The Internet Protocol (IP)

The Blood of the Internet

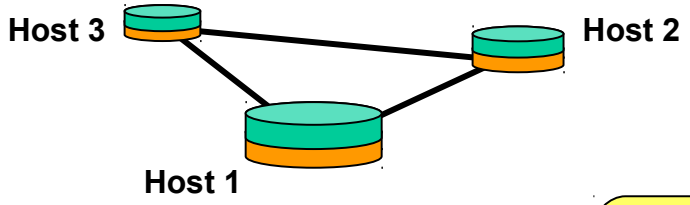
"Information Superhighway is really an acronym for 'Interactive Network For Organizing, Retrieving, Manipulating, Accessing And Transferring Information On National Systems, Unleashing Practically Every Rebellious Human Intelligence, Gratifying Hackers, Wiseacres, And Yahoos'."

Keven Kwaku

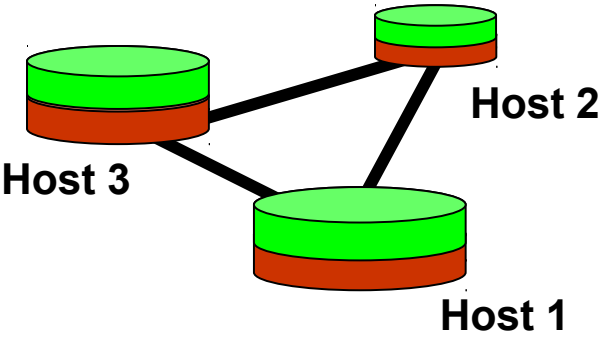
The Internet Protocol (IP)

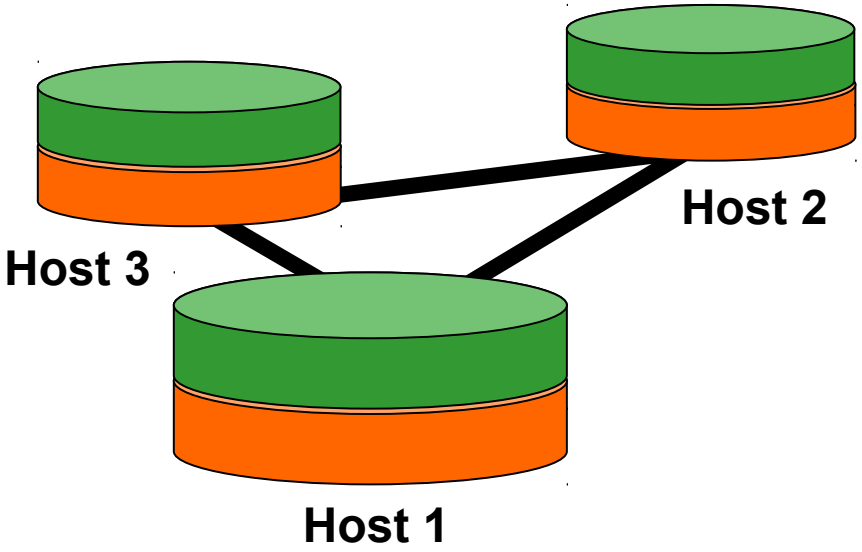
- Introduction
- IP Addressing
  - IP Header
  - IP Address Format
- Address Classes
  - Class A - E
- Subnetting, VLSM
- IP Fragmentation

Need of an Inter-Net Protocol (1)



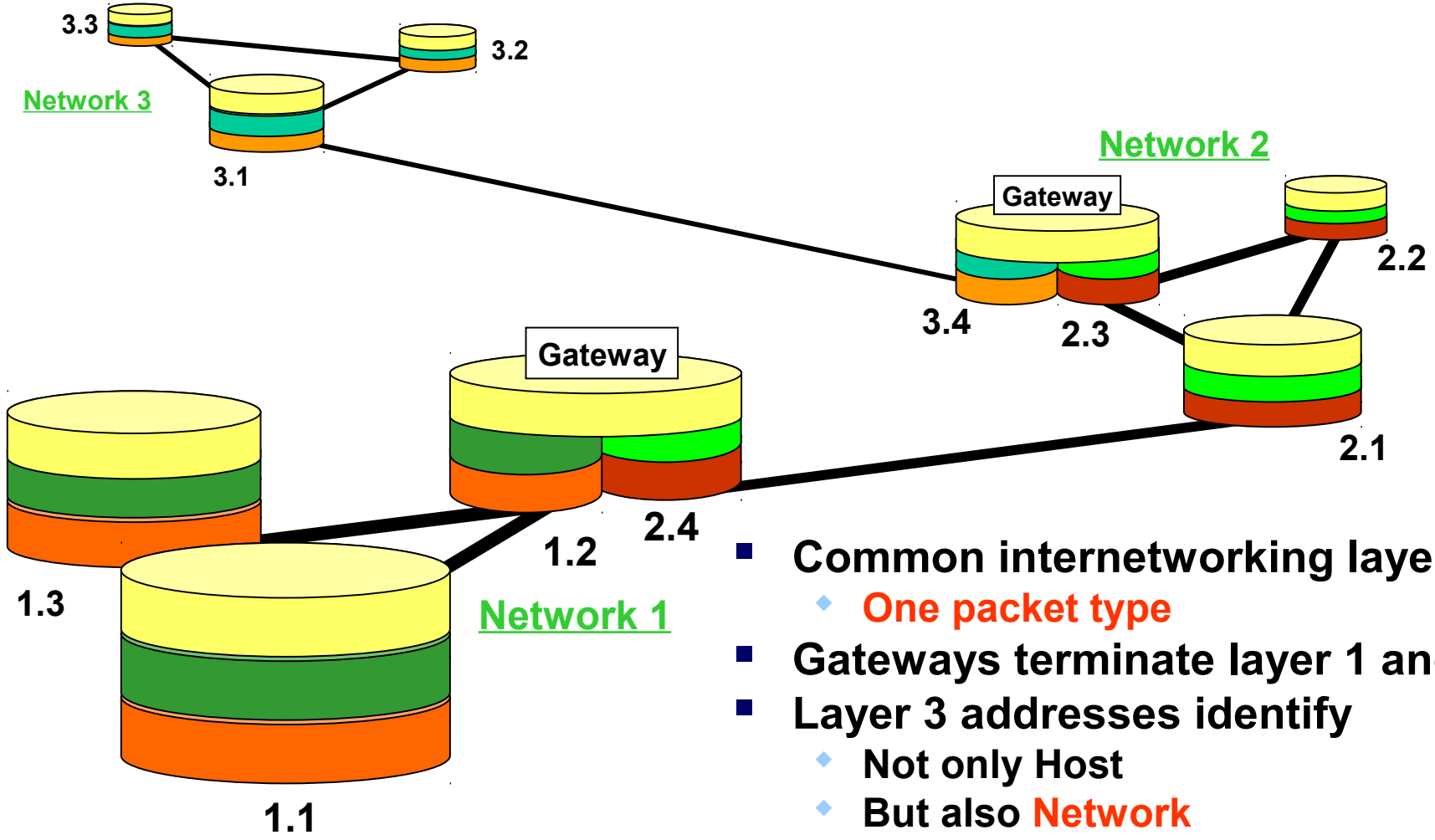
No interconnection possible !!!





