DHCP & NAT

wangth (2018-2021, CC BY-SA)
? (2009-2017)

DHCP –
Dynamic Host Configuration Protocol

DHCP Motivation

- BOOTP (Bootstrap Protocol)
  - 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

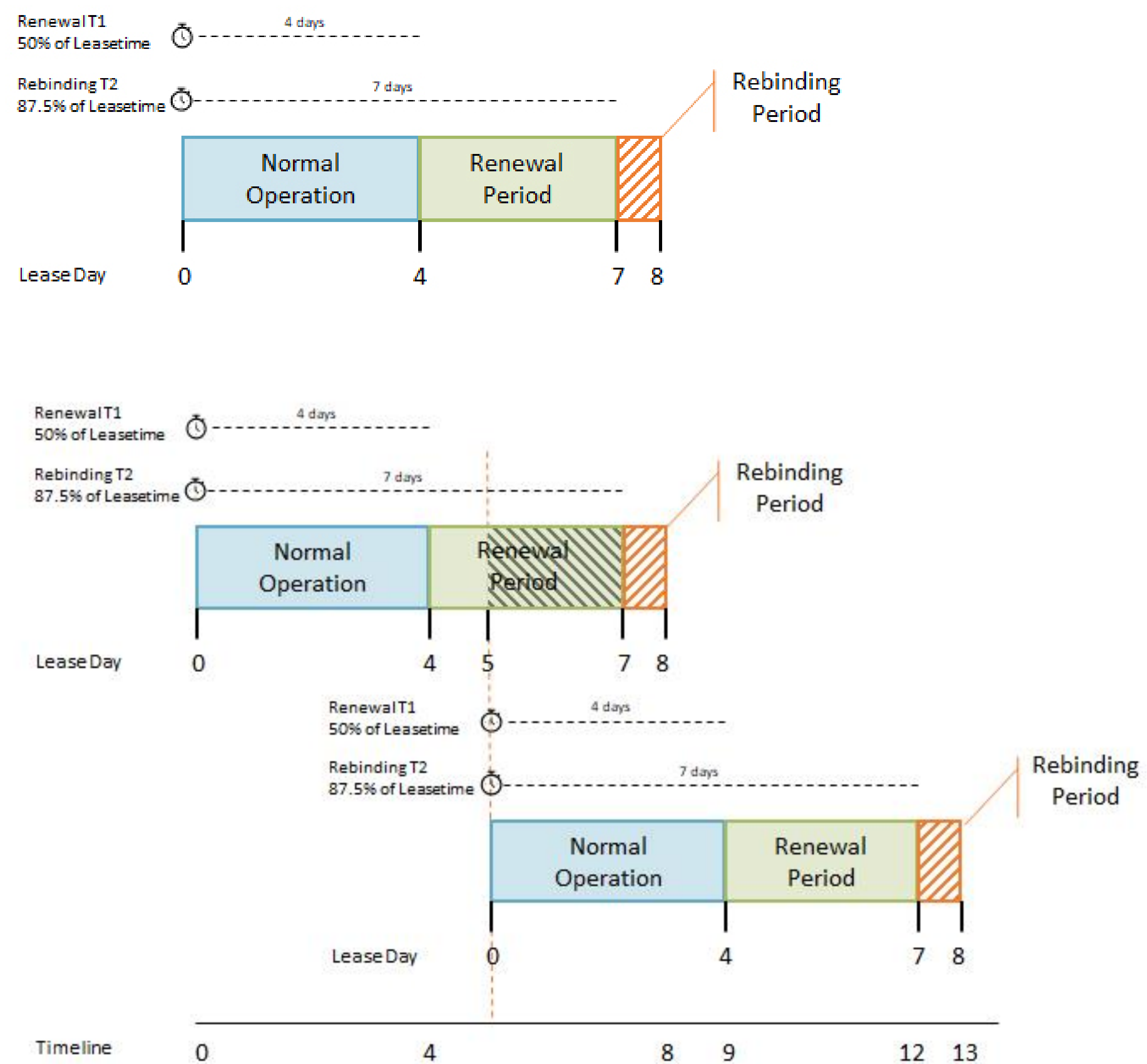
- Benefits for dynamic allocation
  - Automation
    - No intervention for an administrator
  - Centralized management
    - An administrator can easily look to see which devices are using which addresses
  - Address reuse and sharing
  - Portability and universality
    - Do NOT require DHCP server know the identity 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”

