Network Layer

Data Communication and Computer Network Concept

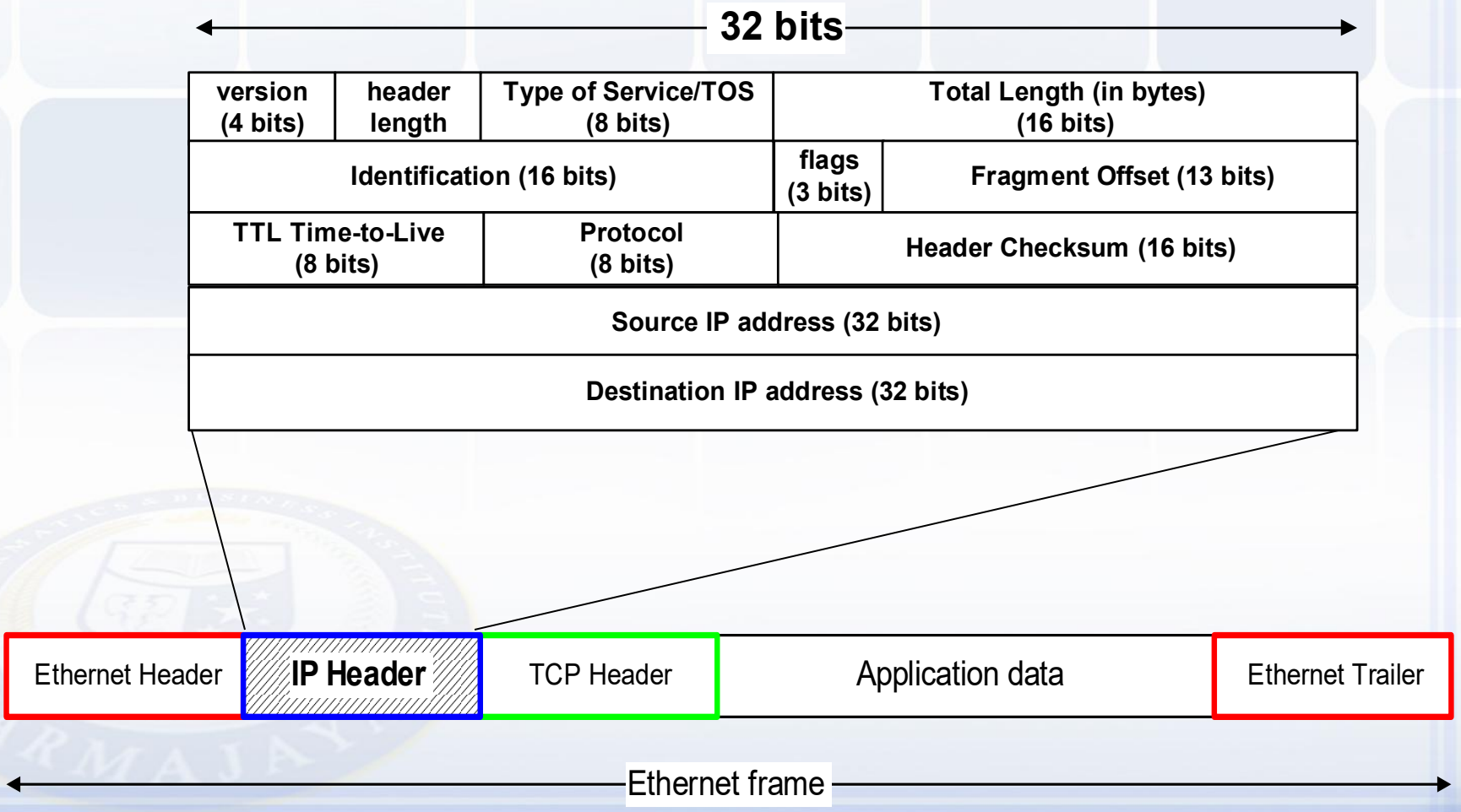
VER 2025

4.1 IP ADDRESS

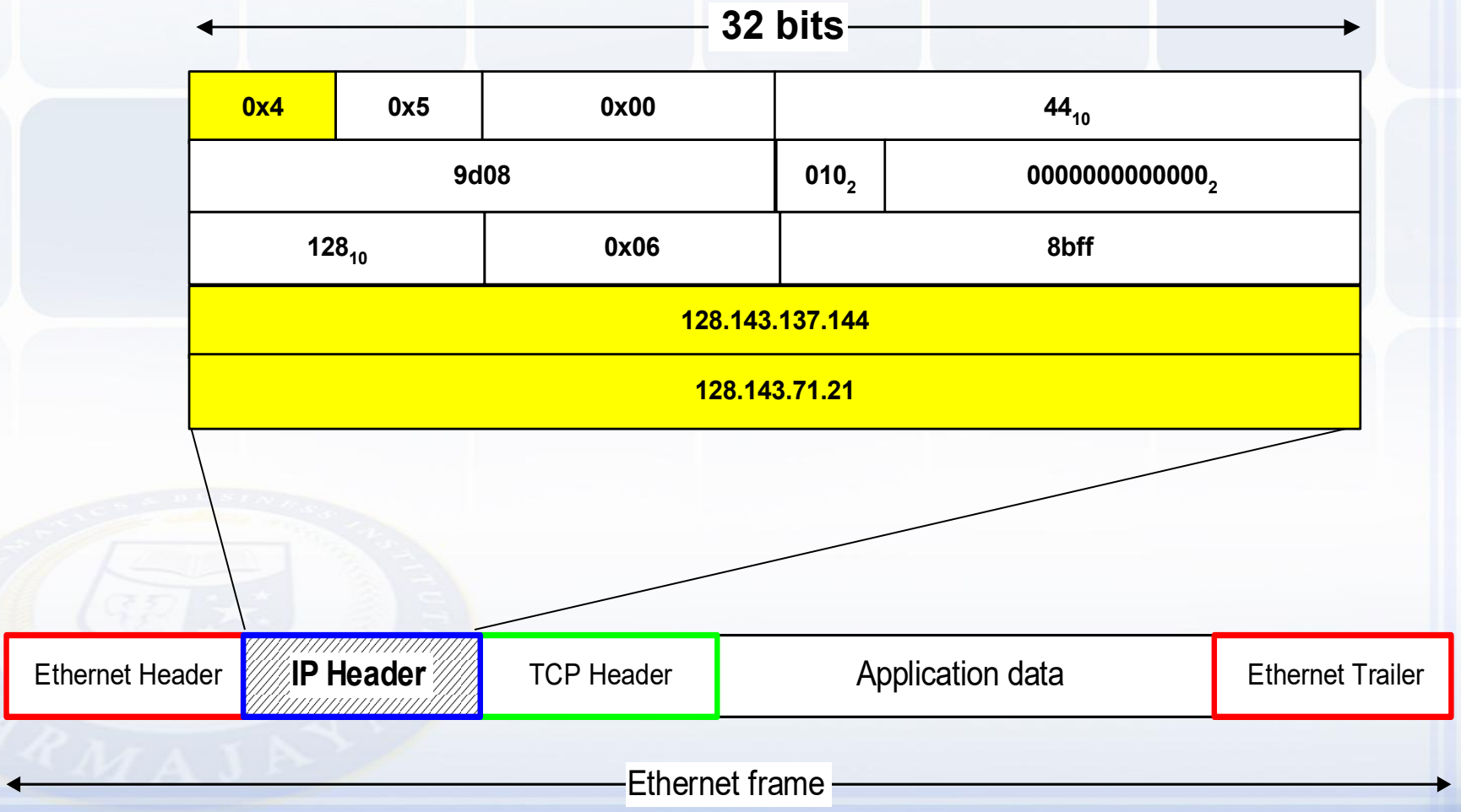
What is an IP Address?

- An IP address is a unique global address for a network interface
- Exceptions:
  - Dynamically assigned IP addresses
  - IP addresses in private networks
- An IP address:
  - is a **32 bit long** identifier (for IPv4)
    - 128 bit for IPv6
