



Network Layer (Private/Public Addressing, NAT and DHCP)

Fundamentos de Redes

Mestrado Integrado em Engenharia de Computadores
e Telemática

DETI-UA, 2018/2019

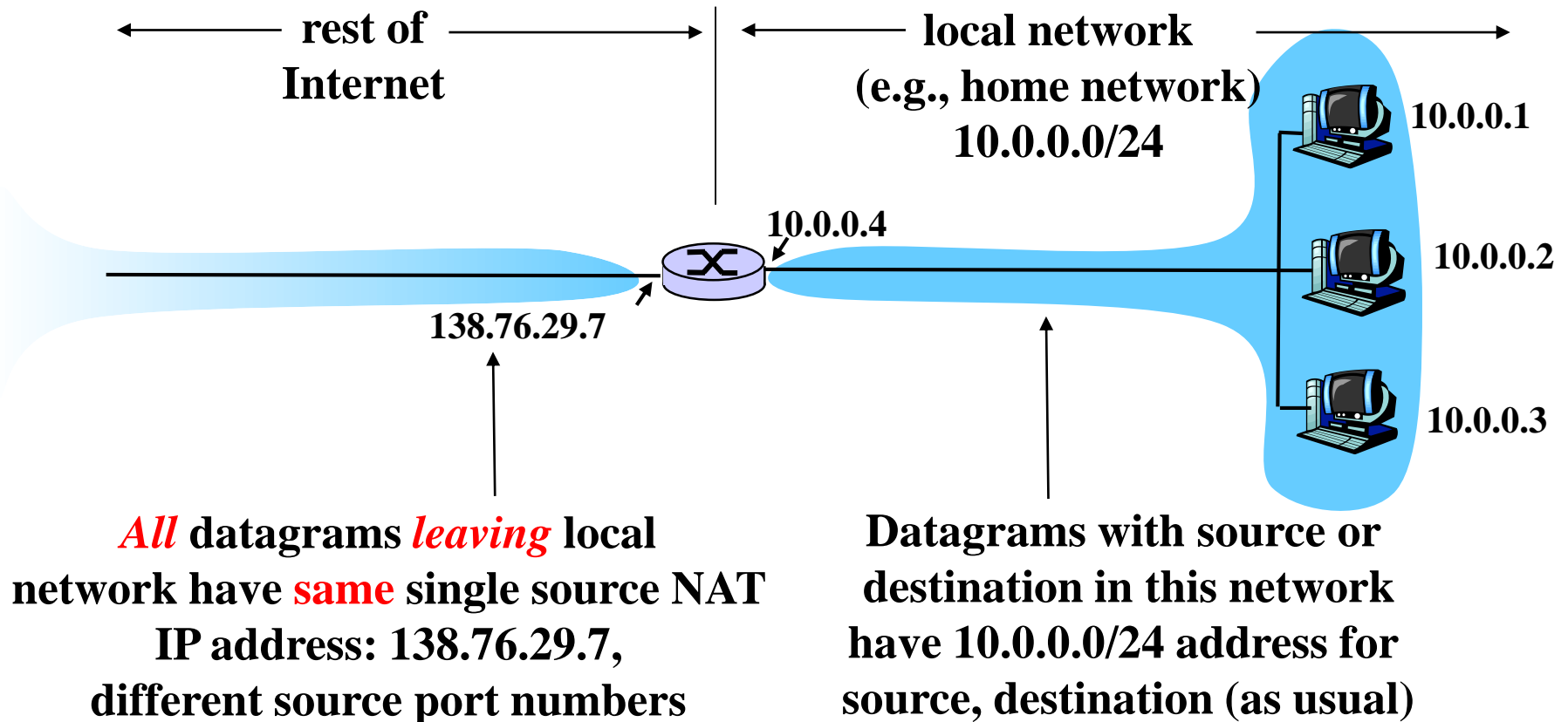
PRIVATE ADDRESSING

Blocks of private addresses

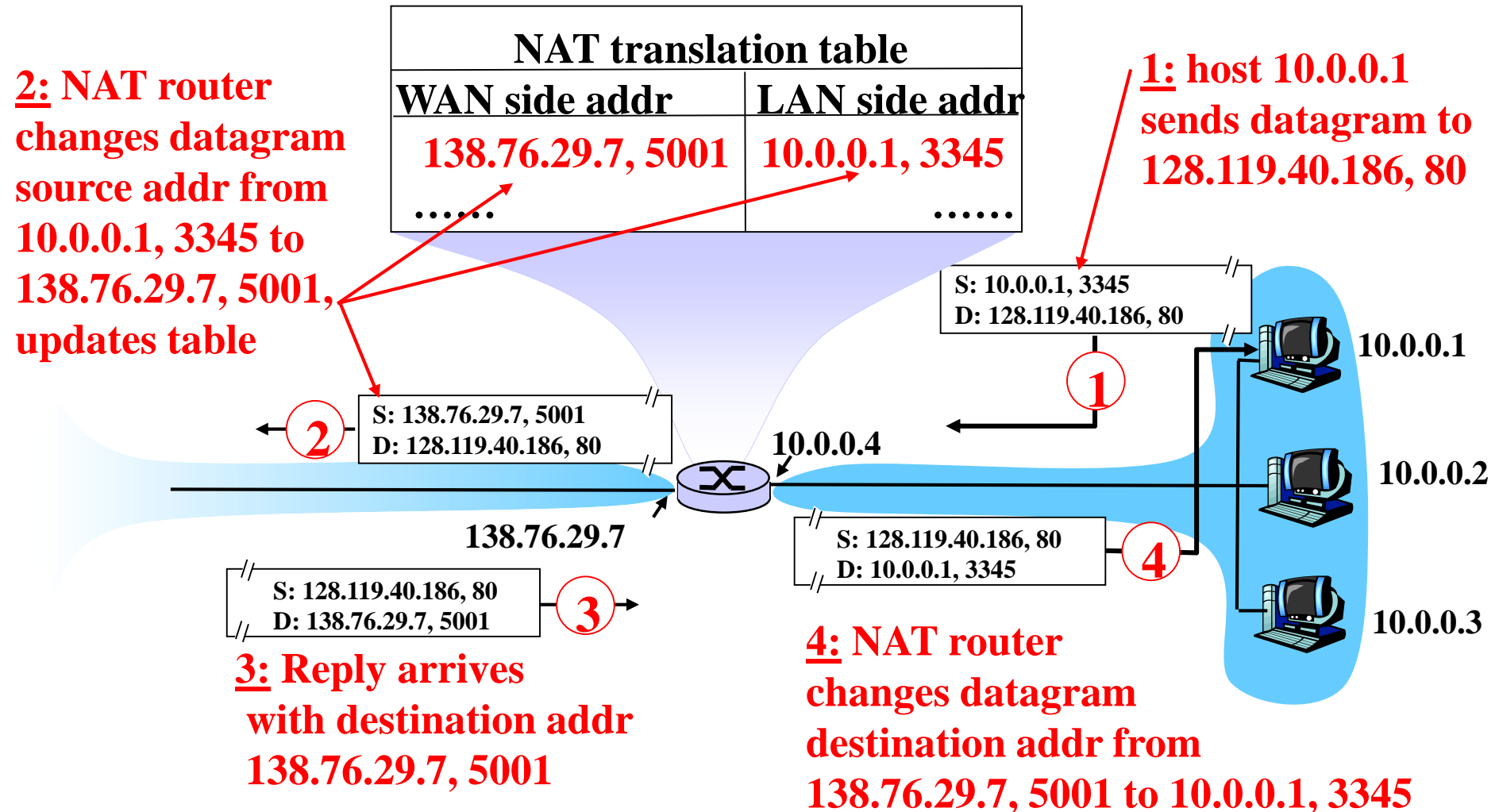
Prefix	Lowest address	Highest address
10/8	10.0.0.0	10.255.255.255
172.16/12	172.16.0.0	172.31.255.255
192.168/16	192.168.0.0	192.168.255.255
169.254/16	169.254.0.0	169.254.255.255

- These addresses can be used freely in private networks
- IP packets with destination addresses belonging to these blocks are not routed in the public network
- For communications with the Internet, the private addresses must be translated into public addresses

NAT: Network Address Translation



NAT: Network Address Translation



NAT: Network Address Translation

Implementation: NAT router must:

- *outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)
 - ... remote clients/servers will respond using (NAT IP address, new port #) as destination addr.
- *remember (in NAT translation table)* every (source IP address, port #) to (NAT IP address, new port #) translation pair
- *incoming datagrams: replace* (NAT IP address, new port #) in dest fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

NAT: Network Address Translation

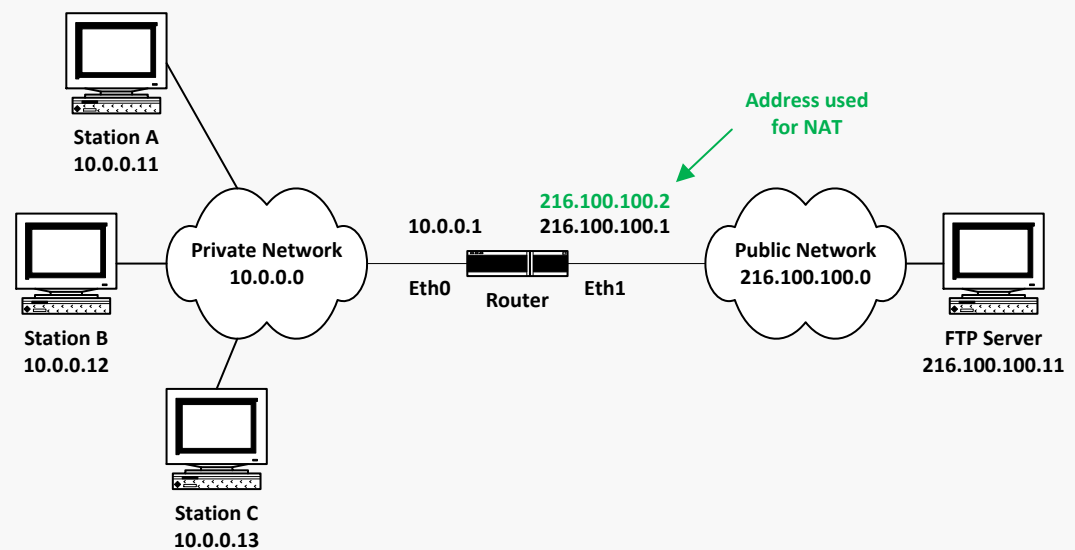
- ❑ **Motivation:** local network uses just one IP address as far as outside world is concerned:
 - range of addresses not needed from ISP: just one (or a few) IP address for all devices
 - can change addresses of devices in local network without notifying outside world
 - can change ISP without changing addresses of devices in local network
 - devices inside local net not explicitly addressable, visible by outside world (a security additional advantage).

