Classful, Classless, CIDR, NAT

Classful- versus Classless-Routing,
Advanced IP Addressing (Supernetting, VLSM)
Classless Inter Domain Routing, Network Address Translation

Agenda

- **Classful Routing**
- **Classless Routing**
- **VLSM**
- **Address Design Aspects**
- **CIDR**
- **NAT**

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Classful Routing

- **routing protocols like RIP, IGRP cannot carry subnetmask information in routing updates**
- **this has several consequences**
  - if a given class A, B or C address is subnetted the subnetmask must be constant in the whole area
    - no variable length subnet mask (VLSM) can be used
  - if a routing update is sent to an interface with an network number different to the subnetted network
    - only the major class A, B or C network number will be announced
    - route summarization will be performed on class boundaries
    - hence a subnetted area must be contiguous
  - classful routing

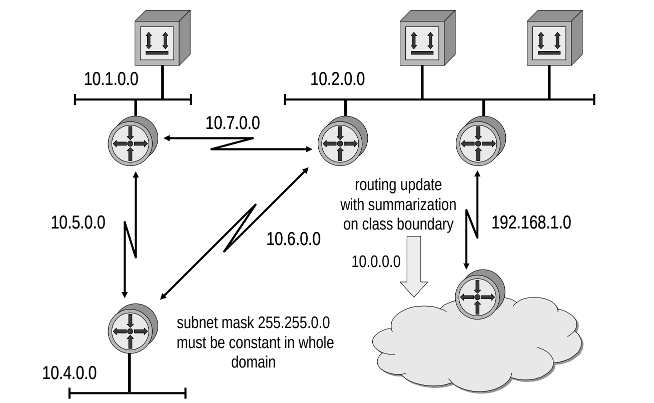
Routing Table Lookup (Classful)

- **assumption:**
  - IP datagram with a given IP address is received by a classful router
- **IP address is interpreted as class A, B or C**
  - the major net is determined
- **next a lookup in the routing table for the major net is performed**
  - if there is no entry the IP datagram will be discarded
- **if there is a match the IP address is compared to every known subnet of this major network**
  - if there is no such subnet the IP datagram will be discarded

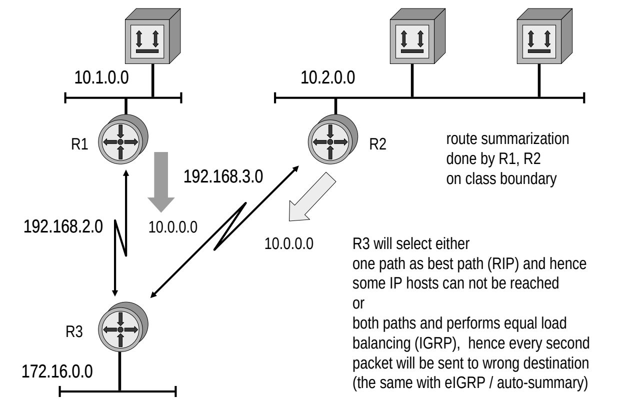
Routing Table Lookup (Classful) cont.

- **hence a problem may arise with default routing**
  - if the major network is known by the router, but the subnet does not exist, the IP datagram will be discarded even if a default route exists
- **therefore**
  - subnetted area must be contiguous
  - all subnets of a given major net must be reachable using only paths with these subnet-IDs
- **remark:**
  - Cisco´s configuration command ***ip classless*** will change such an behavior in case of default routing to the behavior of classless routing even if classful routing is used

Classful Routing



Discontiguous Subnetting Classful



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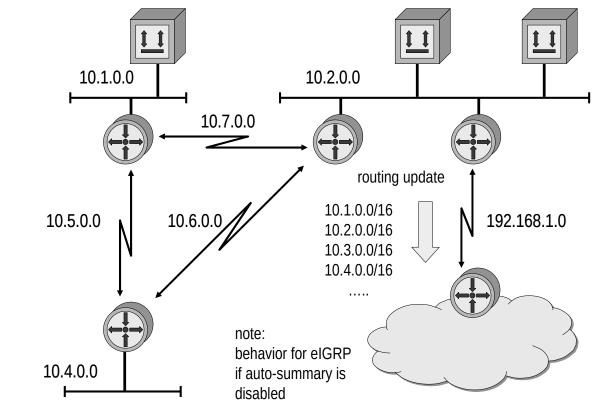
Classless Routing

