# IP Addressing

# IP Addresses

- Structure of an IP address
- Subnetting
- CIDR
- IP Version 6 addresses

# IP Addressing

- Primary job of IP – delivering packets to Unique System
- IP Addressing
  - Network Interface Identification
  - Routing
  - A unique string of numbers separated by full stops that identifies each computer using the Internet Protocol to communicate over a network.

# What is an IP Address?

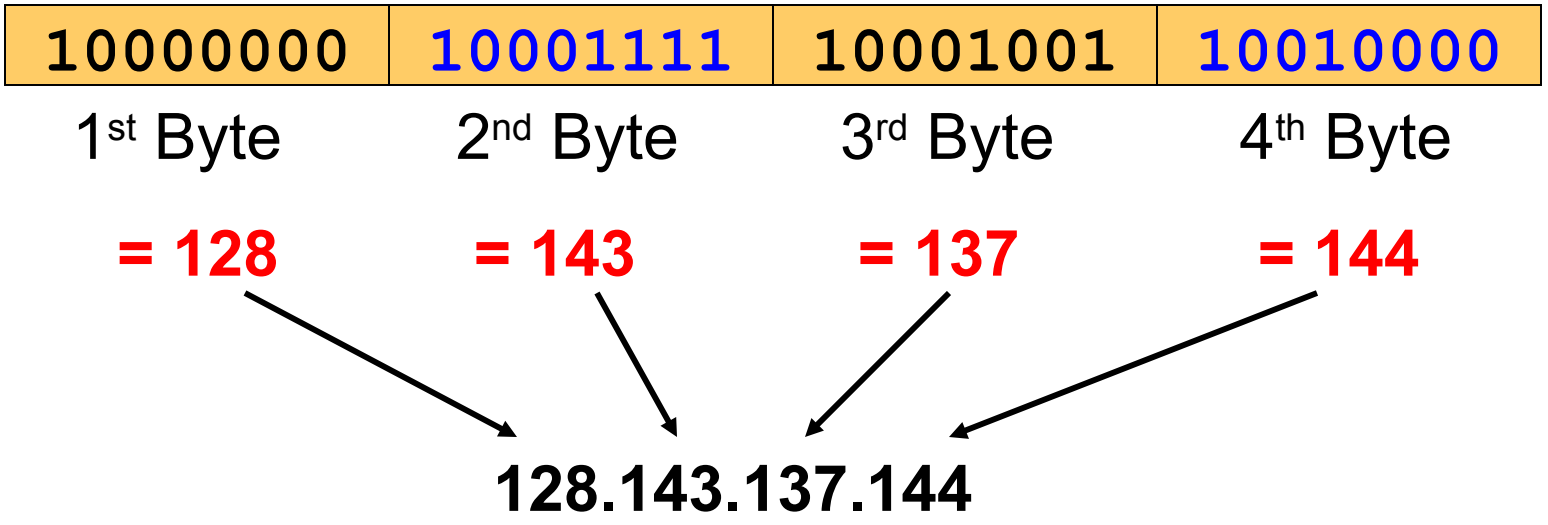
- An IP address is a unique global address for a network interface

- An IP address:
  - is a **32 bit long** identifier
  - encodes a network number (**network prefix**) and a **host number**

# 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:**



# Network prefix and Host number

- The network prefix identifies a network and the host number identifies a specific host (actually, interface on the network).


- **How do we know how long the network prefix is?**
  - The network prefix is implicitly defined (see **class-based addressing**)
  - The network prefix is indicated by a **netmask.**

# Example

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


- Network id is: `128.143.0.0`
- Host number is: `137.144`
- Network mask is: `255.255.0.0` or `ffff0000`

- Prefix notation: `128.143.137.144/16`
  - » Network prefix is 16 bits long

# Dotted decimal notation

- 32 bit binary
- Four 8-bit octets

Ex: 11100011010100101001101110110001

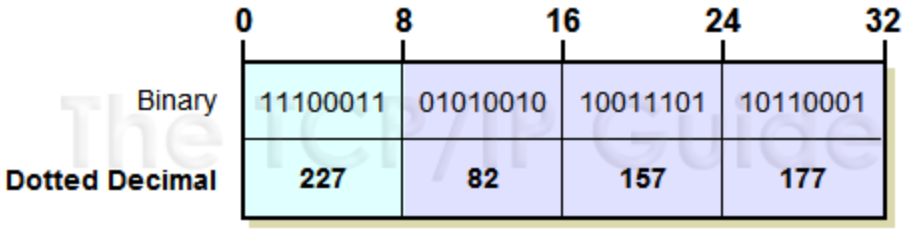
11100011 - 01010010 - 10011101 - 10110001

E3 - 52 - 9D - B1

- *What's a subnet ?*
  - device interfaces with same subnet part of IP address
  - can physically reach each other without intervening router