NAT: Network Address Translation

- ❑ More than one public IP address may be available (NAT versus PAT)
- ❑ 16-bit port-number field:
 - more than 60,000 simultaneous connections with a single public IP address!
- ❑ NAT is controversial:
 - routers should only process up to layer 3
 - violates end-to-end argument
 - NAT possibility must be taken into account by application designers, e.g, P2P applications
 - address shortage should instead be solved by IPv6

Example (I)

Access of A and B to the FTP server :



Exp6RI_c.cap : 1/22 Ethernet packets

No.	Sta.	Source Address	Dest Address	Layer	Summary
1	Ok	10.0.0.12	216.100.100.11	TCP	1032->File
2	Ok	216.100.100.11	10.0.0.12	TCP	File Transf
3	Ok	10.0.0.12	216.100.100.11	TCP	1032->File
4	Ok	216.100.100.11	10.0.0.12	FTP	220 Serv-U
5	Ok	10.0.0.12	216.100.100.11	TCP	1032->File
6	Ok	10.0.0.12	216.100.100.11	FTP	USER anonym
7	Ok	216.100.100.11	10.0.0.12	FTP	331 User nar

Exp6RI_c.cap : 12/22 Ethernet packets

No.	Sta.	Source Address	Dest Address	Layer	Summary
12	Ok	10.0.0.11	216.100.100.11	TCP	1033->File
13	Ok	216.100.100.11	10.0.0.11	TCP	File Transf
14	Ok	10.0.0.11	216.100.100.11	TCP	1033->File
15	Ok	216.100.100.11	10.0.0.11	FTP	220 Serv-U
16	Ok	10.0.0.11	216.100.100.11	TCP	1033->File
17	Ok	10.0.0.11	216.100.100.11	FTP	USER anonym
18	Ok	216.100.100.11	10.0.0.11	FTP	331 User na

Captures in private network

Exp6RE_c.cap : 1/22 Ethernet packets

No.	Sta.	Source Address	Dest Address	Layer	Summary
1	Ok	216.100.100.2	216.100.100.11	TCP	1032->File
2	Ok	216.100.100.11	216.100.100.2	TCP	File Transf
3	Ok	216.100.100.2	216.100.100.11	TCP	1032->File
4	Ok	216.100.100.11	216.100.100.2	FTP	220 Serv-U
5	Ok	216.100.100.2	216.100.100.11	TCP	1032->File
6	Ok	216.100.100.2	216.100.100.11	FTP	USER anonym
7	Ok	216.100.100.11	216.100.100.2	FTP	331 User na

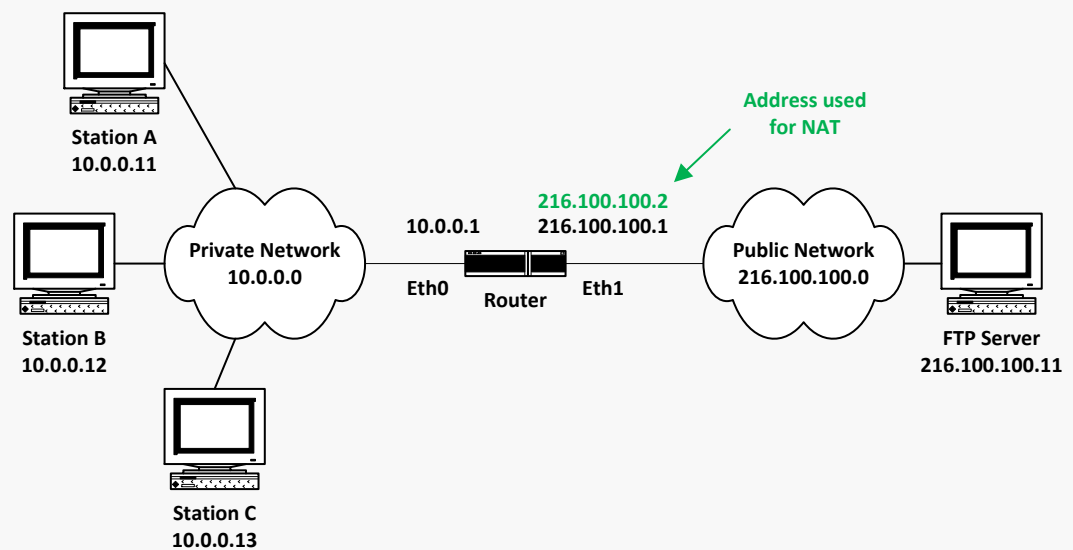
Exp6RE_c.cap : 12/22 Ethernet packets

No.	Sta.	Source Address	Dest Address	Layer	Summary
10	Ok	216.100.100.2	216.100.100.11	TCP	1033->File
10	Ok	216.100.100.11	216.100.100.2	TCP	File Transf
10	Ok	216.100.100.2	216.100.100.11	TCP	1033->File
10	Ok	216.100.100.11	216.100.100.2	FTP	220 Serv-U
10	Ok	216.100.100.2	216.100.100.11	TCP	1033->File
10	Ok	216.100.100.2	216.100.100.11	FTP	USER anonym
10	Ok	216.100.100.11	216.100.100.2	FTP	331 User na

Captures in public network

Example (II)

Access of A and B to the
FTP server :

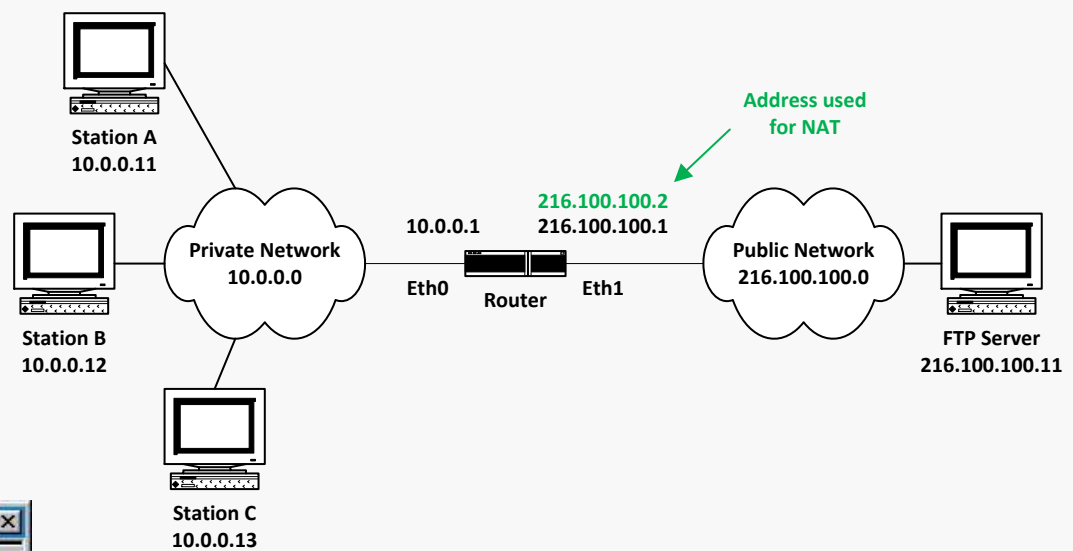


```
Router#show ip nat translation verbose
```

Pro	Inside global	Inside local	Outside local	Outside global
tcp	216.100.100.2:1032	10.0.0.12:1032	216.100.100.11:21	216.100.100.11:21
create 00:00:35, use 00:00:24, left 23:59:35,				
flags:				
extended, use_count: 0				
tcp	216.100.100.2:1033	10.0.0.11:1033	216.100.100.11:21	216.100.100.11:21
create 00:00:12, use 00:00:06, left 23:59:53,				
flags:				
extended, use_count: 0				

Example (III)

Second access of B to the FTP server :



Exp6RI_c2.cap : 1/11 Ethernet packets					
No.	Sta	Source Address	Dest Address	Layer	Summary
1	0k	10.0.0.12	216.100.100.11	TCP	1033->File
2	0k	216.100.100.11	10.0.0.12	TCP	File Transf
3	0k	10.0.0.12	216.100.100.11	TCP	1033->File
4	0k	216.100.100.11	10.0.0.12	FTP	220 Serv-U
5	0k	10.0.0.12	216.100.100.11	TCP	1033->File
6	0k	10.0.0.12	216.100.100.11	FTP	USER anonym
7	0k	216.100.100.11	10.0.0.12	FTP	331 User na

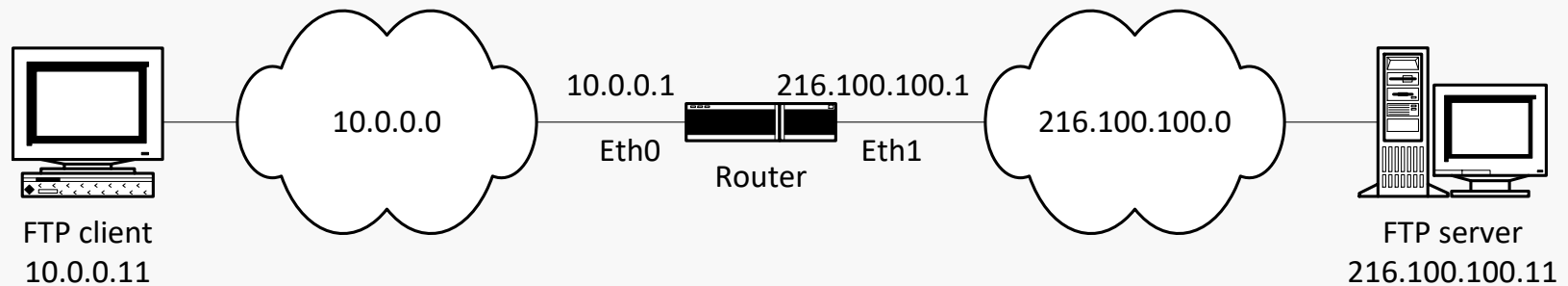
private network

Exp6RE_c2.cap : 1/11 Ethernet packets					
No.	Sta	Source Address	Dest Address	Layer	Summary
1	0k	216.100.100.2	216.100.100.11	TCP	1024->File
2	0k	216.100.100.11	216.100.100.2	TCP	File Transf
3	0k	216.100.100.2	216.100.100.11	TCP	1024->File
4	0k	216.100.100.11	216.100.100.2	FTP	220 Serv-U
5	0k	216.100.100.2	216.100.100.11	TCP	1024->File
6	0k	216.100.100.2	216.100.100.11	FTP	USER anonym
7	0k	216.100.100.11	216.100.100.2	FTP	331 User na

public network

```
Router#show ip nat translation verbose
Pro Inside global      Inside local      Outside local      Outside global
tcp 216.100.100.2:1024 10.0.0.12:1033    216.100.100.11:21 216.100.100.11:21
    create 00:00:49, use 00:00:42, left 23:59:17,
    flags:
    extended, use_count: 0
tcp 216.100.100.2:1032 10.0.0.12:1032    216.100.100.11:21 216.100.100.11:21
    create 00:02:42, use 00:02:31, left 23:57:28,
    flags:
    extended, use_count: 0
tcp 216.100.100.2:1033 10.0.0.11:1033    216.100.100.11:21 216.100.100.11:21
    create 00:02:18, use 00:02:13, left 23:57:46,
    flags:
    extended, use_count: 0
```