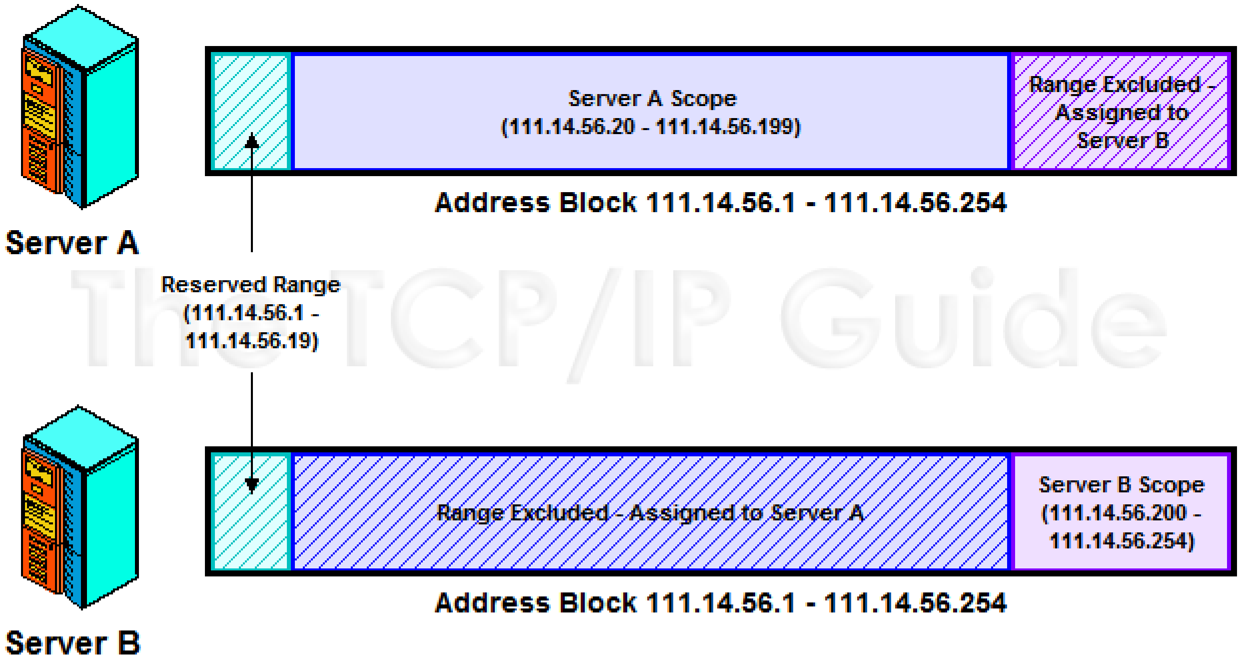
- Life cycle
  - Allocation
  - Reallocation
  - Normal operation
  - Renewal
  - Rebinding
  - Release



[DHCP Lease Time - What is it and How does it work? — LazyAdmin](#)

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



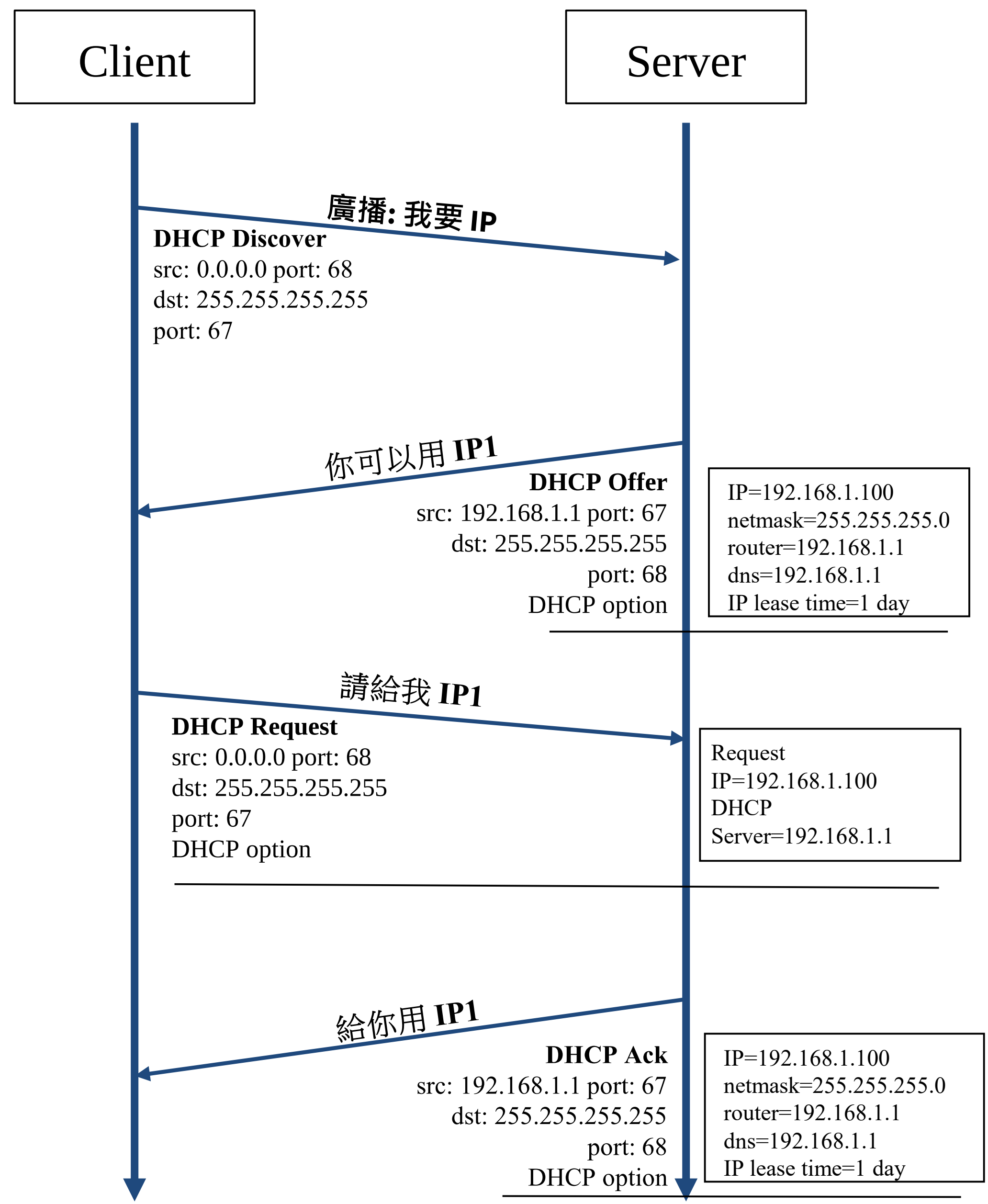
[The TCP/IP Guide - DHCP Lease Address Pools, Ranges (Scopes) and Address Management]

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?