- **routing protocols like RIPv2, OSPF, eIGRP can carry subnet mask information in routing updates**
- **this has several advantages**
  - variable length subnet mask (VLSM) can be used
    - subnetting of a given address can be done according to the number of hosts required on a certain subnet
    - more efficient use of address space ⇨ sub-subnetting
  - route summarization can be performed on any address boundary and not only on class boundaries
    - a routing update contains prefix (relevant part of IP address) and length (number of ones used in subnetmask)
    - supernetting
      - actual subnetmask is smaller than natural subnetmask of given class

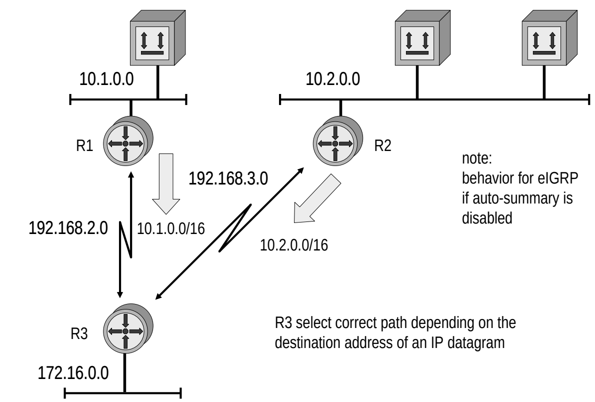
Routing Table Lookup (Classless)

- **assumption:**
  - IP datagram with a given IP address is received by a classless router
- **IP address is not interpreted as class A, B or C**
- **a lookup in the routing table for the best match for this IP address is performed**
  - IP prefixes of the routing table are compared with the given IP address bit by bit from left to right
  - IP datagram is passed on to the network which matches best
  - "Longest Match Routing Rule"
  - result: IP addresses with any kind of subnetting can be used independent from the underlying network topology

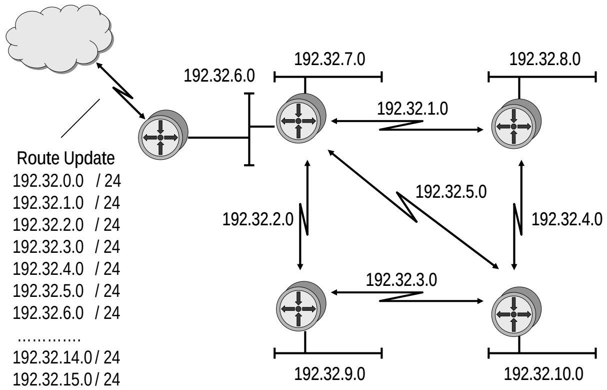
Classless Routing



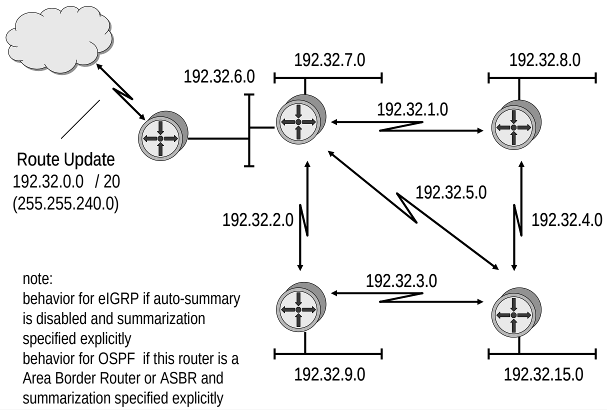
Discontiguous Subnetting Classless



Routing Updates without Supernetting



Route Summarization with Supernetting



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VLSM Example (1)

- **First step 6 bit subnetting of 172.16.0.0**
  - 172.16.0.0 with 255.255.252.0 (172.16.0.0 / 22)
  - subnetworks:
    - 172.16.0.0
    - 172.16.4.0
    - 172.16.8.0
    - 172.16.12.0
    - 172.16.16.0

