

# RAČUNARSKE MREŽE

07 – IPv4

# Anatomija IPv4 adrese

- IPv4 adresa 32 bita, *dotted decimal* reprezentacija
- Dva dijela – *network* i *host*
- Dva načina razgraničavanja network i host dijela:
  1. prefix length – broj bita koji pripadaju network dijelu

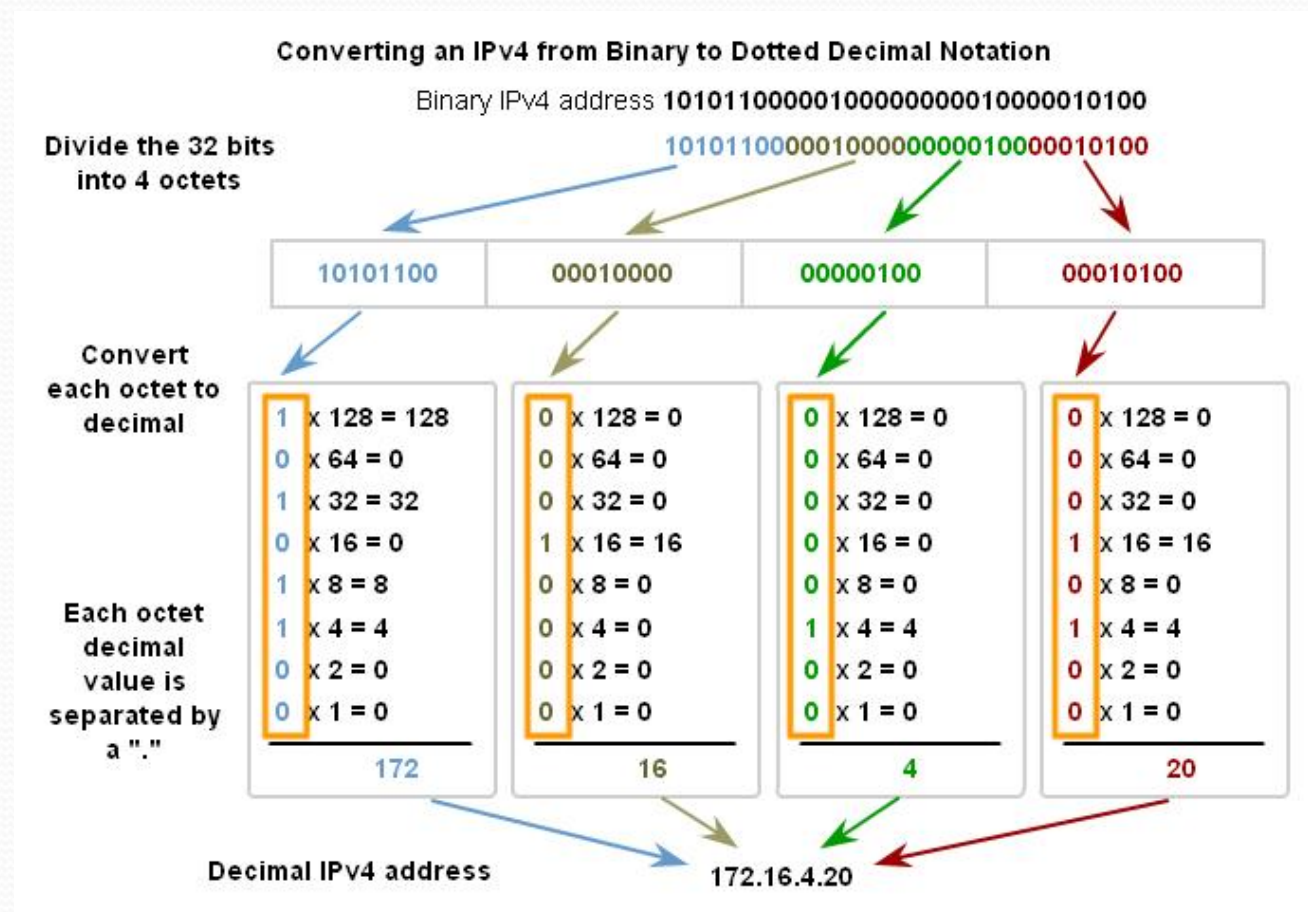
192.168.10.1 /24

2. subnet maska – 32 bita – jedinice network, nule host

192.168.10.1 255.255.255.0

# Binarna -> *dotted decimal* notacija

- Pozicioni brojni sistemi, osnova br.sistema



# Dotted decimal -> binarna notacija

## Convert Decimal to Binary

Decimal IPv4 address 172.16.4.20

Separate and convert each decimal number separately

### Convert 172

$$172 - 128 = 44 \longrightarrow 1 \times 128$$

$$44 < 64 = 0 \longrightarrow 0 \times 64$$

$$44 - 32 = 12 \longrightarrow 1 \times 32$$

$$12 < 16 = 0 \longrightarrow 0 \times 16$$

$$12 - 8 = 4 \longrightarrow 1 \times 8$$

$$4 - 4 = 0 \longrightarrow 1 \times 4$$

$$0 < 2 = 0 \longrightarrow 0 \times 2$$

$$0 < 1 = 0 \longrightarrow 0 \times 1$$

10101100

### Convert 16

$$16 < 128 \longrightarrow 0 \times 128$$

$$16 < 64 \longrightarrow 0 \times 64$$

$$16 < 32 \longrightarrow 0 \times 32$$

$$16 - 16 = 0 \longrightarrow 1 \times 16$$

$$0 < 8 \longrightarrow 0 \times 8$$

$$0 < 4 \longrightarrow 0 \times 4$$

$$0 < 2 \longrightarrow 0 \times 2$$

$$0 < 1 \longrightarrow 0 \times 1$$

00010000

### Convert 4

$$4 < 128 \longrightarrow 0 \times 128$$

$$4 < 64 \longrightarrow 0 \times 64$$

$$4 < 32 \longrightarrow 0 \times 32$$

$$4 < 16 \longrightarrow 0 \times 16$$

$$4 < 8 \longrightarrow 0 \times 8$$

$$4 - 4 = 0 \longrightarrow 1 \times 4$$

$$0 < 2 \longrightarrow 0 \times 2$$

$$0 < 1 \longrightarrow 0 \times 1$$

00000100

### Convert 20

$$20 < 128 \longrightarrow 0 \times 128$$