- Different Data-Link Layer
  - Different frames
  - Different protocol handling
- Different Physical Layer
  - Different hardware
  - Different signals

Need of an Inter-Net Protocol (2)



- Common internetworking layer
  - One packet type
- Gateways terminate layer 1 and 2
- Layer 3 addresses identify
  - Not only Host
  - But also Network

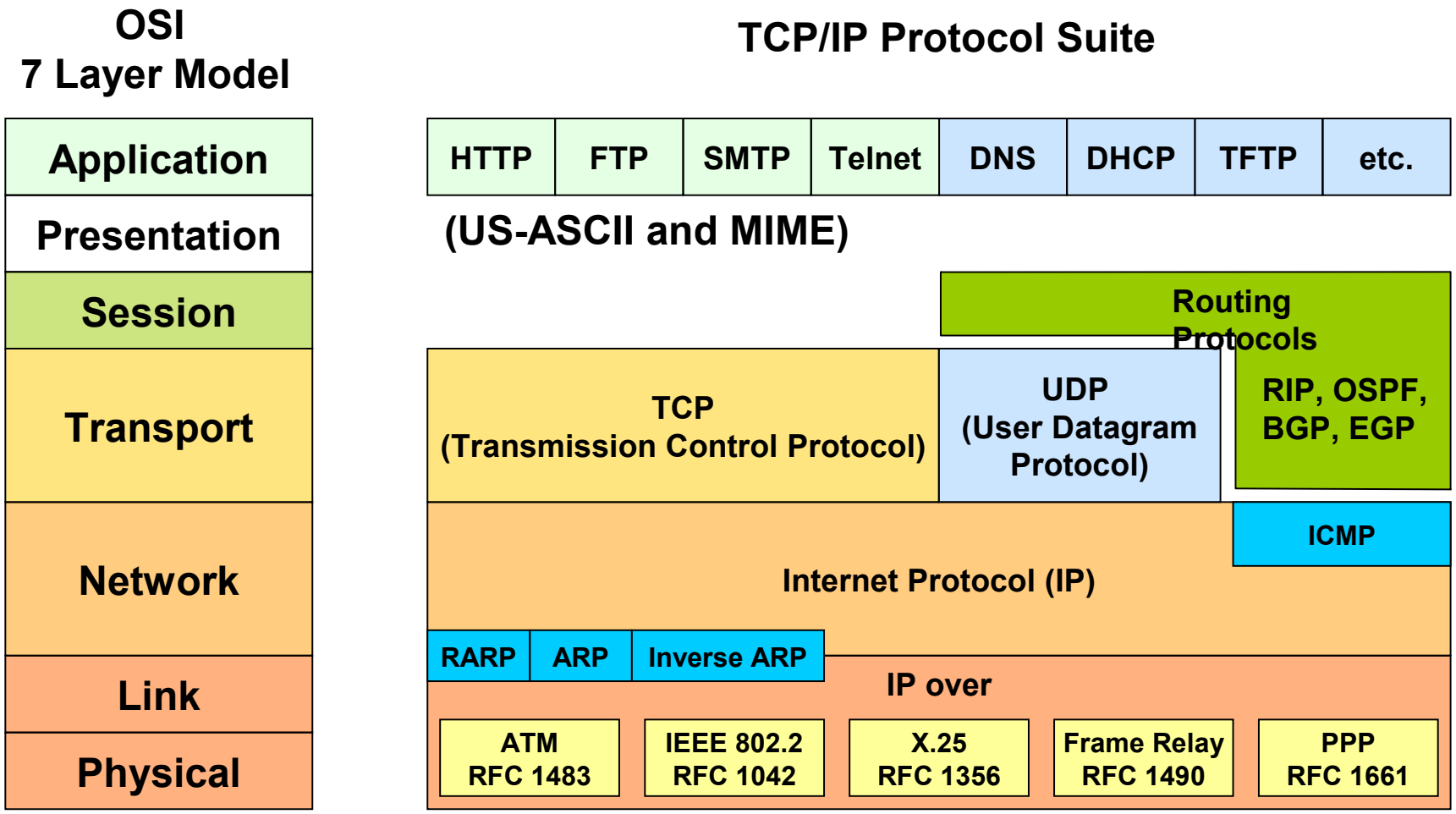
IP Introduction (1)

- Packet switching technology
  - Packet switch = router = "gateway" (IETF terminology)
  - End system is called IP host
  - Layer 3 address (Structured)
- Datagram Service
  - Connectionless
  - Best effort delivery

IP Introduction (2)

- Shared responsibility
  - Both network and hosts must take care for delivery (!)
  - Routers deliver datagrams to remote hosts based on IP address
  - Hosts responsible for end-to-end control
- End-to-end control relies on TCP
  - Layer 4

IP Introduction (3)



IP Introduction (4)

- IP over anything: Overlay Technique
  - IP can be easily integrated upon layer 2 technologies
  - Open development quickly adapts to new transport and switching methods
- End-to-end principle
  - Only hosts must be intelligent (TCP)
  - Routers remain simple

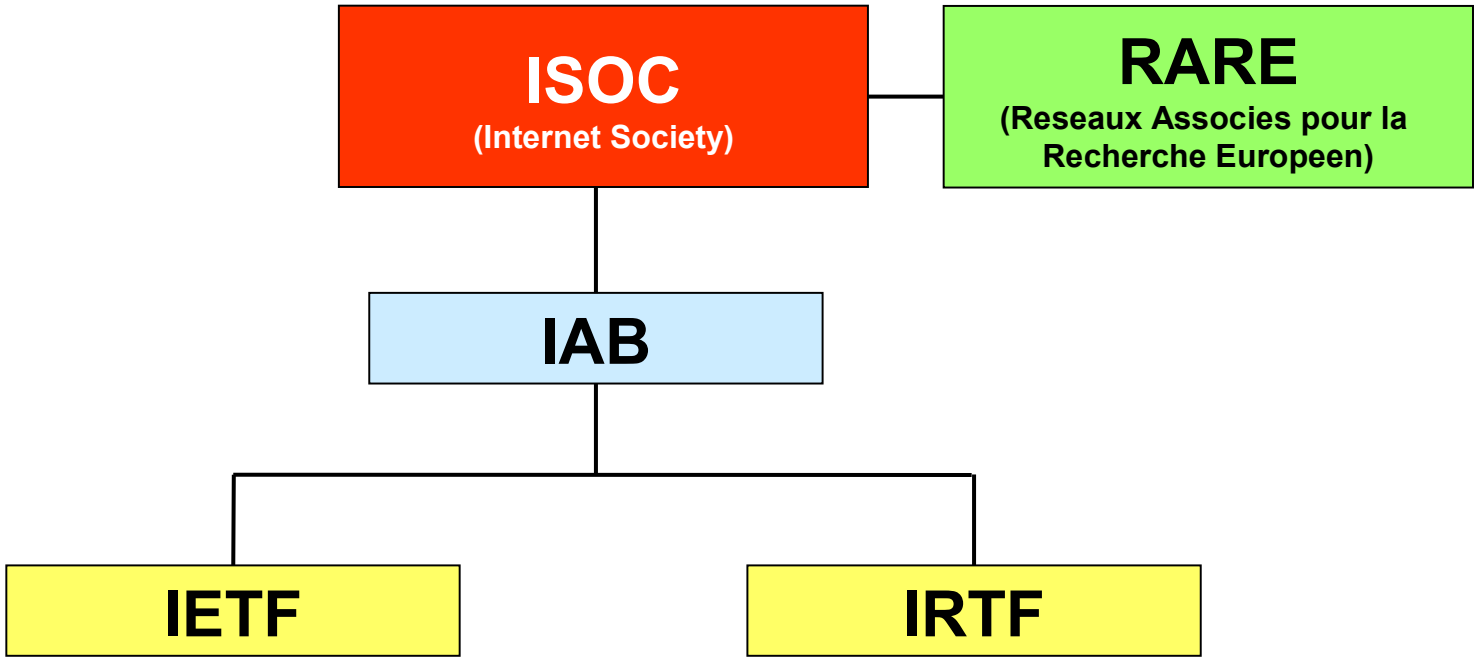
IP Introduction (5)

