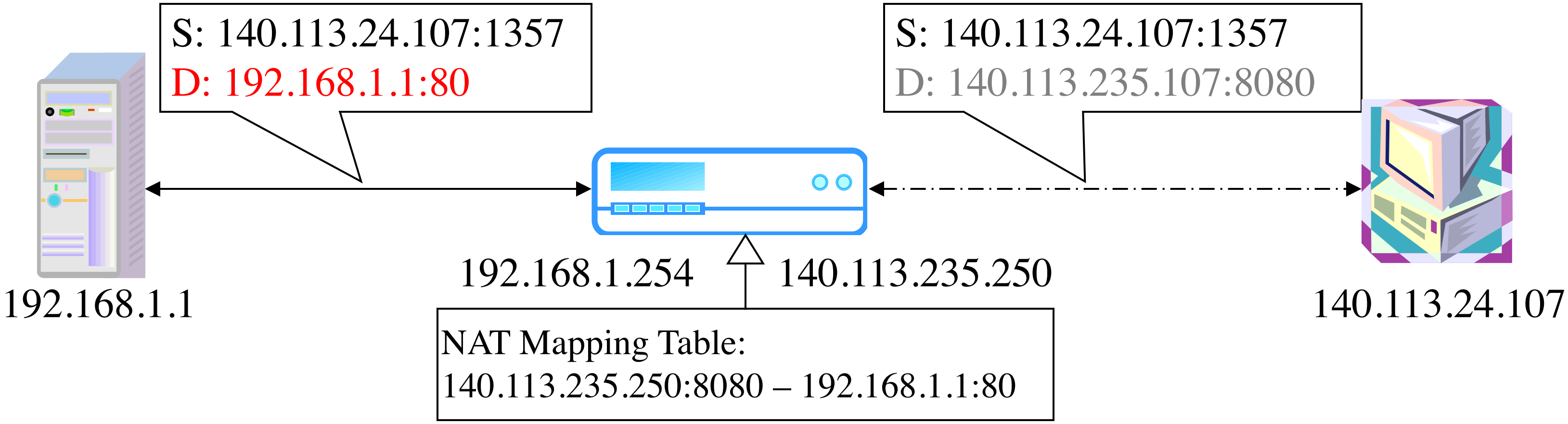
❑ SNAT & DNAT

- S: Source D: Destination
- SNAT
  - ➢ Rewrite the source IP and/or Port.
  - ➢ The rewritten packet looks like one sent by the NAT server.



DNAT

- DNAT
  - ➢ Rewrite the destination IP and/or Port.
  - ➢ The rewritten packet will be redirect to another IP address when it pass through NAT server.