$$20 < 64 \longrightarrow 0 \times 64$$

$$20 < 32 \longrightarrow 0 \times 32$$

$$20 - 16 = 4 \longrightarrow 1 \times 16$$

$$4 < 8 \longrightarrow 0 \times 8$$

$$4 - 4 = 0 \longrightarrow 1 \times 4$$

$$0 < 2 \longrightarrow 0 \times 2$$

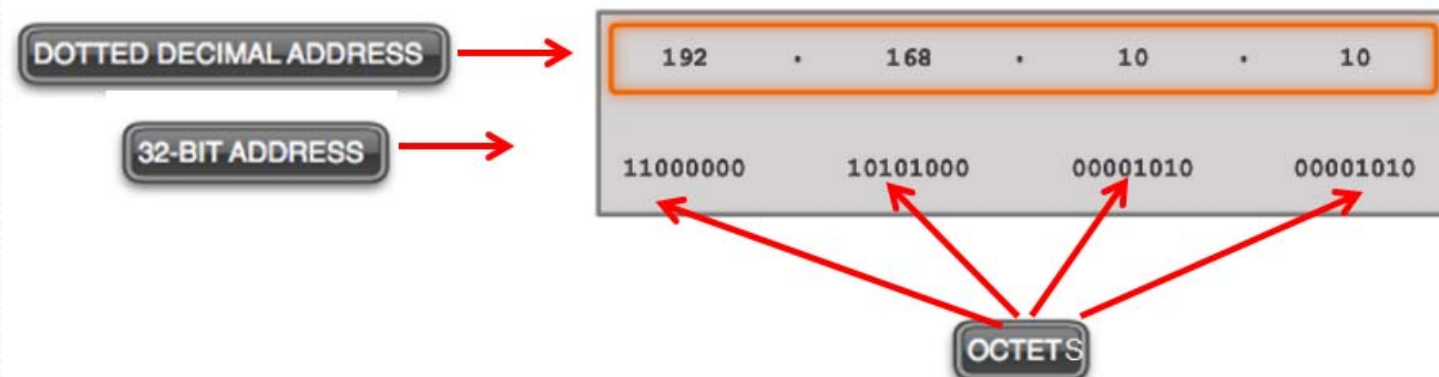
$$0 < 1 \longrightarrow 0 \times 1$$

00010100

Binary IPv4 address 10101100 000100000000010000010100



# Primjer:



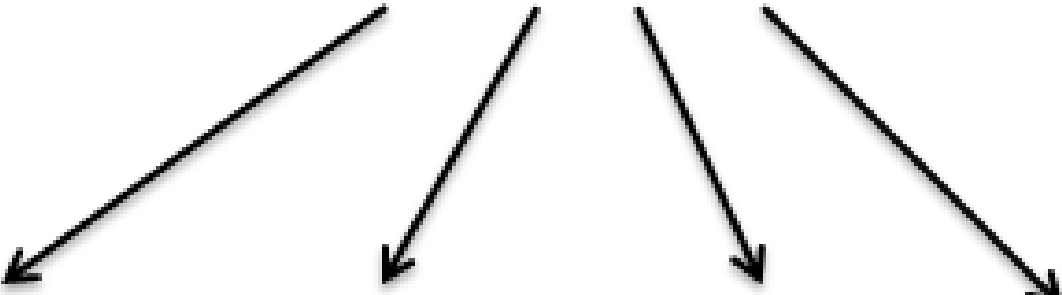
Radix	2	2	2	2	2	2	2	2
Exponent	7	6	5	4	3	2	1	0
Octet Bit Values	128	64	32	16	8	4	2	1
Binary Address	1	1	0	0	0	0	0	0
Binary Bit Values	128	64	0	0	0	0	0	0

Add the binary bit values.  
 $128 + 64 = 192$

*Primjer:*

**Convert Decimal to Binary**

**192.168.10.10**



<b>192</b>	<b>168</b>	<b>10</b>	<b>10</b>
<b>11000000</b>	<b>10101000</b>	<b>00001010</b>	<b>00001010</b>

## *Dva dijela – network i host*

	Network Portion			Host Portion		
IPv4 Address	192	.	168	.	10	10
	11000000 10101000 00001010			00001010		
Subnet Mask	255	.	255	.	0	0
	11111111 11111111 11111111			00000000		

# Tipovi IP adresa

- *network, broadcast, host*

Address Types

	Network			Host
Network Address	10	0	0	0
	00001010	00000000	00000000	00000000
Broadcast Address	10	0	0	255
	00001010	00000000	00000000	11111111
Host Address	10	0	0	1
	00001010	00000000	00000000	00000001

Roll over to learn more.

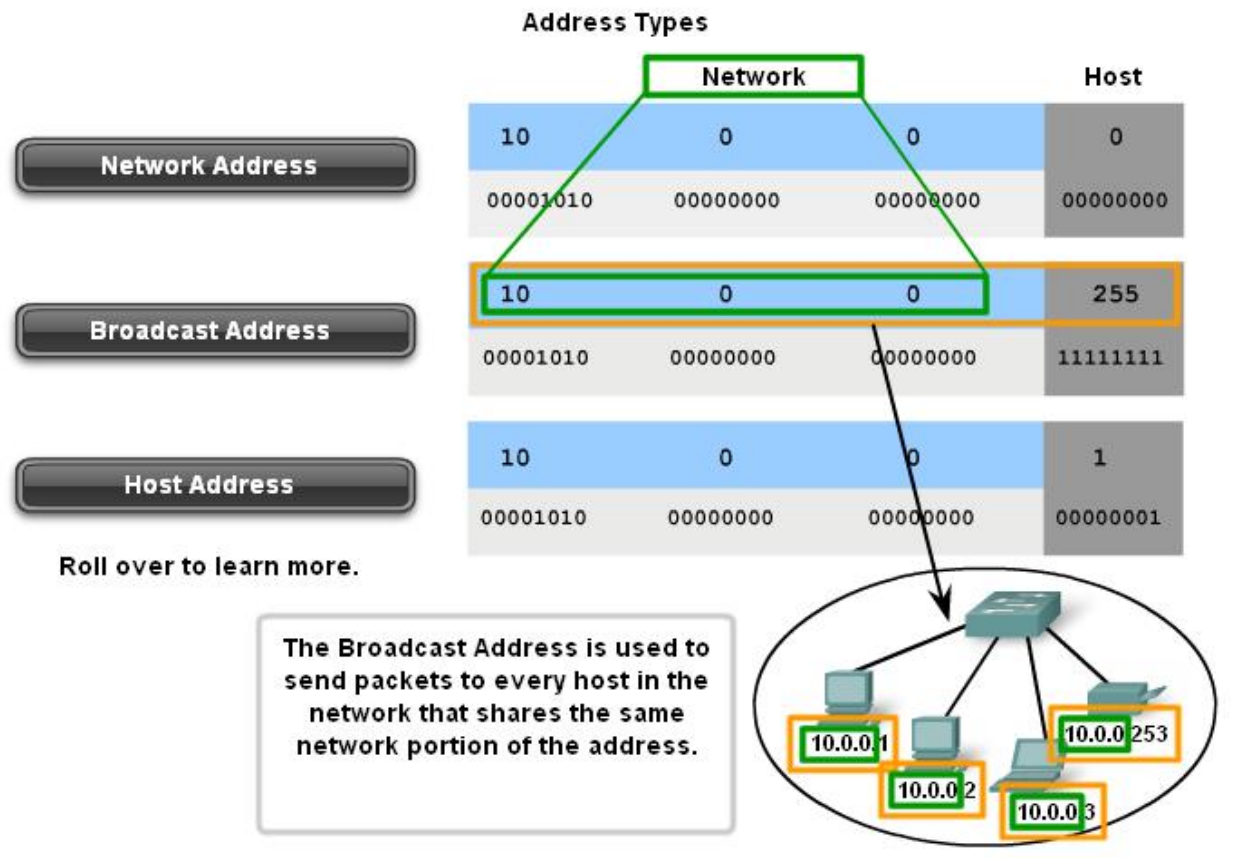
10.0.0.0 is used to refer to the network as a whole. All devices in this network have the same network address bits.

The diagram illustrates a network topology where a central router is connected to four devices. The devices have IP addresses 10.0.0.1, 10.0.0.2, 10.0.0.3, and 10.0.0.253. An arrow points from the '10.0.0.0' network address in the table to the router, indicating that the router represents the entire network.