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)

Three-way handshake

- 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

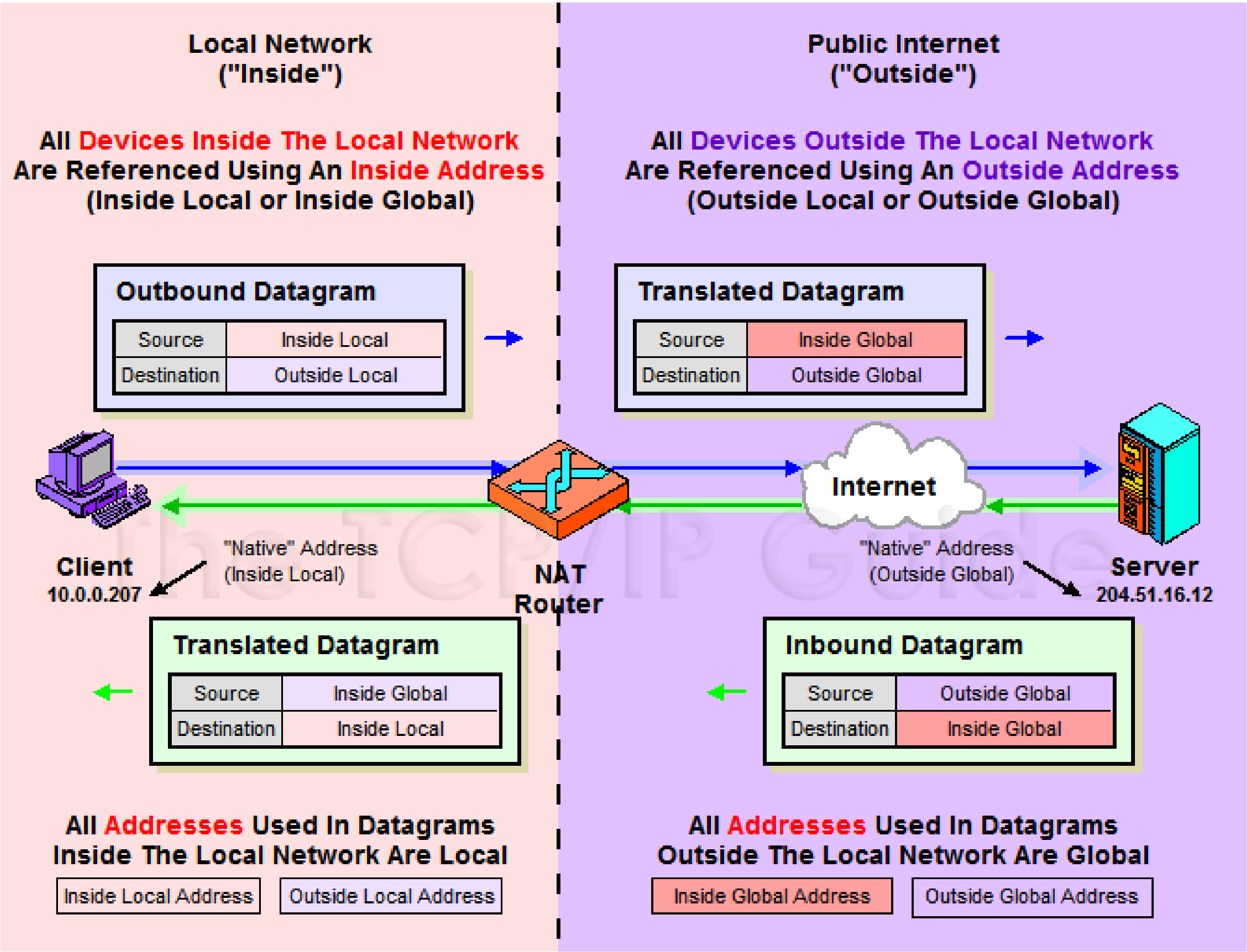
Private Address Space

- 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



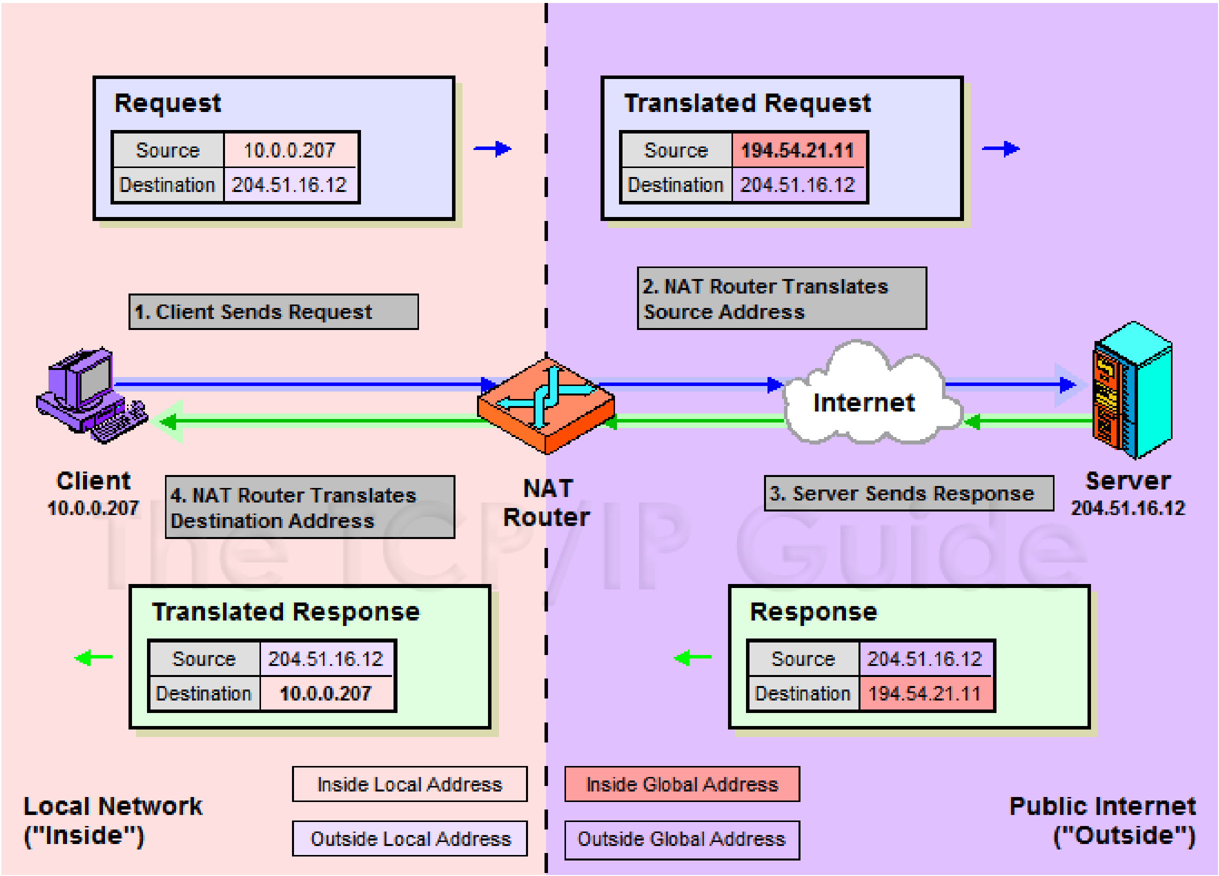
[The TCP/IP Guide - IP NAT Address Terminology]

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



[The TCP/IP Guide - IP NAT Unidirectional (Traditional/Outbound) Operation]

