


# 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**

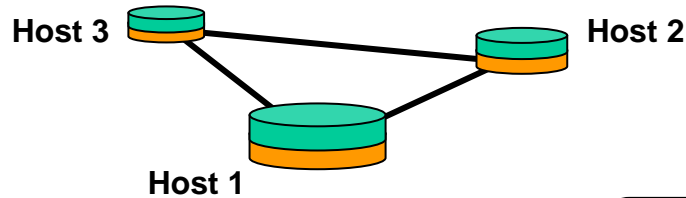
# The Internet Protocol (IP)

---

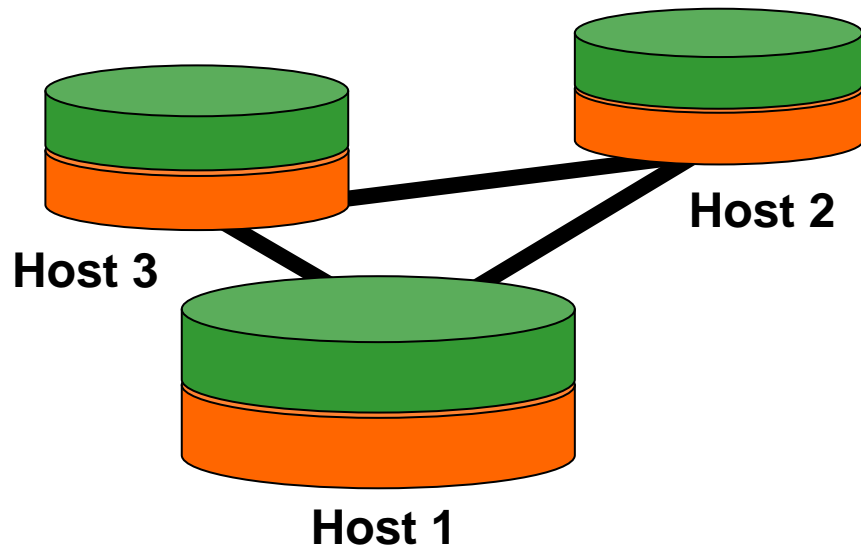
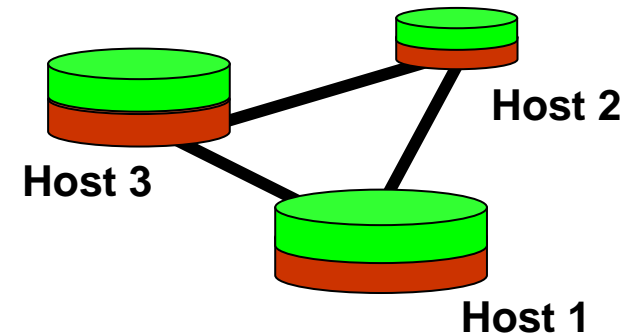


- **Introduction**
- **IP Addressing**
  - ◆ IP Header
  - ◆ IP Address Format
- **Address Classes**
  - ◆ Class A - E
- **Subnetting, VLSM**
- **IP Fragmentation**