Example (IV)



Translation of IP address in FTP message (Layer 5):

```
ETHER-II: 00-60-97-9B-9E-07 ==> 00-D0-58-A9-3E-37
Internet Protocol
  Version(MSB 4 bits): 4
  Header length(LSB 4 bits): 5 (32-bit word)
  Service type: Preced=Routine,Delay=Normal,Thrput=Normal,Reli=Normal
  Total length: 61 (Octets)
  Fragment ID: 14595
  Flags: Do not fragment,Last fragment,Offset=0 (0x00)
  Time to live: 128 seconds/hops
  IP protocol type: TCP (0x06)
  Checksum: 0x7B3D
  IP address 10.0.0.11 ->216.100.100.11
  No option
  TCP: 1036->File Transfer (Control),S=82367,A=171360,W=86
  File Transfer Protocol
  PORT 10,0,0,11,4,13
  Sliced Packet( Data Length = 75)
```

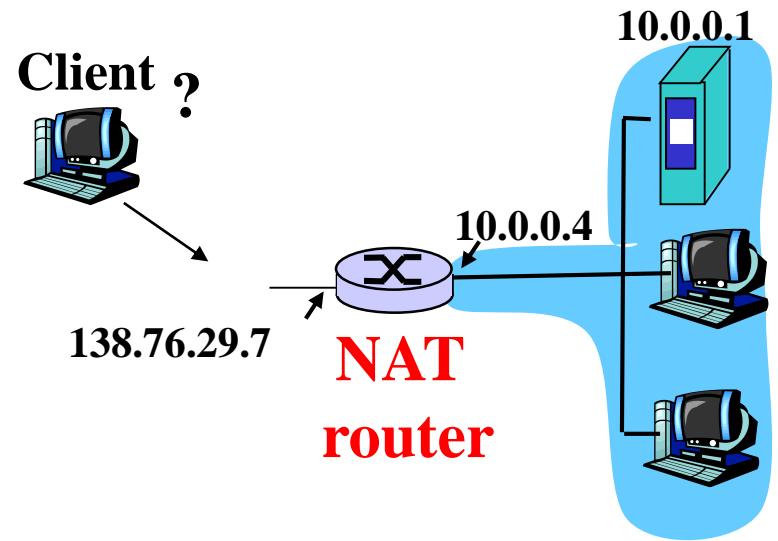
private network

```
ETHER-II: 00-D0-58-A9-3E-38 ==> 00-60-97-D4-9F-9A
Internet Protocol
  Version(MSB 4 bits): 4
  Header length(LSB 4 bits): 5 (32-bit word)
  Service type: Preced=Routine,Delay=Normal,Thrput=Normal,Reli=Normal
  Total length: 65 (Octets)
  Fragment ID: 14595
  Flags: Do not fragment,Last fragment,Offset=0 (0x00)
  Time to live: 127 seconds/hops
  IP protocol type: TCP (0x06)
  Checksum: 0x49DD
  IP address 216.100.100.2 ->216.100.100.11
  No option
  TCP: 1036->File Transfer (Control),S=82367,A=171360,W=8610
  File Transfer Protocol
  PORT 216,100,100,2,4,13
  Sliced Packet( Data Length = 79)
```

public network

NAT traversal problem

- ❑ client wants to connect to server with address 10.0.0.1
 - server address 10.0.0.1 local to LAN (client cannot use it as destination address)
 - only one externally visible NATted address: 138.76.29.7
- ❑ solution 1: statically configure NAT to forward incoming connection requests at given port to server
 - e.g., (138.76.29.7, port 2500) always forwarded to 10.0.0.1 port 25000

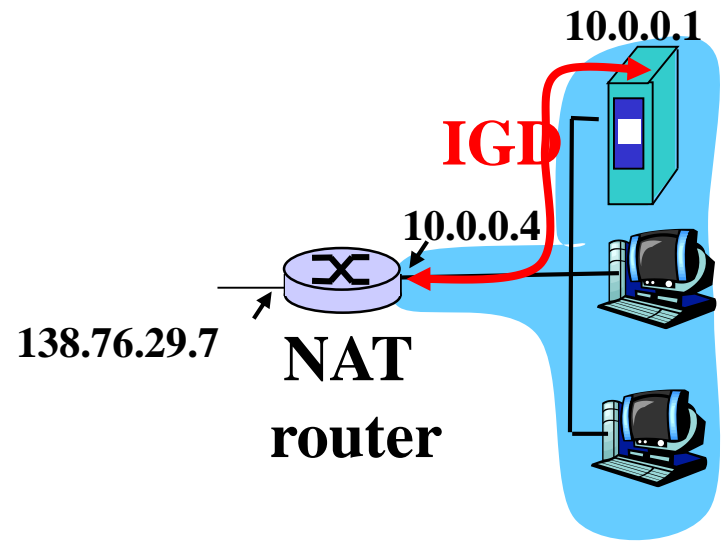


NAT traversal problem

□ solution 2: Universal Plug and Play (UPnP) Internet Gateway Device (IGD) Protocol. Allows NATted host to:

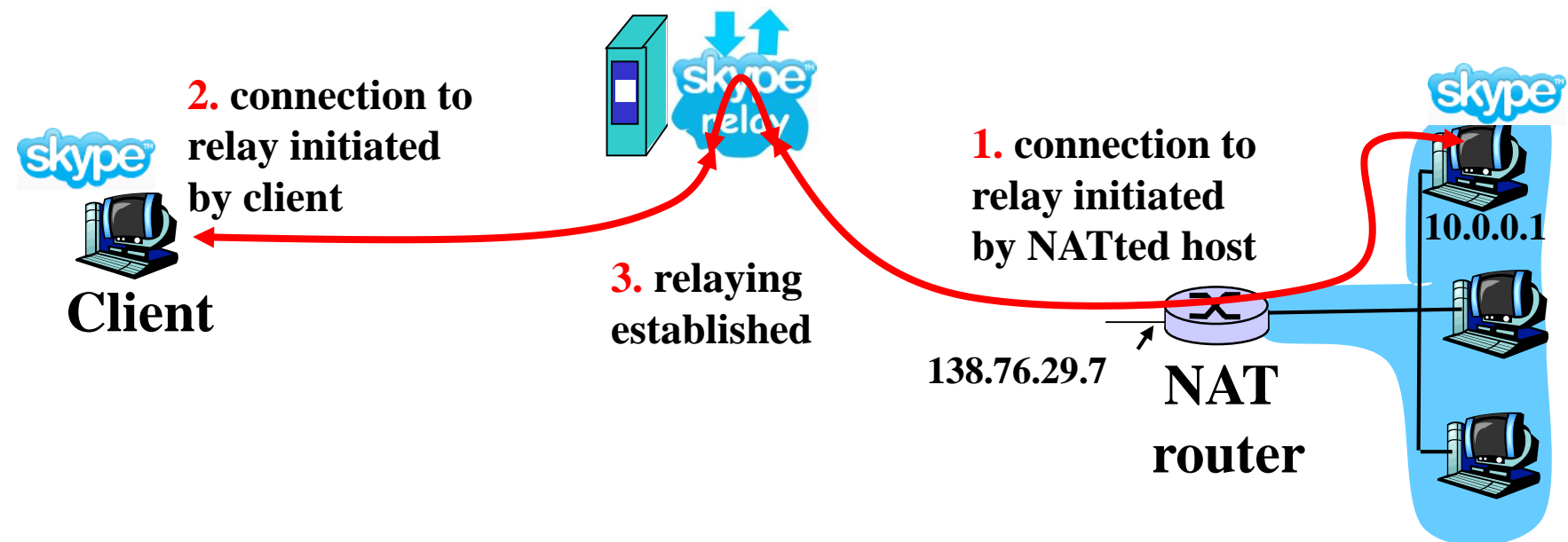
- Application running on NATted host requests mapping between (private IP address, private port number) and (public IP address, public port number)
- Application can advertise (public IP address, public port number)

i.e., automate static NAT port map configuration



NAT traversal problem

- solution 3: relaying (used in Skype)
 - NATed server establishes connection to Relay
 - External client connects to Relay
 - Relay bridges packets between two connections



DHCP

DHCP: Dynamic Host Configuration Protocol

Goal: allow host to *dynamically* obtain its IP address from network server when it joins network

Can renew its lease on address in use

Allows reuse of addresses (only hold address while connected and "on")