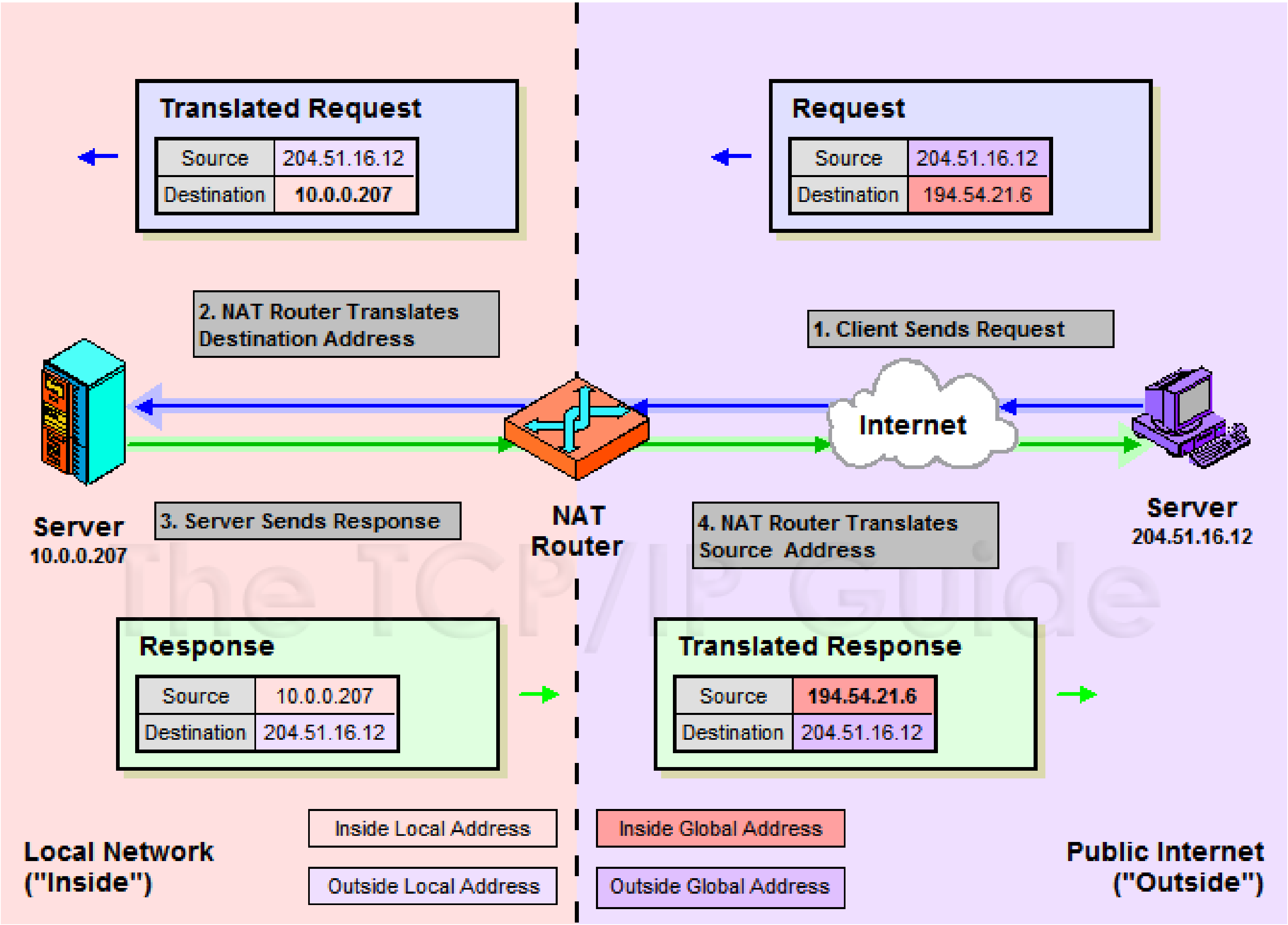
NAT Bidirectional Operation

- 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