# Need of an Inter-Net Protocol (1)

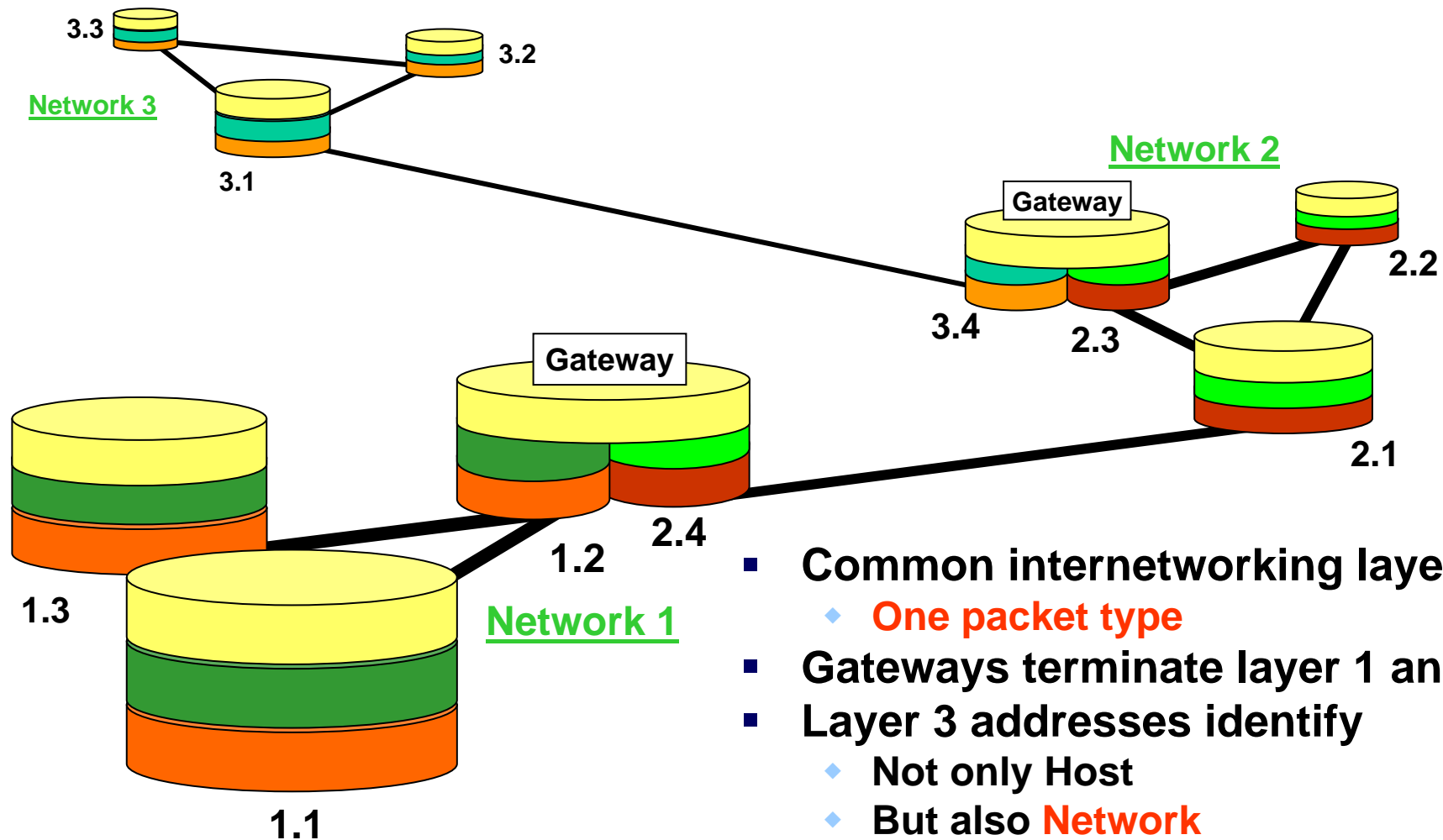


No interconnection possible !!!



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

# Need of an Inter-Net Protocol (2)



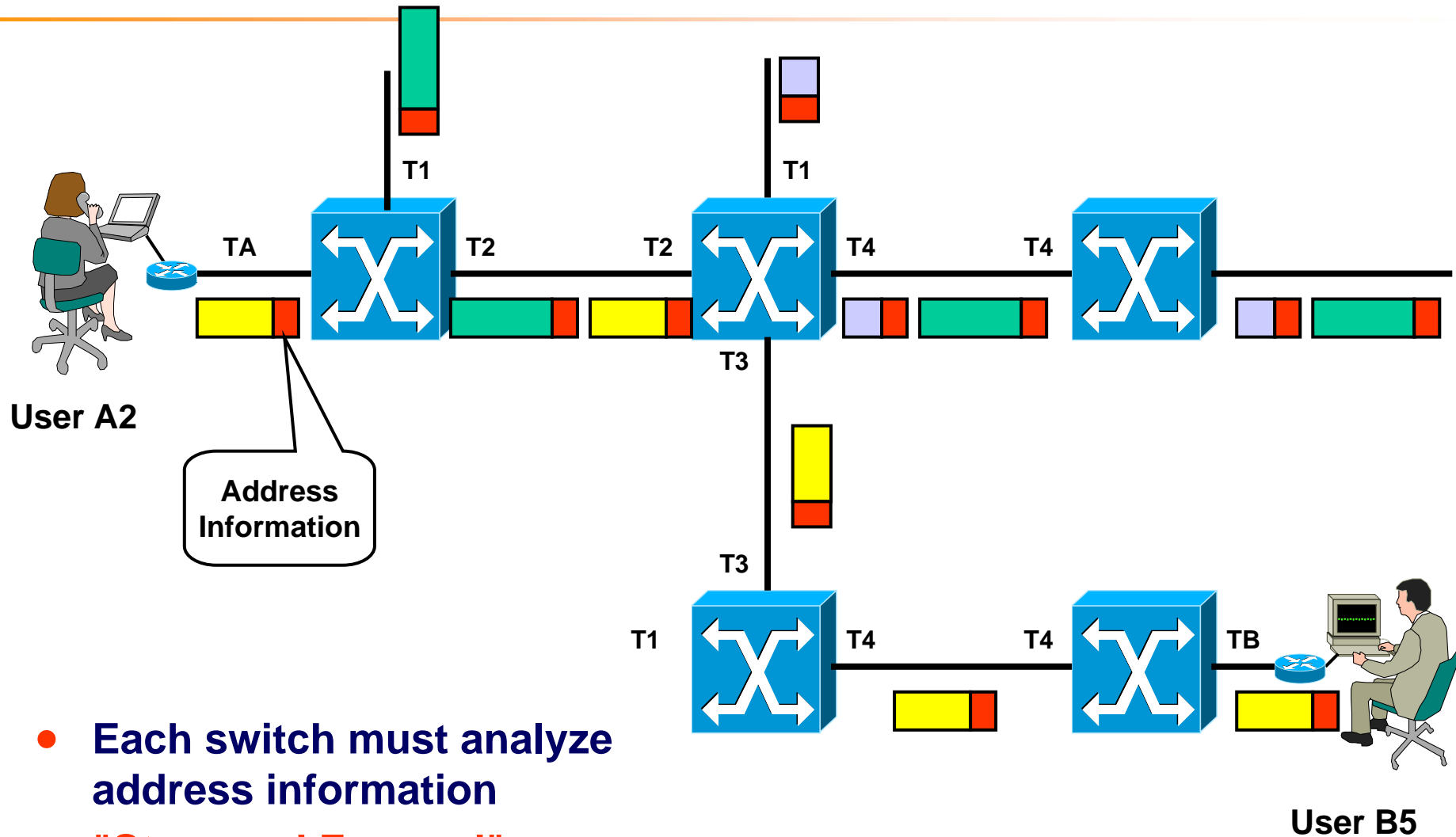
# IP Introduction (1)