S: 140.113.24.107:1357
D: 192.168.1.1:80

S: 140.113.24.107:1357
D: 140.113.235.107:8080

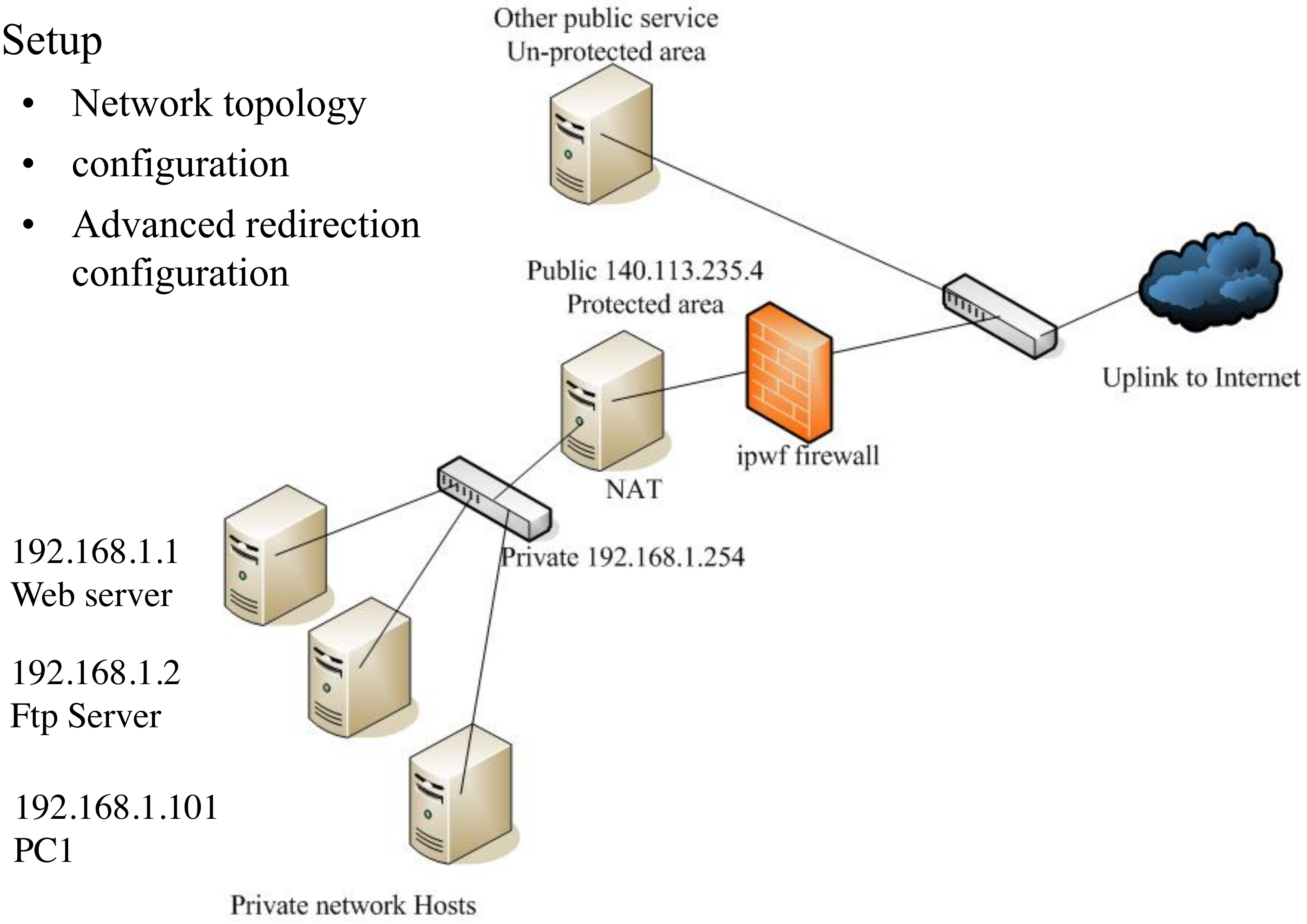
NAT Mapping Table:
140.113.235.250:8080 – 192.168.1.1:80

- Both SNAT and DNAT are usually used together in coordination for two-way communication.

NAT on FreeBSD (1)

❑ Setup

- Network topology
- configuration
- Advanced redirection configuration



Other public service
Un-protected area

Public 140.113.235.4
Protected area

Uplink to Internet

ipwf firewall

NAT

Private 192.168.1.254

192.168.1.1
Web server

192.168.1.2
Ftp Server

192.168.1.101
PC1

Private network Hosts

NAT on FreeBSD (2)

- ❑ IP configuration (in /etc/rc.conf)

```
ifconfig_fxp0="inet 140.113.235.4  netmask 255.255.255.0 media autoselect"
ifconfig_fxp1="inet 192.168.1.254  netmask 255.255.255.0 media autoselect“
defaultrouter="140.113.235.254“
```

- ❑ Enable NAT
  - Here we use Packet Filter (PF) as our NAT server
  - Configuration file: /etc/pf.conf
    - nat
    - rdr
    - binat

```
# macro definitions
extdev='fxp0‘
intranet='192.168.1.0/24‘
webserver=‘192.168.1.1’
ftpserver=‘192.168.1.2’
pc1=‘192.168.1.101’

# nat rules
nat on $extdev inet from $intranet to any -> $extdev
rdr on $extdev inet proto tcp to port 80 -> $webserver port 80
rdr on $extdev inet proto tcp to port 443 -> $webserver port 443
rdr on $extdev inet proto tcp to port 21 -> $ftpserver port 21
```

NAT on FreeBSD (3)

```
# macro definitions
extdev='fxp0‘
intranet='192.168.219.0/24‘
winxp=‘192.168.219.1’
server_int=‘192.168.219.2’
server_ext=‘140.113.214.13’

# nat rules
nat on $extdev inet from $intranet to any -> $extdev
rdr on $extdev inet proto tcp to port 3389 -> $winxp port 3389
binat on $extdev inet from $server_int to any -> $server_ext
```