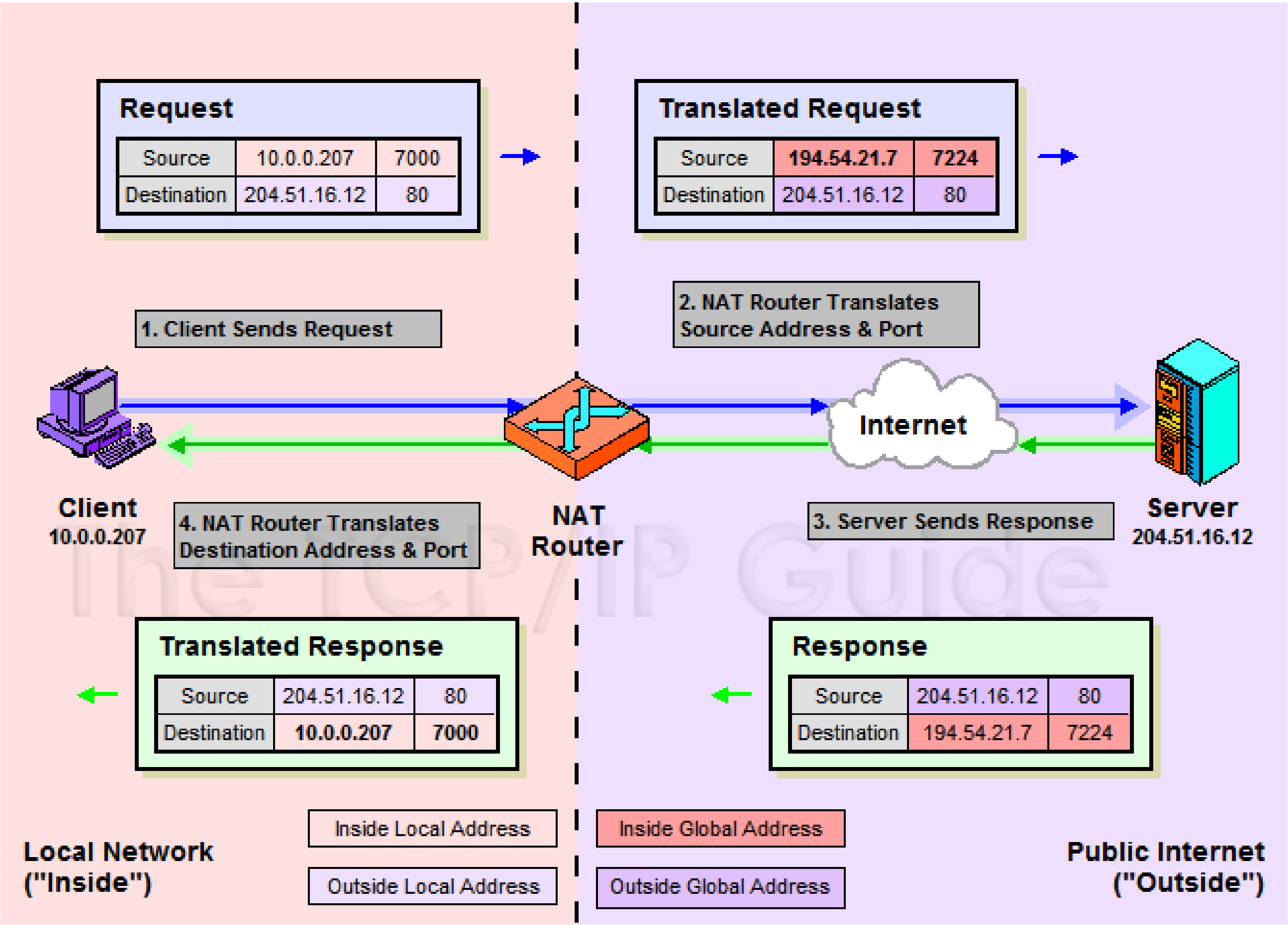


[The TCP/IP Guide - IP NAT Bidirectional (Two-Way/Inbound) Operation]