---

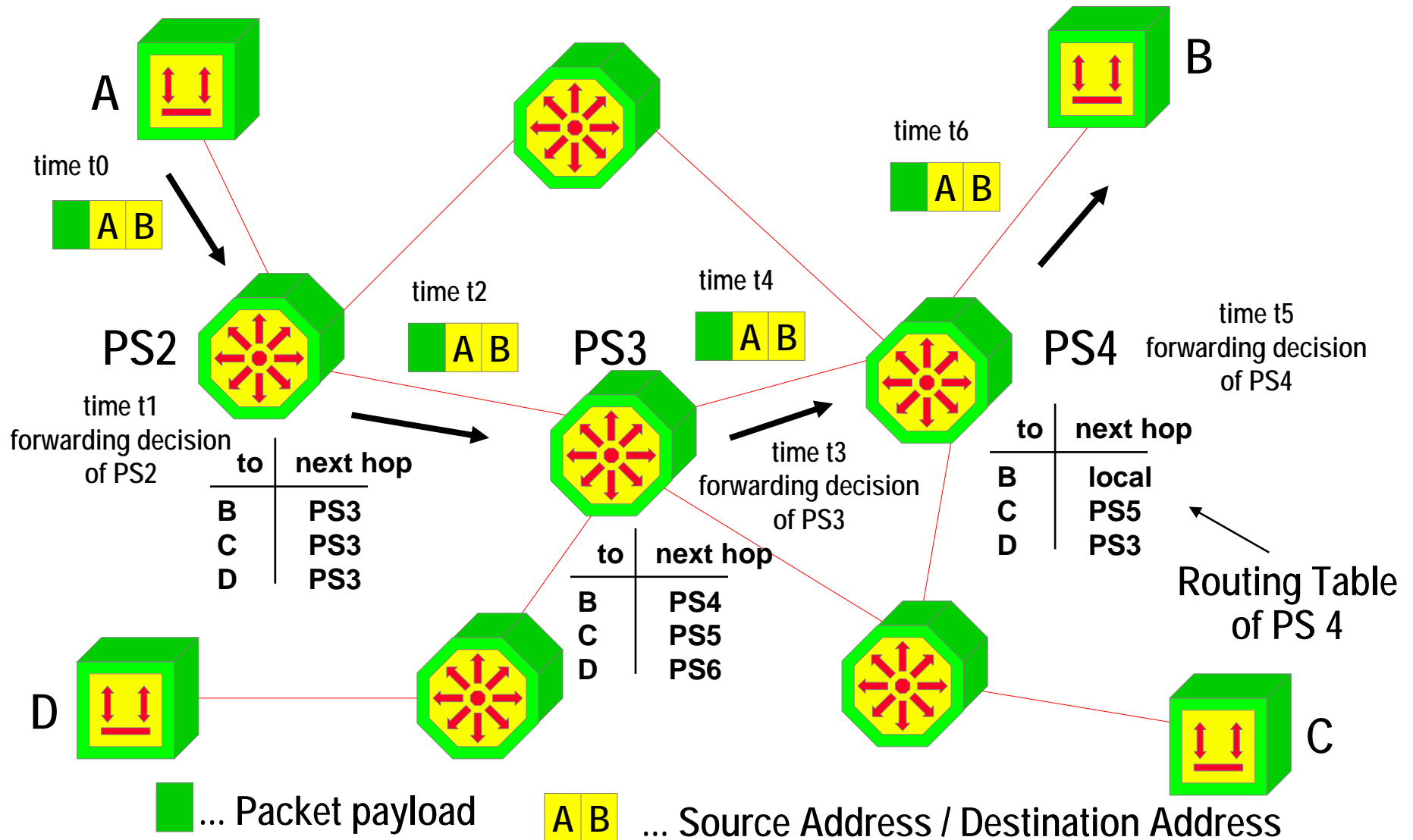


- **Packet switching technology**
  - ◆ Packet switch = router = "**gateway**" (IETF terminology)
  - ◆ End system is called **IP host**
  - ◆ Layer 3 address (Structured)
- **Datagram Service**
  - ◆ Connectionless
  - ◆ Best effort delivery