Support for mobile users who want to join network

Also allows client to learn subnet mask, default gateway, local DNS server

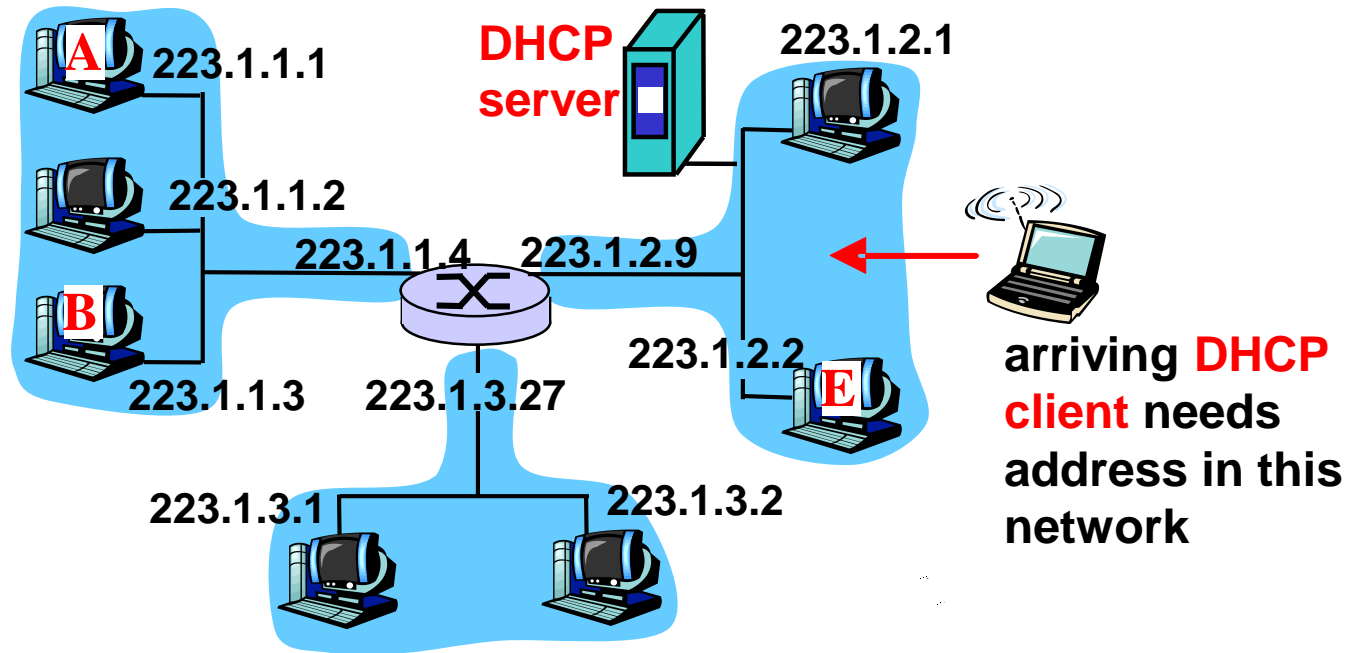
DHCP overview:

- host broadcasts "DHCP discover" message
- DHCP server responds with "DHCP offer" message
- host requests IP address: "DHCP request" message
- DHCP server sends address: "DHCP ack" message

Configuration of a DHCP server

- ❑ Lease address range
 - Pool of IP addresses to be leased defined by the first and the last address
- ❑ Excluding address range
 - Pool of IP addresses inside the lease address range that are not to be leased
- ❑ Reserved addresses
 - IP addresses to be assigned statically for specific MACs
- ❑ Lease time
 - Time duration of the lease of an address

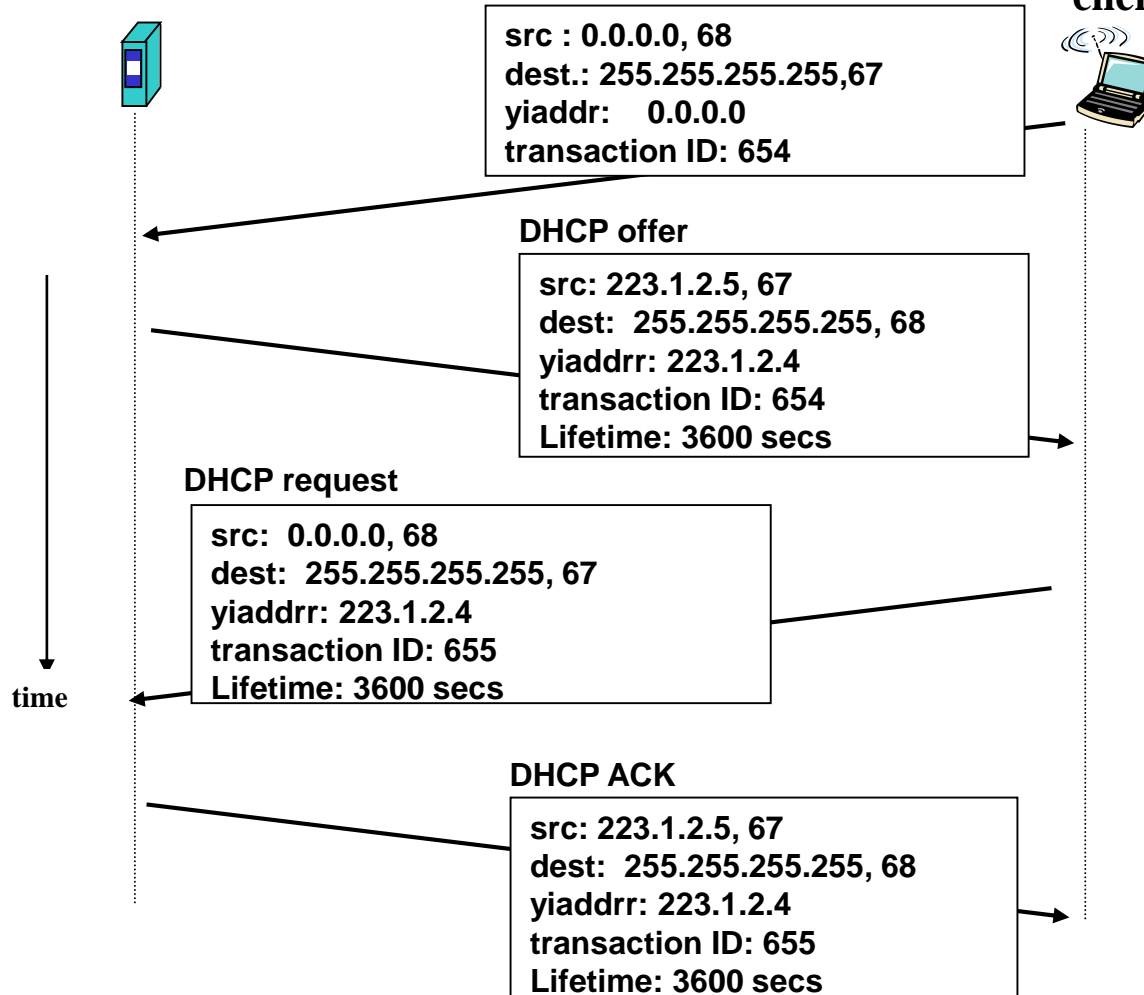
DHCP client-server scenario



DHCP client-server scenario

DHCP server: 223.1.2.5

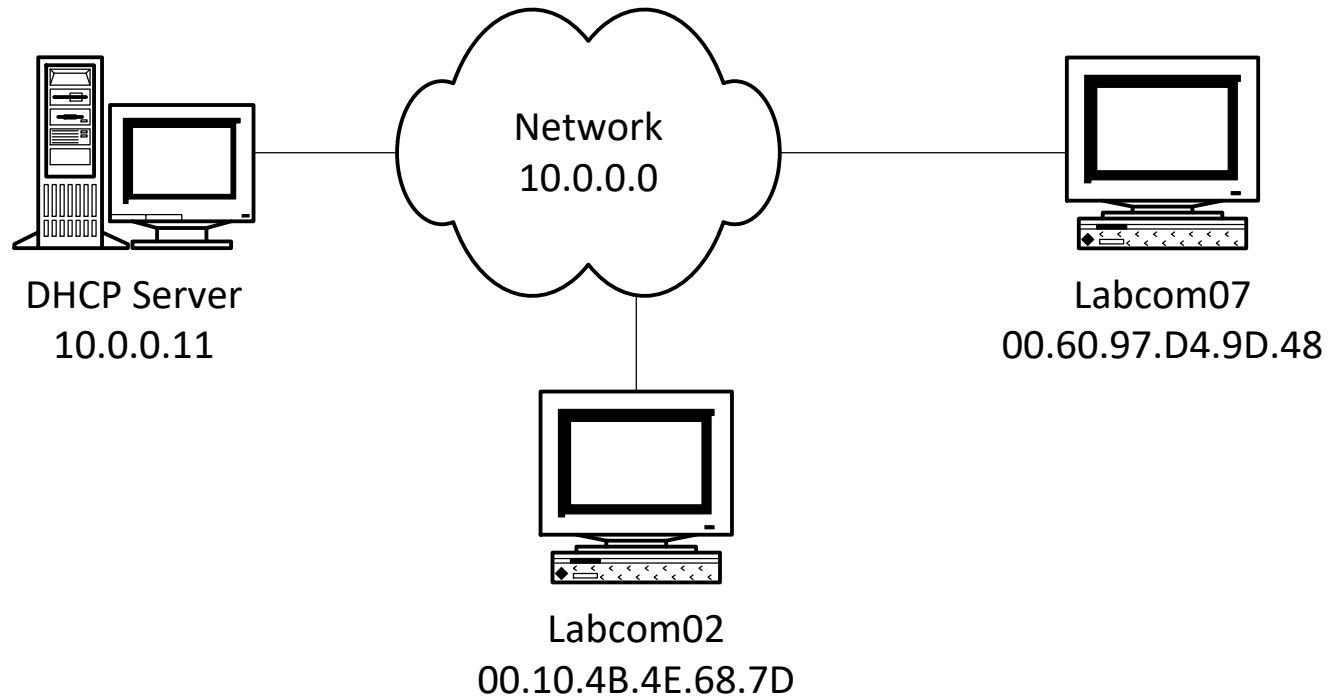
arriving
client



DHCP versus BOOTP

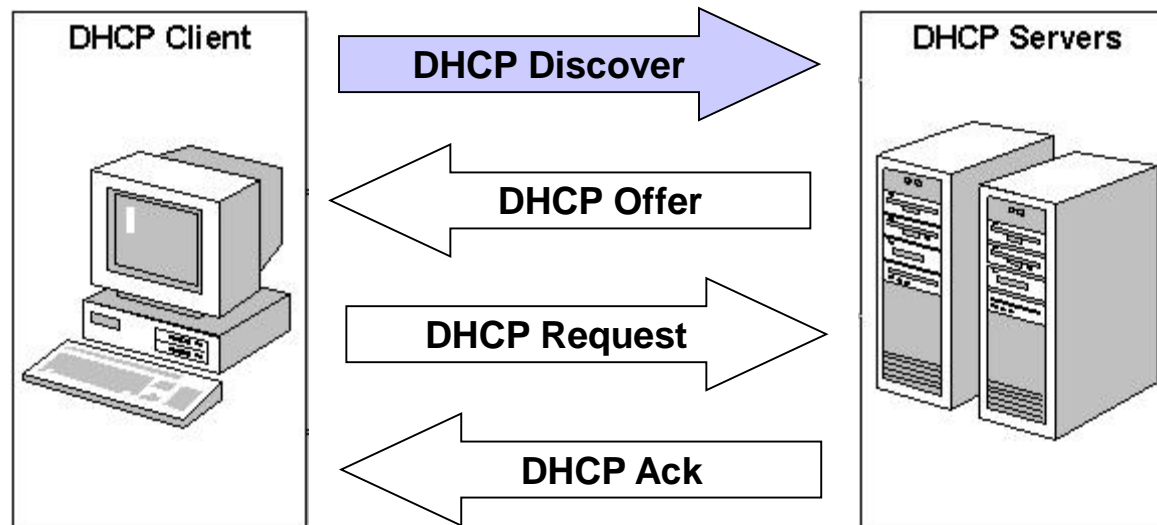
- ❑ Extension of *Bootstrap Protocol*, BOOTP, (RFC 1542)
 - Run over UDP
 - Server port number: 67
 - Client port number: 68
 - Originally, BOOTP enables a diskless terminal to find its IP address, a server address and a configuration filename to be requested to the server and locally executed.