  - encodes a network number (**network prefix**) and a **host number**
- The network prefix identifies a network and the host number identifies a specific host.

IP Addresses

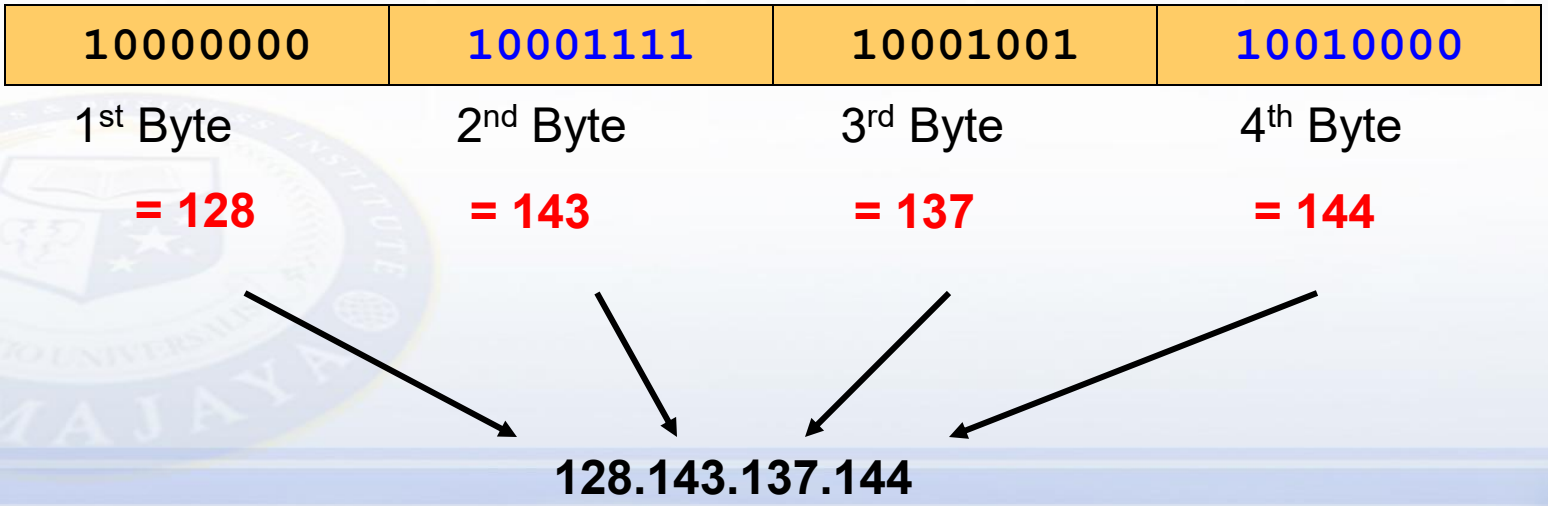


IP Addresses



Dotted Decimal Notation

- IP addresses are written in a so-called ***dotted decimal* notation**
- Each byte is identified by a decimal number in the range [0..255]:
- **Example:**