- TCP cares for reliability
  - Connection oriented
  - Error recovery
  - Flow control
  - Sequencing
- IP is the router's language
  - No idea about applications
  - Best effort delivery

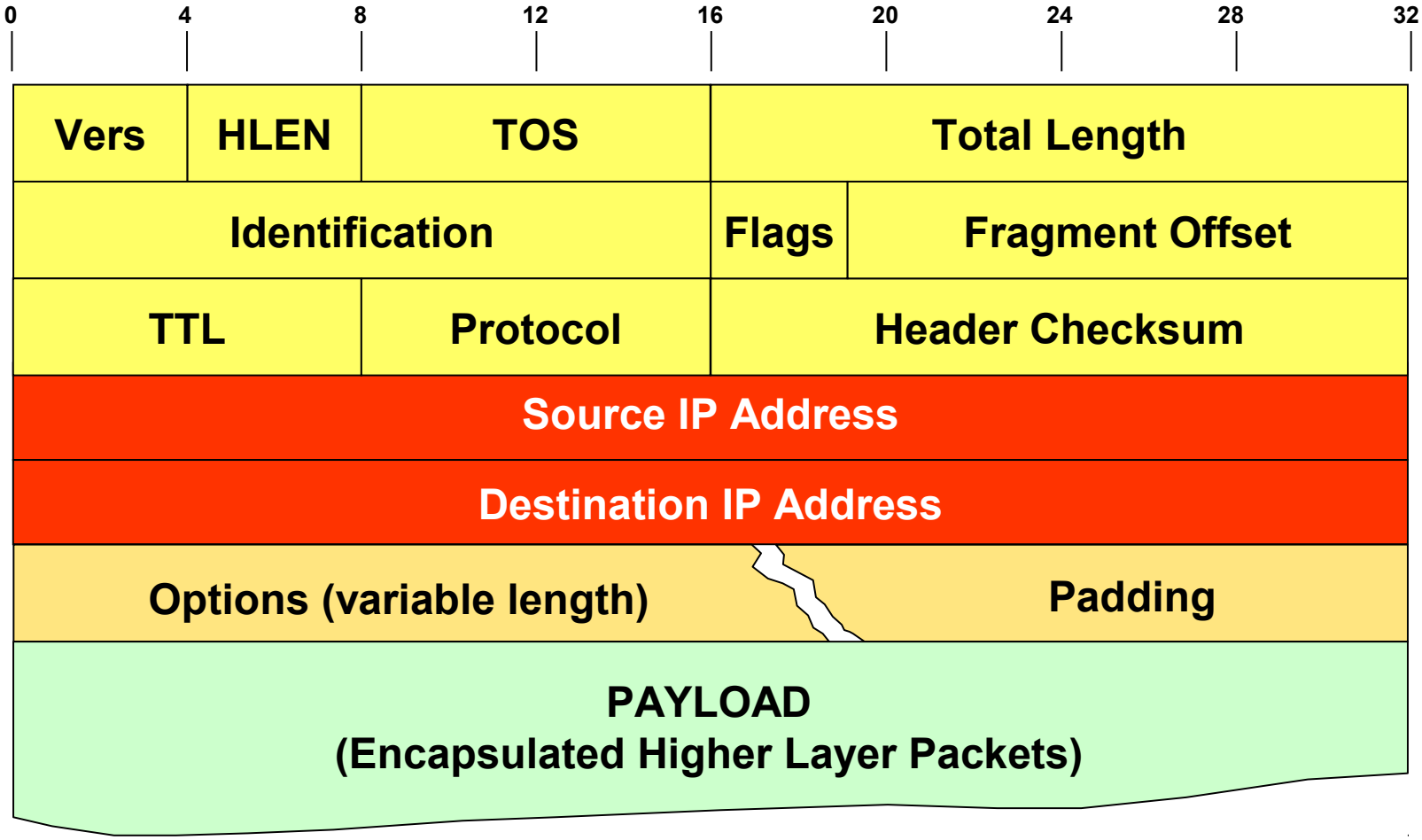
IP Introduction (6)

- Request for Comments (RFCs)
  - De facto standards for the Internet
  - Initially posted by snail mail
  - IETF (Internet Engineering Task Force) reviews and confirms them
  - RFCs are numbered in sequence of publishing
  - Everybody may write an RFC (!)

Internet Organizations



The IP Header



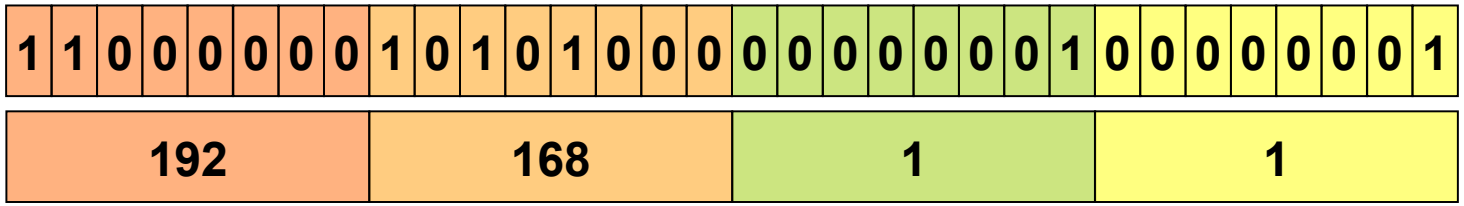
The IP Address

- **Dotted Decimal Notation**

Binary IP Address: 11000000101010000000000100000001

Decimal Value: 3232235777

Decimal Representation *per byte*:



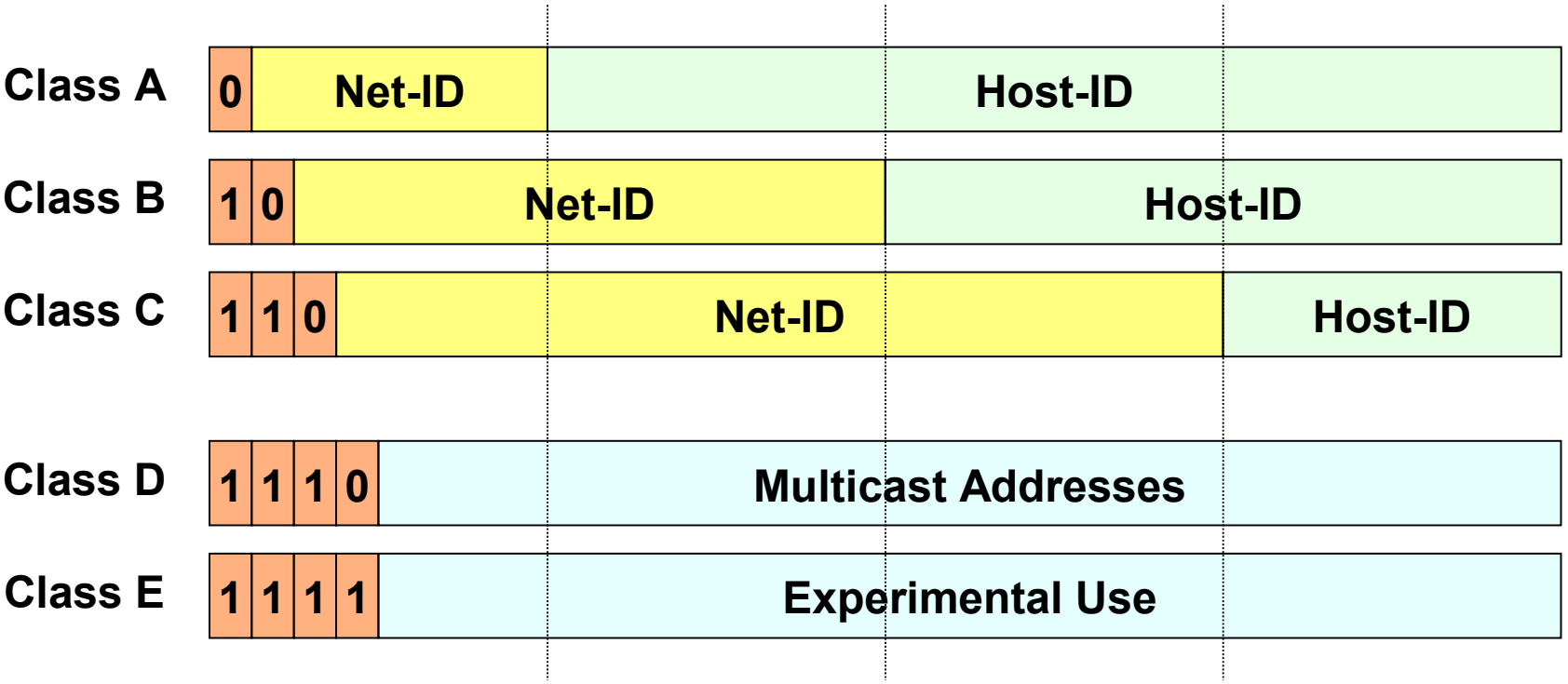
→ **192 . 168 . 1 . 1**

IP Address Classes

- Net-ID? Host-ID?
- 5 Classes defined!
  - A (1-127)
  - B (128-191)
  - C (192-223)
  - D (224-239, Multicast)
  - E (240-254, Experimental)
- Classes define number of address-bits for net-id

IP Address Classes

Classes are defined by *„first octet rule“*



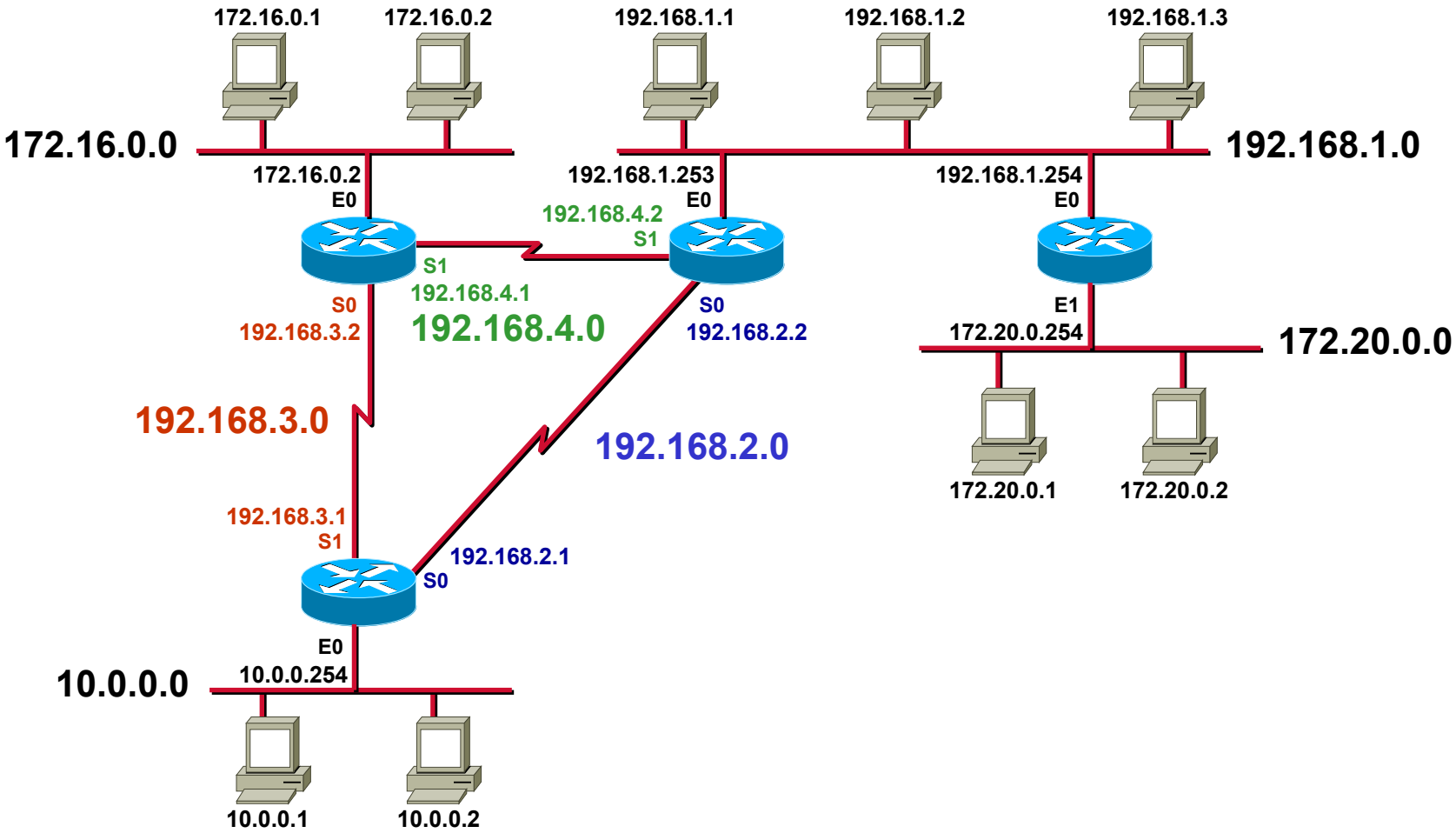
Broadcasts and Networks

- All ones in the host-part represents „network-broadcast“ (10.255.255.255)
- All ones in the net-part and host-part represents „limited broadcast in this network” (255.255.255.255)
- All zeros in the host-part represents the „network-address“ (10.0.0.0)