# Packet Switching Principle

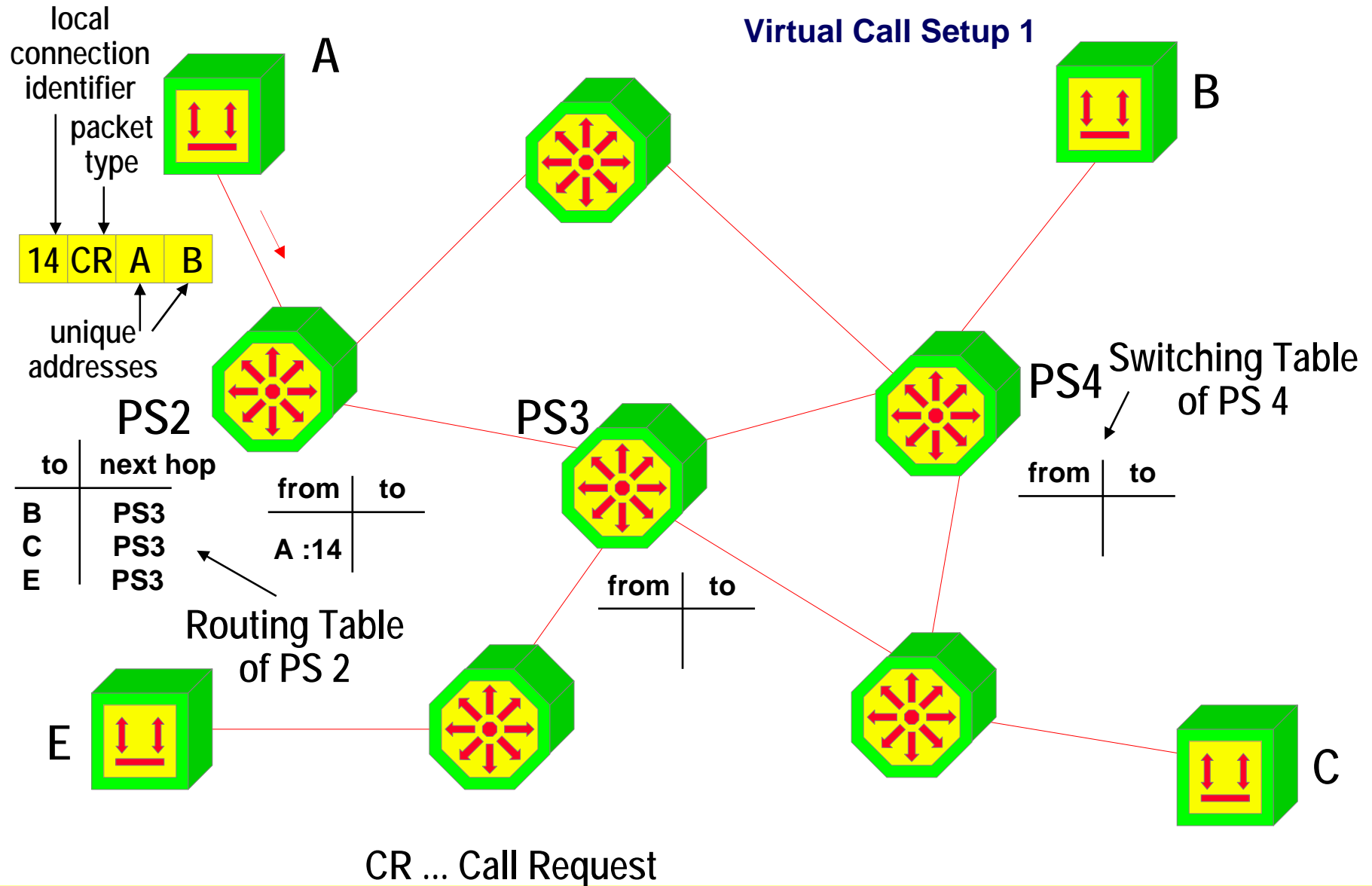


# IP packet forwarding is based on routing tables only (Connectionless PS, Best-Effort Service, Datagram Service)

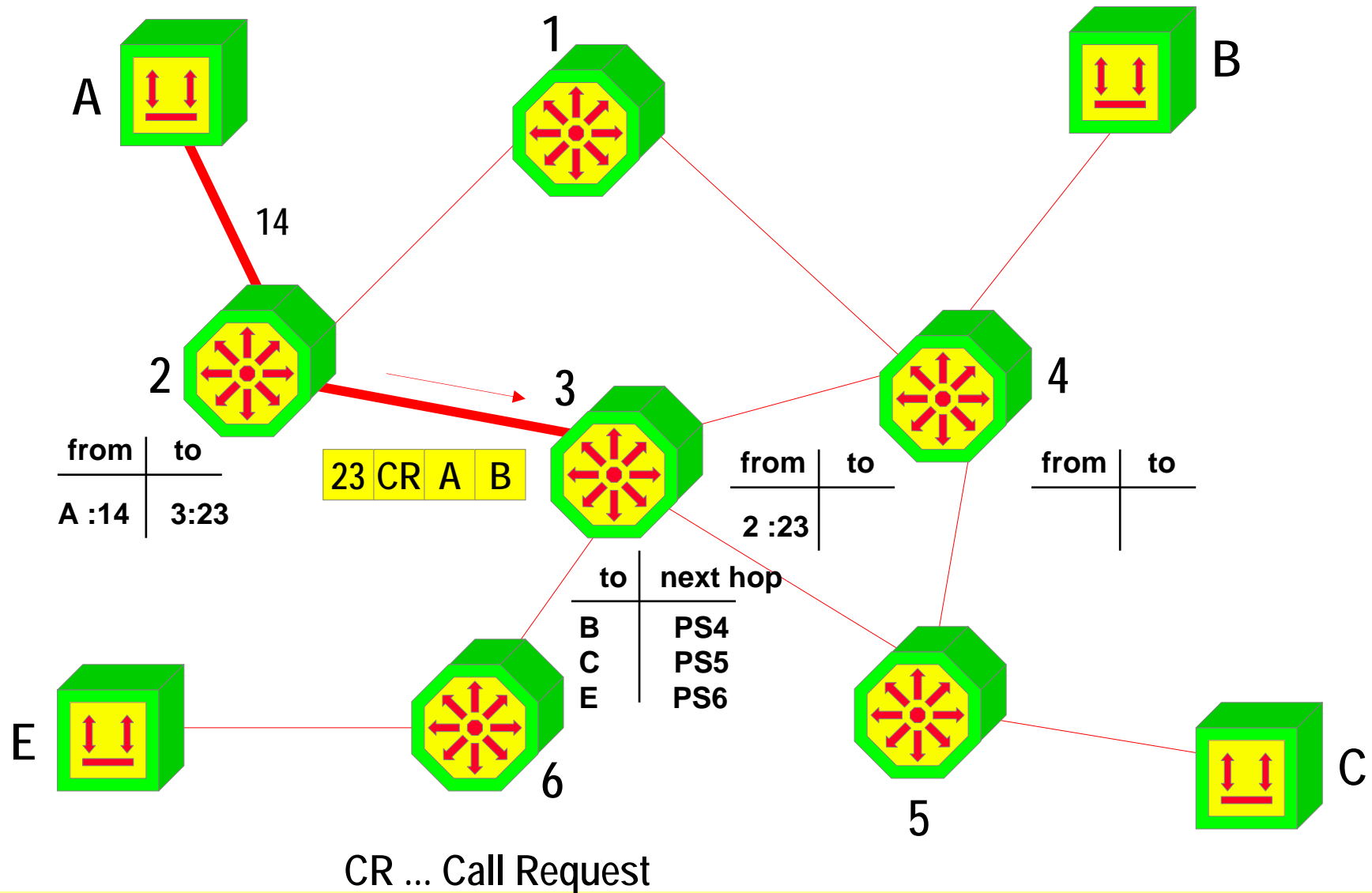