Example

- **Example**: ellington.cs.virginia.edu

- Network address is: **128.143.0.0 (or 128.143)**
- Host number is: **137.144**
- Netmask is: **255.255.0.0** (or **ffff0000**)

Special IP Addresses

- **Reserved or (by convention) special addresses:**

  Loopback interfaces

  - Most systems use 127.0.0.1 as loopback address
  - loopback interface is associated with name "localhost"

  Broadcast address

  - Host number is all ones, e.g., 128.143.**255.255**
  - Broadcast goes to all hosts on the network
  - Often ignored due to security concerns

Special IP Addresses

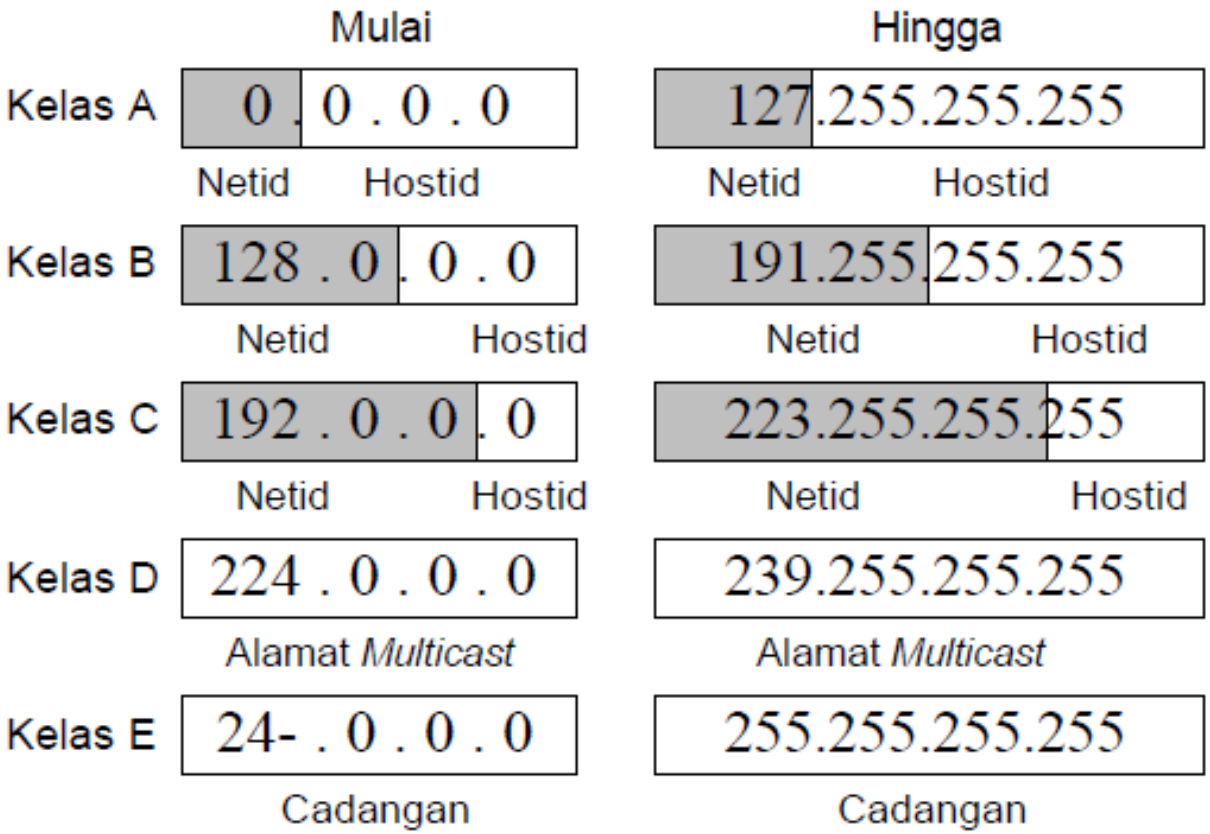
- **Test / Experimental addresses**
  Certain address ranges are reserved for “experimental use”. Packets should get dropped if they contain this destination address (see RFC 1918 for detail information):