      ……….
    - 172.16.248.0
    - 172.16.252.0
  - 64 subnetworks each of them capable of addressing 1022 IP systems

VLSM Example (2)

- **next step sub-subnetting**
  - basic subnet 172.16.4.0 255.255.252.0 (172.16.4.0 / 22)
  - sub-subnetworks with mask 255.255.255.252 (/ 30):
    - 172.16.4.0 / 30
    - 172.16.4.4 / 30
      - 172.16.4.4 net-ID
      - 172.16.4.5 first IP host of subnet 172.16.4.4
      - 172.16.4.6 last IP host of subnet 172.16.4.4
      - 172.16.4.7 directed broadcast of subnet 172.16.4.4
    - 172.16.4.8 / 30
    - 172.16.4.12 / 30
    - ……….
    - 172.16.4.252 / 30
  - 64 sub-subnetworks each of them capable of addressing 2 IP systems

VLSM Example (3)

- **next step sub-subnetting**
  - basic subnet 172.16.8.0 255.255.252.0 (172.16.8.0 / 22)
  - sub-subnetworks with mask 255.255.255.0 (/ 24):
    - 172.16.8.0 / 24
    - 172.16.9.0 / 24
      - 172.16.9.0 net-ID
      - 172.16.9.1 first IP host of subnet 172.16.9.0

      - 172.16.9.254 last IP host of subnet 172.16.9.0
      - 172.16.9.255 directed broadcast of subnet 172.16.9.0
    - 172.16.10.0 / 24
    - 172.16.11.0 / 24
  - 4 sub-subnetworks each of them capable of addressing 254 IP systems

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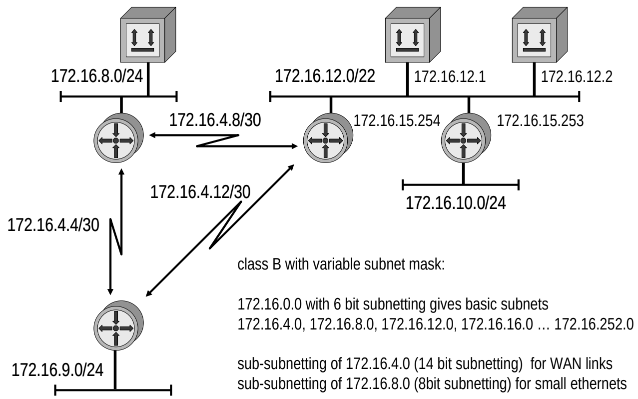
VLSM Example (4)

- **no sub-subnetting for basic subnet 172.16.12.0**
  - 172.16.12.0 with 255.255.252.0 (172.16.12.0 / 22)
      - 172.16.12.0 net-ID
      - 172.16.12.1 first IP host of subnet 172.16.12.0

      - 172.16.15.254 last IP host of subnet 172.16.12.0
      - 172.16.15.255 directed broadcast of subnet 172.16.12.0
  - one subnetwork capable of addressing 1022 IP systems

VLSM Classless



class B with variable subnet mask:

172.16.0.0 with 6 bit subnetting gives basic subnets
172.16.4.0, 172.16.8.0, 172.16.12.0, 172.16.16.0 … 172.16.252.0

sub-subnetting of 172.16.4.0 (14 bit subnetting) for WAN links
sub-subnetting of 172.16.8.0 (8bit subnetting) for small ethernets

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Address Design Issues 1

- **facts of classful routing**
  - subnetting of a given class A, B or C address must be contiguous
    - summary on class boundary
  - subnetmask of a given class A, B or C address must be constant
    - no VLSM
  - addressing must obey these principles
    - be careful

Address Design Issues 2

- **facts of classless routing**
  - in principle any IP address with any subnetmask can be located anywhere in the network
    - VLSM possible
    - longest match routing rule
  - but in order to keep number of routing table entries small
    - addressing of networks should be done in a way to use route summarization most efficient
    - that is important for core routers in large networks like the Internet
  - therefore addressing should follow physical topology
    - e.g. networks of a certain region could be advertised towards the core as one single supernetted network
    - renumbering of networks may be necessary to achieve this