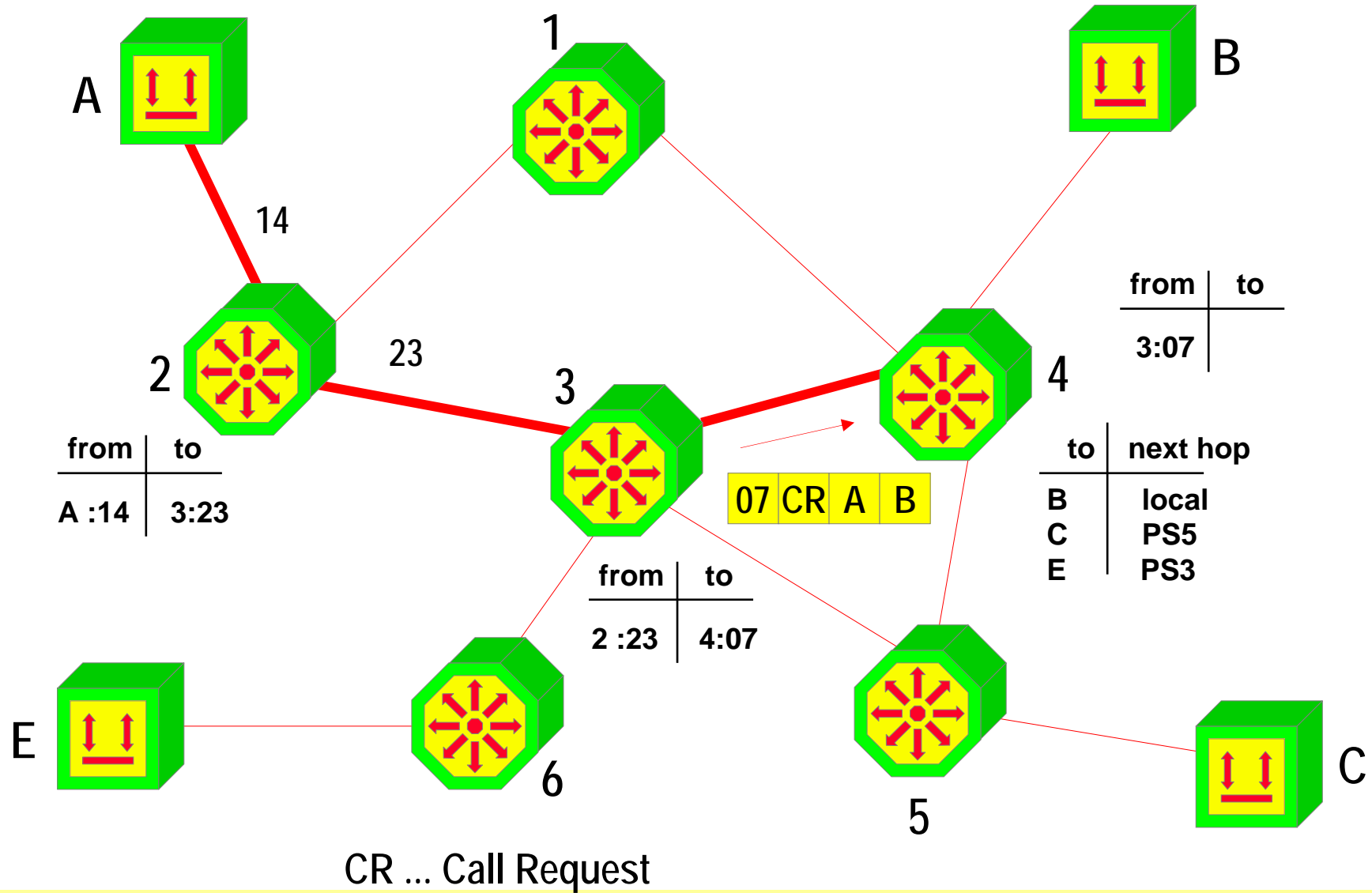
# X.25/FR/ATM packet forwarding is based on X25/FR/ATM switching tables; but call-setup uses routing tables (Connection Oriented PS, Virtual Call Service)