# Tipovi IP adresa (2)

- *network*, ***broadcast***, *host*



# Tipovi IP adresa (3)

- *network, broadcast, host*

Address Types

	Network			Host
Network Address	10	0	0	0
	00001010	00000000	00000000	00000000
Broadcast Address	10	0	0	255
	00001010	00000000	00000000	11111111
Host Address	10	0	0	1
	00001010	00000000	00000000	00000001

Roll over to learn more.

Each host in this network has a unique address.

10.0.0.1  
10.0.0.2  
10.0.0.3  
10.0.0.253

# Primjer

- 172.16.20.0/25

## Network address

172 . 16 . 20 . 0 /25  
10101100.00010000.00010100.00000000  
|-----Network -----| - host -|  
 $0+0+0+0+0+0+0+0=0$   
Network address = 172.16.20.0

## Step 1

## First host address

172 . 16 . 20 . 1  
10101100.00010000.00010100.00000001  
|-----Network -----| - host -|  
 $0+0+0+0+0+0+0+1=1$   
Lowest host address = 172.16.20.1

## Step 2

## Broadcast address

172 . 16 . 20 . 127  
10101100.00010000.00010100.01111111  
|-----Network -----| - host -|  
 $0+64+32+16+8+4+2+1=127$   
Broadcast address = 172.16.20.127

## Step 3

## Last host address

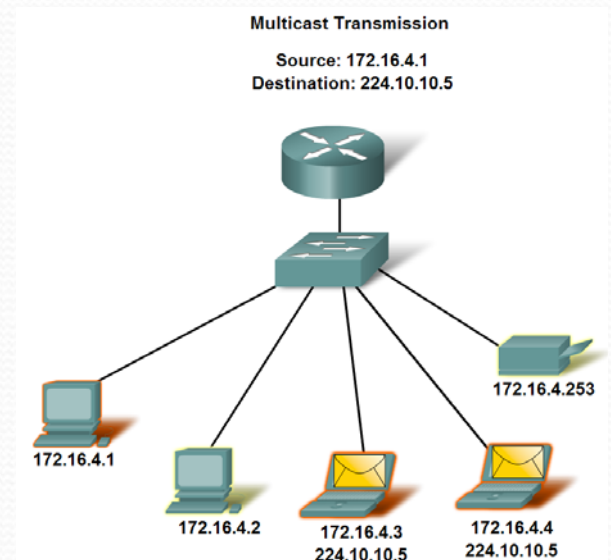
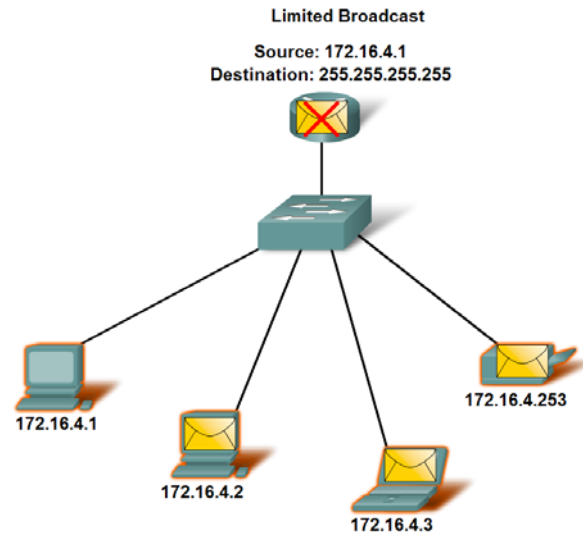
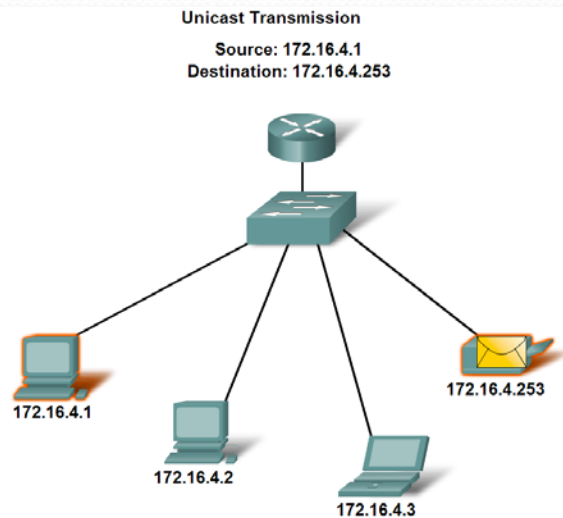
172 . 16 . 20 . 126  
10101100.00010000.00010100.01111110  
|-----Network -----| - host -|  
 $0+64+32+16+8+4+2+0=126$   
Highest host address = 172.16.20.126

## Step 4



# Tipovi komunikacije

- *Unicast* (1 -> 1)
- *Broadcast* (1 -> svima) – *limited* (svojoj) i *directed* (određenoj)
- *Multicast* (1 -> grupi)





# Rezervisani adresni opsezi

- Ne mogu se koristiti sve adrese iz čitavog opsega (0.0.0.0 – 255.255.255.255)

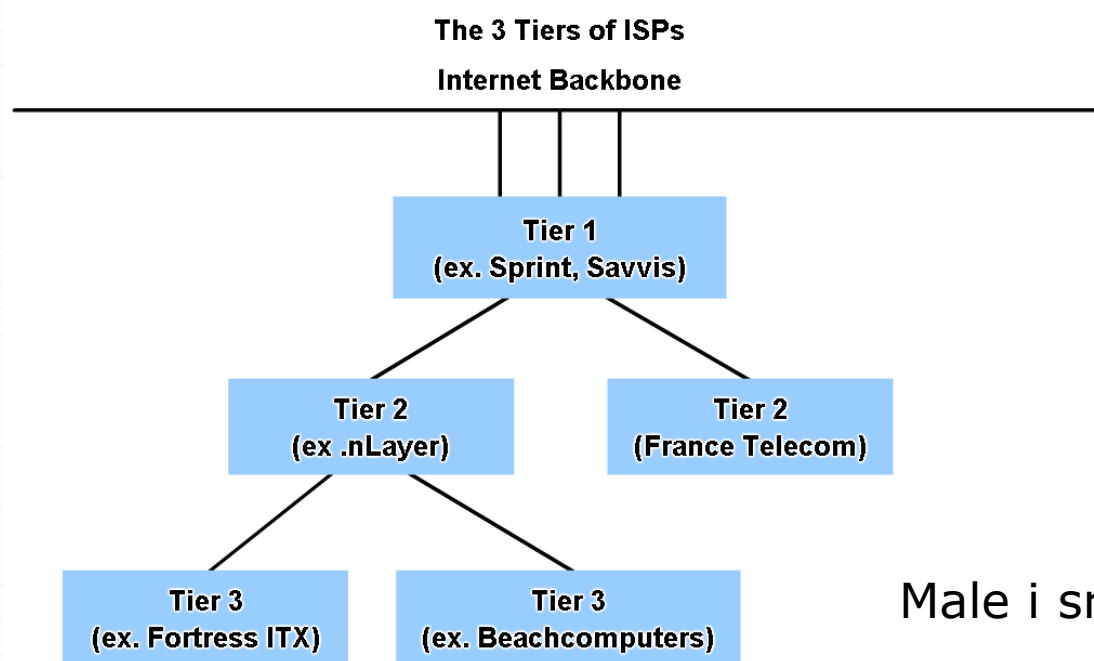
Type of Address	Usage	Reserved IPv4 Address Range	RFC
Host Address	used for IPv4 hosts	0.0.0.0 to 223.255.255.255	790
Multicast Addresses	used for multicast groups on a local network	224.0.0.0 to 239.255.255.255	1700
Experimental Addresses	<ul style="list-style-type: none"><li>• used for research or experimentation</li><li>• cannot currently be used for hosts in IPv4 networks</li></ul>	240.0.0.0 to 255.255.255.254	1700 3330