Address Design Issues 3

- **route summarization**
  - classful routing (RIP, IGRP)
    - on class boundary
  - classless routing (OSPF)
    - on any address boundary
    - possible only at Area Border Router or ASBR
  - classless routing (eIGRP with auto-summary)
    - on class boundary
    - backward compatibility to IGRP
  - classless routing (eIGRP no auto-summary)
    - on any address boundary
    - on any router

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IP Address Space Depletion

- **the growing demand of IP addresses**
  - has put a strain on the classful model
  - class B exhaustion
  - class C are to small for most organization
  - many class C addresses given to a certain organization leads to explosion of routing table entries in the Internet core routers
- **measures to handle these problems**
  - creative IP address allocation
  - CIDR
  - private IP addresses and network address translation (NAT)
  - IPv6

CIDR

- **Classless Interdomain Routing (CIDR)**
  - address assignment and aggregation (route summarization) strategy
  - temporary solution to overcome depletion of IP address space and explosion of routing tables in the Internet core routers
- **basic ideas**
  - classless routing (prefix, length)
  - supernetting
  - coordinated address allocation
    - until 1992 IP addresses had no relation at all to the networks topology

CIDR

- **CIDR address allocation**
  - addressing plan for class C addresses by continents
    - 192.0.0.0 - 193.255.255.255 … Multiregional
    - 194.0.0.0 - 195.255.255.255 … Europe
    - 198.0.0.0 - 199.255.255.255 … North America
    - 200.0.0.0 - 201.255.255.255 … Central/South America
  - provider addressing strategy
    - Internet Service Providers (ISP) are given contiguous blocks of class C addresses which in turn are granted to their customers
    - consequence: change of provider means renumbering
  - class C network numbers are allocated in such a way that route summarization (or sometimes called route aggregation) into supernets is possible

CIDR

- **definitions of terms often used interchangeably**
  - CIDR block
    - is the <prefix, length> notation
  - supernets
    - have a prefix length shorter than the networks natural mask
  - aggregates
    - indicate any summary route
- **in order to implement CIDR**
  - classless routing protocols between routing domains must be used
    - BGP-4 as interdomain routing protocol
  - classless routing within an routing domain
    - RIPv2, OSPF, eIGRP

Private Address Range - RFC 1918

- **Three blocks of address ranges are reserved for addressing of private networks**
  - 10.0.0.0 - 10.255.255.255 (10/8 prefix)
  - 172.16.0.0 - 172.31.255.255 (172.16/12 prefix)
  - 192.168.0.0 - 192.168.255.255 (192.168/16 prefix)
  - Note:
    - In pre-CIDR notation the first block is nothing but a single class A network number, while the second block is a set of 16 contiguous class B network numbers, and third block is a set of 256 contiguous class C network numbers.
- **Translation between private addresses and globally unique addresses -> NAT**

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  - PAT
  - DNS Aspects
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Reasons for Network Address Translation

- **Mitigate Internet address depletion**
  - NAT was originally developed as an interim solution to combat IPv4 address depletion by allowing globally registered IP addresses to be reused or shared by several hosts (RFC 1631)
- **Save global addresses (and money)**
  - NAT is most often used to map IPs from the nonroutable private address spaces defined by RFC 1918
    - 10.0.0.0/8, 172.16.0.0/16, 192.168.0.0/16
- **Conserve internal address plan**
- **TCP load sharing**
- **Hide internal topology**

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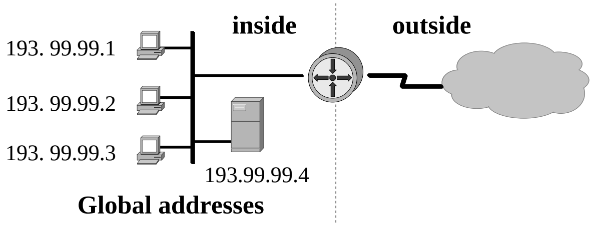
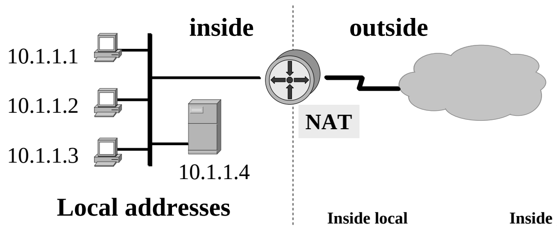
Terms (1)