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



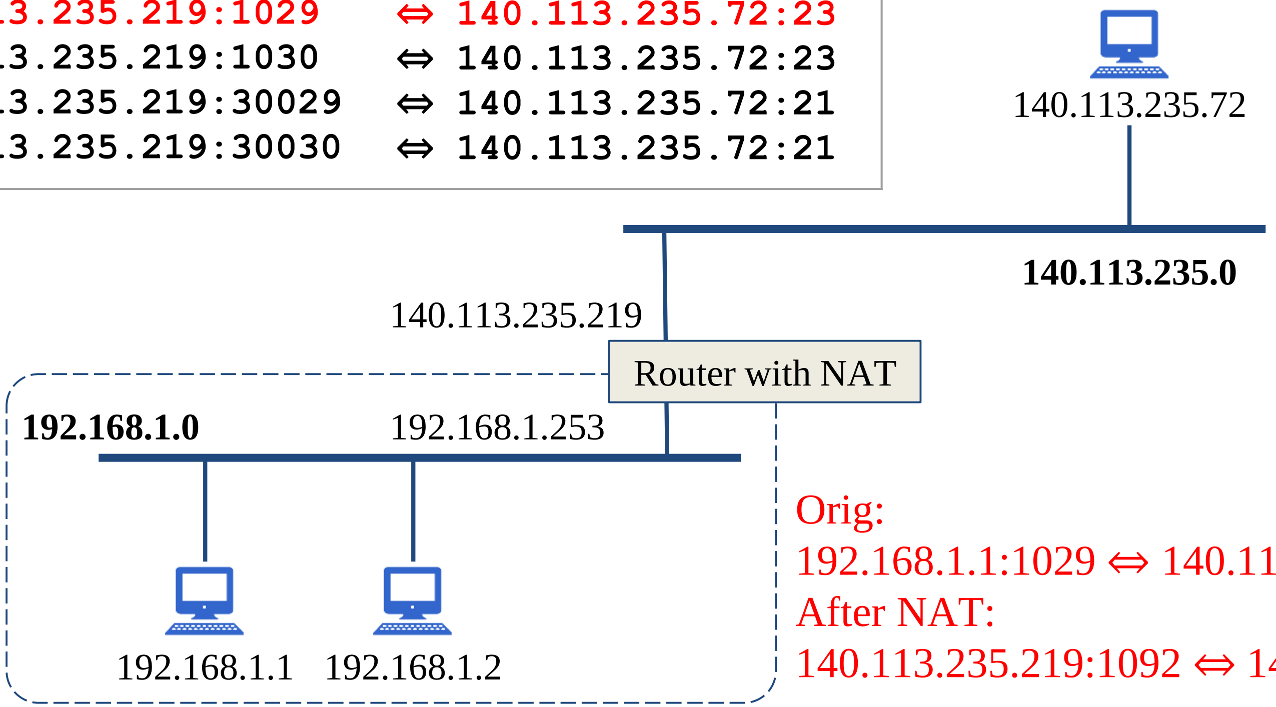
[The TCP/IP Guide - IP NAT Port-Based ("Overloaded") Operation: Network Address Port Translation (NAPT) / Port Address Translation (PAT)]()

NAT Port-Based Operation

- NAT example:

NAT mapping table

Orig	Alias	Remote
192.168.1.1:1029	140.113.235.219:1029	⇔ 140.113.235.72:23
192.168.1.1:1030	140.113.235.219:1030	⇔ 140.113.235.72:23
192.168.1.2:1029	140.113.235.219:30029	⇔ 140.113.235.72:21
192.168.1.2:1030	140.113.235.219:30030	⇔ 140.113.235.72:21



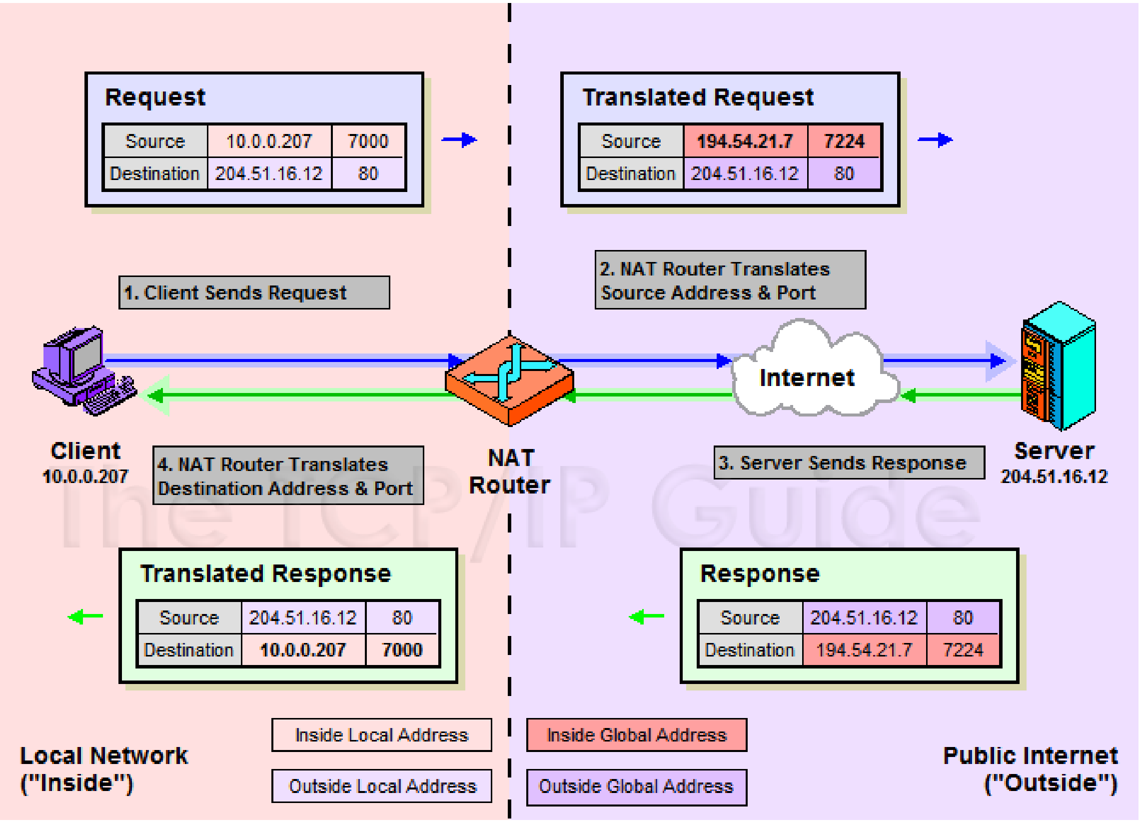
Orig:
192.168.1.1:1029 ⇔ 140.113.235.72:23
After NAT:
140.113.235.219:1092 ⇔ 140.113.235.72:23