Example



DHCP Discover

DHCP Discover message is encapsulated on a *BootP Request* message. It is sent to discover available DHCP servers. The client can also indicate an IP address.



DHCP Discover

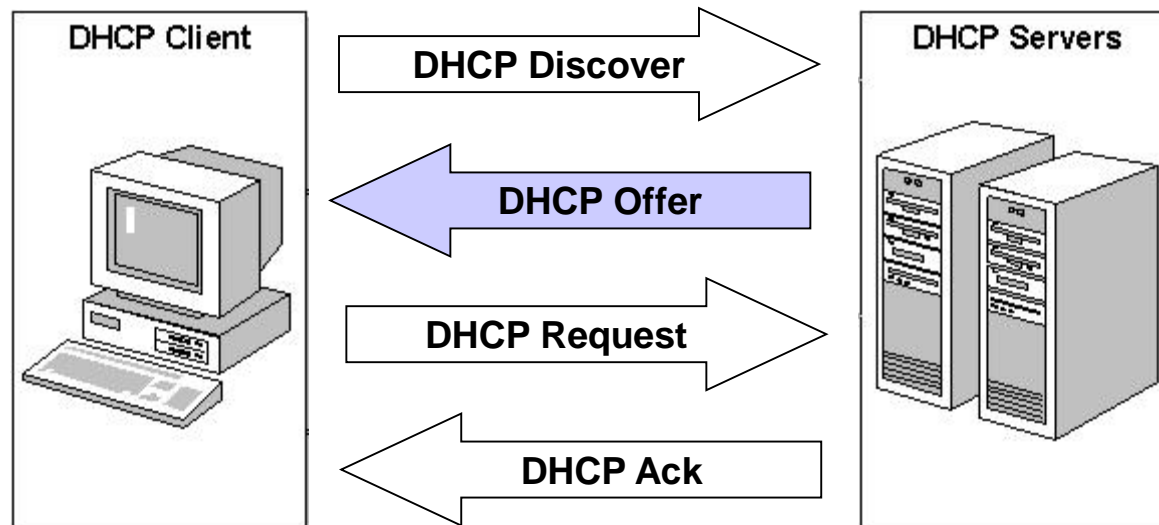
Exp3.cap : 3/20 Ethernet packets									
No	Sta	Source Address	Dest Address	Layer	Summary	Len	Rel. Time		
3	Ok	0.0.0.0	BROADCAST	BOOTP	OP=1 (Request), Hops=0, XID=1565545288	346	0:02:09.671		
4	Ok	10.0.0.11	BROADCAST	BOOTP	OP=2 (Reply), Hops=0, XID=1565545288	364	0:02:09.672		
5	Ok	0.0.0.0	BROADCAST	BOOTP	OP=1 (Request), Hops=0, XID=102576364	346	0:02:09.674		
6	Ok	10.0.0.11	BROADCAST	BOOTP	OP=2 (Reply), Hops=0, XID=102576364	364	0:02:09.676		

ETHER-II: 00-60-97-D4-9D-48 ==> FF-FF-FF-FF-FF-FF
IP: 0.0.0.0->BROADCAST, ID=0
UDP: Bootp Client->Bootp Server, Len=308
IP Bootstrap Protocol
OP Code: 1 (Request)
Hardware Type: 1 (Ethernet)
Hardware Address Length: 6
Hops: 0
Transaction ID: 1565545288
Seconds: 0
Client IP Address: 0.0.0.0
Your IP Address: 0.0.0.0
Server IP Address: 0.0.0.0
Gateway IP Address: 0.0.0.0
Client Hardware Address: 006097D49D4800000000000000000000
Server Host Name
Boot File Name
Vendor Specific Area: 99.130.83.99
Code: DHCP Message Type, Length: 1, Type: Discover
Code: DHCP Client ID, Length: 7, 01006097D49D48
Code: DHCP Requested IP Address, Length: 4
Address: 10.0.0.13
Code: Host Name, Length: 9, Name: LABCOM07
Code: DHCP Parameter Request List, Length: 7, Option List 010F032C2E2F06
Code: End Option
Data 0000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Data 0010: 00 00 00 00 00 00
Sliced Packet(Data Length = 342)

Decode	Matrix	Host	Protocol Dist.	Summary
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DHCP Offer

DHCP Offer message is encapsulated on a ***BootP Reply*** message. Each server offers one IP address to lease (if possible, servers offer the IP address indicated by the client).

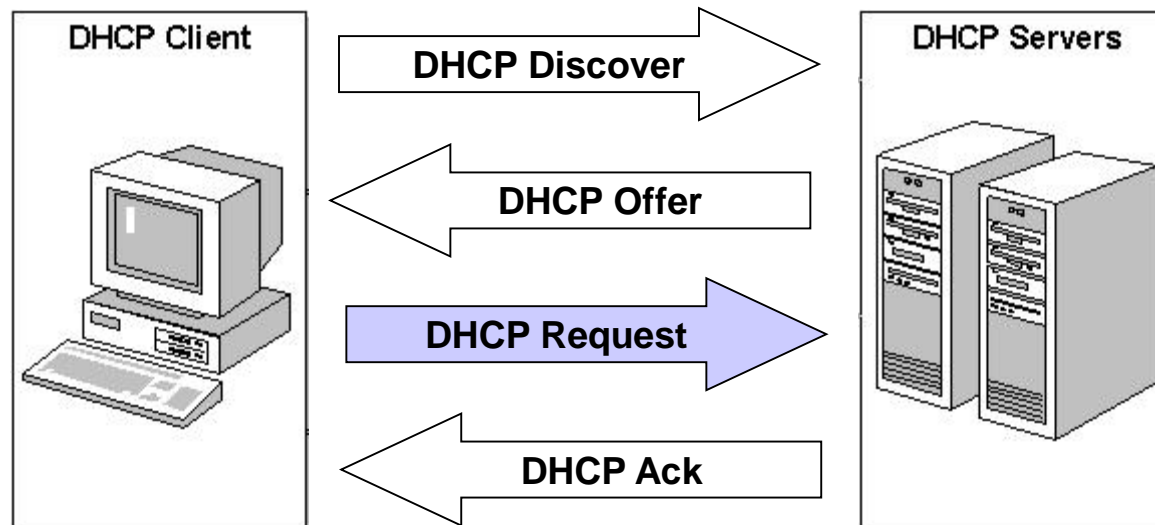


DHCP Offer

```
+ [ETHER-II: 00-60-97-9B-9B-3F ==> FF-FF-FF-FF-FF-FF]
+ [Y IP: 10.0.0.11->BROADCAST, ID=4250]
+ [UDP: Bootp Server->Bootp Client, Len=326]
- [IP Bootstrap Protocol]
  [OP Code: 2 (Reply)]
  [Hardware Type: 1 (Ethernet)]
  [Hardware Address Length: 6]
  [Hops: 0]
  [Transaction ID: 1565545288]
  [Seconds: 0]
  [Client IP Address: 0.0.0.0]
  [Your IP Address: 10.0.0.13]
  [Server IP Address: 10.0.0.11]
  [Gateway IP Address: 0.0.0.0]
  [Client Hardware Address: 006097D49D4800000000000000000000]
  [Server Host Name]
  [Boot File Name]
  [Vendor Specific Area: 99.130.83.99]
  [Code: DHCP Message Type, Length: 1, Type: Offer]
  [Code: Subnet Mask, Length: 4, Address: 255.0.0.0]
  [Code: DHCP Renewal (T1) Time, Length: 4, Value: 150]
  [Code: DHCP Rebinding (T2) Time, Length: 4, Value: 262]
  [Code: DHCP IP Address Lease Time, Length: 4, Value: 300]
  [Code: DHCP Server ID, Length: 4, Address: 10.0.0.11]
  [Code: Domain Name, Length: 17, Name: labcom.det.ua.pt]
  [Code: Router, Length: 4, Address: 10.0.0.1]
  [Code: NetBIOS Name Server, Length: 8, Address: 193.136.173.202]
  [Code: NetBIOS over TCP/IP, Length: 1, Node Type: 0x8 H-node]
  [Code: Domain Name Server, Length: 4, Address: 10.0.0.11]
  [Code: End Option]
- [Sliced Packet( Data Length = 360)]
```

DHCP Request

DHCP Request message is encapsulated on a ***BootP Request*** message. After selecting one of the offers, the client indicates the selected IP address.