  e.g 10.0.0.0

  172.16.0.0

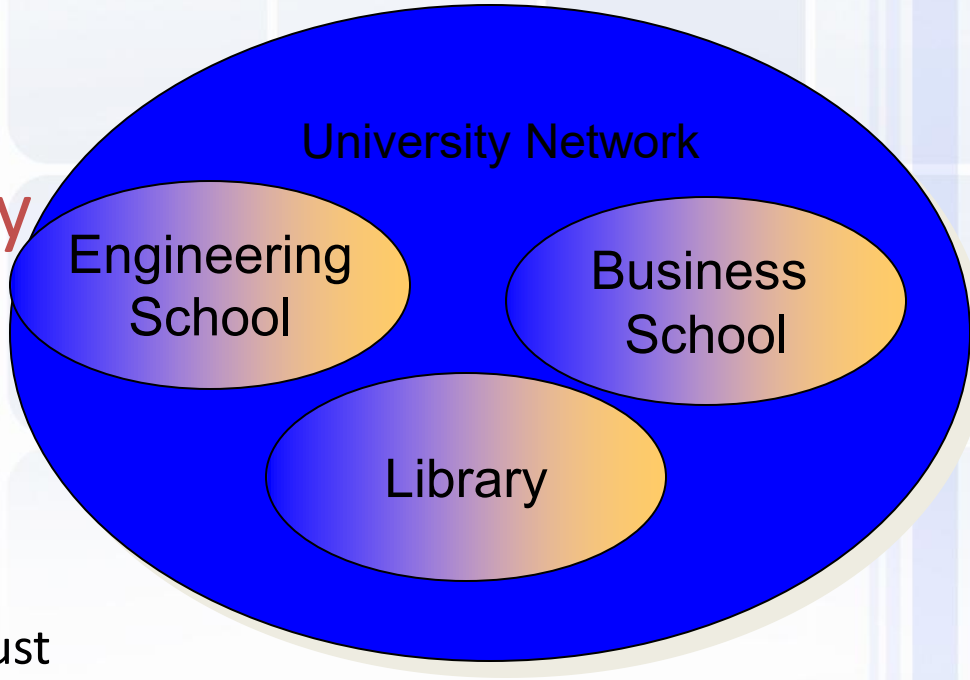
- **Convention (but not a reserved address)**
  Default gateway has host number set to ‘1’, e.g.,
  192.0.1.**1**

IP address


Mulai
Hingga
Kelas A
0 . 0 . 0 . 0
127.255.255.255
Netid
Hostid
Netid
Hostid
Kelas B
128 . 0 . 0 . 0
191.255.255.255
Netid
Hostid
Netid
Hostid
Kelas C
192 . 0 . 0 . 0
223.255.255.255
Netid
Hostid
Netid
Hostid
Kelas D
224 . 0 . 0 . 0
239.255.255.255
Alamat Multicast
Alamat Multicast
Kelas E
24- . 0 . 0 . 0
255.255.255.255
Cadangan
Cadangan

Subnetting

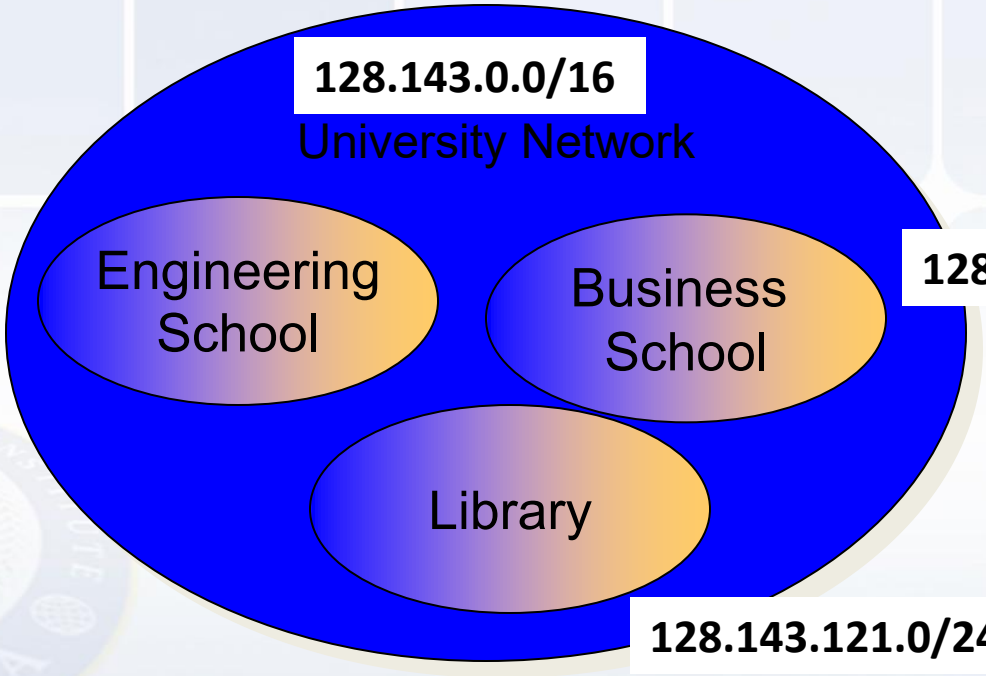
- **Problem**: Organizations have multiple networks which are independently managed
  - **Solution 1:** Allocate a separate network address for each network
    - Difficult to manage
    - From the outside of the organization, each network must be addressable.
  - **Solution 2:** Add another level of hierarchy to the IP addressing structure