# Internet IP Address Structure

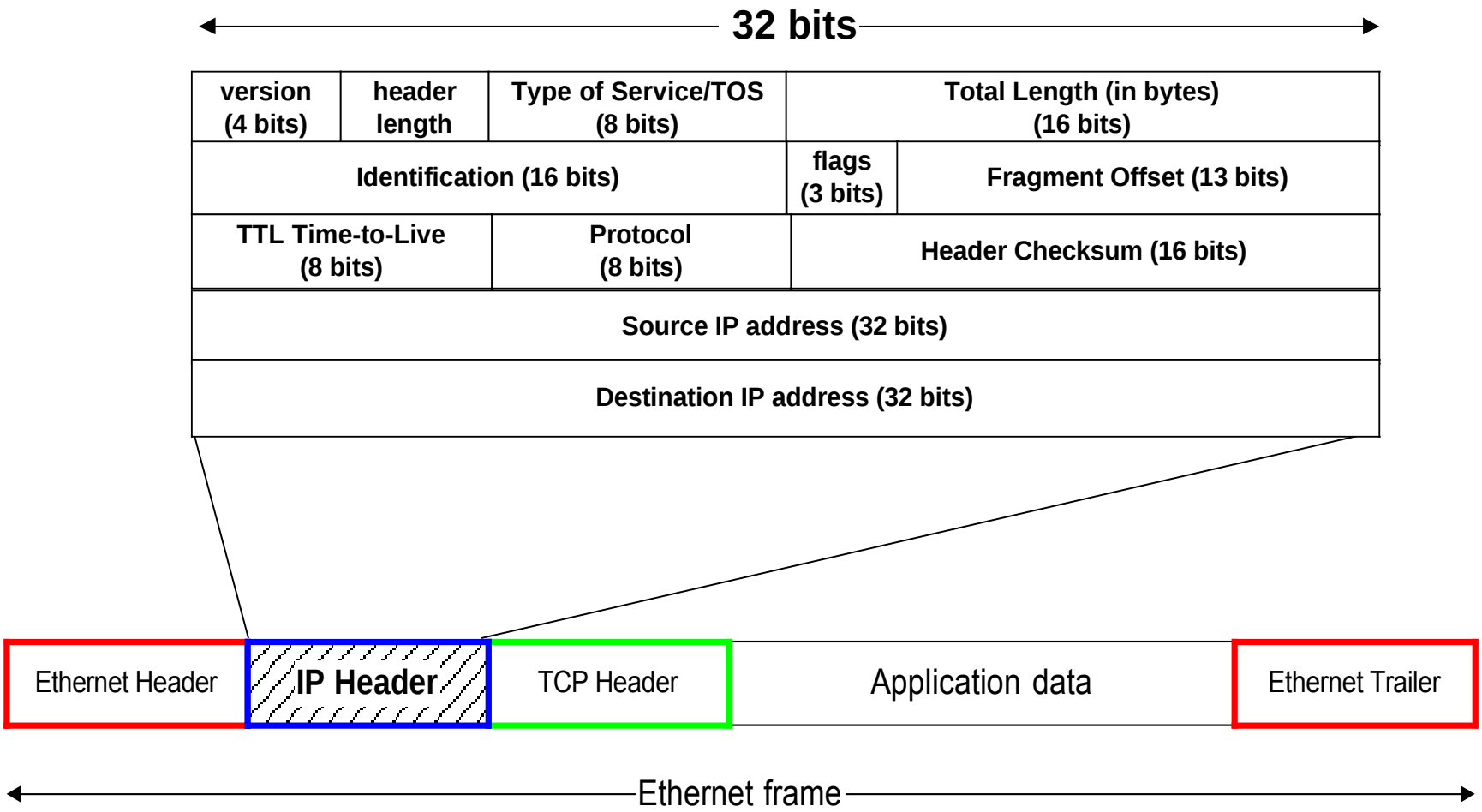
- 32 bits have an internal structure with 2 components
  - Network Identifier (Network ID)
  - Host Identifier (Host ID)
  - Like a telephone number! (401) 555-7777



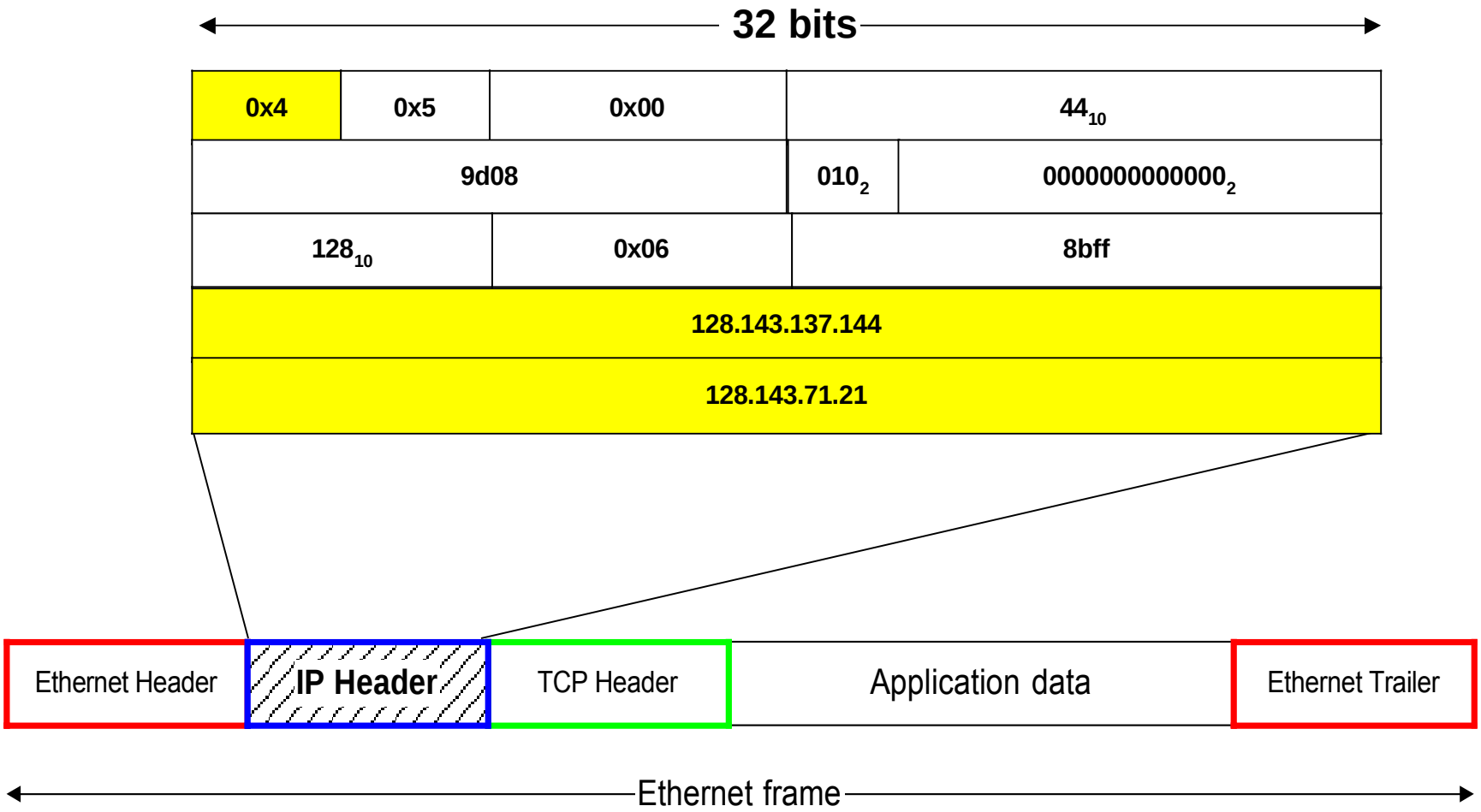

**IP Address: 227.82.157.177**
**Split Into 8-Bit Network ID and 24-Bit Host ID**

- The fundamental division of the bits of an IP address is into a network ID and host ID.
- Here ,The network ID is 8 bits long, shown in cyan, and the host ID is 24 bits in length.