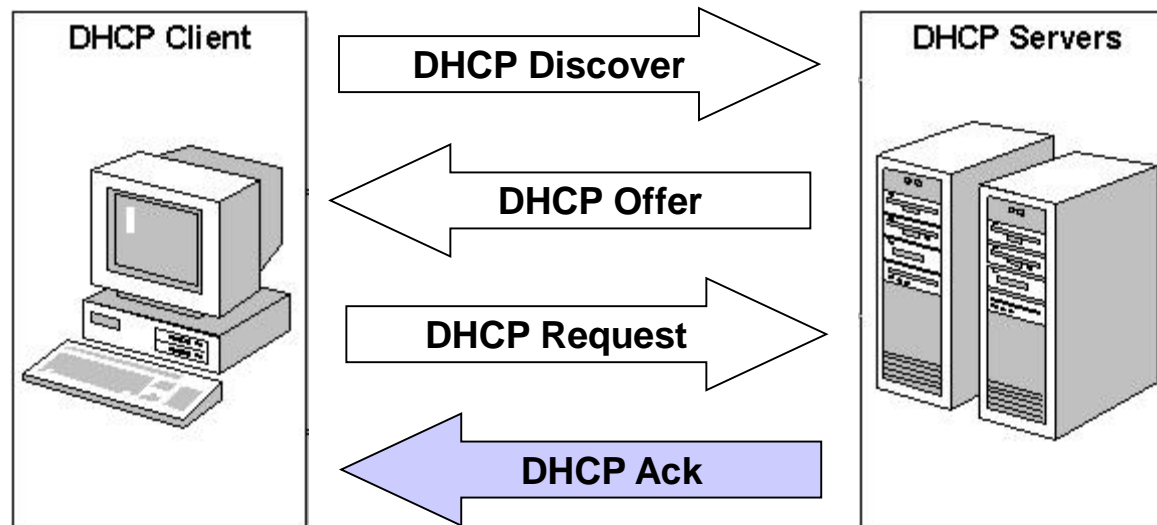


DHCP Request

```
+ [ETHER-II: 00-60-97-D4-9D-48 ==> FF-FF-FF-FF-FF-FF]
+ [Y IP: 0.0.0.0->BROADCAST,ID=256]
+ [UDP: Bootp Client->Bootp Server,Len=308]
+ [IP Bootstrap Protocol]
  [OP Code: 1 (Request)]
  [Hardware Type: 1 (Ethernet)]
  [Hardware Address Length: 6]
  [Hops: 0]
  [Transaction ID: 1025766432]
  [Seconds: 0]
  [Client IP Address: 0.0.0.0]
  [Your IP Address: 0.0.0.0]
  [Server IP Address: 0.0.0.0]
  [Gateway IP Address:0.0.0.0]
  [Client Hardware Address: 006097D49D480000000000000000000000]
  [Server Host Name]
  [Boot File Name]
  [Vendor Specific Area: 99.130.83.99]
  [Code: DHCP Message Type, Length: 1, Type: Request]
  [Code: DHCP Client ID, Length: 7, 01006097D49D48]
  [Code: DHCP Requested IP Address, Length: 4]
    Address: 10.0.0.13
  [Code: DHCP Server ID, Length: 4]
    Address: 10.0.0.11
  [Code: Host Name, Length: 9, Name: LABCOM07]
  [Code: DHCP Parameter Request List, Length: 7, Option List010F032C2E2F06]
  [Code: End Option]
  [Data 0000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 | .....
+ [Sliced Packet( Data Length = 342)]
```

DHCP Ack

DHCP Ack message is encapsulated in a ***BootP Reply*** message. The server acknowledges positively the lease of the IP address indicating also other information of interest.



DHCP Ack

```
+ [ETHER-II: 00-60-97-9B-9B-3F ==> FF-FF-FF-FF-FF-FF]
+ [Y IP: 10.0.0.11->BROADCAST,ID=4251]
+ [UDP: Bootp Server->Bootp Client,Len=326]
- [IP Bootstrap Protocol]
  [OP Code: 2 (Reply)]
  [Hardware Type: 1 (Ethernet)]
  [Hardware Address Length: 6]
  [Hops: 0]
  [Transaction ID: 1025766432]
  [Seconds: 0]
  [Client IP Address: 0.0.0.0]
  [Your IP Address: 10.0.0.13]
  [Server IP Address: 0.0.0.0]
  [Gateway IP Address:0.0.0.0]
  [Client Hardware Address: 006097D49D4800000000000000000000]
  [Server Host Name]
  [Boot File Name]
  [Vendor Specific Area: 99.130.83.99]
  [Code: DHCP Message Type, Length: 1, Type: Ack]
  [Code: DHCP Renewal (T1) Time, Length: 4, Value:150]
  [Code: DHCP Rebinding (T2) Time, Length: 4, Value:262]
  [Code: DHCP IP Address Lease Time, Length: 4, Value:300]
  [Code: DHCP Server ID, Length: 4]
  [Address: 10.0.0.11]
  [Code: Subnet Mask, Length: 4 Address255.0.0.0]
  [Code: Domain Name, Length: 17, Name: labcom.det.ua.pt]
  [Code: Router, Length: 4]
  [Address: 10.0.0.1]
  [Code: NetBIOS Name Server, Length: 8]
  [Address: 193.136.173.202]
  [Address: 193.136.173.203]
  [Code: NetBIOS over TCP/IP, Length: 1, Node Type:0x8 H-node]
  [Code: Domain Name Server, Length: 4]
  [Address: 10.0.0.11]
  [Code: End Option]
+ [Sliced Packet( Data Length = 360)]
```


Address leasing

❑ *Renewal Time (50% of Lease Time)*

- at this time, the client should try to renew the lease in the server that has assigned its IP address

❑ *Rebinding Time (85% of Lease Time)*

- at this time, the client should try to renew the lease of its IP address (if it didn't succeed before) in any available server

❑ *Lease Time*

- if the lease could not be renewed, at this time, the client stop using the IP address

Other DHCP messages

❑ *DHCP Decline:*

- The client rejects the offer of a server and restarts the acquisition of an IP address

❑ *DHCP Nack:*

- The server informs that it cannot renew the lease of an IP address

❑ *DHCP Release:*

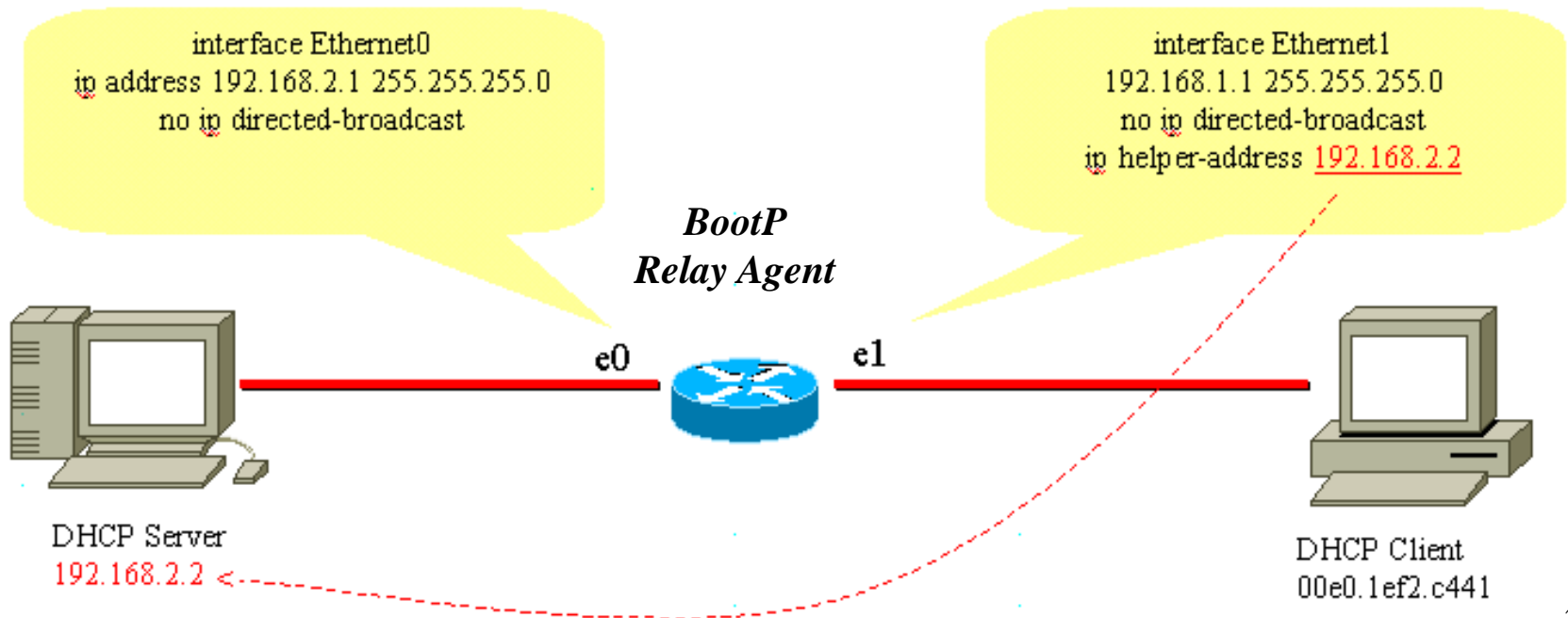
- The client informs the server that it is no longer interested on an IP address

❑ *DHCP Inform:*

- The client requests additional information (in this case, the client has an IP address but requires, for example, the DNS server address)

Client and server in different subnets

- It is necessary to make routers behave as *BootP Relay Agents*
- Routers reroute *BootP Request* messages to the IP address of the DHCP server inserting the IP address of the receiver interface in the *Gateway IP* address field of the DHCP messages
- DHCP server sends *BootP Reply* messages to the *Gateway IP* address



Gateway IP address field

Exp3.cap : 3/20 Ethernet packets									
No.	Sta.	Source Address	Dest Address	Layer	Summary	Len	Rel. Time	De	
3	Ok	0.0.0.0	BROADCAST	BOOTP	OP=1 (Request), Hops=0, XID=1565	346	0:02:09.671		
4	Ok	10.0.0.11	BROADCAST	BOOTP	OP=2 (Reply), Hops=0, XID=15655	364	0:02:09.672		
5	Ok	0.0.0.0	BROADCAST	BOOTP	OP=1 (Request), Hops=0, XID=1025	346	0:02:09.674		
6	Ok	10.0.0.11	BROADCAST	BOOTP	OP=2 (Reply), Hops=0, XID=10257	364	0:02:09.676		

ETHER-II: 00-60-97-D4-9D-48 ==> FF-FF-FF-FF-FF-FF
IP: 0.0.0.0->BROADCAST,ID=0
UDP: Bootp Client->Bootp Server,Len=308
IP Bootstrap Protocol
OP Code: 1 (Request)
Hardware Type: 1 (Ethernet)
Hardware Address Length: 6
Hops: 0
Transaction ID: 1565545288
Seconds: 0
Client IP Address: 0.0.0.0
Your IP Address: 0.0.0.0
Server IP Address: 0.0.0.0
Gateway IP Address: 0.0.0.0
Client Hardware Address: 006097D49D4800000000000000000000
Server Host Name
Boot File Name
Vendor Specific Area: 99.130.83.99
Code: DHCP Message Type, Length: 1, Type: Discover
Code: DHCP Client ID, Length: 7, 01006097D49D48
Code: DHCP Requested IP Address, Length: 4
Address: 10.0.0.13
Code: Host Name, Length: 9, Name: LABCOM07
Code: DHCP Parameter Request List, Length: 7, Option List010F032C2E2F06
Code: End Option
Data 0000: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0010: 00 00 00 00 00 00
Sliced Packet(Data Length = 342)

