

Computer Networks
Lab 10

The Network Layer: Data Plane
Internet Protocol (IP)

Ahmed Nouralla, Mikhail Kuskov, Gerald B. Imbugwa

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Lab Agenda

- Internet Protocol (IPv4 and IPv6)
- IP packet header, address format, and special ranges
- Classless Inter-Domain Routing (CIDR)
- Subnetting and CIDR notation

Recap: Internet Protocol

- IP is the network layer protocol used by the Internet for transferring data packets between hosts across network boundaries
- Hosts and network-aware devices (e.g., routers) may have one or more physical network interfaces (e.g., an Ethernet NIC and a Wi-Fi adapter)
- A virtual network interface is an OS abstraction that allows a host to interact with its physical interfaces. One or more IP addresses can be attached to a virtual interface
- IPv4 is the dominant version of IP. IPv6 is being slowly adopted since 2006
- Public IP addresses are globally reachable, while private addresses are used for local communication within a LAN. Servers typically have public IPs and clients don't

Recap: IP Address Format

IPv4

Address Size:

32-bit number

Address Format:

Dotted Decimal Notation:

192.168.1.1

Prefix Notation:

255.255.255.0

/24

Number of addresses:

$2^{32} = 4,294,967,296$

IPv6

Address Size:

128-bit number

Address Format:

Hexadecimal Notation:

fe80::94db:946e:8d4e:129e

Prefix Notation:

/64

Number of addresses:

$2^{128} =$

340,282,366,920,938,463,463,374,607,
431,768,211,456

Recap: IP Packet Header

IPv4 Header

Version	IHL	Type of Service	Total Length	
Identification			Flags	Fragment Offset
TTL	Protocol		Header Checksum	
Source Address				
Destination Address				
Options			Padding	

Legend

- Fields **kept** in IPv6
- Fields **kept** in IPv6, but name and position changed
- Fields **not kept** in IPv6
- Fields that are **new** in IPv6

IPv6 Header

Version	Traffic Class	Flow Label		
Payload Length			Next Header	Hop Limit
Source Address				
Destination Address				

Recap: Classless Inter-Domain Routing (CIDR)

- **Classful addressing** divided IP address ranges into classes from A to E
 - Classes A-C (unicast) provided large address spaces of 2^{24} , 2^{16} , and 2^8 , respectively
 - Such organization made it difficult to construct small networks
- **Classless addressing** gives more flexibility through variable-length subnet masks
 - **Subnet mask** is a binary string of multiple consecutive ones followed by zeros
 - It divides an IP address into network prefix and host identifier as follows:
 - IP address & subnet mask = network prefix (bitwise “AND”)
 - IP address & (NOT subnet mask) = host identifier (bitwise “NOT”)
- CIDR implements routing based on the longest match of network prefix

Lab Tasks: Introduction

The following commands can show network interfaces' configuration on your machine:

- **ipconfig** on Windows
- **ifconfig** or **ip address show** (or **ip addr** for short) on Linux/macOS

```
uniuser@InnoVM001: ~  
uniuser@InnoVM001:~$ ifconfig  
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 10.90.137.244 netmask 255.255.252.0 broadcast 10.90.139.255  
    inet6 fe80::21d:d8ff:feb7:3971 prefixlen 64 scopeid 0x20<link>  
    ether 00:1d:d8:b7:39:71 txqueuelen 1000 (Ethernet)  
    RX packets 80229149 bytes 7232704977 (7.2 GB)  
    RX errors 0 dropped 126 overruns 0 frame 0  
    TX packets 885570 bytes 878889041 (878.8 MB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0  
  
uniuser@InnoVM001:~$
```

Lab Task 1: Calculating Network Properties

The following IP address was assigned to our computer (or VM):