(NAT not necessary in this case)

Terms (2)



Static one-to-one mapping is maintained by router-internal NAT–Table

Inside local IP address		Inside global IP address
10.1.1.1	⟷	193.99.99.1
10.1.1.2	⟷	193.99.99.2
10.1.1.3	⟷	193.99.99.3
10.1.1.4	⟷	193.99.99.4

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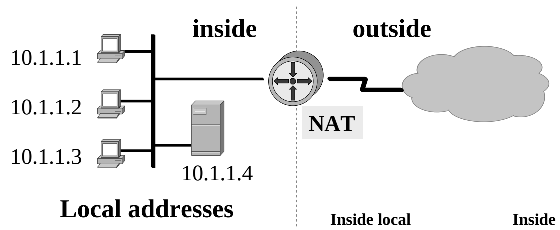
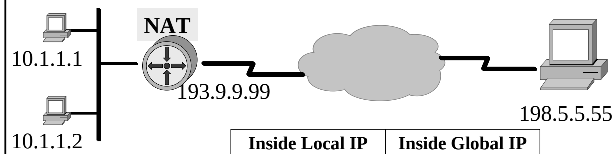
Terms (3)



Dynamic mapping via pool is maintained by router-internal NAT–Table

Inside local IP address		Inside global IP address
10.1.1.1	⟷	193.99.99.5
10.1.1.2	⟷	193.99.99.6
10.1.1.3		
10.1.1.4		

Basic Principle (1a)



Simple NAT Table

Inside Local IP	Inside Global IP
10.1.1.1	193.9.9.1
10.1.1.2	193.9.9.2
....	....

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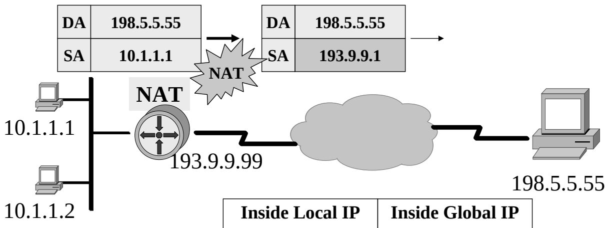
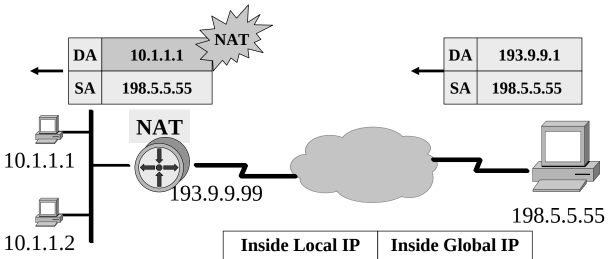
Basic Principle (1b)



Simple NAT Table

Inside Local IP	Inside Global IP
10.1.1.1	193.9.9.1
10.1.1.2	193.9.9.2
....	....

Basic Principle (1c)

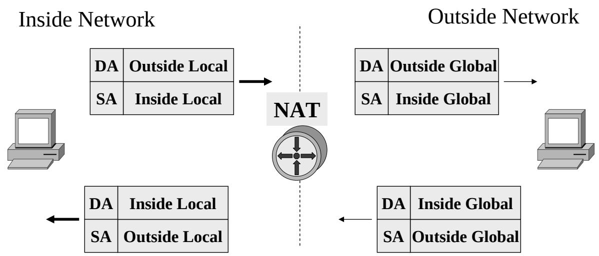


Simple NAT Table

Inside Local IP	Inside Global IP
10.1.1.1	193.9.9.1
10.1.1.2	193.9.9.2
....	....