Bibliography to study

- ❑ J. Kurose, K. Ross, "Computer Networking: A Top-Down Approach", Addison-Wesley, 4th Edition
 - Section 4.4.2 "IPv4 Addressing"

IPv6

IPv6 Features

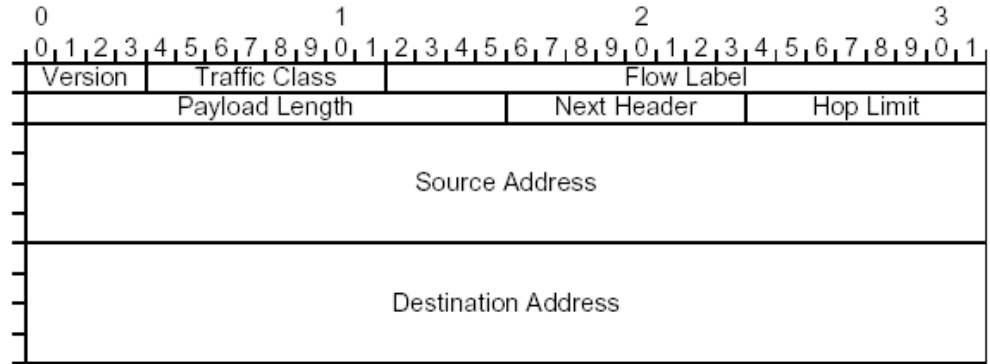
- Larger address space enabling:
 - Global reachability, flexibility, aggregation, multihoming, autoconfiguration, “plug and play” and renumbering
- Simpler header enabling:
- Routing efficiency, performance and forwarding rate scalability
- Improved option support

IPv6 Addressing

- IPv4: 4bytes/32 bits
 - ~ 4,294,967,296 possible addresses
- IPv6: 16bytes/128 bits
 - 340,282,366,920,938,463,463,374,607,431,768,211,456 possible addresses
- Representation
 - 16-bit hexadecimal numbers
 - Hex numbers are not case sensitive
 - Numbers are separated by (:)
 - Abbreviations are possible
 - Leading zeros in contiguous block could be represented by (::)
 - Example:
 - 2001:0db8:0000:130F:0000:0000:087C:140B = 2001:0db8:0:130F::87C:140B
 - Double colon only appears once in the address
 - Address's prefix is represented as: prefix/mask_number_of_bits

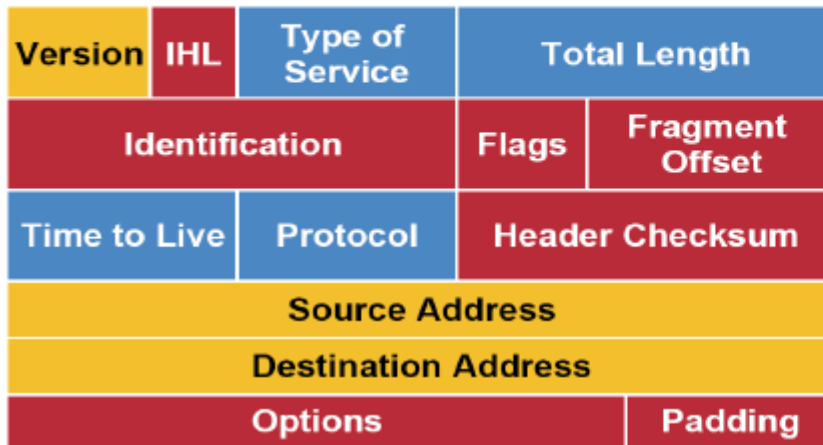
Header

- ❑ Fixed-length
40 byte header
- ❑ Checksum removed
- ❑ No options in base header
- ❑ New flow label field (use is currently not defined, actually several uses exist for each purpose)
- ❑ Faster packet processing (with hardware support)
- ❑ Options in flexible and extensible extension headers (can be transparent for transit nodes)

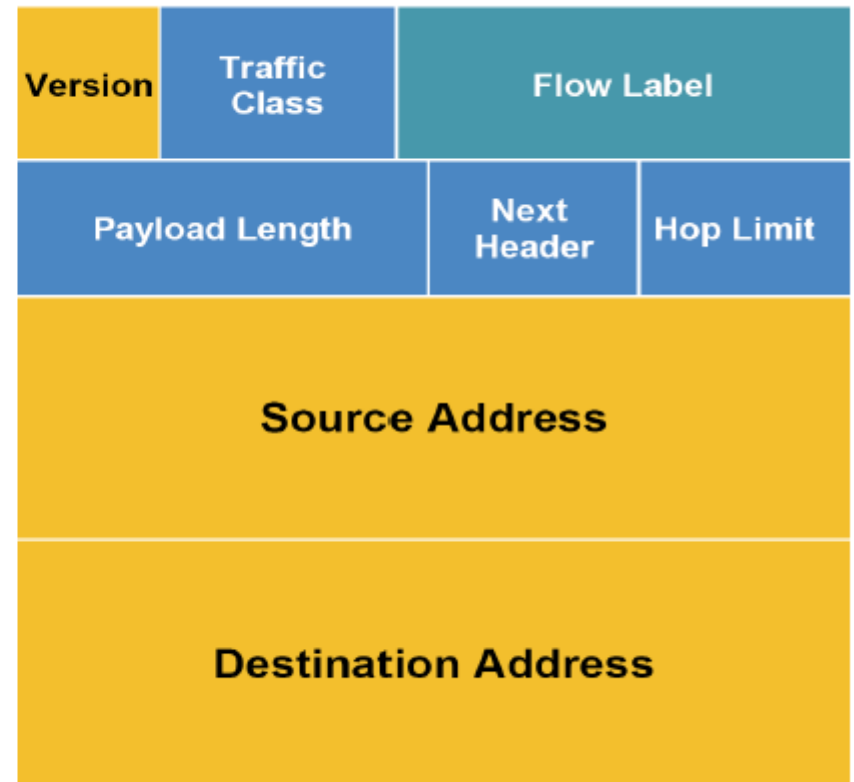


IPv6 Header compared to IPv4 Header

IPv4 Header



IPv6 Header



Legend

- Field's Name Kept from IPv4 to IPv6
- Fields Not Kept in IPv6
- Name and Position Changed in IPv6
- New Field in IPv6

Extension Headers

- ❑ Hop-by-hop (various, e.g. discard packet w/o ICMP)
- ❑ Routing (address list → source routing)
- ❑ Fragment (fragmentation only done by source)
- ❑ Destination options (various , e.g. discard packet w/o ICMP)
- ❑ Authentication (integrity and data origin auth.)
- ❑ Encapsulating security payload (confidentiality)

IPv6 address format

2001:0DA8:E800:0000:0260:3EFF:FE47:0001

- ❑ 8 groups of 4 hexadecimal digits
 - Each group represents 16 bits
 - Separator is ":"
 - Case-independent
- ❑ Addresses in IPv6 very complex
 - Auto configured
 - Local addresses

IPv6 Addressing

Type	Binary	Hexadecimal
<i>Global Unicast Address</i>	0010	2
<i>Link-Local Unicast Address</i>	1111 1110 10	FE80::/10
<i>Unique-Local Unicast Address</i>	1111 1100 1111 1101	FC00::/8 FD00::/8
<i>Multicast Address</i>	1111 1111	FF00::/16

Examples

- ❑ 2200:A:A::1/64
- ❑ 2001:db8:a0b:12f0::1/64
- ❑ 2731:54:65fe:2::a7/64
- ❑ fe80::19b3:fddb:75f9:740/64

- ❑ My PC
 - IPv6 address:
2001:0:9d38:90d7:30a6:16a4:3f57:e09e
 - Link local IPv6
address: fe80::30a6:16a4:3f57:e09e

IPv6 Addressing Scheme

❑ Interface have multiple addresses

❑ Addresses have scope:

○ Link Local

- Valid within the same LAN or link

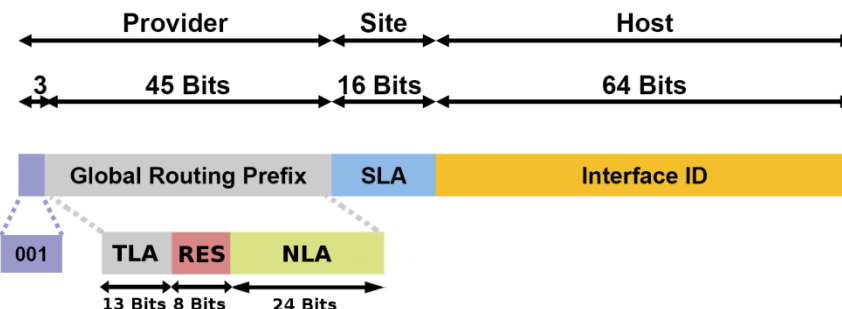
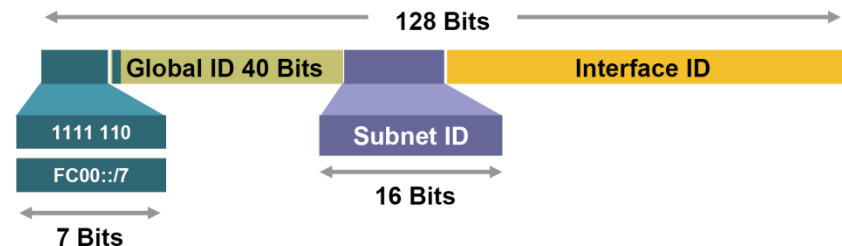
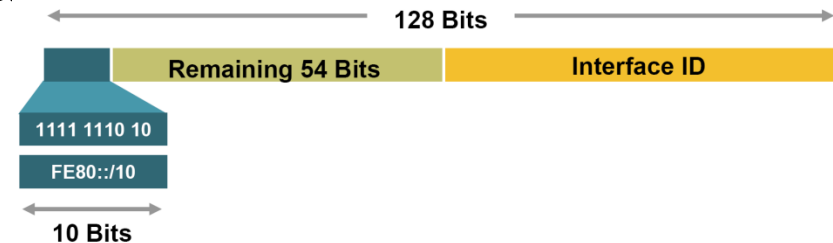
○ Unique Local