# IP Addresses



# IP Addresses

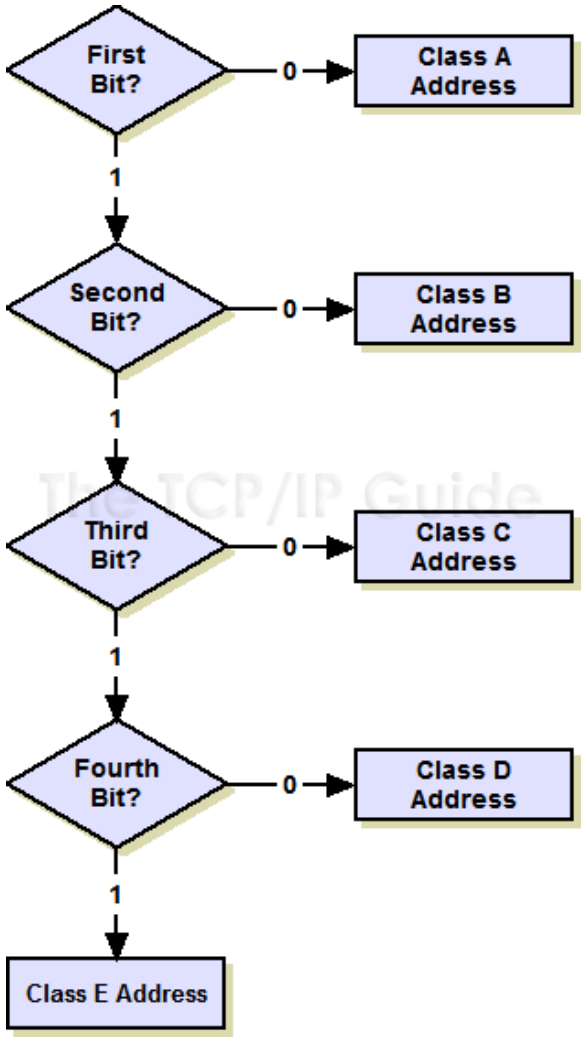


# Classful Addressing

| IP Address Class | Fraction of Total IP Address Space | Number Of Network ID Bits | Number Of Host ID Bits | Intended Use |
|---|---|---|---|---|
| **Class A** | 1/2 | 8 | 24 | Unicast addressing for very large organizations with hundreds of thousands or millions of hosts to connect to the Internet. |
| **Class B** | 1/4 | 16 | 16 | Unicast addressing for medium-to-large organizations with many hundreds to thousands of hosts to connect to the Internet. |
| **Class C** | 1/8 | 24 | 8 | Unicast addressing for smaller organizations with no more than about 250 hosts to connect to the Internet. |
| **Class D** | 1/16 | n/a | n/a | IP multicasting. |
| **Class E** | 1/16 | n/a | n/a | Reserved for “experimental use”. |

# "Classful" Addressing Class Determination Algorithm

- If the first bit is a “0”, it's a class A address and we're done. (Half the address space has a “0” for the first bit, so this is why class A takes up half the address space.) If it's a “1”, continue to step two.
- If the second bit is a “0”, it's a class B address and we're done. (Half of the remaining non-class-A addresses, or one quarter of the total.) If it's a “1”, continue to step three.
- If the third bit is a “0”, it's a class C address and we're done. (Half again of what's left, or one eighth of the total.) If it's a “1”, continue to step four.
- If the fourth bit is a “0”, it's a class D address. (Half the remainder, or one sixteenth of the address space.) If it's a “1”, it's a class E address. (The other half, one sixteenth.)



# Summary of "Classful" Addressing Issues

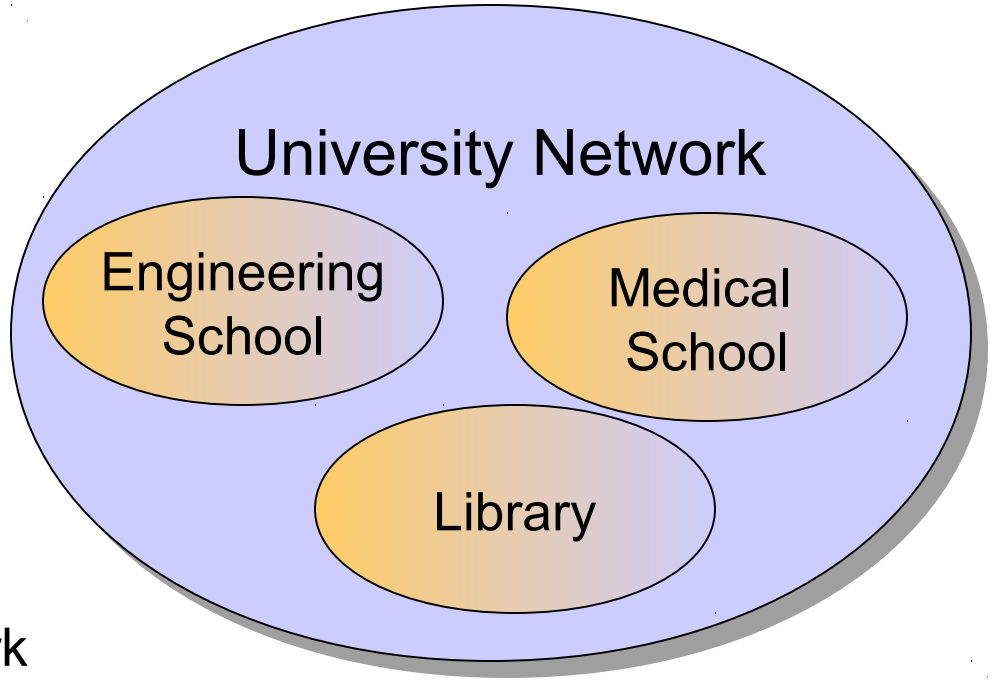
- **Lack of Internal Address Flexibility**
  - Big organizations are assigned large, "monolithic" blocks of addresses that don't match well the structure of their underlying internal networks.

- **Inefficient Use of Address Space**
  - The existence of only three block sizes (classes A, B and C) leads to waste of limited IP address space.

- **Proliferation of Router Table Entries**
  - As the Internet grows, more and more entries are required for routers to handle the routing of IP datagrams, which causes performance problems for routers. Attempting to reduce inefficient address space allocation leads to even more router_table entries.