→ **Subnetting**

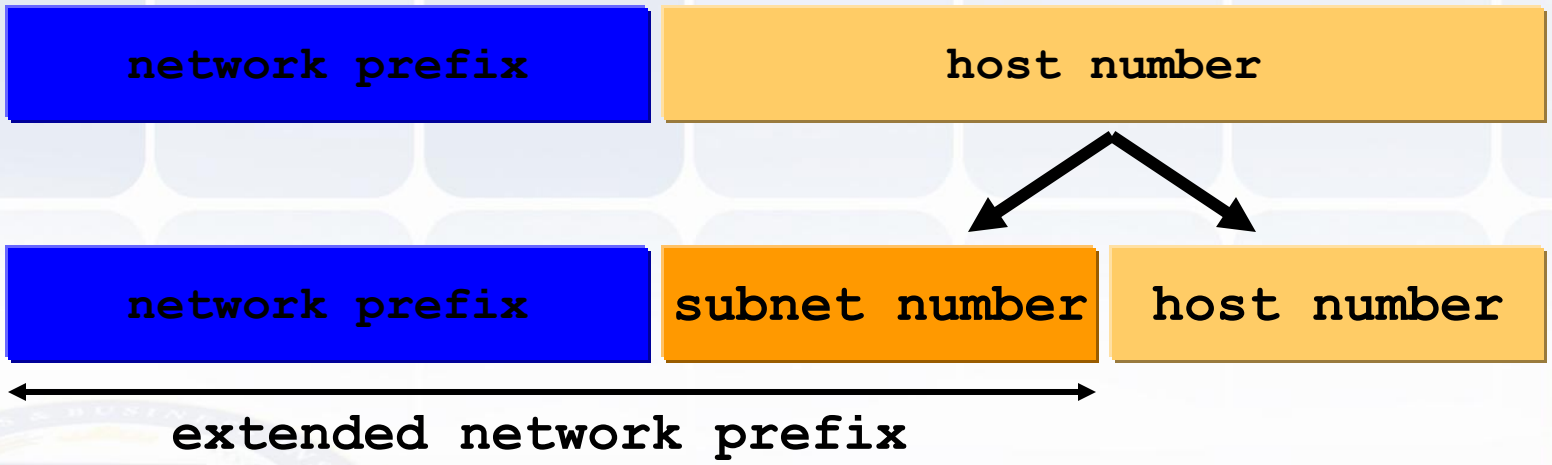
Address assignment with subnetting

- Each part of the organization is allocated a range of IP addresses (subnets or subnetworks)
- Addresses in each subnet can be administered locally



Basic Idea of Subnetting

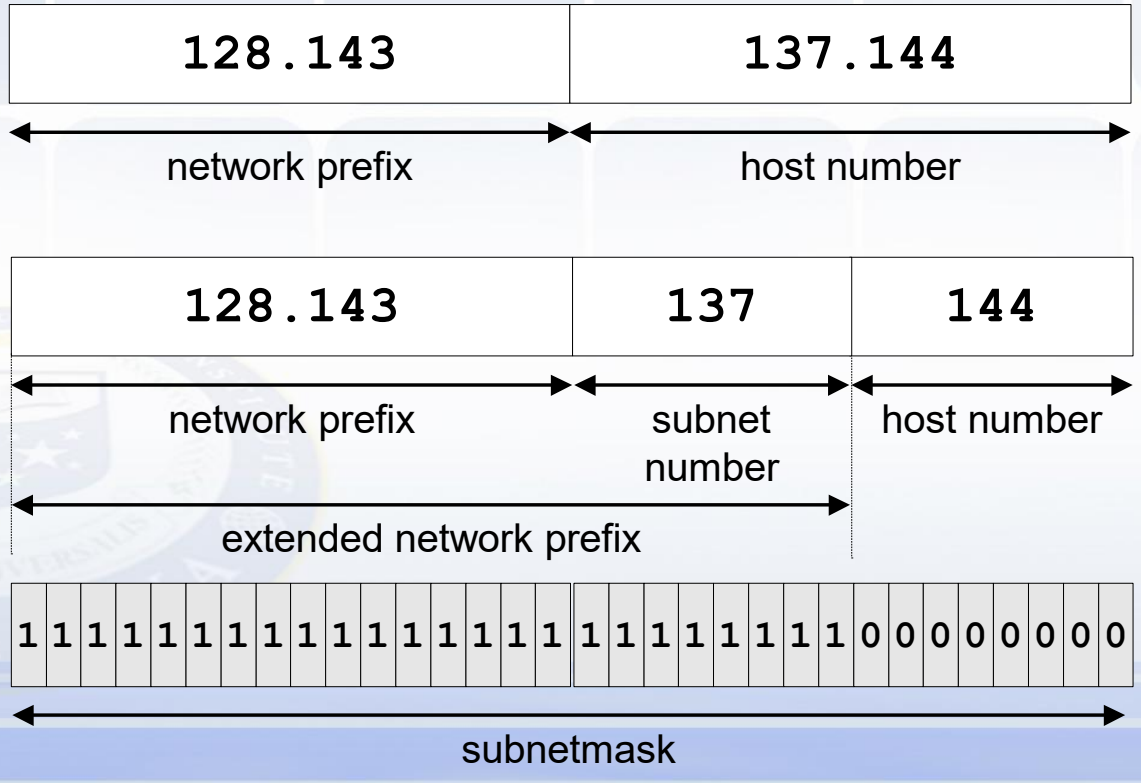
- Split the host number portion of an IP address into a **subnet number** and a (smaller) **host number**.
- Result is a 3-layer hierarchy



- Then:
  - Subnets can be freely assigned within the organization
  - Internally, subnets are treated as separate networks
  - Subnet structure is not visible outside the organization

Subnetmask

- Routers and hosts use an **extended network prefix (subnetmask)** to identify the start of the host numbers.