- Valid within the same private domain
- Can not be used in Internet

○ Global

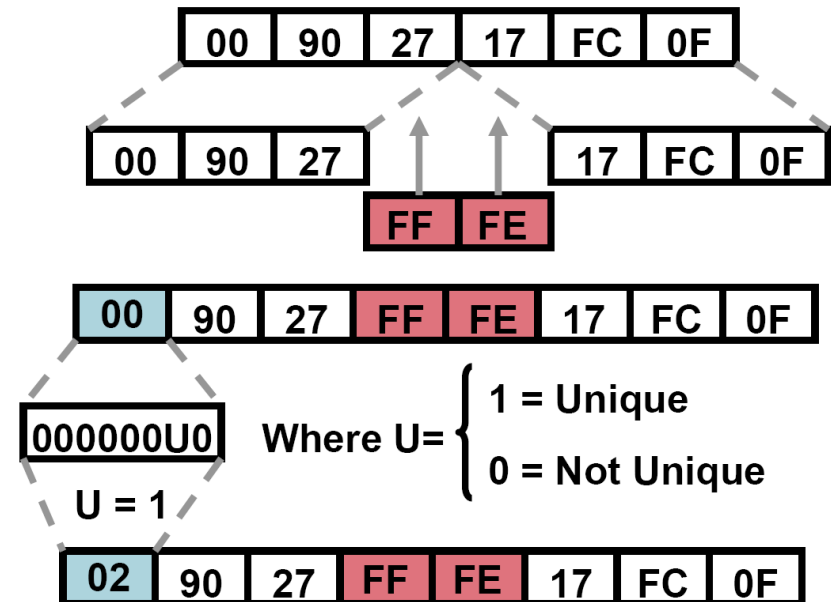
❑ Addresses have lifetime

- Valid and preferred lifetime



IPv6 Interface Identifier

- Lowest-Order 64-Bit field of any address:
 - Auto-configured from a 64-bit EUI-64, or expanded from a 48-bit MAC address (e.g. Ethernet address)
 - Auto-generated pseudo-random number
 - Assigned via DHCP
 - Manually configured



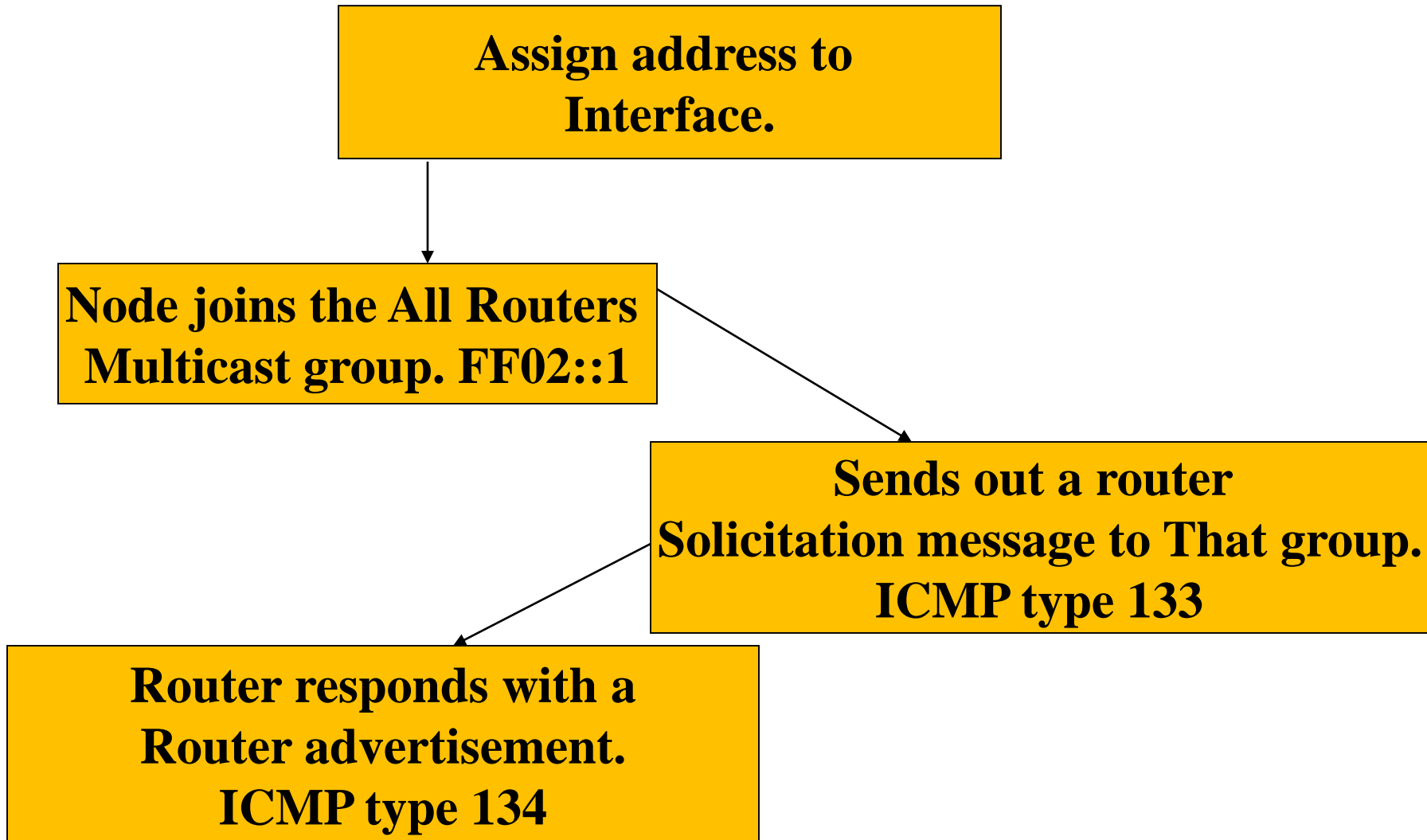
Auto-configuration

- ❑ Important concept in the IPv6 birth
 - Terminal needs to automatically obtain its configuration information;
 - Network configuration elements can be changed and automatically propagated to all terminals.
- ❑ Auto-configuration methods
 - Stateless: configuration determined by the network;
 - Stateful: configuration determined by the network management.
- ❑ Process:
 - Link-local is created;
 - Verify the uniqueness of the link-local address (DAD-duplicate address detection)
 - Selection of the configuration method;
 - Determine the information to be auto-configured (addresses, gateways, ...)

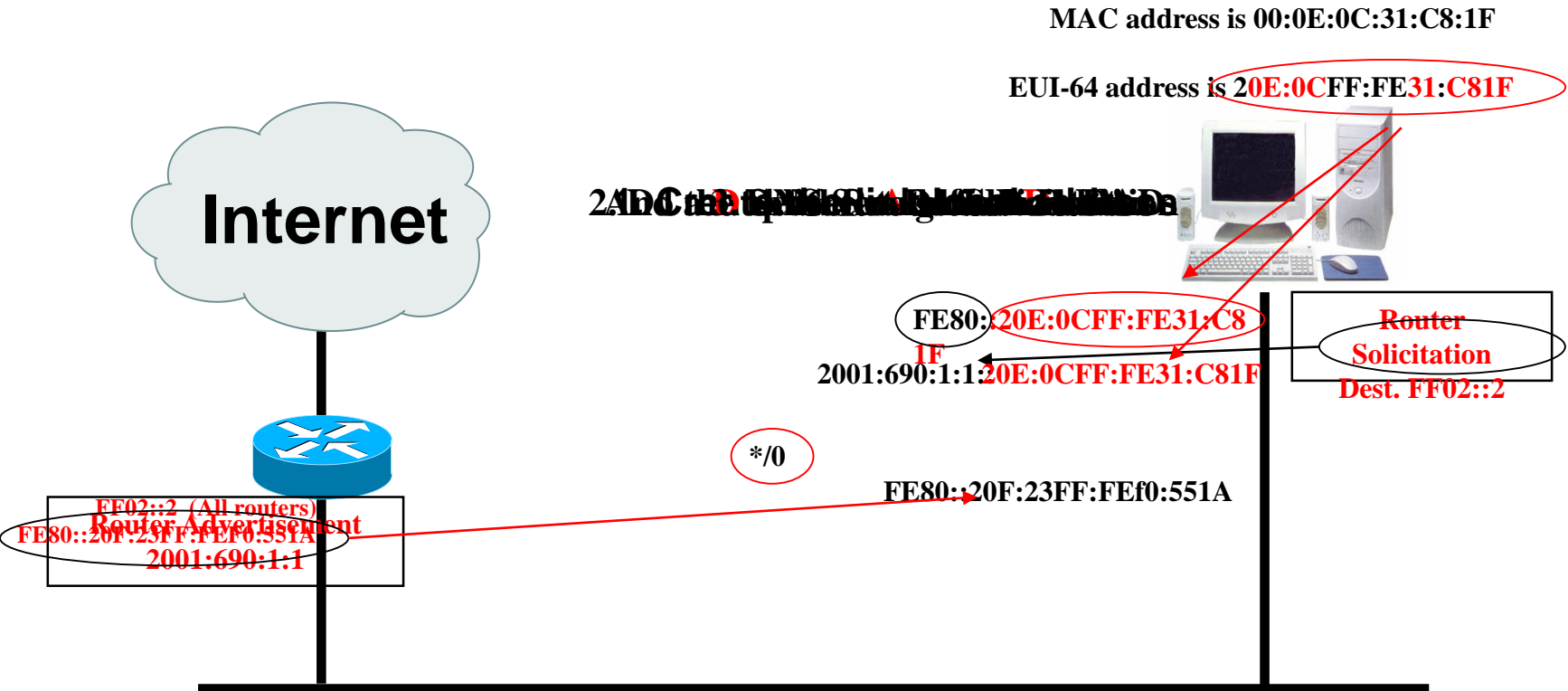
Stateless auto-configuration

- ❑ Terminal generates its own address. It combines
 - Local information (e.g. MAC address);
 - Information is advertised by routers (prefix defines the local sub-network).
- ❑ Advantages:
 - No manual configuration of the terminals;
 - Minimal configuration in the routers;
 - No additional servers.
- ❑ If there are no routers, terminal creates its link-local address
 - This address is sufficient to allow a communication in the same local network segment.

Stateless auto-configuration



Stateless auto-configuration



Statefull auto-configuration

- ❑ Configuration based on a client-server model
 - Use the Dynamic Host Control Protocol (DHCPv6).
- ❑ DHCPv6 allows:
 - Allocation of IPv6 addresses to the terminals;
 - Delivery of specific configuration information of each terminal.
- ❑ Guarantees larger configuration control (no DADs required);
- ❑ Supports IPv6 concepts of automatic configuration
 - E.g. automatic change of addresses.