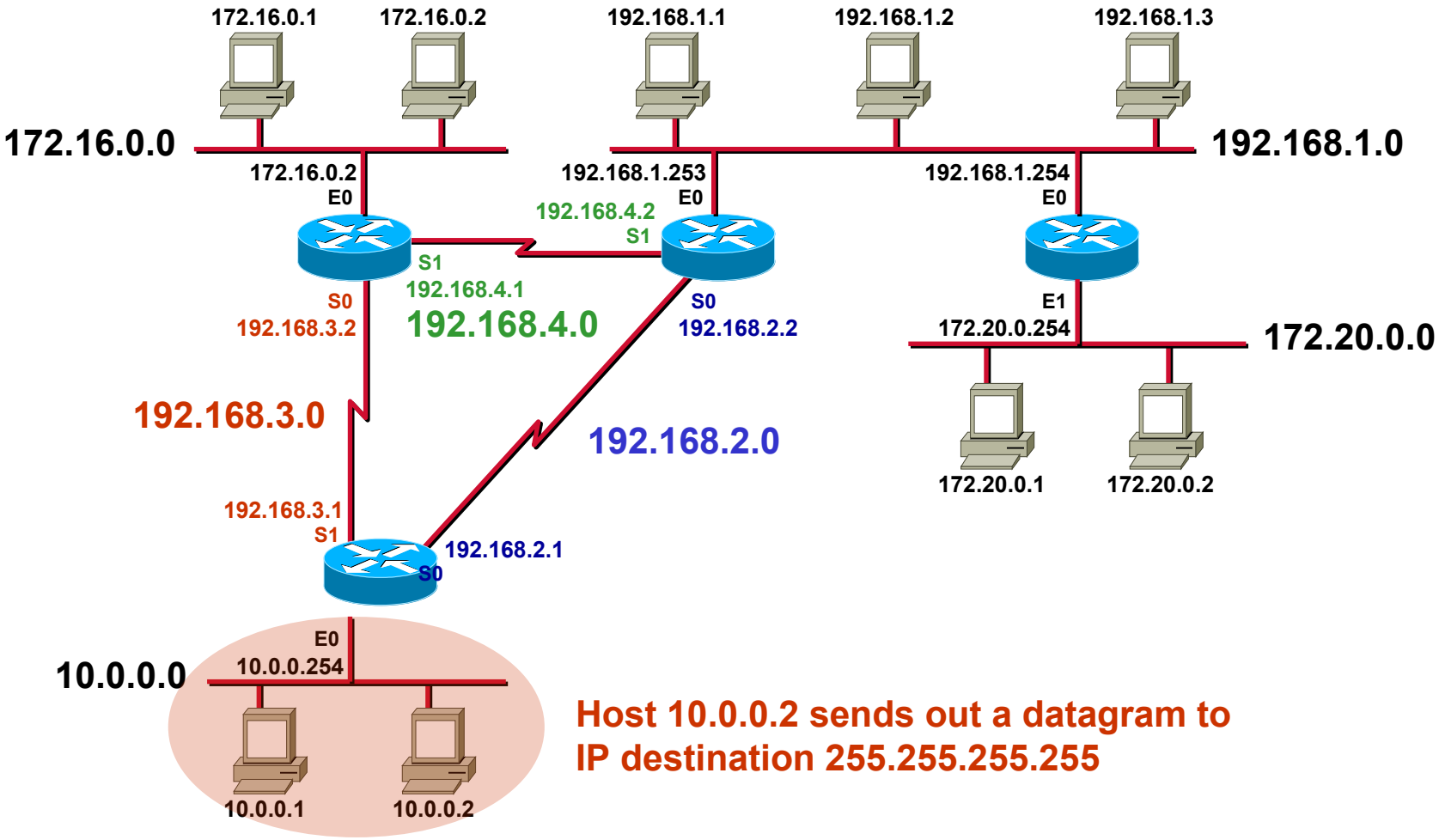
Reserved Addresses

- Address range for private use
  - 10.0.0.0 - 10.255.255.255
  - 172.16.0.0 - 172.31.255.255
  - 192.168.0.0 - 192.168.255.255
- RFC 1918
- Network 127.x.x.x is reserved for "Loopback"