# Dodjeljivanje IP adresa

- Na početku postojanja Interneta adrese je dodeljivala organizacija koja se zvala Internet Network Information Center (InterNIC).
- InterNIC više ne postoji, njega je nasledila organizacija Internet Assigned Numbers Authority (IANA).
- IANA dodeljuje Regionalnim Internet Registrima (RIR) delove IP adresnog prostora, da ih oni dodeljuju u regionima za koje su zaduženi.
- RIR registri su:
  - RIPE - Réseaux IP Européens
  - ARIN - American Registry for Internet Numbers
  - APNIC – Asia Pacific Network Informations Centre
  - LACNIC – Latin American and Caribbean IP Address Registry
  - AfriNIC – African RIR

# ISP

- IANA – organizacija zadužena za dodjeljivanje adresa
- ISP (*Internet Service Provider*) – omogućavaju pristup na Internet dodjeljujući dobijene adrese (6-8, više po potrebi)
- Troslojna, hijerarhijska organizacija (pouzdanost, brzina, cijena)



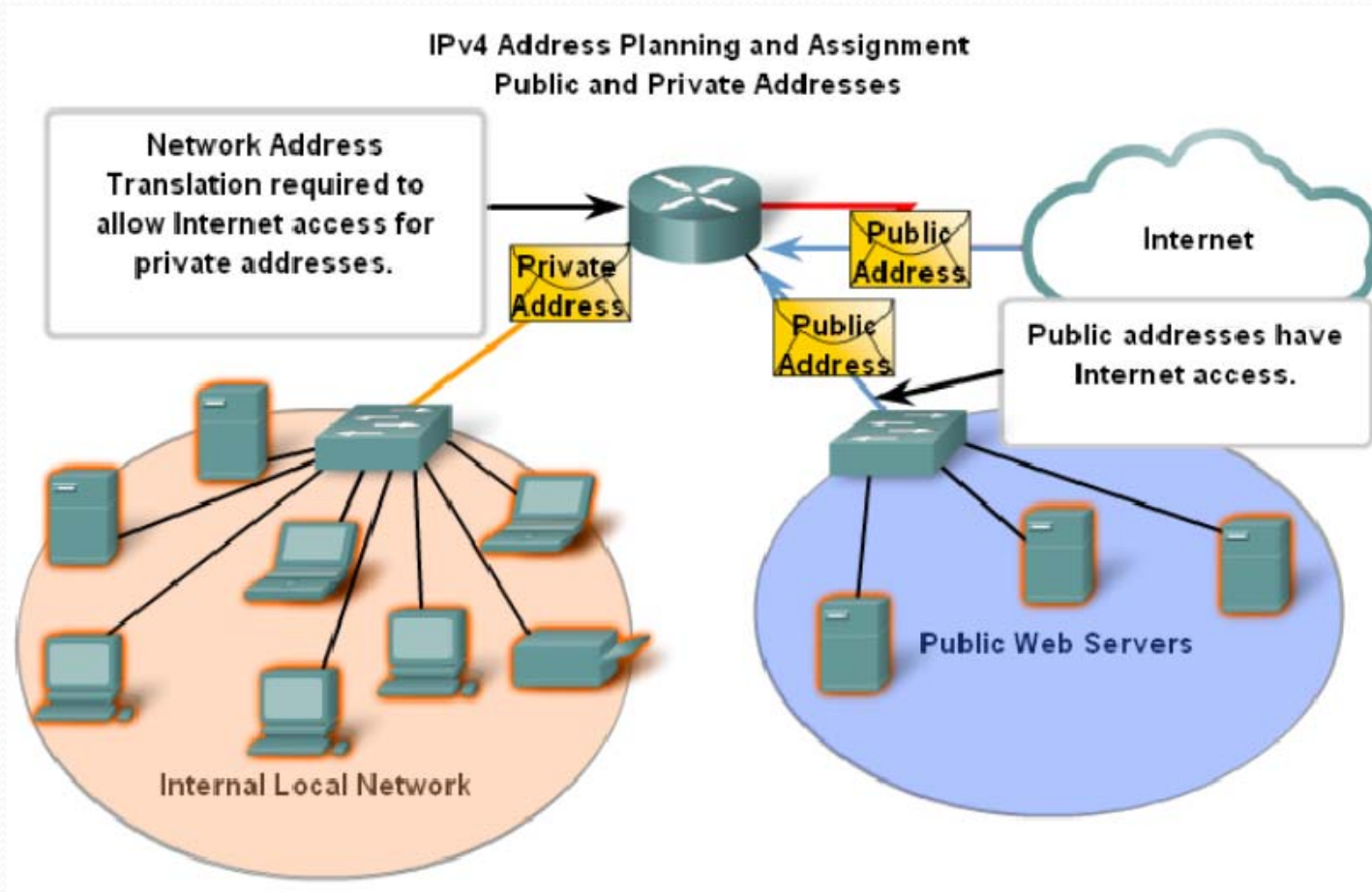
Vrlo velike kompanije

Velike kompanije

Male i srednje kompanije, kuće



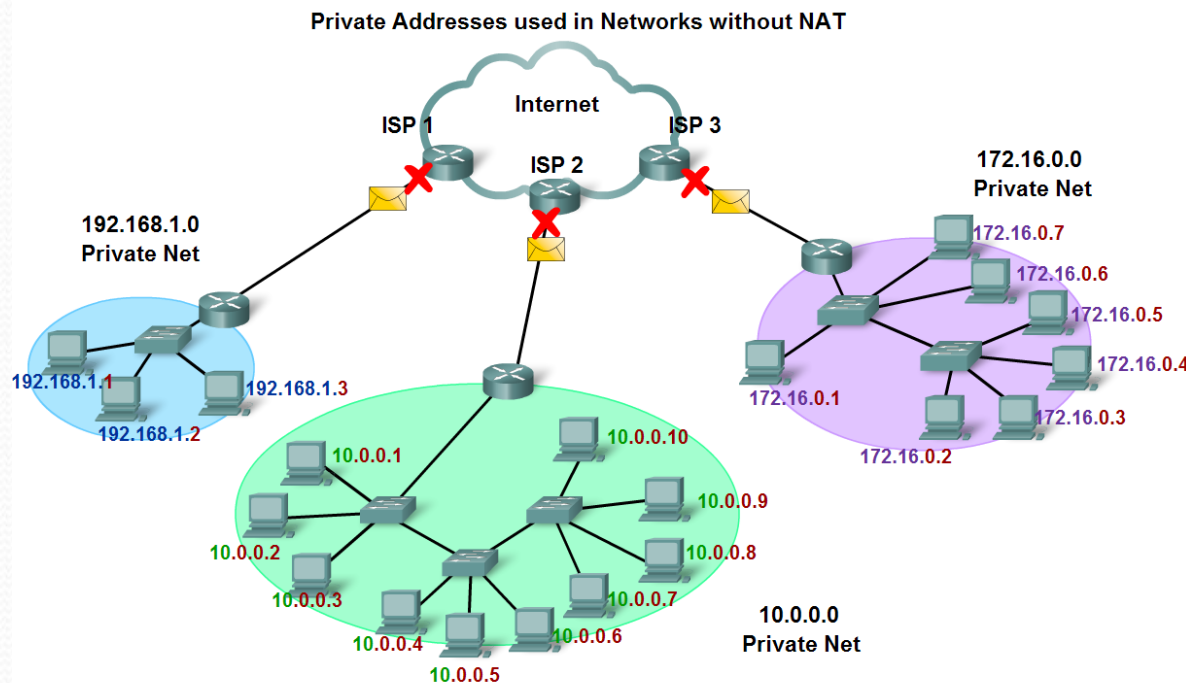
# Javne i privatne adrese (2)





# Javne i privatne adrese

- Blokovi privatnih adresa:
  - 10.0.0.0 – 10.255.255.255 (10.0.0.0 /8)
  - 172.16.0.0 – 172.31.255.255 (172.16.0.0 /12)
  - 192.168.0.0 – 192.168.255.255 (192.168.0.0 /16)



Privatne adrese moraju biti jedinstvene samo na toj mreži!