# Subnetting

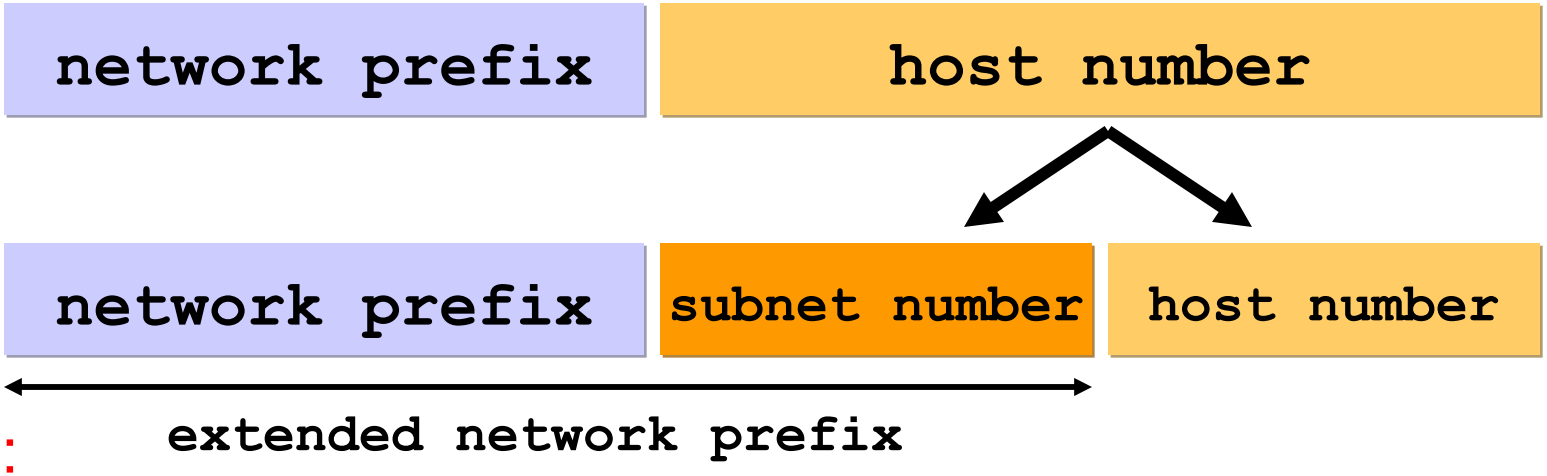
- **Problem**: Organizations have multiple networks which are independently managed
  - **Solution 1:** Allocate one or more addresses for each network
    - Difficult to manage
    - From the outside of the organization, each network must be addressable.
  - **Solution 2:** Add another level of hierarchy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




→ **Subnetting**

# Basic Idea of Subnetting

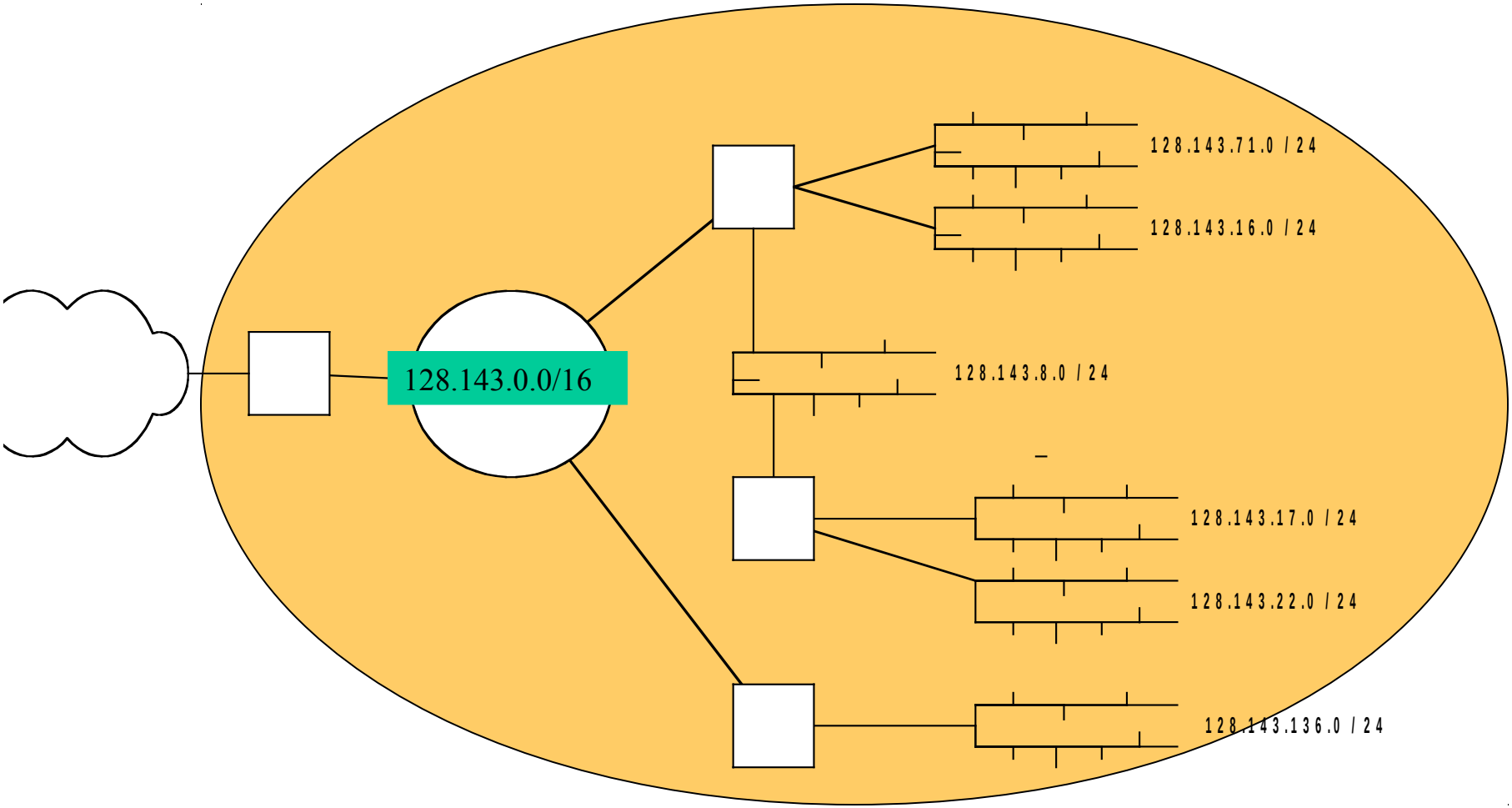
- Split the host number portion of an IP address into a **subnet number** and a (smaller) **host number**.
- Result is a 3-layer hierarchy




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

# Typical Addressing Plan for an Organization that uses subnetting

- Each layer-2 network (Ethernet segment, FDDI segment) is allocated a subnet address.



# Advantages of Subnetting

- With subnetting, IP addresses use a 3-layer hierarchy:
  - » Network
  - » Subnet
  - » Host
- Improves efficiency of IP addresses by not consuming an entire address space for each physical network.
- 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.