Addressing Example

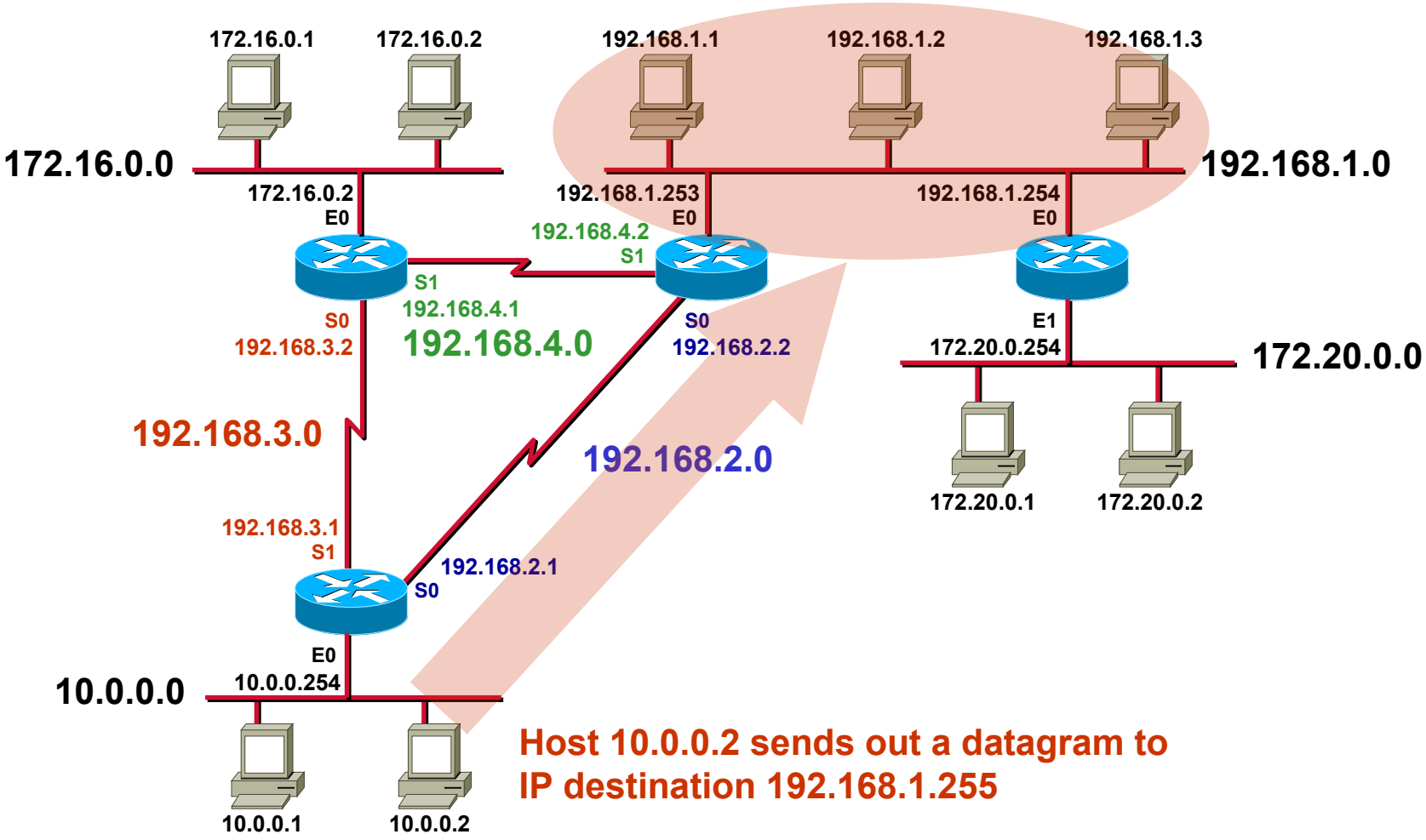


IP Limited Broadcast



Host 10.0.0.2 sends out a datagram to IP destination 255.255.255.255

IP Directed Broadcast



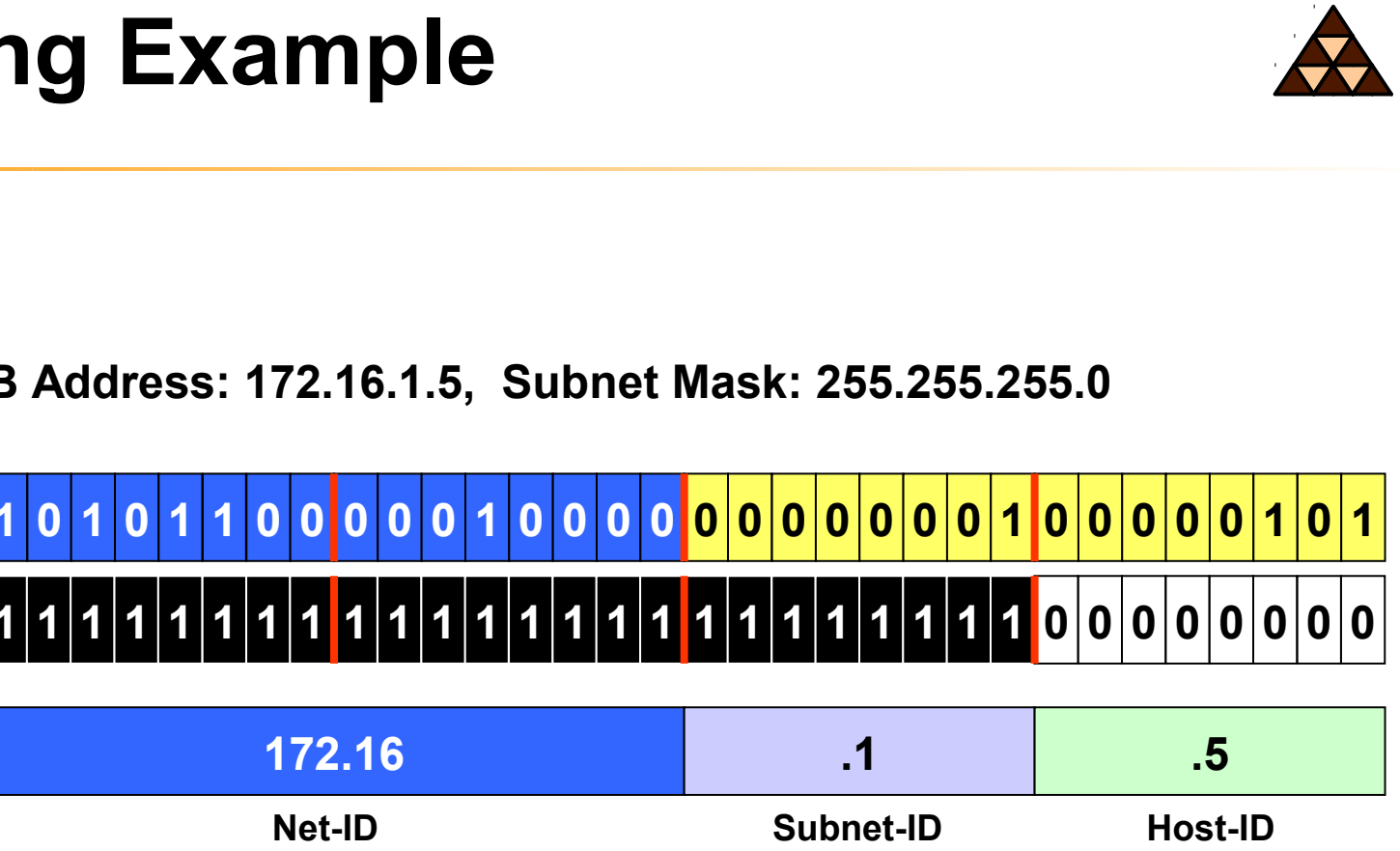
Classful Address Waste

	Total	Allocated	Allocated %
Class A	126	48	54%
Class B	16383	7006	43%
Class C	2097151	40724	2%

Network Number Statistics, April 1992 (Source: RFC 1335)

- Two-level hierarchy was sufficient in the early days of the Internet
- The growing sizes of LANs demanded for a third hierarchical level
- "Subnetting" allows to identify some bits of the host-ID to be interpreted as "Subnet"