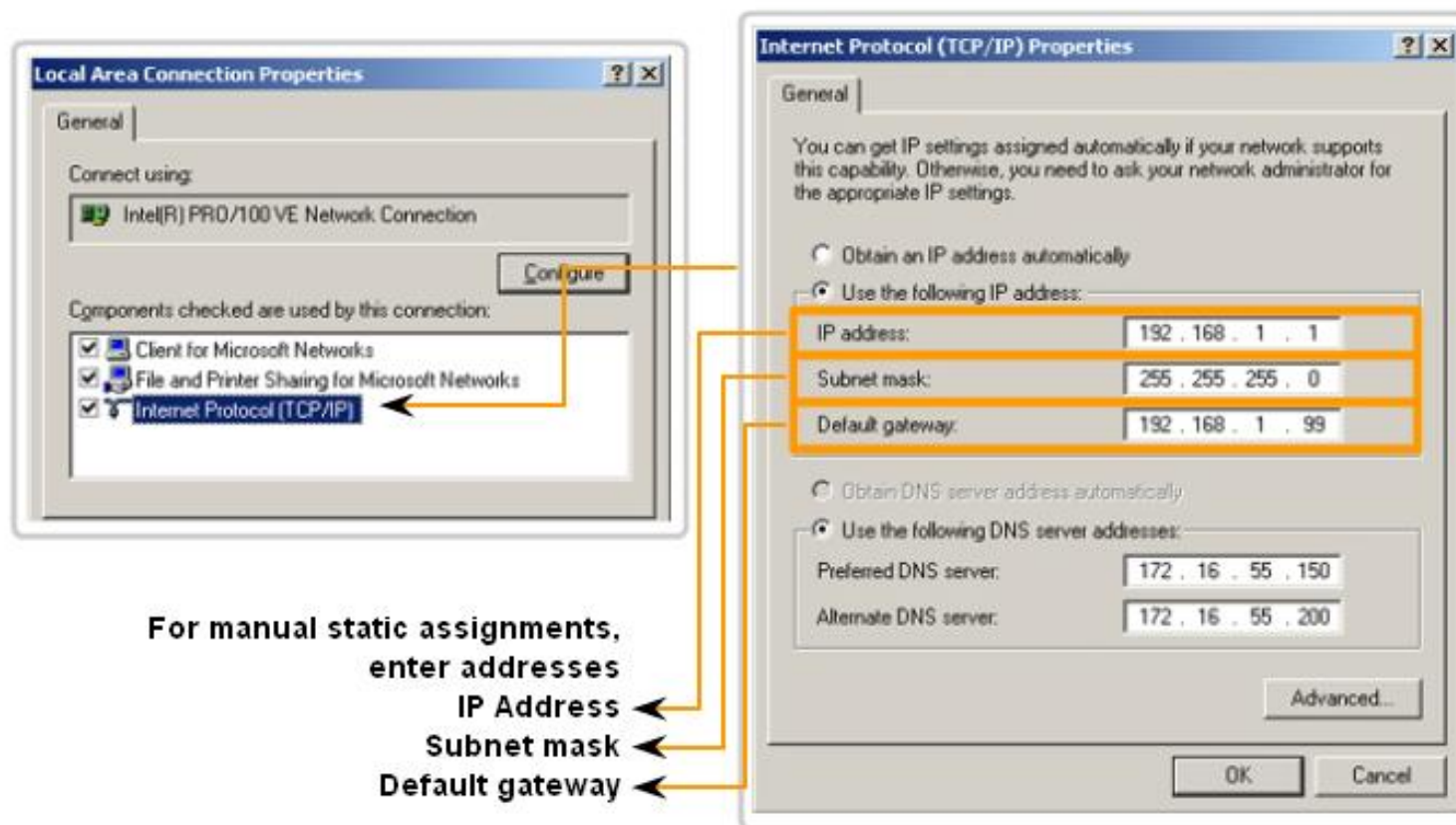
Pristup Internetu?  
=> NAT

# Specijalne IPv4 adrese

- Ne mogu se dodijeliti hostovima:
  1. Network i broadcast adrese – prva i posljednja adresa u mreži
  2. Default route (0.0.0.0) – rezervisan cijeli blok 0.0.0.0/8
  3. Loopback (127.0.0.1) – specijalna adresa za slanje samom sebi; rezervisan cijeli blok 127.0.0.0/8
  4. Link-local adrese (169.254.0.0/16) – operativni sistem dodjeljuje ove adrese hostovima automatski kad nije dostupna IP konfiguracija; ne mogu se koristiti na javnoj mreži
  5. TEST-NET adrese (192.0.2.0/24) – za svrhe učenja i predavanja; mogu se koristiti na javnoj mreži
  6. Multicast i eksperimentalne adrese (na jednom od prethodnih slajdova)

# Statičko adresiranje hosta

## Addressing End Devices





# Dinamičko adresiranje hosta

## Assigning Dynamic Addresses

The image shows two windows from a Windows XP system. The left window is 'Internet Protocol (TCP/IP) Properties' with the 'General' tab selected. The 'Obtain an IP address automatically' radio button is selected. The right window is 'Command Prompt' showing the output of the 'ipconfig /all' command. A yellow box highlights the dynamic IP configuration details for the 'Ethernet adapter Local Area Connection'. Arrows point from a text box to the DHCP settings and the command prompt output.

**Using DHCP**  
These addresses are assigned dynamically:

- IP Address
- Subnet mask
- Default gateway
- DHCP server

**Command Prompt Output:**

```
C:\>ipconfig /all

Windows IP Configuration

Host Name . . . . . : Host-1
Primary Dns Suffix . . . . . : 
Node Type . . . . . : Hybrid
IP Routing Enabled. . . . . : No
WINS Proxy Enabled. . . . . : No
DNS Suffix Search List. . . . . : woh.rr.com

Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . : woh.rr.com
   Description . . . . . : Intel(R) PRO/100 VE Network Connection
   Physical Address. . . . . : 00-07-E9-63-CE-53
   Dhcp Enabled. . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IP Address. . . . . : 192.168.1.100
   Subnet Mask . . . . . : 255.255.255.0
   Default Gateway . . . . . : 192.168.1.1
   DHCP Server . . . . . : 192.168.1.1
   Lease Obtained. . . . . : Thursday, December 28, 2006 10:50:49 AM
   Lease Expires . . . . . : Friday, December 29, 2006 10:50:49 AM
```



# Prevaziđeno IPv4 adresiranje

- *classful* vs. *classless* adresiranje (ograničenja, zaostaci)

IP Address Classes

Address Class	1st octet range (decimal)	1st octet bits (green bits do not change)	Network(N) and Host(H) parts of address	Default subnet mask (decimal and binary)	Number of possible networks and hosts per network
A	1-127**	00000000-01111111	N.H.H.H	255.0.0.0	128 nets ( $2^7$ ) 16,777,214 hosts per net ( $2^{24-2}$ )
B	128-191	10000000-10111111	N.N.H.H	255.255.0.0	16,384 nets ( $2^{14}$ ) 65,534 hosts per net ( $2^{16-2}$ )
C	192-223	11000000-11011111	N.N.N.H	255.255.255.0	2,097,150 nets ( $2^{21}$ ) 254 hosts per net ( $2^{8-2}$ )
D	224-239	11100000-11101111	NA (multicast)		
E	240-255	11110000-11111111	NA (experimental)		

\*\* All zeros (0) and all ones (1) are invalid hosts addresses.