Advantages of Subnetting

- With subnetting, IP addresses use a 3-layer hierarchy:
  - » Network
  - » Subnet
  - » Host
- Reduces router complexity. Since external routers do not know about subnetting, the complexity of routing tables at external routers is reduced.
- Note: Length of the subnet mask need not be identical at all subnetworks.

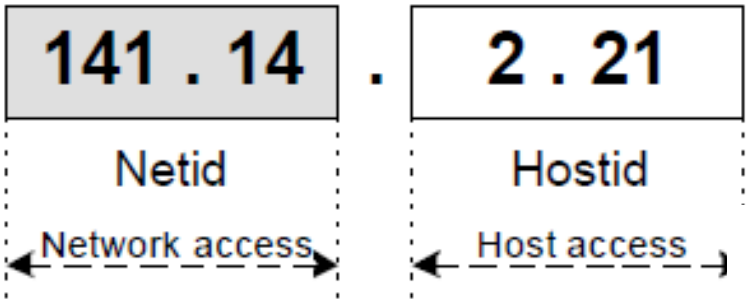
Example: Subnetmask

- 128.143.0.0/16 is the IP address of the network
- 128.143.137.0/24 is the IP address of the subnet

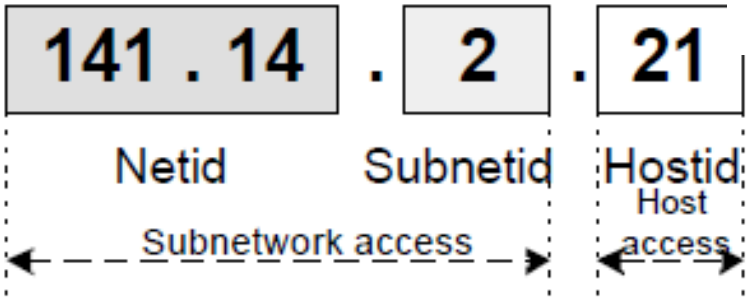
- 128.143.137.144 is the IP address of the host
- 255.255.255.0 (or ffffff00) is the subnetmask of the host

- When subnetting is used, one generally speaks of a “subnetmask” (instead of a netmask) and a “subnet” (instead of a network)
- Use of subnetting or length of the subnetmask if decided by the network administrator
- Consistency of subnetmasks is responsibility of administrator

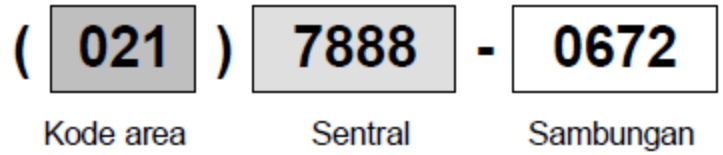
Non subnetting vs Subnetting



a. Tanpa subnetting

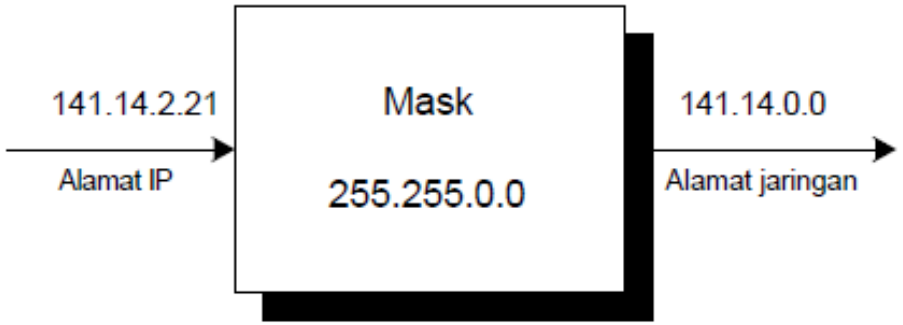


b. Dengan subnetting

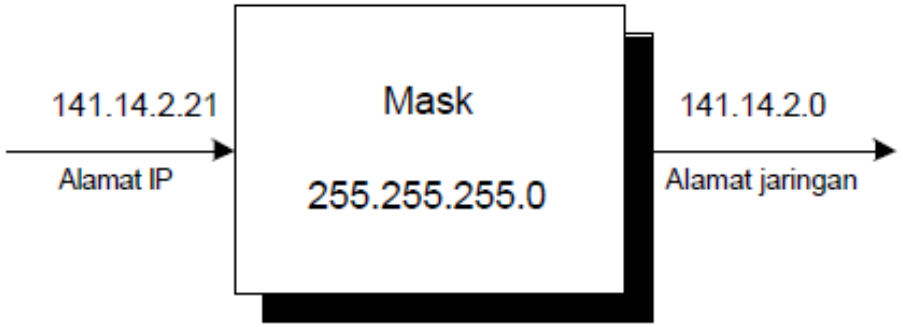


Gambar 5.4 Konsep hierarki dalam nomor telepon

Non subnetting vs Subnetting



a. Tanpa subnetting



b. Dengan subnetting

Gambar 5.5 Masking

Classless Inter Domain Routing

- IP address is commonly written in form
  - 192.168.1.2. and
  - 192.168.1.2/24
    - Means IP address 192.168.1.2 with subnet mask 255.255.255.0.
    - /24 is taken by calculation that 24 bit subnet mask is covered by binary 1.
    - Thus, the subnet mask is
      - 11111111.11111111.11111111.00000000 (255.255.255.0).
      - This concept is called CIDR (Classless Inter-Domain Routing).