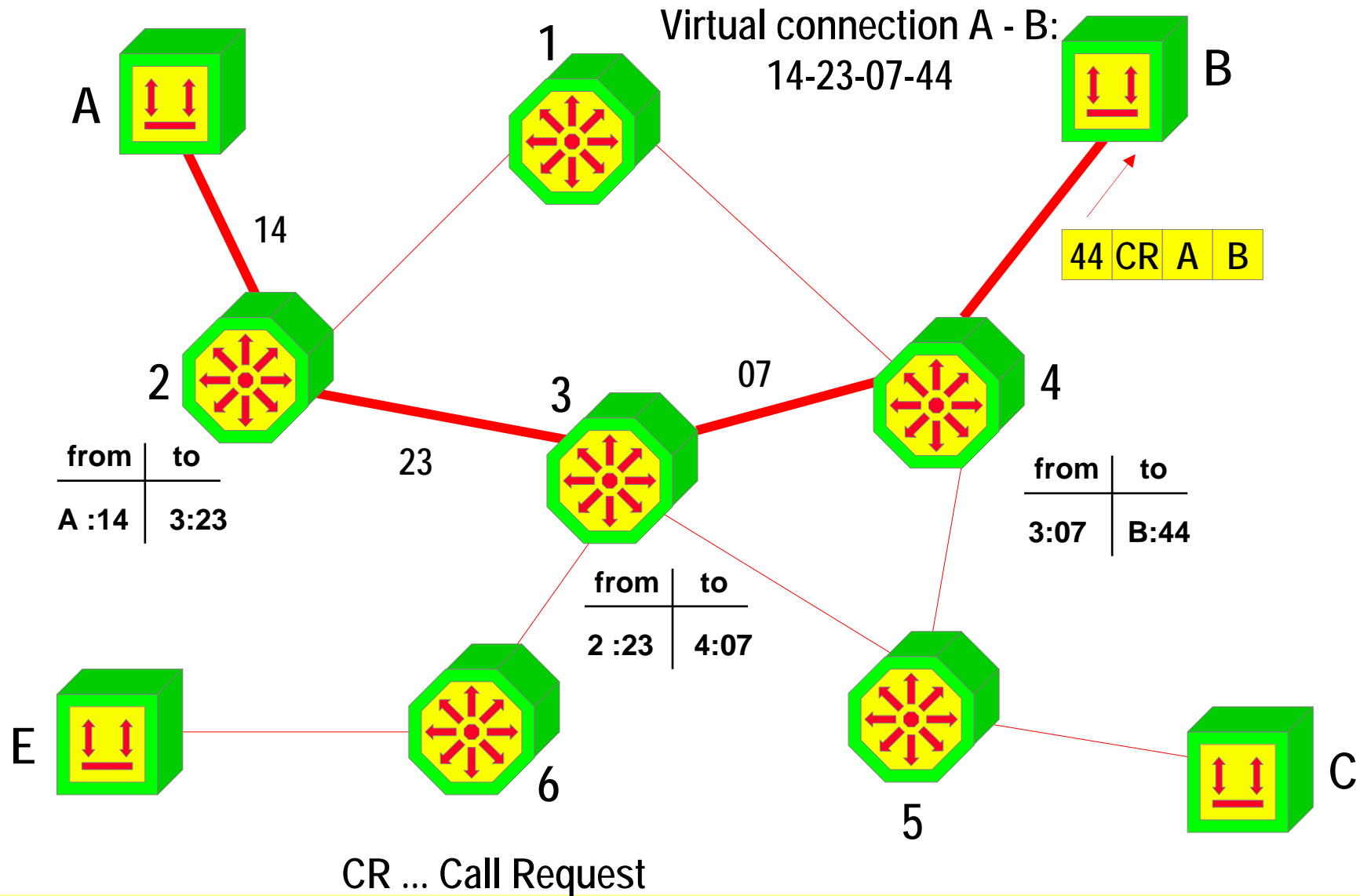
# Virtual Call Setup 2



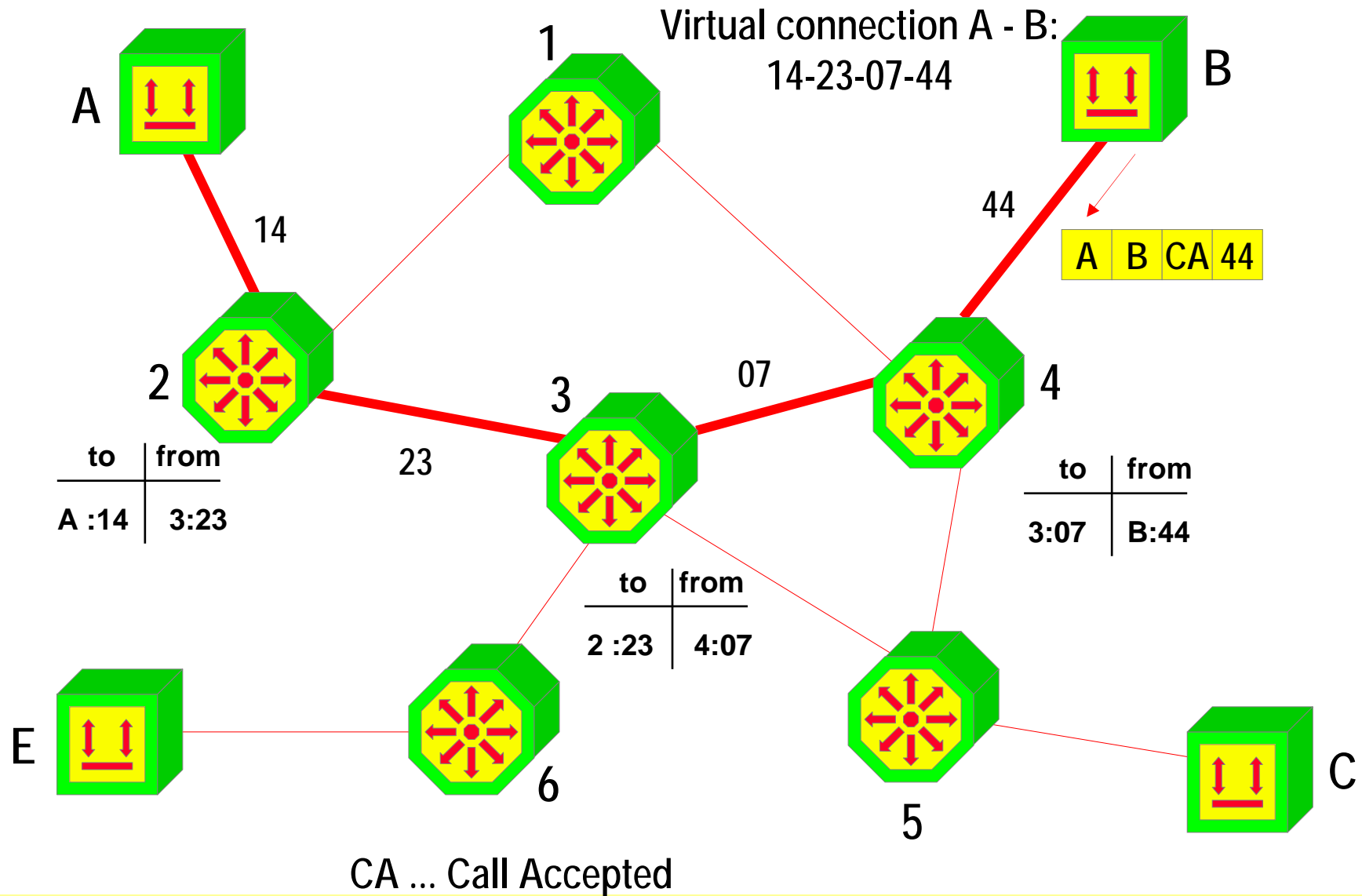