Terms Summary

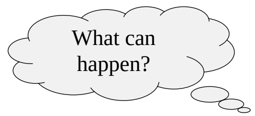
- *Local* versus *global* address
  - Reflects area of usage (inside or outside)
- *Inside* versus *outside* world
  - Reflects origin



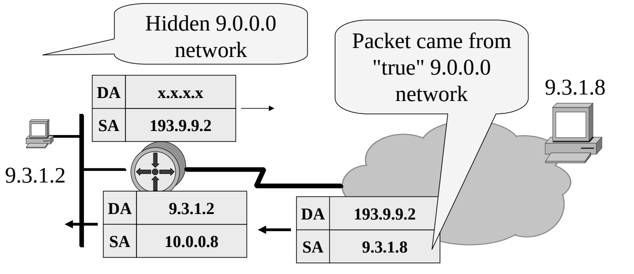
Overlapping Networks

= Same addresses **are used**

locally <u>and</u> ***globally***



Outside Address Translation



Inside Local	Inside Global	Outside Local	Outside Global
9.3.1.2	193.9.9.2	10.0.0.8	9.3.1.8

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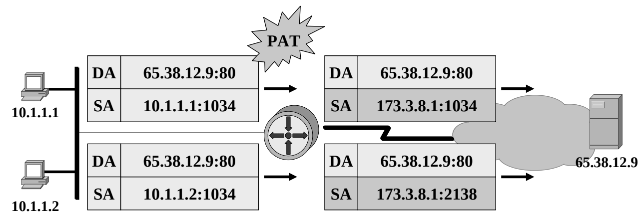
  - Load Balancing

Overloading (PAT)

- Common problem:
  - **Many hosts inside**
  - **But only one or a few inside-global addresses available**
- Solution:
  - **Many-to-one Translation**
  - **Aka *"Overloading Inside Global Addresses*"**
  - **Aka "*PAT„***
  - ***Port Address Translation***

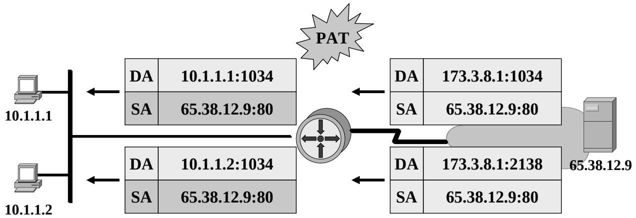
Overloading Example (1)



Prot.	Inside Local	Inside Global	Outside Local	Outside Global
TCP	10.1.1.1:1034	173.3.8.1:1034	65.38.12.9:80	65.38.12.9:80
TCP	10.1.1.2:1034	173.3.8.1:2138	65.38.12.9:80	65.38.12.9:80

Extended Translation Table

Overloading Example (2)



Prot.	Inside Local	Inside Global	Outside Local	Outside Global
TCP	10.1.1.1:1034	173.3.8.1:1034	65.38.12.9:80	65.38.12.9:80
TCP	10.1.1.2:1034	173.3.8.1:2138	65.38.12.9:80	65.38.12.9:80

Extended Translation Table

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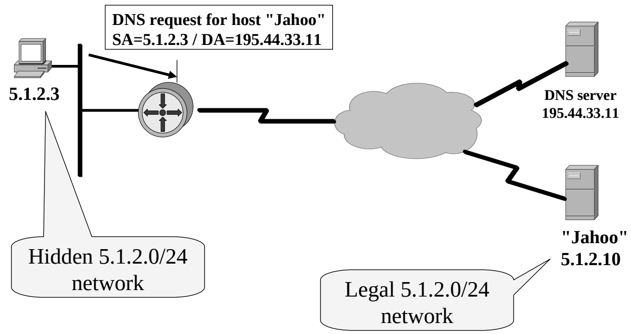
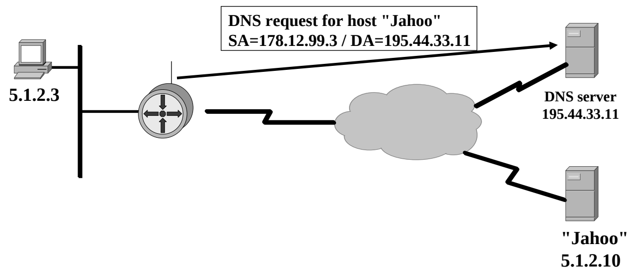
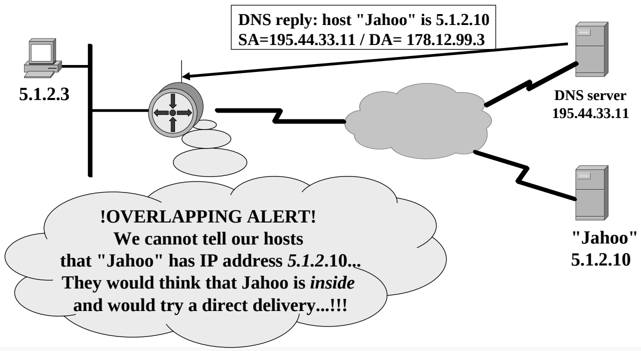
DNS Problem (1)