Subnetting Example



Alternative (newer) notation: 172.16.1.5 /24

Subnet Zero / Subnet Broadcast

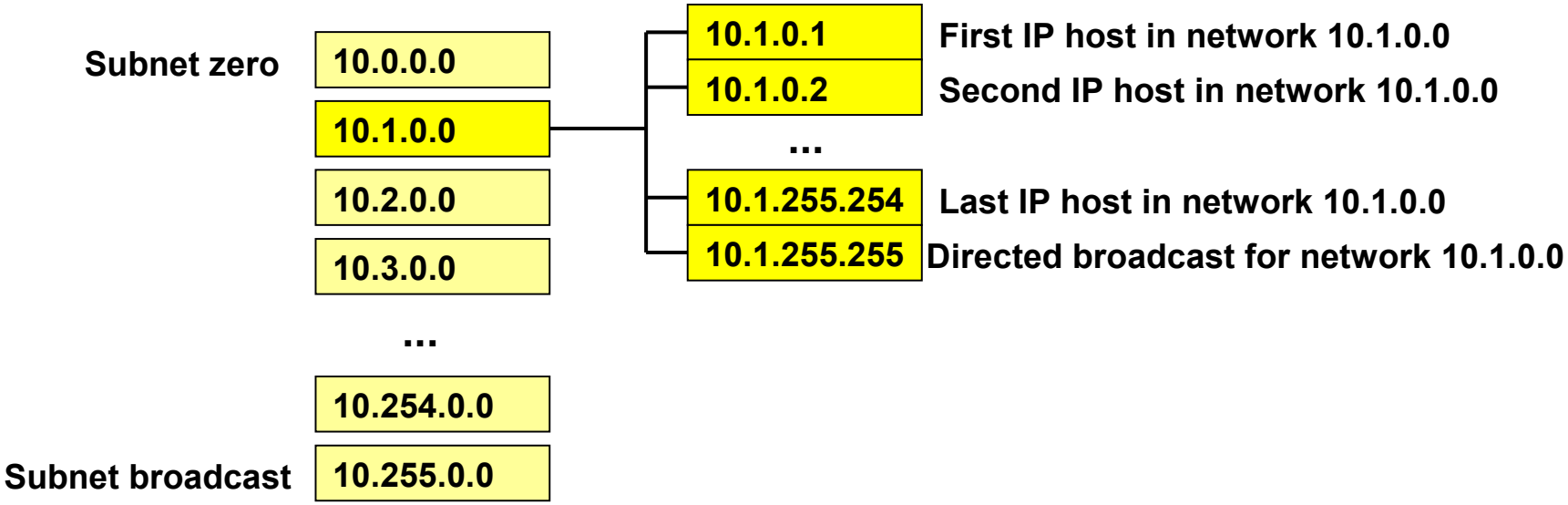
- Consider network 10.0.0.0
  - Is it a class A net "10" ?
  - Or do we have a subnet "10.0" ?
- Consider broadcast 10.255.255.255
  - Is it a directed broadcast for the whole net 10 ?
  - Or only for the subnet 10.255 ?
- Subnet zero and subnet broadcast can be ambiguous!

Subnet Example 1

"Use the class A network 10.0.0.0 and 8 bit subnetting"

1) That is: 10.0.0.0 with 255.255.0.0 (pseudo class B)
   or 10.0.0.0/16

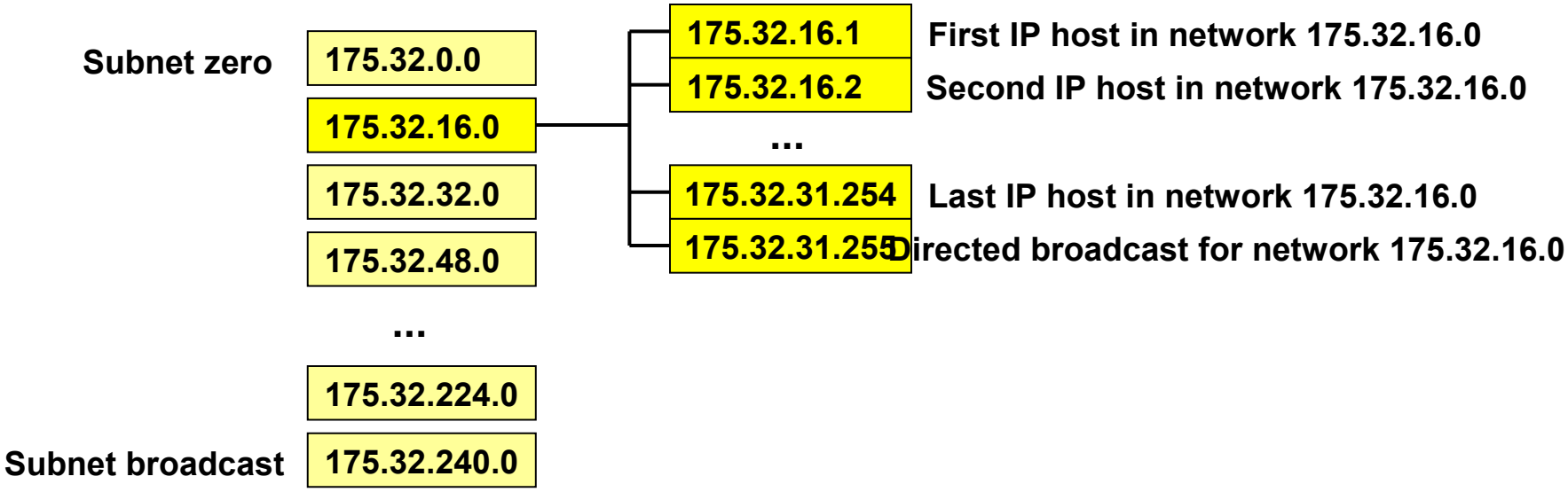
2) Resulting subnetworks:



Subnet Example 2

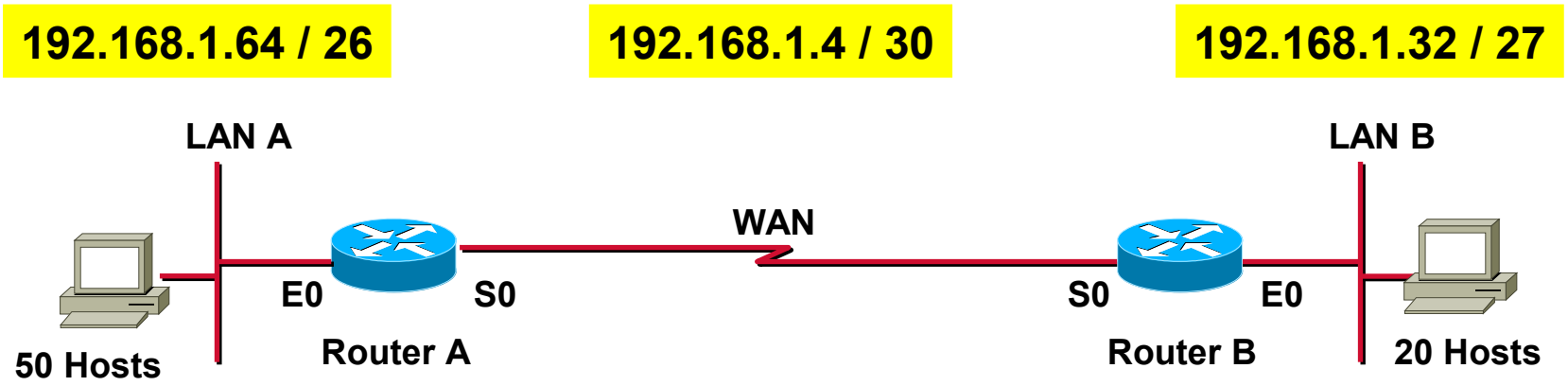
"Use the class B network 175.32.0.0 and 4 bit subnetting"