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

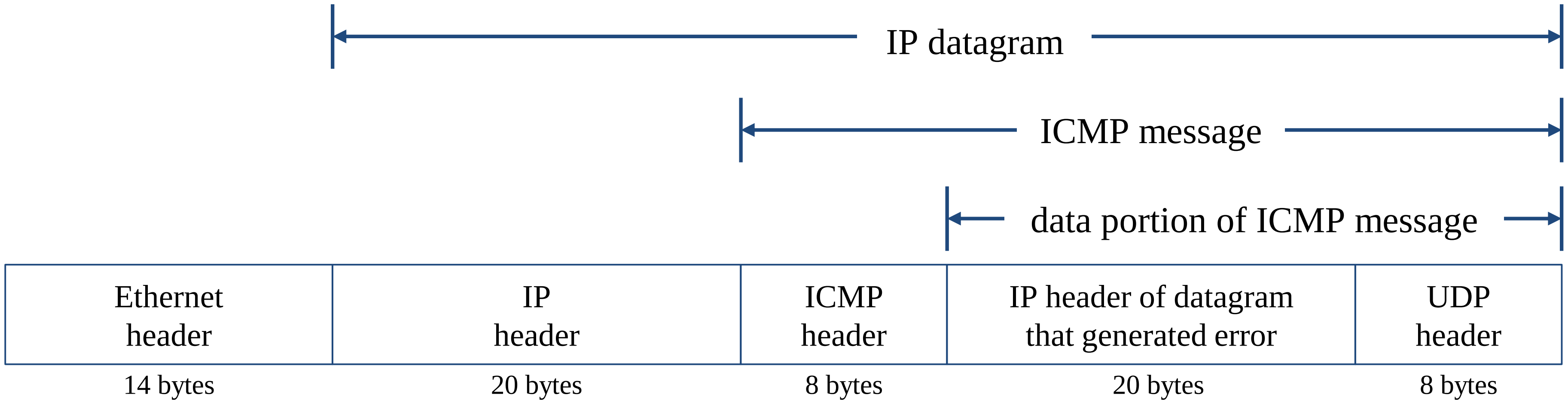
- A client, 18.0.0.18, wants to send a request to the server www.twicenat.mit.edu, 18.1.2.3.
  - 18.0.0.18 sends a DNS request
  - NAT router intercepts this DNS request
    - Consult its tables to find a special mapping for this outside host
  - NAT router returns 172.16.44.55 to the source client



[The TCP/IP Guide - IP NAT Port-Based ("Overloaded") Operation: Network Address Port Translation (NAPT) / Port Address Translation (PAT)]