# CIDR - Classless Interdomain Routing

- **Goals:**
  - Restructure IP address assignments to increase efficiency
  - Hierarchical routing aggregation to minimize route table entries

**Key Concept:** The length of the network id (prefix) in the IP addresses is kept arbitrary

- Consequence: Routers advertise the IP address and the length of the prefix

# CIDR Example

- CIDR notation of a network address:

  **192.0.2.0/18**

  - "18" says that the first 18 bits are the network part of the address (and 14 bits are available for specific host addresses)
- The network part is called the prefix

- Assume that a site requires a network address with 1000 addresses
- With CIDR, the network is assigned a continuous block of 1024 addresses with a 22-bit long prefix

# CIDR: Prefix Size vs. Host Space

| CIDR Block Prefix | # of Host Addresses |
|---|---|
| /27 | 32 hosts |
| /26 | 64 hosts |
| /25 | 128 hosts |
| /24 | 256 hosts |
| /23 | 512 hosts |
| /22 | 1,024 hosts |
| /21 | 2,048 hosts |
| /20 | 4,096 hosts |
| /19 | 8,192 hosts |
| /18 | 16,384 hosts |
| /17 | 32,768 hosts |
| /16 | 65,536 hosts |
| /15 | 131,072 hosts |
| /14 | 262,144 hosts |
| /13 | 524,288 hosts |

# CIDR and Address assignments

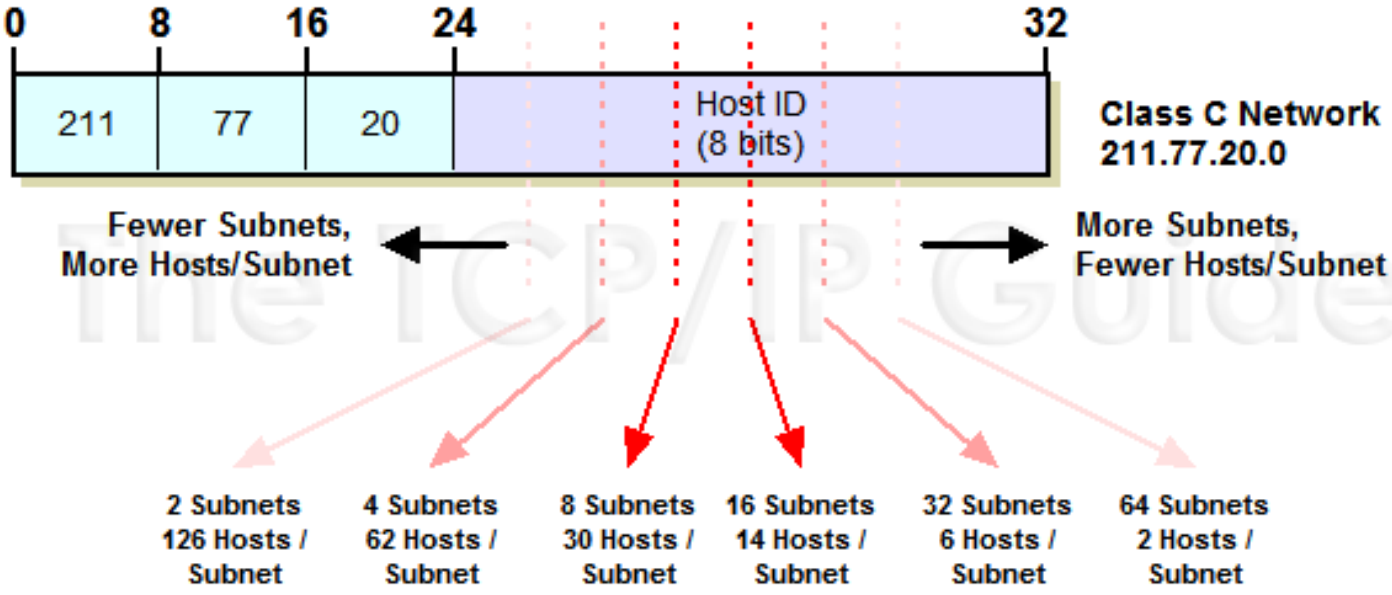
- Backbone ISPs obtain large block of IP addresses space and then reallocate portions of their address blocks to their customers.

**Example:**

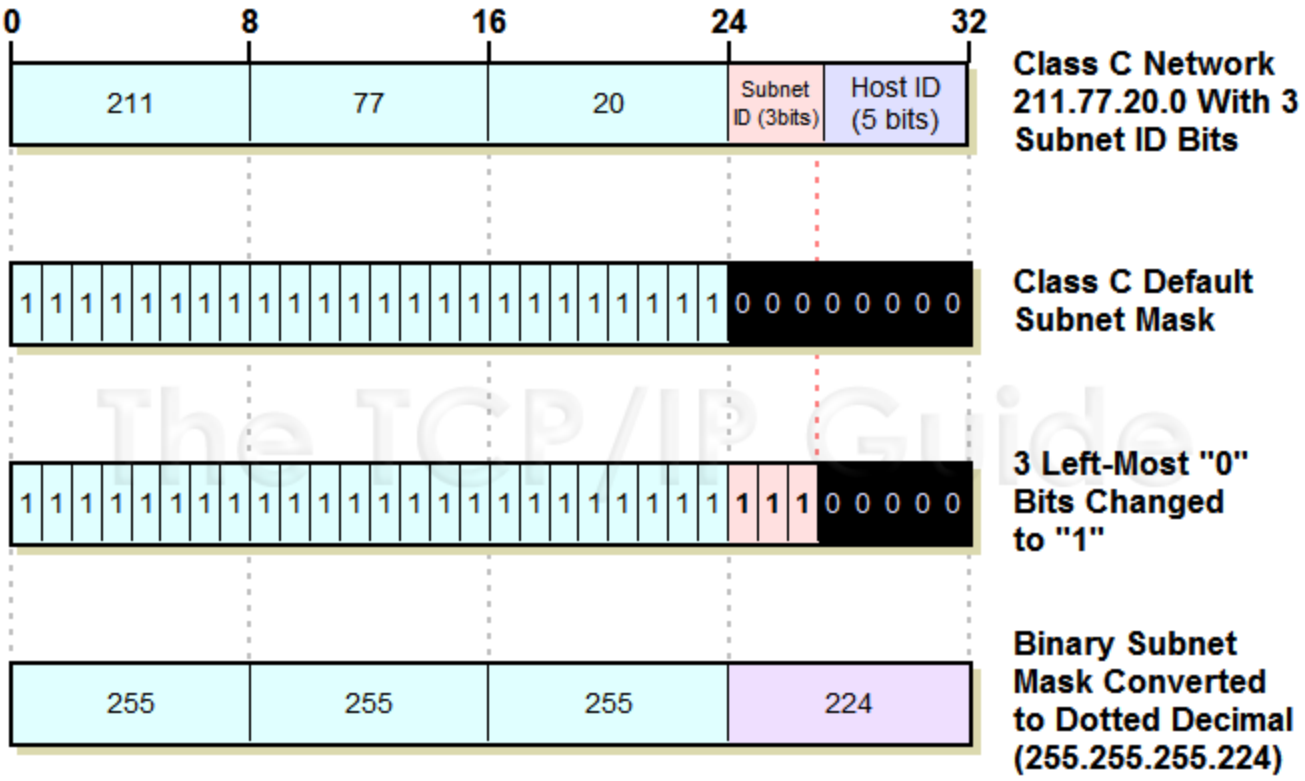
- Assume that an ISP owns the address block 206.0.64.0/18, which represents 16,384 ($2^{32-18}=2^{14}$) IP addresses
- Suppose a client requires 800 host addresses
- Assign a /22 block ($512=2^9<800<1024=2^{10}$ -> 32-10=22), e.g., 206.0.68.0/22 gives a block of 1,024 ($2^{10}$) IP addresses.