DNS Problem (2)



DNS Problem (3)



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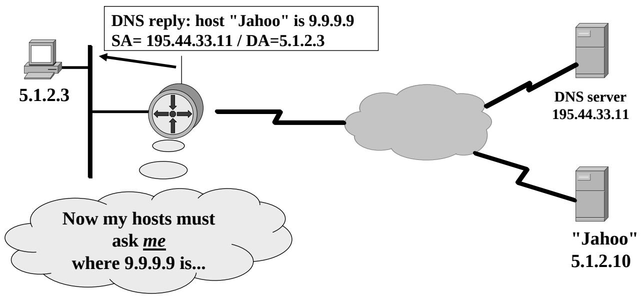
DNS Problem (4)



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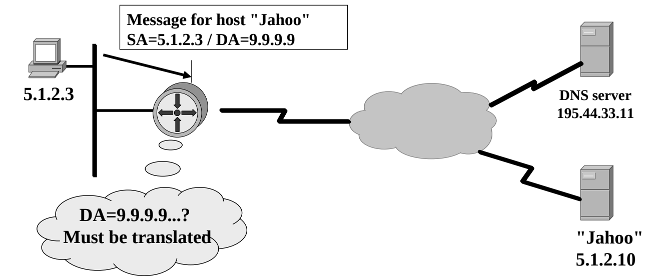
DNS Problem (5)



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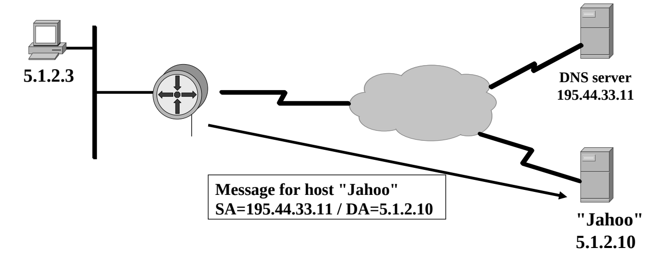
DNS Problem (6)



NAT Table

Inside Local	Inside Global	Outside Global	Outside Local
5.1.2.3	195.44.33.11	**5.1.2.10**	**9.9.9.9**

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TCP Load Sharing (1)

- **Multiple servers represented by a single inside-global IP address**
  - *Virtual host* address
- **New TCP session requests to the Virtual Host are forwarded to one of a group of real hosts**
  - *Rotary group*

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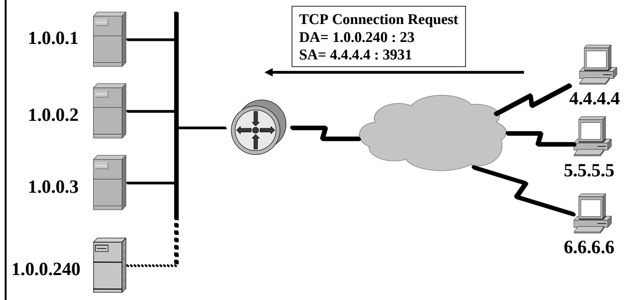
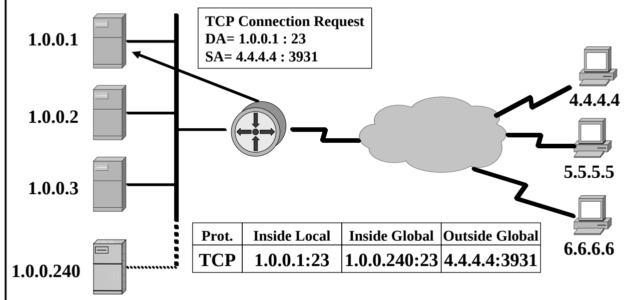
TCP Load Sharing (2)