# *Classless Interdomain Routing (CIDR)*

- *Classfull adresiranje: koristi default subnet masku za adresu koja pripada nekoj klasi. Nedostatak je što se, bez obzira na stvarne potrebe, troši preveliki broj IP adresa.*
- *Classless Interdomain Routing (CIDR) je uveden kao mehanizam koji poboljšava iskoristivost adresnog prostora i skalabilnost rutiranja. Kod CIDR-a su za razliku od tradicionalne podjele mreža na klase, te su mreže predstavljene IP adresom i brojem bitova u subnet maski.*

# Logičko I (ANDing)

- $1 \& 1 = 1$ ,  $1 \& 0 = 0$ ,  $0 \& 1 = 0$ ,  $0 \& 0 = 0$

Applying the Subnet Mask

A device with address 192.0.0.1 belongs to network 192.0.0.0

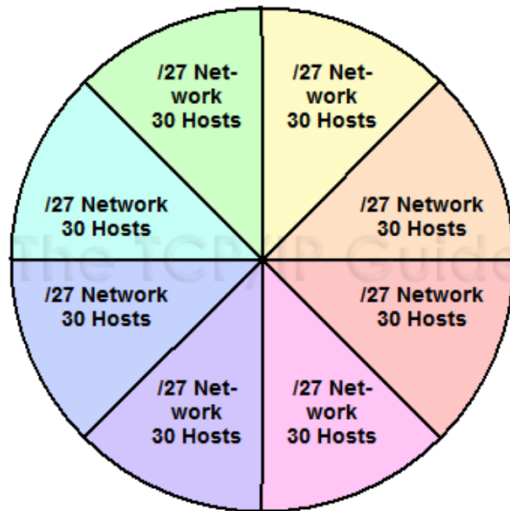
	High order bits Prefix /16		Low order bits	
	192	0	0	1
Host	11000000	00000000	00000000	00000001
Subnet	255	255	0	0
	11111111	11111111	00000000	00000000
Network	11000000	00000000	00000000	00000000
Network	192	0	0	0

- Ruter upotrebljava ANDing odredišne adrese pristiglog paketa i *subnet* maske da bi odredio odredišnu mrežu
- Host upotrebljava ANDing radi utvrđivanja da li je željeno odredište na njegovoj mreži ili da šalje *default gateway-u*

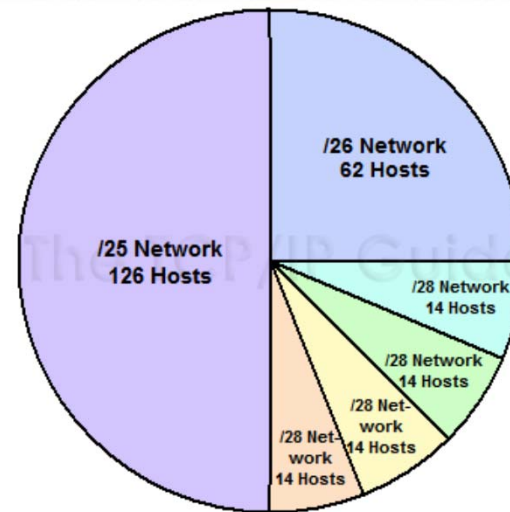


# VLSM – Variable Length Subnet Masking

- Obezbjedenje što bolje iskoristivosti dodijeljenog adresnog prostora



Class C (/24) Network (254 Hosts)



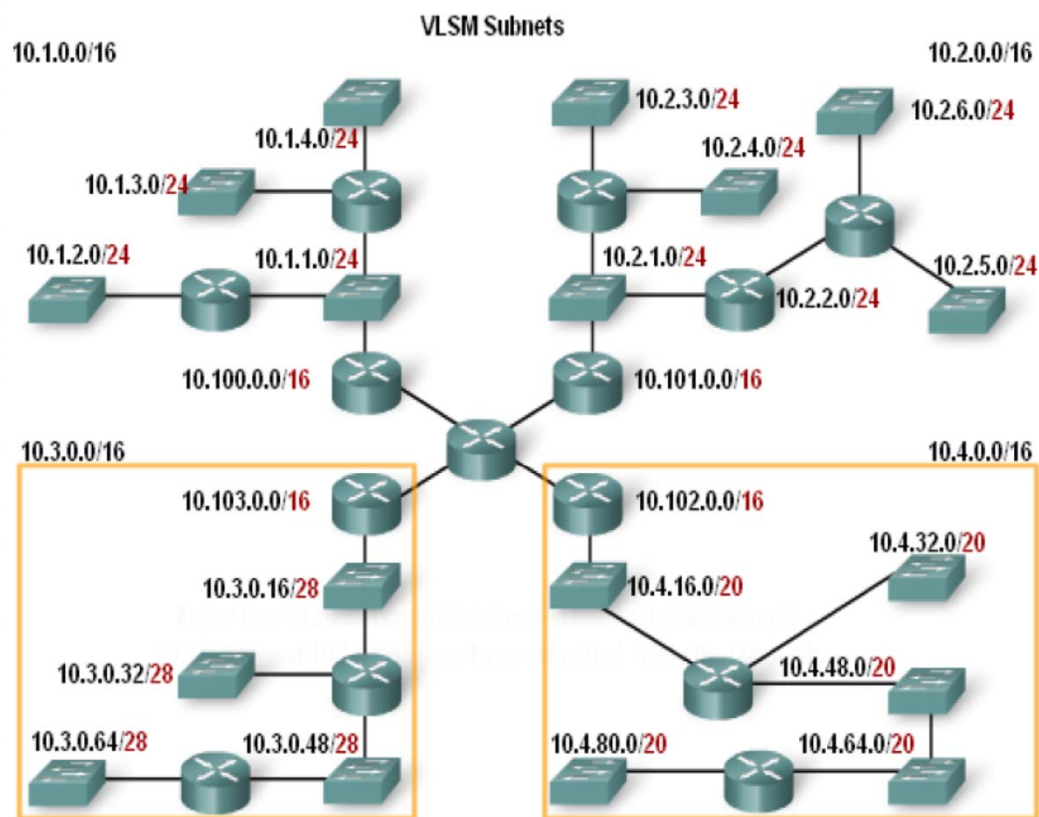
Class C (/24) Network (254 Hosts)

- Ako sve podmreže imaju identične dužine mrežne maske-dosta IP adresa se neće iskoristiti
- VLSM:
  - jedna mreža se može podijeliti na podmreže različitih dužina
  - kreirati podmreže za postojeće podmreže