# Virtual Call Setup 3



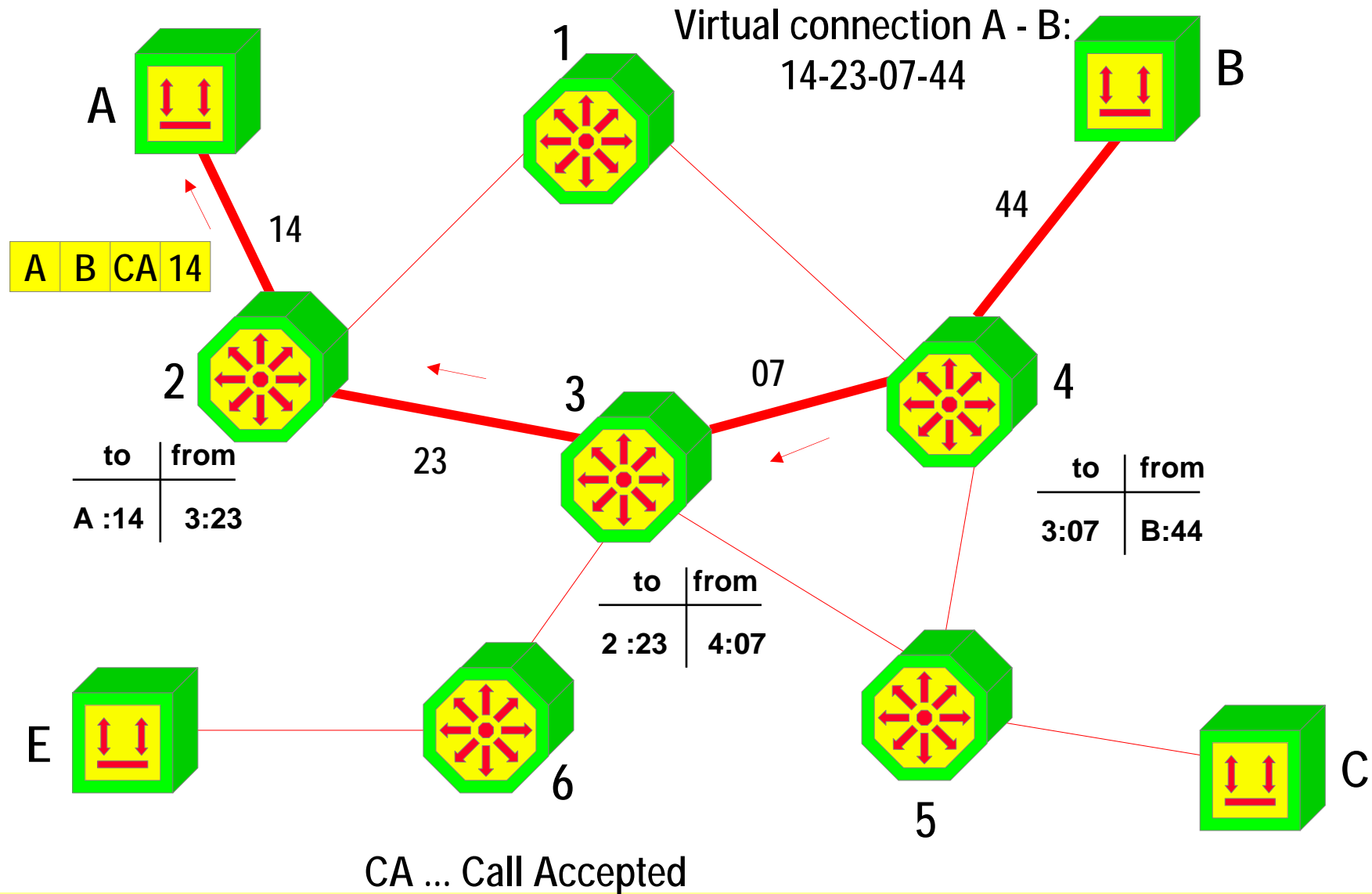
# Virtual Call Setup 4



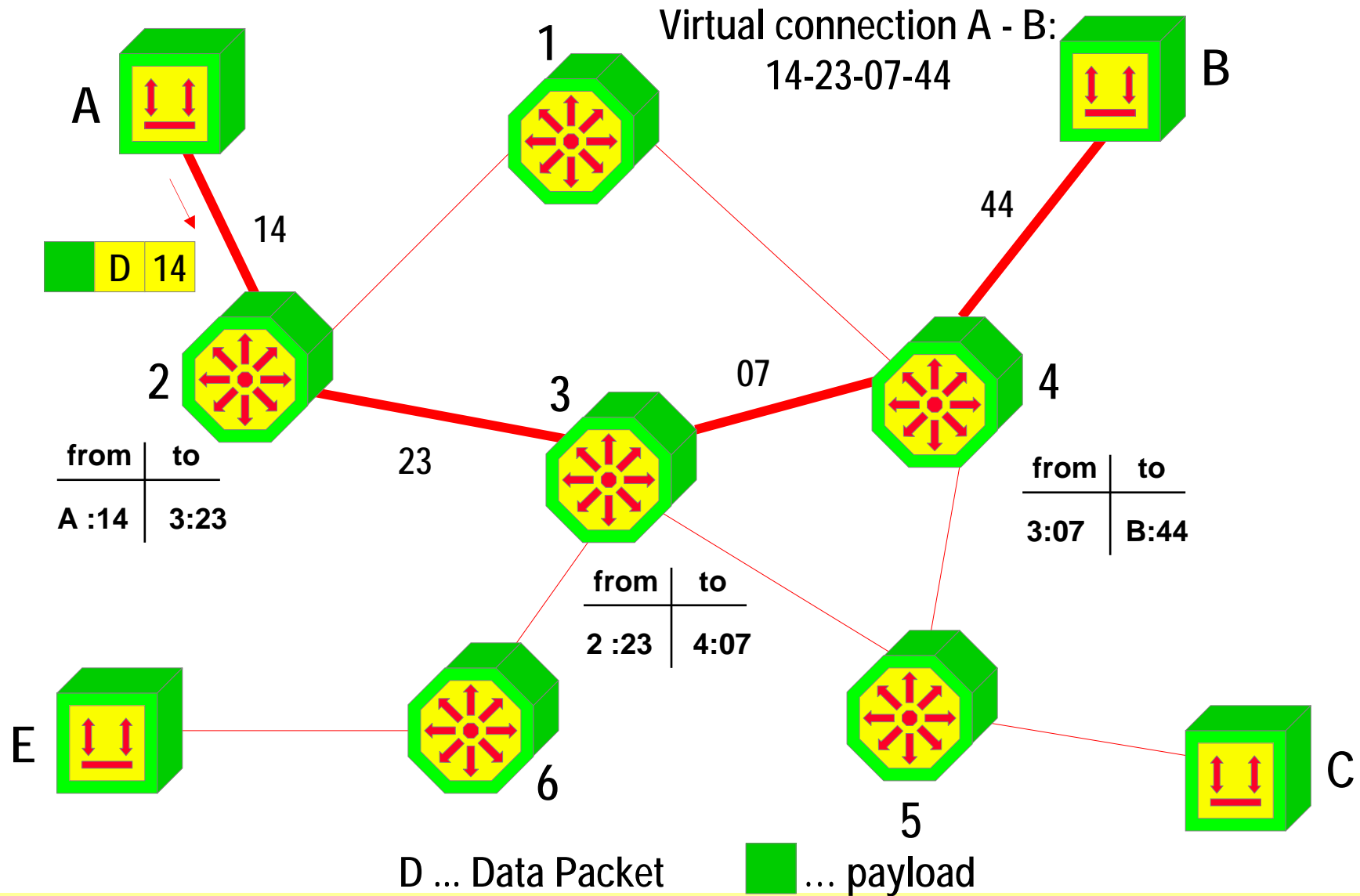