# Example: IP Subnetting

- Requirements
  - Class, how many hosts, scalability, min, max



- Class C Custom Subnet Mask Calculation Example
  - 3 for subnet ID and 5 for host ID

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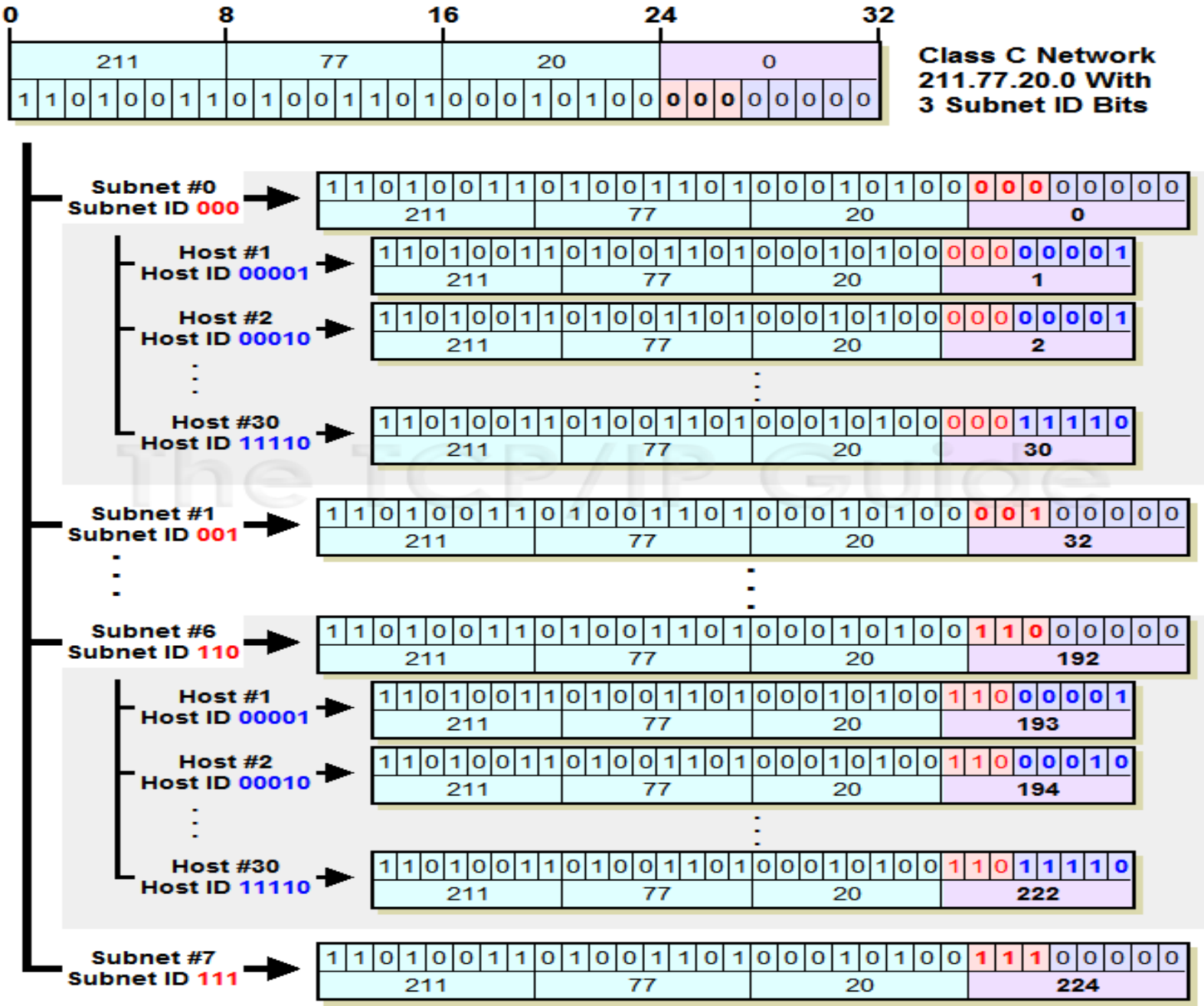
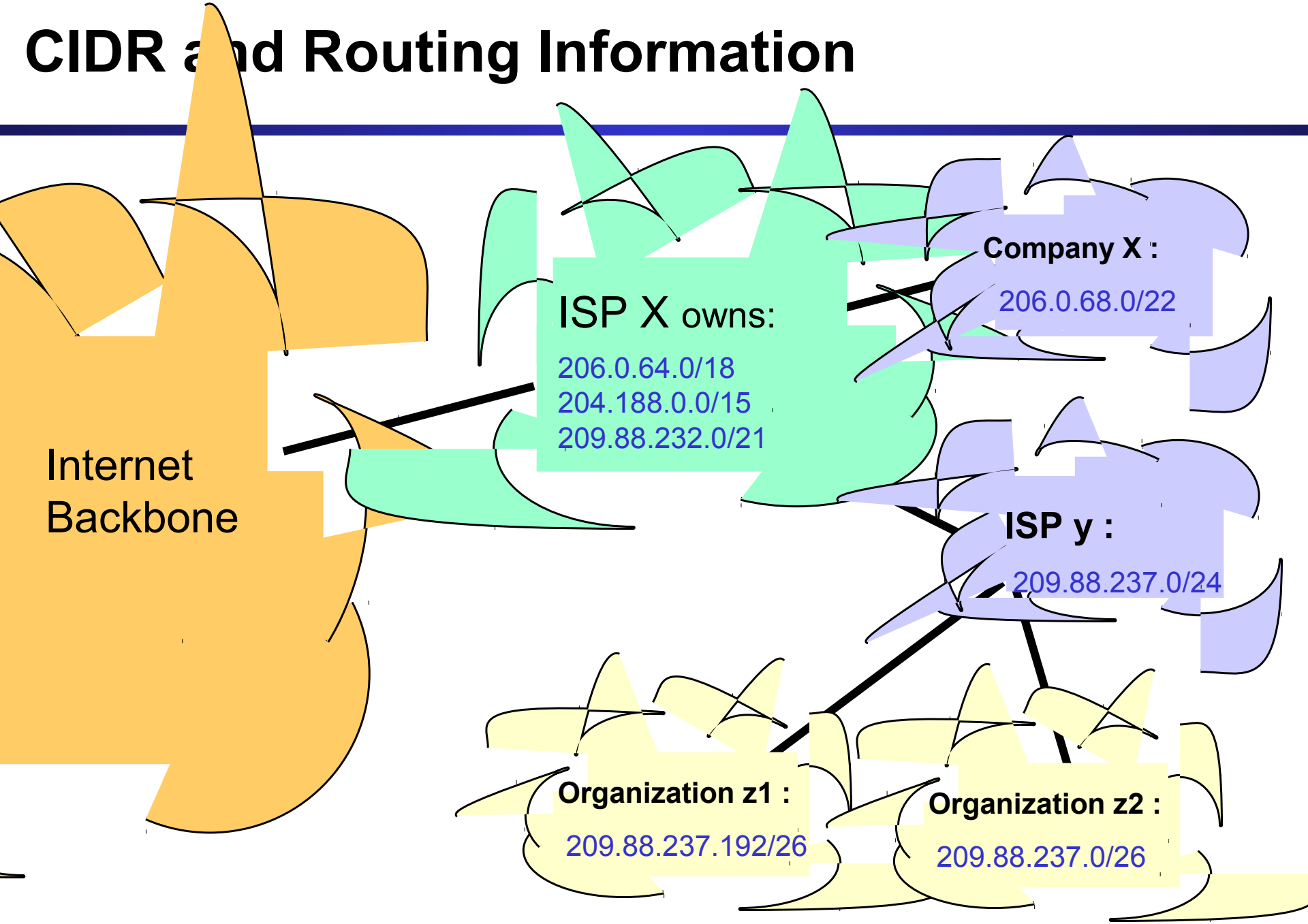