10.90.137.244/22

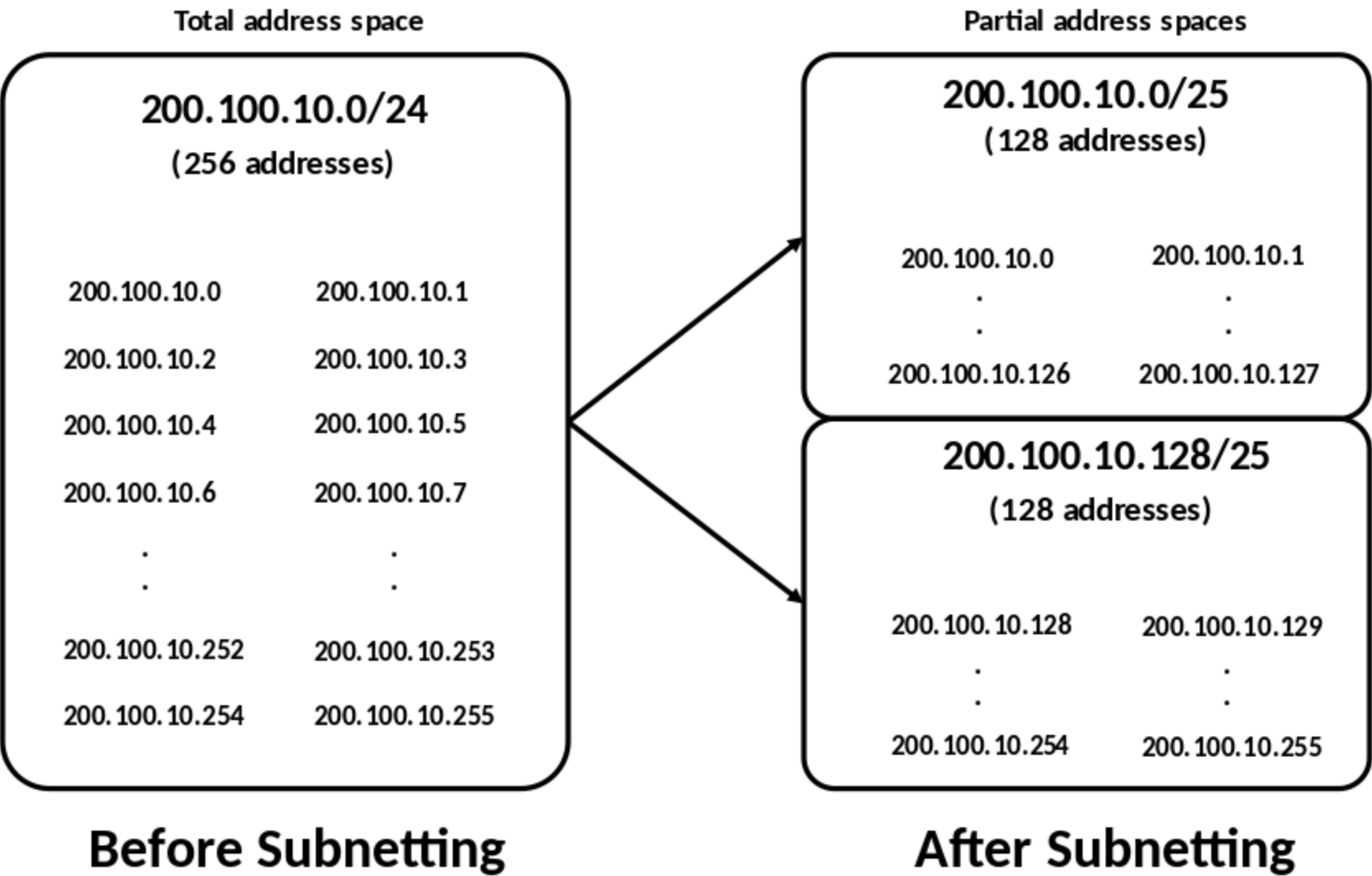
Calculate the following details identifying the network:

- Network address
- Broadcast address
- Min Host address
- Max Host address
- Number of hosts

Recap: Subnetting

- **Subnetting** logically divides a network into smaller networks for easier management, better performance and security, and to conserve addresses
- Example IP address and subnet mask in CIDR notation: **10.0.0.0/24**
 - Network address is **10.0.0.0** and broadcast address is **10.0.0.255**
 - Number of usable hosts is **254** (ranging from 10.0.0.1 to 10.0.0.254)
 - Such network can be divided into two subnets
 - **10.0.0.0/25** (from 0 to 127) and **10.0.0.128/25** (from 128 to 255)
- Private IPv4 ranges: 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16
- Special IPv4 ranges: 0.0.0.0/8, 127.0.0.0/8 (loopback), 169.254.0.0/16 (link-local)

Recap: Subnetting Example



Lab Task 2: Subnetting

Imagine ISP provides you a network IP address (according to your variant)

Organize 3 subnetworks in the given network as follows:

- The first subnet must use half of all given addresses
- The second and third subnets must equally use the other half of the addresses

For example, for 10.0.0.0/24 network:

- The first subnet will use 128 addresses
- The second and third 64 addresses each accordingly

So, all the $2^8 = 128 + 64 + 64 = 256$ addresses will be in use

Lab Task 2: Subnetting Variants

Fill in the “Network, Broadcast, minHost, maxHost addresses and numHosts” for each of the 3 subnetworks according to your variant:

- | | | | |
|---------------------|---------------------|--------------------|--------------------|
| 1) 192.168.0.45/15 | 9) 10.244.0.245/10 | 17) 68.88.96.46/19 | 25) 13.15.17.18/19 |
| 2) 192.168.23.46/14 | 10) 10.11.0.245/11 | 18) 68.87.98.15/20 | 26) 61.64.78.13/18 |
| 3) 192.168.28.99/13 | 11) 200.20.20.20/12 | 19) 25.64.78.64/21 | 27) 12.36.14.17/17 |
| 4) 82.15.0.0/12 | 12) 201.21.30.20/13 | 20) 65.89.48.13/22 | 28) 48.64.87.15/15 |
| 5) 83.15.0.22/11 | 13) 211.12.10.20/14 | 21) 43.34.12.51/23 | 29) 64.33.44.11/14 |
| 6) 84.87.98.33/10 | 14) 30.15.14.7/15 | 22) 77.88.99.44/22 | 30) 14.78.97.64/13 |
| 7) 74.23.12.15/9 | 15) 94.25.68.64/17 | 23) 15.45.78.98/21 | |
| 8) 75.24.12.15/9 | 16) 69.87.56.26/18 | 24) 65.59.78.74/20 | |

Extra Task: Coding a Subnet Calculator (not graded)

To better understand IP addressing and subnetting, write a subnet calculator in your favorite programming/scripting language. Example output for input “37.10.128.5/17”

IP Address:	37.10.128.5
Network Address:	37.10.128.0
Usable Host IP Range:	37.10.128.1 - 37.10.255.254
Broadcast Address:	37.10.255.255
Total Number of Hosts:	32,768
Number of Usable Hosts:	32,766
Subnet Mask:	255.255.128.0
Wildcard Mask:	0.0.127.255
Binary Subnet Mask:	11111111.11111111.10000000.00000000
IP Class:	B
CIDR Notation:	/17
IP Type:	Public