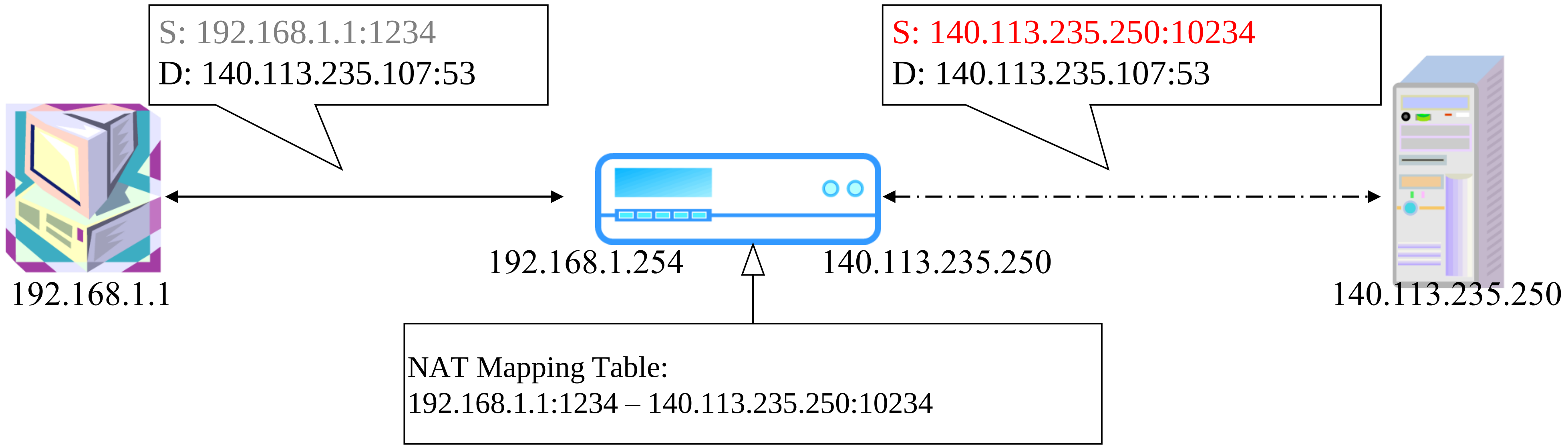
NAT Compatibility Issues

- 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



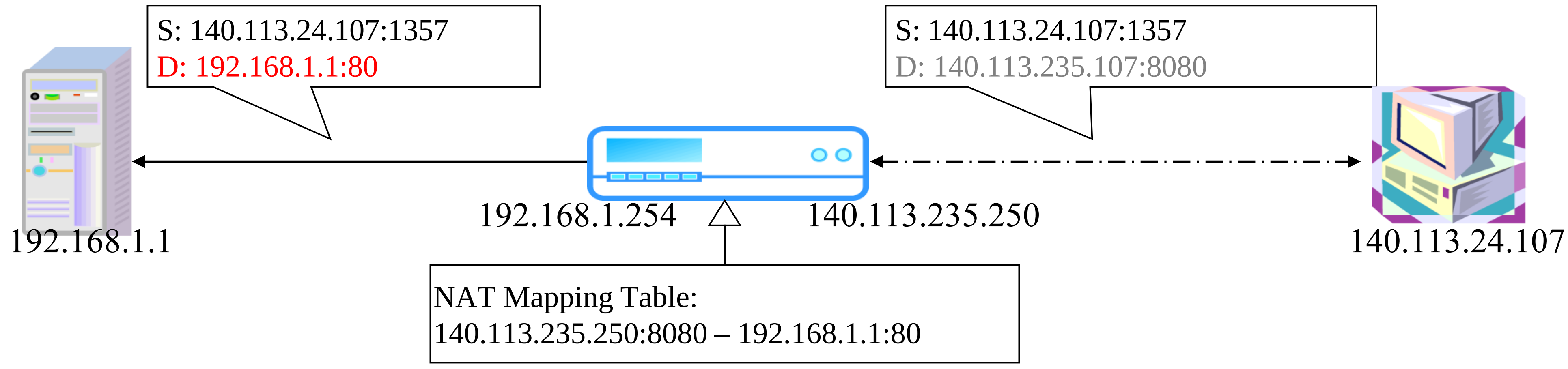
SNAT

- 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

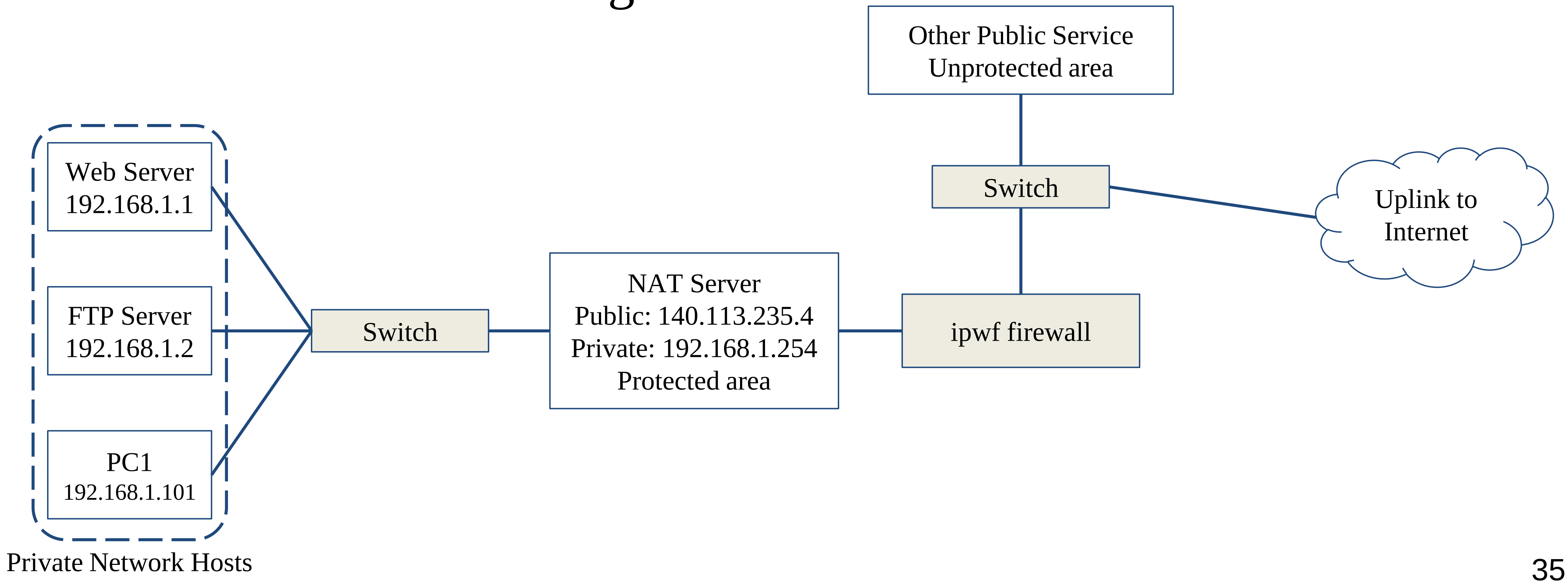
- DNAT
  - Rewrite the destination IP and/or Port.
  - The rewritten packet will be redirect to another IP address when it pass through NAT server.



- 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



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
```