Classless Inter Domain Routing

- We have IP Address : **192.168.1.0/26**
- We need data about :
  1. A number of subnets?
  2. Host per subnet ?
  3. Total block subnet ?
  4. Broadcast address ?

Solution (1)

- 192.168.1.0
  - Means Class C
  - Subnet Mask /26 means 11111111.11111111.11111111.11000000 (255.255.255.192).
- **Number of Subnets**= 2^x,
  - x is a number of binary 1 at last octet of subnet mask.
    - (For class B is 2 last octet, for class A is 3 last octet)
    - Thus, number of subnets is $2^2 = 4$ subnets

Solution (2)

- **Host per Subnet** = $2^y - 2$,
  - y is number of binary 0 at last octet
  - Thus, host per subnet is : $2^6 - 2 = 62$ host
- **Block Subnet** = 256 – 192 (nilai oktet terakhir subnet mask) = 64.
  - Next Subnet is 64 + 64 = 128 and 128+64=192.
  - The complete Subnet is : **0, 64, 128, 192**.

Solution (3)

- **host and broadcast addresses.**
  - **Note**
    - 1st Host is first number after subnet
    - Broadcast is last number berfore the next subnet.

Subnet	192.168.1.**0**	192.168.1.**64**	192.168.1.**128**	192.168.1.**192**
1st Host	192.168.1.**1**	192.168.1.**65**	192.168.1.**129**	192.168.1.**193**
Last Host	192.168.1.**62**	192.168.1.**126**	192.168.1.**190**	192.168.1.**254**
Broadcast	192.168.1.**63**	192.168.1.**127**	192.168.1.**191**	192.168.1.**255**

Example (2)

- Class B.
- network address **172.16.0.0/18**.
  - 172.16.0.0
    - Means Class B,
    - Subnet Mask /18 means 11111111.11111111.11000000.00000000 (255.255.192.0).

Solution (1)

- **Number of Subnets** = 2^x,
  - x is a number of binary 1 at 2 last octet.
    - Thus, subnet is $2^2 = 4$ subnet
- **Host per Subnet** = $2^y - 2$,
  - Y is a number of binary 0 at last 2 octet.
    - Thus, host per subnet is $2^{14} - 2 = 16.382$ host

Solution (2)

- **Block Subnet** = 256 – 192 = 64.
  - The next subnet is 64 + 64 = 128, and 128+64=192.
  - The complete subnet is **0, 64, 128, 192**.
- **Host and broadcast addresses?**

Solution (3)

Subnet	172.16.**0.0**	172.16.**64.0**	172.16.**128.0**	172.16.**192.0**
1st Host	172.16.**0.1**	172.16.**64.1**	172.16.**128.1**	172.16.**192.1**
Last Host	172.16.**63.254**	172.16.**127.254**	172.16.**191.254**	172.16.**255.254**
Broadcast	172.16.**63.255**	172.16.**127.255**	172.16.**191.255**	172.16..**255.255**

Variable Length Subnet Masking

- VLSM atau *Variable Length Subnet Mask* adalah sebuah teknik *subnetting* yang memungkinkan kita untuk membagi satu blok alamat IP menjadi beberapa sub-jaringan (subnet) dengan ukuran yang berbeda-beda.
- Ini adalah pengembangan dari metode *subnetting* klasik, yang disebut *Fixed-Length Subnet Mask* (FLSM), di mana semua subnet memiliki ukuran yang sama.