# VLSM prednosti

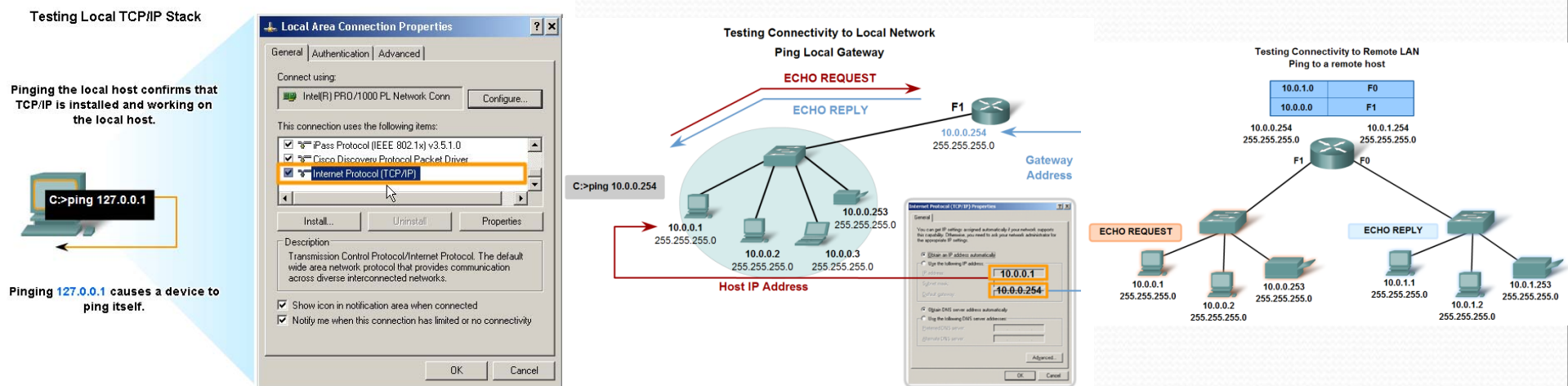
- efikasnije korišćenje adresnog prostora
- fleksibilnija preraspodjela adresa
- skalabilan rast mreže i dodavanje novih adresa



In this example, 10.3.0.0/16 has been subnetted using the /28 mask and 10.4.0.0/16 has been subnetted using the /20 mask.

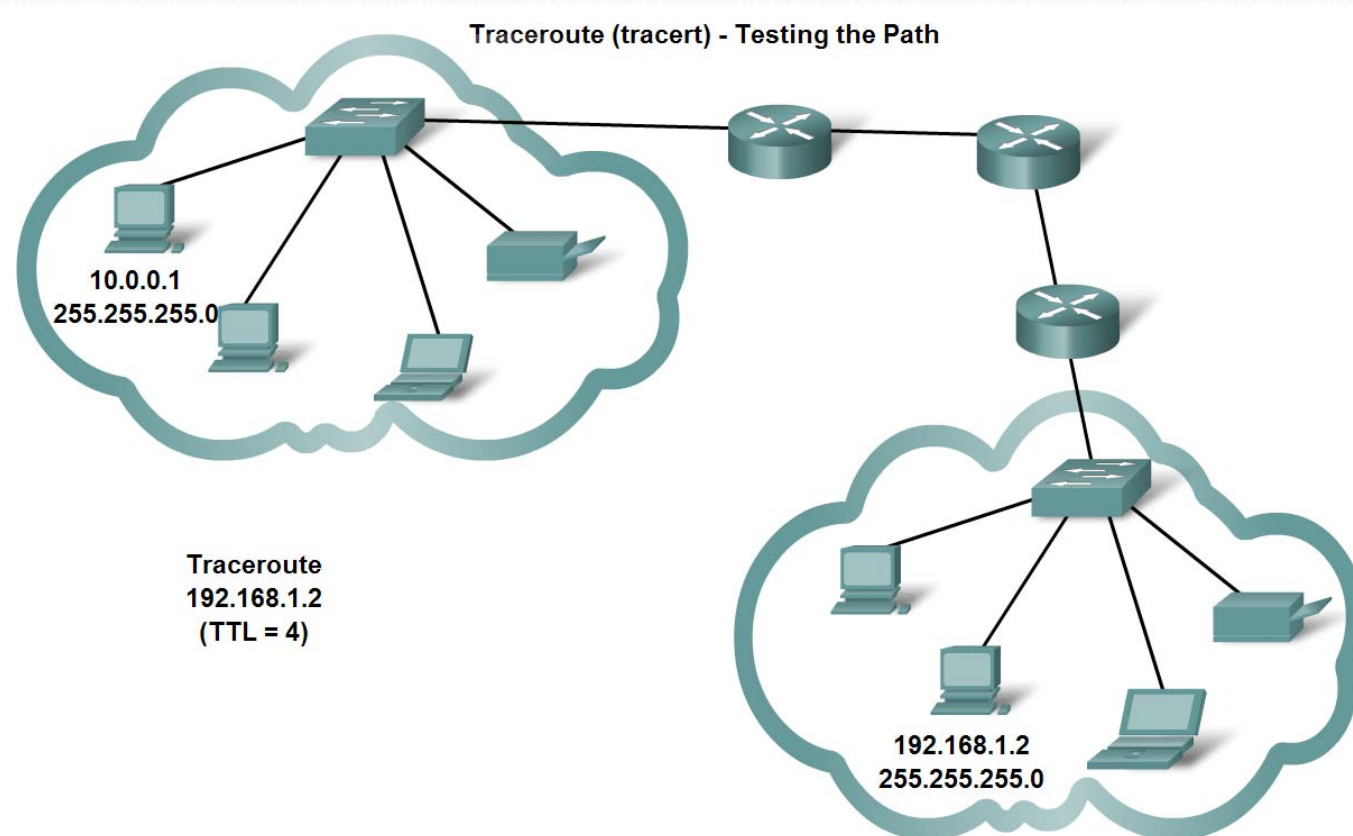
# Testiranje mrežnog sloja - ping

- ICMP protokol, ICMP *Echo Request & Reply*, mjerenje intervala
- ping 127.0.0.1 – testiranje TCP/IP protokol steka na hostu
- ping *default gateway-a* – testiranje konekcije na LAN-u
- ping *remote* hosta – testiranje konekcije prema *remote* LAN-u



# Testiranje mrežnog sloja - traceroute (tracert)

- testiranje putanje
- gdje je greška, \* - ispis greške





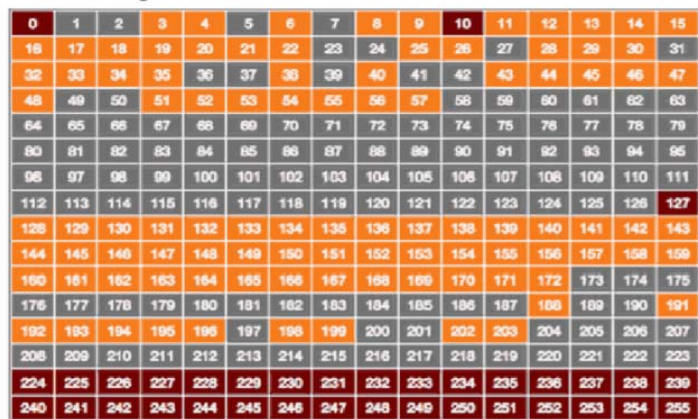
# ICMPv4

- *Internet Control Message Protocol*
- Ne čini IP protokol pouzdanim, več samo obavještava o greškama
- *control & error* poruke, koriste ga ping i traceroute
- Vrste ICMPv4 poruka:
  - *Host confirmation* (npr. *Echo Reply*)
  - *Unreachable Destination or Service*  
kodovi: 0 – *net unreachable*, 1 – *host unreachable* (0,1 ruter)  
2 – *protocol unreachable*, 3 – *port unreachable* (2,3 host)
  - *Time Exceeded* (TTL = 0)
  - *Route Redirection* (poruka hostovima da postoji bolja putanja za traženo odredište)
  - *Source quench* (poruka hostovima da uspore slanje)