# Determining Host Address for each Subnet

# CIDR and Routing Information



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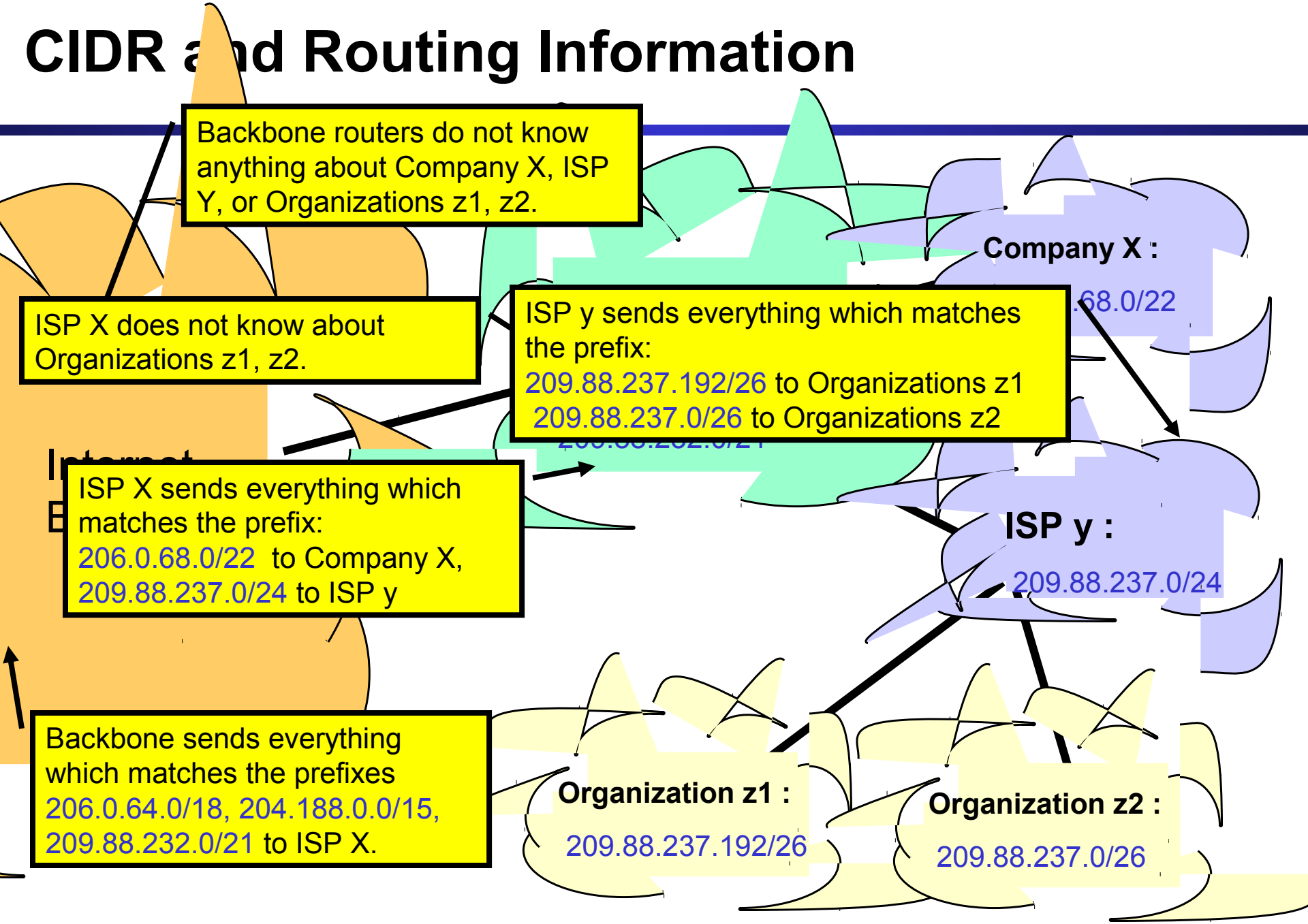


# CIDR and Routing

- **Aggregation** of routing table entries:
  - 128.143.0.0/16 and 128.142.0.0/16 are represented as 128.142.0.0/15
- **Longest prefix match**: Routing table lookup finds the routing entry that matches the longest prefix

What is the outgoing interface for 128.143.137.0 ?

| Prefix | Interface |
|---|---|
| 128.143.128.0/17 | interface #1 |
| 128.128.0.0/9 | interface #2 |
| 128.0.0.0/4 | interface #5 |