TCP Load Sharing (3)



Prot.	Inside Local	Inside Global	Outside Global
TCP	1.0.0.1:23	1.0.0.240:23	4.4.4.4:3931

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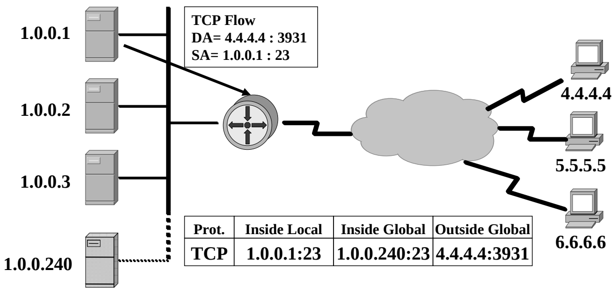
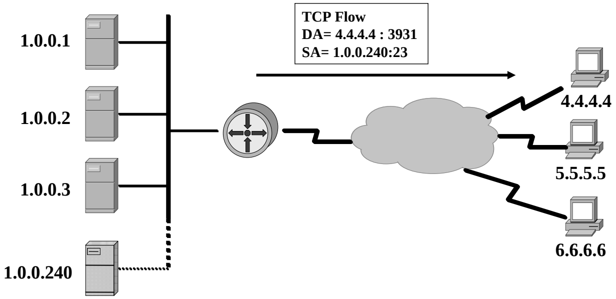
TCP Load Sharing (4)

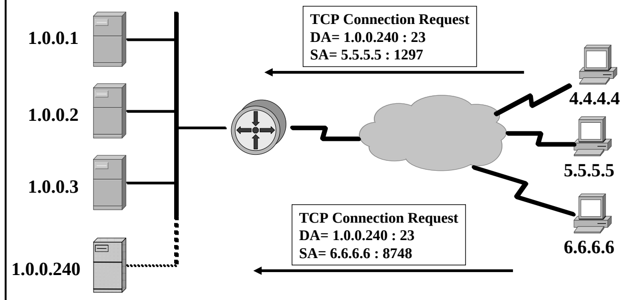


Prot.	Inside Local	Inside Global	Outside Global
TCP	1.0.0.1:23	1.0.0.240:23	4.4.4.4:3931

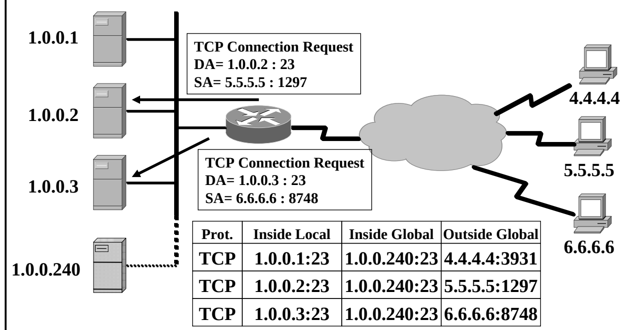
TCP Load Sharing (5)



TCP Load Sharing (6)



TCP Load Sharing (7)



Prot.	Inside Local	Inside Global	Outside Global
TCP	1.0.0.1:23	1.0.0.240:23	4.4.4.4:3931
TCP	1.0.0.2:23	1.0.0.240:23	5.5.5.5:1297
TCP	1.0.0.3:23	1.0.0.240:23	6.6.6.6:8748

Further Information

- **RFC 1631 (NAT)**
- **RFC 3022 (Traditional NAT)**
- **RFC 2694 (DNS ALG)**
- **RFC 2766 (IPv4 to IPv6 Translation)**
- **NAT Friendly Application Design Guidelines (Draft)**
- **Internet Protocol Journal**
  - www.cisco.com/ipj
    - Issue Volume 3, Number 4 (December 2000)
    - „The Trouble with NAT“