# IPv6 – razlozi za korištenje

Assigned IP Address Blocks

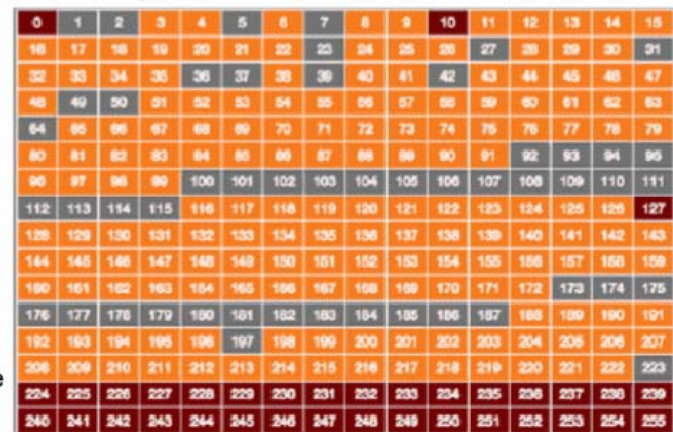
Blocks Assigned - 1993



1993

Allocated  
Unavailable  
Available

Blocks Assigned - 2007



2007

Allocated  
Unavailable  
Available

- Projected RIR Address Pool Exhaustion Dates:
  - APNIC (Asia Pacific): **19-Apr-2011**
  - RIPENCC (Euroasia): **14-Sep-2012**
  - LACNIC (Latin America): **10-Jun-2014**
  - ARIN (North America): **24-Sep-2015**
  - AFRINIC (Africa): **28-Nov-2018**

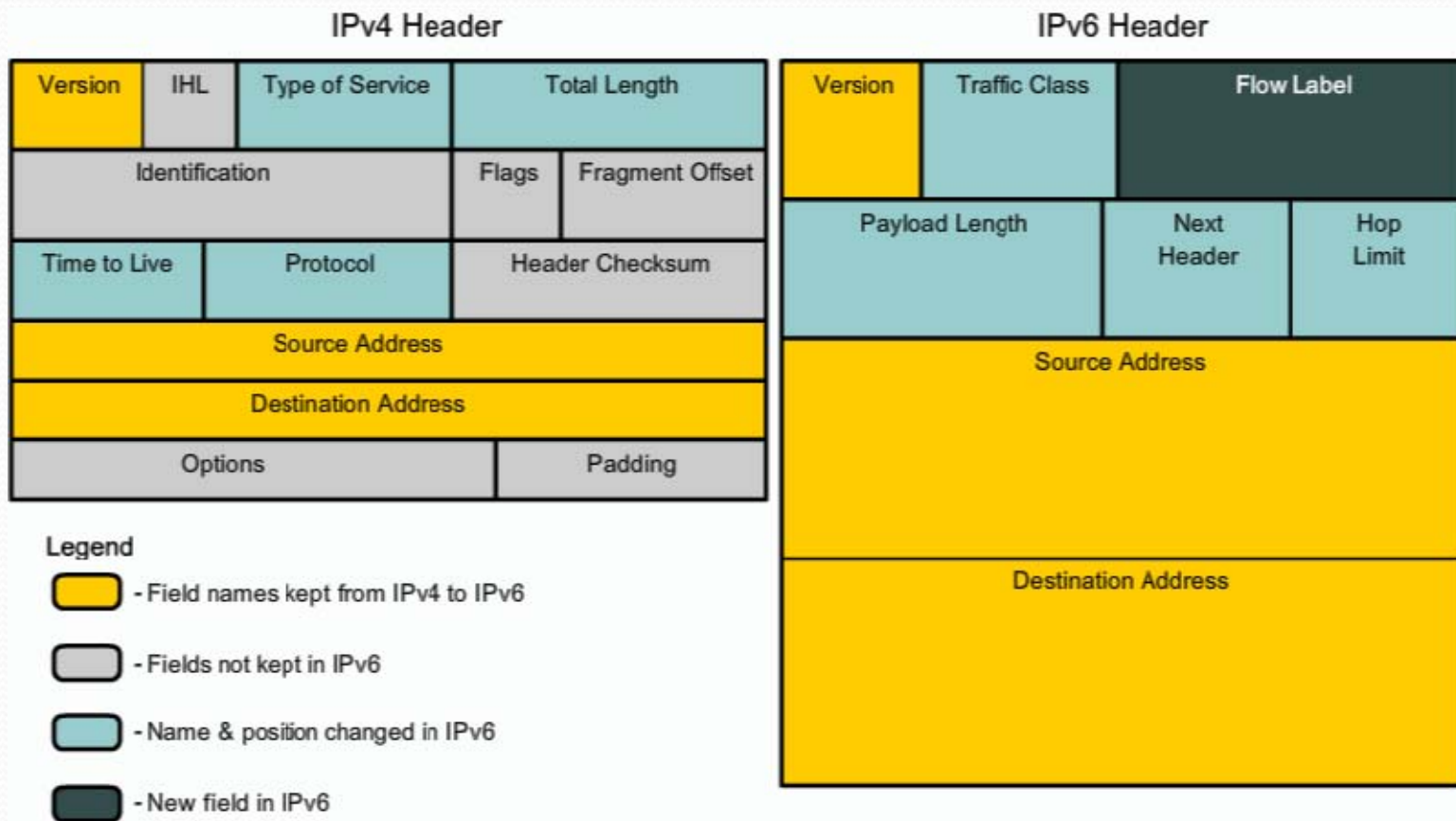


# IPv6 – poboljšanja

- Osim znatno većeg adresnog prostora, iskoristila se prilika da se poprave i neke druge loše stvari protokola IPv4!
- Novi samo novi protokol, već skup protokola (npr. ICMPv6)
- Bitna poboljšanja:
  - Adresiranje – autokonfiguracija
  - Mobilnost i sigurnost – IPsec obavezan
  - Jednostavnije zaglavlje – rutiranje efikasnije, ne postoje broadcast domeni, fragmentacija onemogućena!
  - Bogatstvo tranzicije sa IPv4 na IPv6 :
    - ❑ dual stack – istom interfejsu dodijeljena i IPv4 i IPv6 adresa
    - ❑ Tuneli – IPv6 paket se enkapsulira u IPv4 paket (IPv4 mreža zapravo most između IPv6 ostrva)



# IPv4 header vs. IPv6 header



# Reprezentacija adrese

- 128 bita
- x:x:x:x:x:x:x, x – 16-bitno heksadecimalno polje
- Vodeće nule su opcionalne
- Uzastopne nule mogu da se predstavljaju kao ::, ali samo jednom u adresi!

- Primjeri:

➤ 2031:0000:130F:0000:0000:09C0:876A:130B

Ekvivalentno – 2031:0:130F::9C0:876A:130B,

Ali ne može 2031::130F::09C0:876A:130B

➤ FF01:0:0:0:0:0:0:1 → FF01::1

➤ 0:0:0:0:0:0:0:1 → ::1

➤ 0:0:0:0:0:0:0:0 → ::