Cara Kerja VLSM

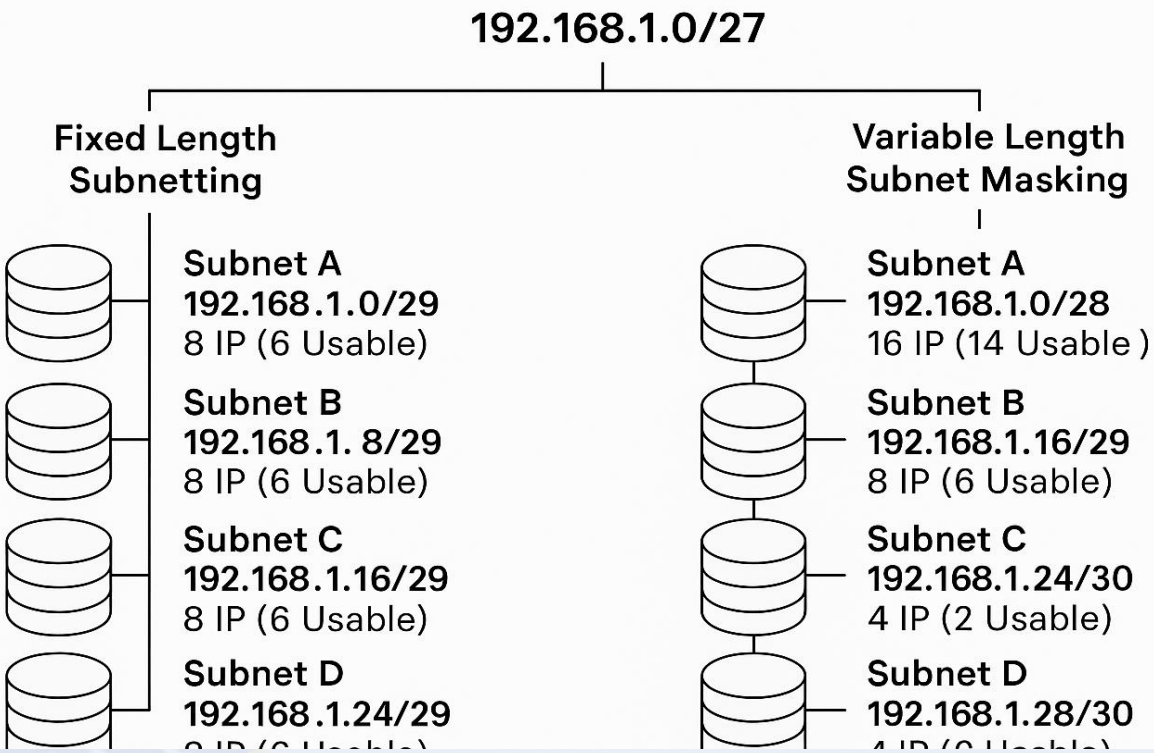
VLSM bekerja dengan membagi sebuah jaringan menjadi beberapa sub-jaringan secara hierarkis. Prosesnya biasanya dimulai dari kebutuhan host yang paling besar hingga yang paling kecil.
Contoh : IP Address 192.168.1.0/24 yang akan dibagi untuk tiga departemen dengan kebutuhan host yang berbeda:

- Departemen A: 50 host
- Departemen B: 20 host
- Departemen C: 10 host

- **Departemen A (50 host):** Kebutuhan 50 host akan membutuhkan subnet mask yang menyediakan setidaknya 50 alamat host yang bisa digunakan. Subnet mask yang paling efisien adalah /26, yang menyediakan 62 host yang dapat digunakan.
- **Departemen B (20 host):** Sisa alamat IP dari Departemen A akan digunakan. Kebutuhan 20 host bisa dipenuhi dengan subnet mask /27, yang menyediakan 30 host yang dapat digunakan.
- **Departemen C (10 host):** Sisa IP yang masih tersedia akan dialokasikan untuk Departemen C. Kebutuhan 10 host bisa menggunakan subnet mask /28, yang menyediakan 14 host yang dapat digunakan.

- **Protokol Routing yang Mendukung VLSM**
- Tidak semua protokol routing dapat bekerja dengan VLSM. Untuk dapat menggunakan VLSM, protokol routing yang digunakan harus mendukung *classless routing* (routing tanpa kelas), seperti:
- RIP versi 2 (RIPv2)
- OSPF (Open Shortest Path First)
- EIGRP (Enhanced Interior Gateway Routing Protocol)
- BGP (Border Gateway Protocol)
- Protokol lama seperti RIP versi 1 (RIPv1) tidak dapat bekerja dengan VLSM karena hanya mendukung *classful routing*.

Fixed Length Subnetting vs Variable Length Subnet Masking



Tabel perbandingan antara **Fixed Length Subnetting** dan **Variable Length Subnet Masking (VLSM)** menggunakan blok IP yang sama, yaitu 192.168.1.0/27:

Aspek	Fixed Length Subnetting	Variable Length Subnet Masking (VLSM)
Blok IP Awal	192.168.1.0/27	192.168.1.0/27
Jumlah IP Total	32 alamat IP (30 usable)	32 alamat IP (30 usable)
Jumlah Subnet	Tergantung pembagian rata (misal: 4 subnet /30)	Bisa beragam tergantung kebutuhan host masing-masing subnet
Pembagian	Tiap subnet berisi jumlah host yang sama	Subnet memiliki ukuran berbeda sesuai kebutuhan host
Contoh Pembagian	Misal 4 subnet: 192.168.1.0/30 (2 host usable) 192.168.1.4/30 192.168.1.8/30 192.168.1.12/30	Misal kebutuhan: Subnet A: 10 host → /28 Subnet B: 6 host → /29 Subnet C: 2 host → /30 Subnet D: 2 host → /30
Efisiensi Alamat	Kurang efisien jika jumlah host berbeda-beda	Sangat efisien karena alokasi sesuai kebutuhan
Sisa IP	Banyak IP terbuang jika host-nya kecil	Minim sisa IP, tergantung perencanaan
Kompleksitas Perhitungan	Mudah, karena semua subnet sama	Lebih kompleks karena harus hitung bit untuk tiap subnet
Contoh Use Case	Jaringan kecil dengan jumlah host seragam	Jaringan dengan variasi jumlah host (router, server, user, dll)

4.2 IP VER 6

IPv6 Address

- IPv6 adresses are 128 bit in lenght.
- IPv6 allows three types of addresses:
  - Unicats : an identifier for a single interface. A packet sent to unicast address is delivered to the interfece identified by the address.
  - Anycast : an identifier for a set of interfaces (typically belonging to different nodes). A packet sent to an anycast address is delivered to one of the interfaces identified by the address.
  - Multicast : an identifier for a set of interfaces (typically belonging to different nodes). A packet sent to anmulticast address is delivered to all of the interfaces identified by the address.

END