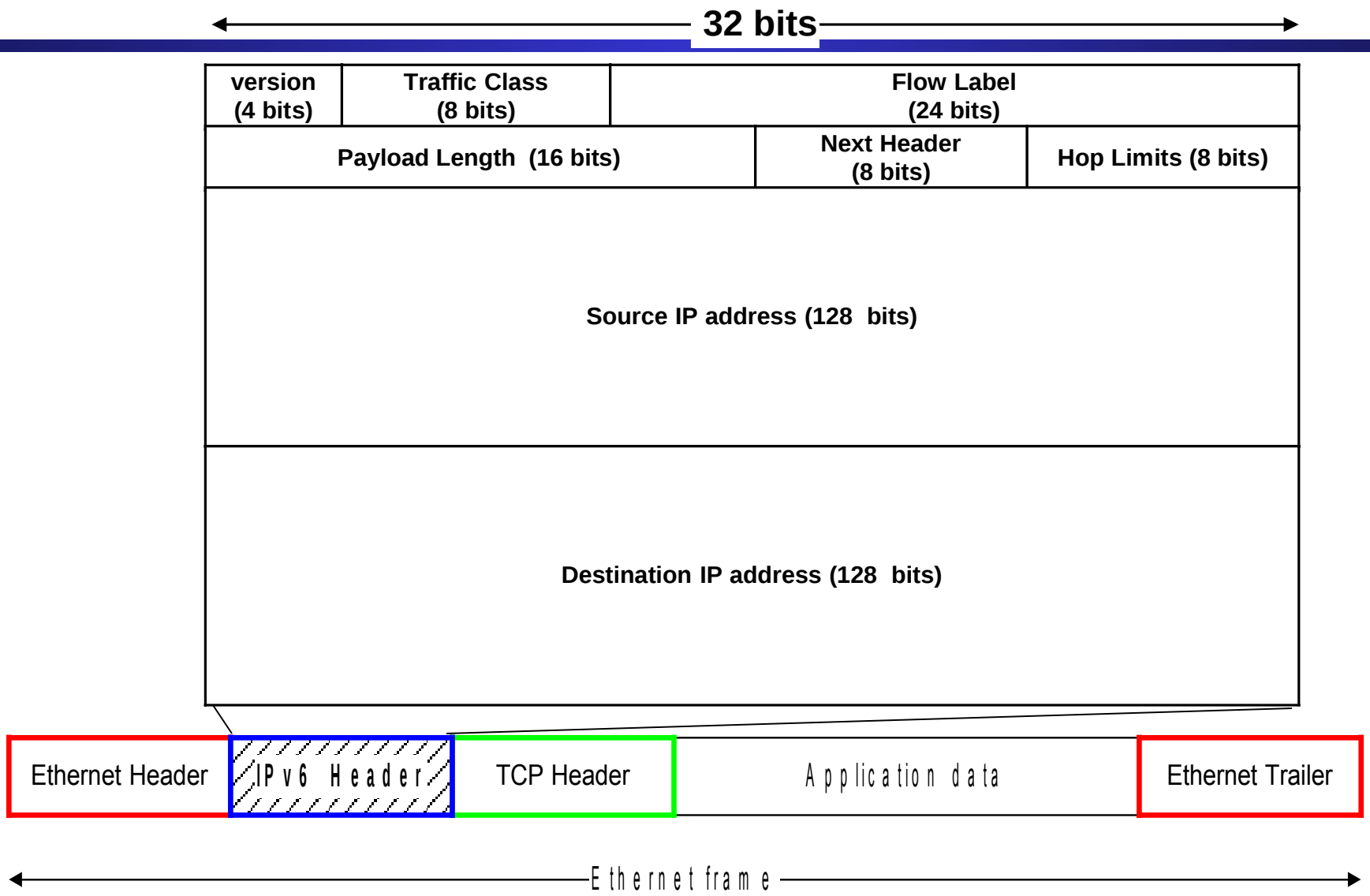
Routing table

# IPv6 - IP Version 6

- **IP Version 6**
  - Is the successor to the currently used IPv4
  - Specification completed in 1994
  - Makes improvements to IPv4 (no revolutionary changes)

- One (not the only !) feature of IPv6 is a significant increase in size of the IP address to **128 bits (16 bytes)**
    - IPv6 will solve – for the foreseeable future – the problems with IP addressing

# IPv6 Header


32 bits
version (4 bits)
Traffic Class (8 bits)
Flow Label (24 bits)
Payload Length (16 bits)
Next Header (8 bits)
Hop Limits (8 bits)
Source IP address (128 bits)
Destination IP address (128 bits)
Ethernet Header
IPv6 Header
TCP Header
Application data
Ethernet Trailer
Ethernet frame

# IPv6 vs. IPv4: Address Comparison

- **IPv4** has a maximum of

  $2^{32} \approx$ 4 billion addresses

- **IPv6** has a maximum of

  **$2^{128} = (2^{32})^4 \approx$ 4 billion x 4 billion x 4 billion x 4 billion addresses**

# Notation of IPv6 addresses

- **Convention**: The 128-bit IPv6 address is written as **eight 16-bit integers** (using hexadecimal digits for each integer)

  **CEDF:BP76:3245:4464:FACE:2E50:3025:DF12**

- **Short notation:**
- Abbreviations of leading zeroes:

  **CEDF:BP76:0000:0000:009E:0000:3025:DF12**

  **→ CEDF:BP76:0:0:9E :0:3025:DF12**
- “:0000:0000” can be written as “::”

  **CEDF:BP76:0:0:FACE:0:3025:DF12 → CEDF:BP76::FACE:0:3025:DF12**
- IPv6 addresses derived from IPv4 addresses have 96 leading zero bits. Convention allows to use IPv4 notation for the last 32 bits.

  **::80:8F:89:90 → ::128.143.137.144**

# IPv6 Provider-Based Addresses

- The first IPv6 addresses will be allocated to a provider-based plan


- Type: Set to “010” for provider-based addresses
- Registry: identifies the agency that registered the address

*The following fields have a variable length (recommeded length in “()”)*

- Provider: Id of Internet access provider *(16 bits)*
- Subscriber: Id of the organization at provider *(24 bits)*
- Subnetwork: Id of subnet within organization *(32 bits)*
- Interface: identifies an interface at a node *(48 bits)*

# More on IPv6 Addresses

- The provider-based addresses have a similar flavor as CIDR addresses

- IPv6 provides address formats for:
  - Unicast – identifies a single interface
  - Multicast – identifies a group. Datagrams sent to a multicast address are sent to all members of the group
  - Anycast – identifies a group. Datagrams sent to an anycast address are sent to one of the members in the group.