1) That is: 175.32.0.0 with 255.255.240.0 or 175.32.0.0/20
2) Resulting subnetworks:



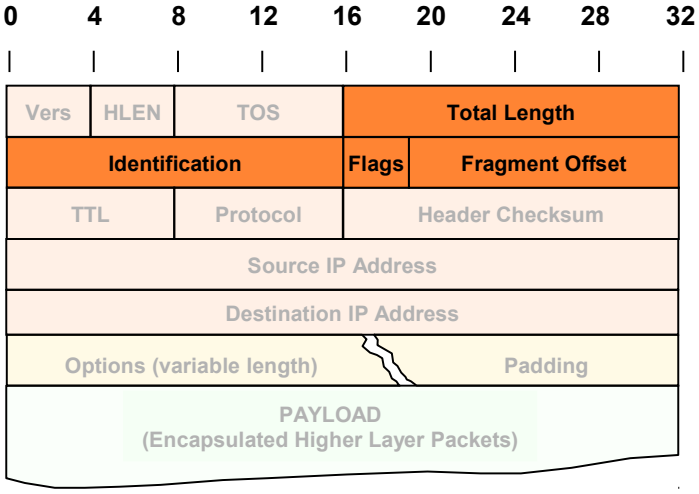
Variable Length Subnetting (VLSM)

- Remember:
  - IP-routing is only possible between different "IP-Networks"
  - Every link must have an IP net-ID
- Today IP addresses are rare!
- The assigment of IP-Addresses must be as efficient as possible!



IP Fragmentation (1)

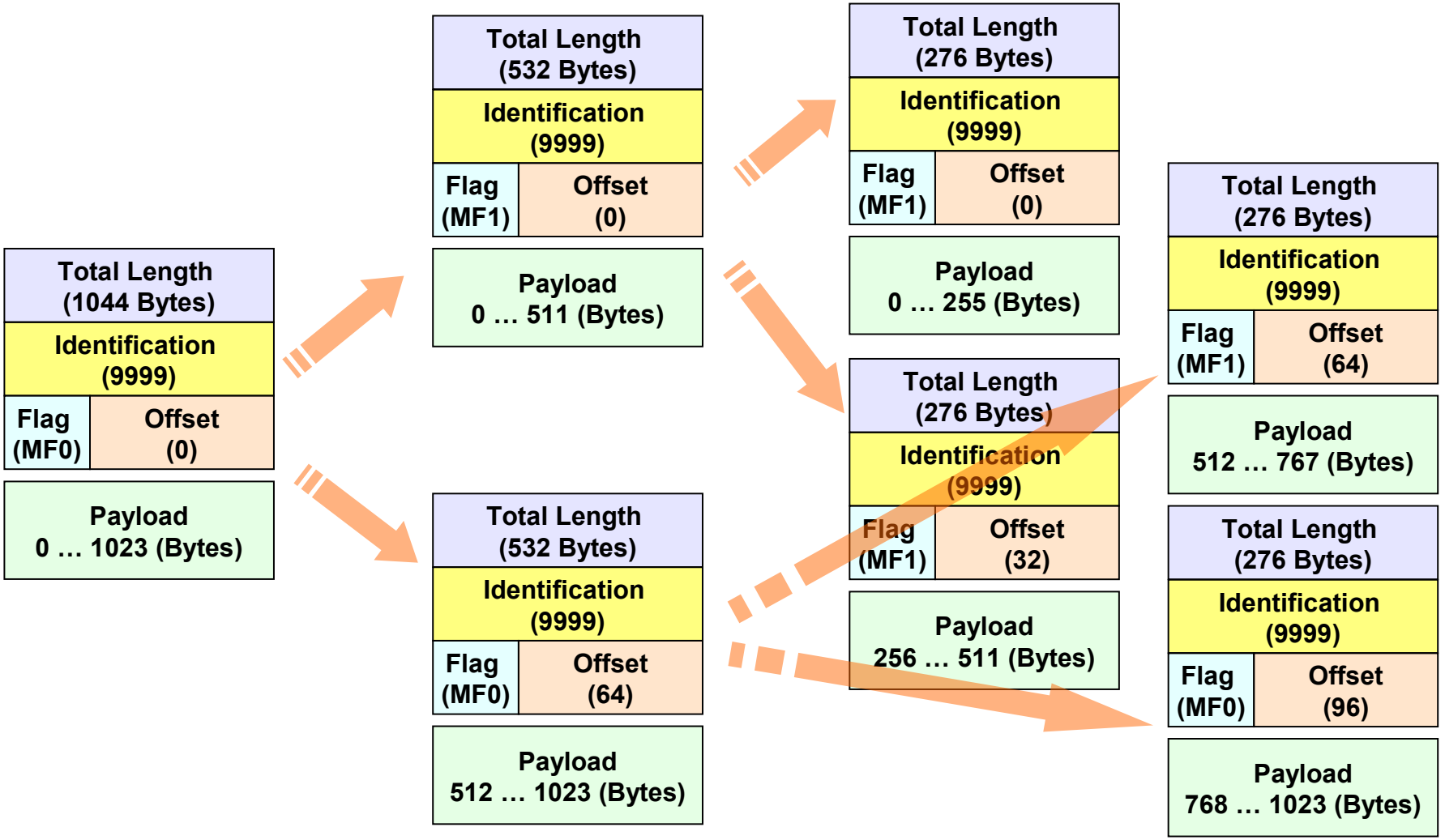
- Typical task of a Network Layer
- Used when packet length > link MTU
- 4 IP header fields are used
  - Identification
  - Flag "DF"
  - Flag "MF"
  - Fragment Offset



IP Fragmentation (2)

- Identification
  - Each fragment of a IP datagram must carry the same identification number
  - Necessary for reassembly
- Flags
  - DF (don't fragment)
  - MF (more fragments)
- Fragment Offset
  - Indicates the position of a fragment in the original datagram
  - Multiple of 8 octets

IP Fragmentation (3)



IP Fragmentation (4)

- Reassembly is done at the destination
  - Buffer space has to be provided at the receiver
- The first arriving fragment issues a reassembly timer
  - Provided that MF=1 and/or Offset <> 0
- The reassembly timer limits the lifetime of an incomplete datagram and allows better use of buffer resources

Summary

- The Internet Protocol
  - Is an "open" (RFC defined) standard
- An IP Address is a 32 bit value but structured
- To define net-ID and host-ID
  - Classes A, B, C
  - Subnetting and VLSM allows to utilize the address-space much more efficient

Quiz

- Why is there also a source address in the IP header?
- Why is there no field for the subnet-mask in the IP Header?
- Is Subnet-Zero used in "Real Life"?
- Do Routers today really care about IP-Classes?
- Is VLSM still important? (why / why not)