# Virtual Call Setup 5



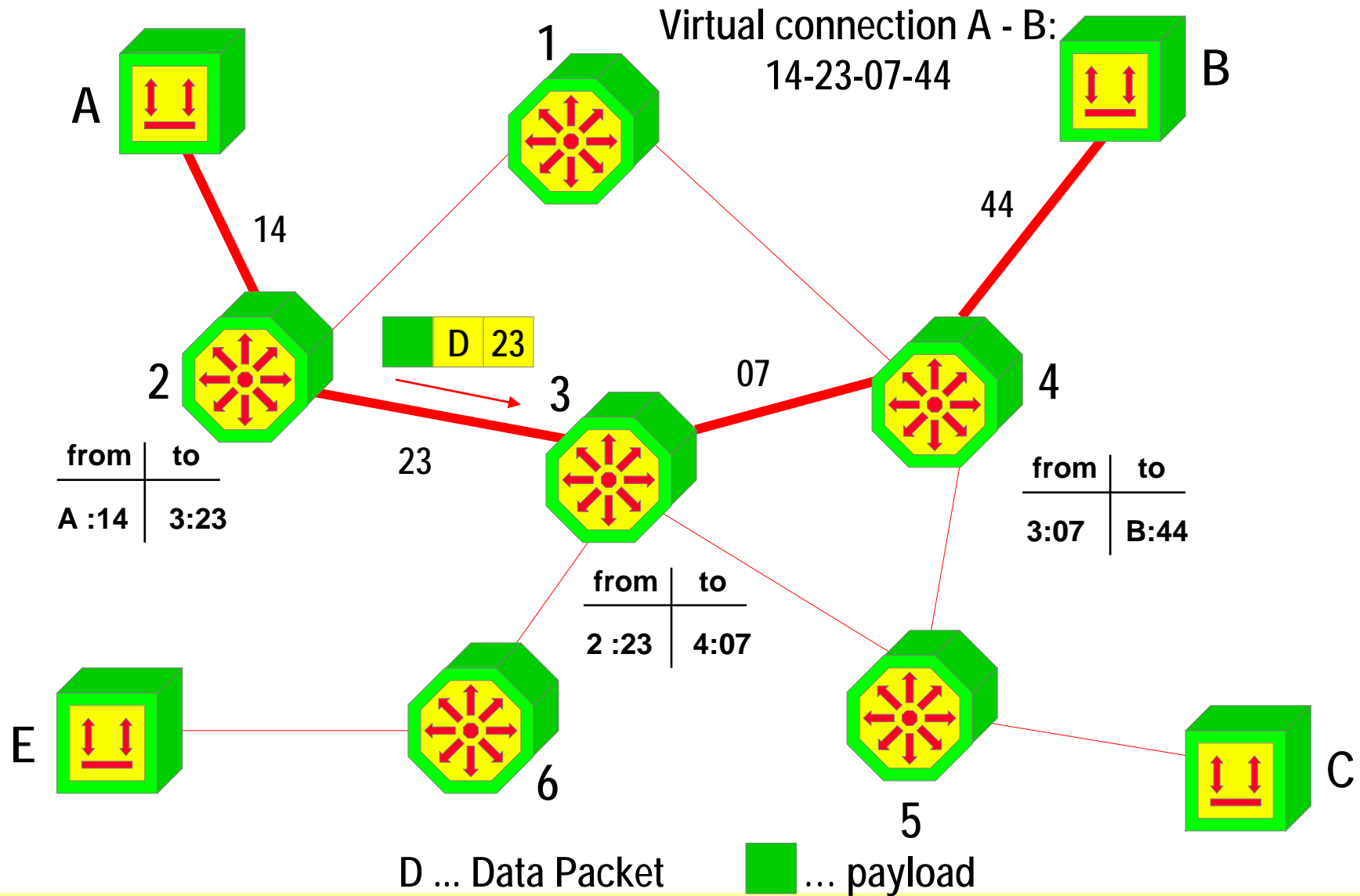
# Virtual Call Setup 6



# Data Transfer 1

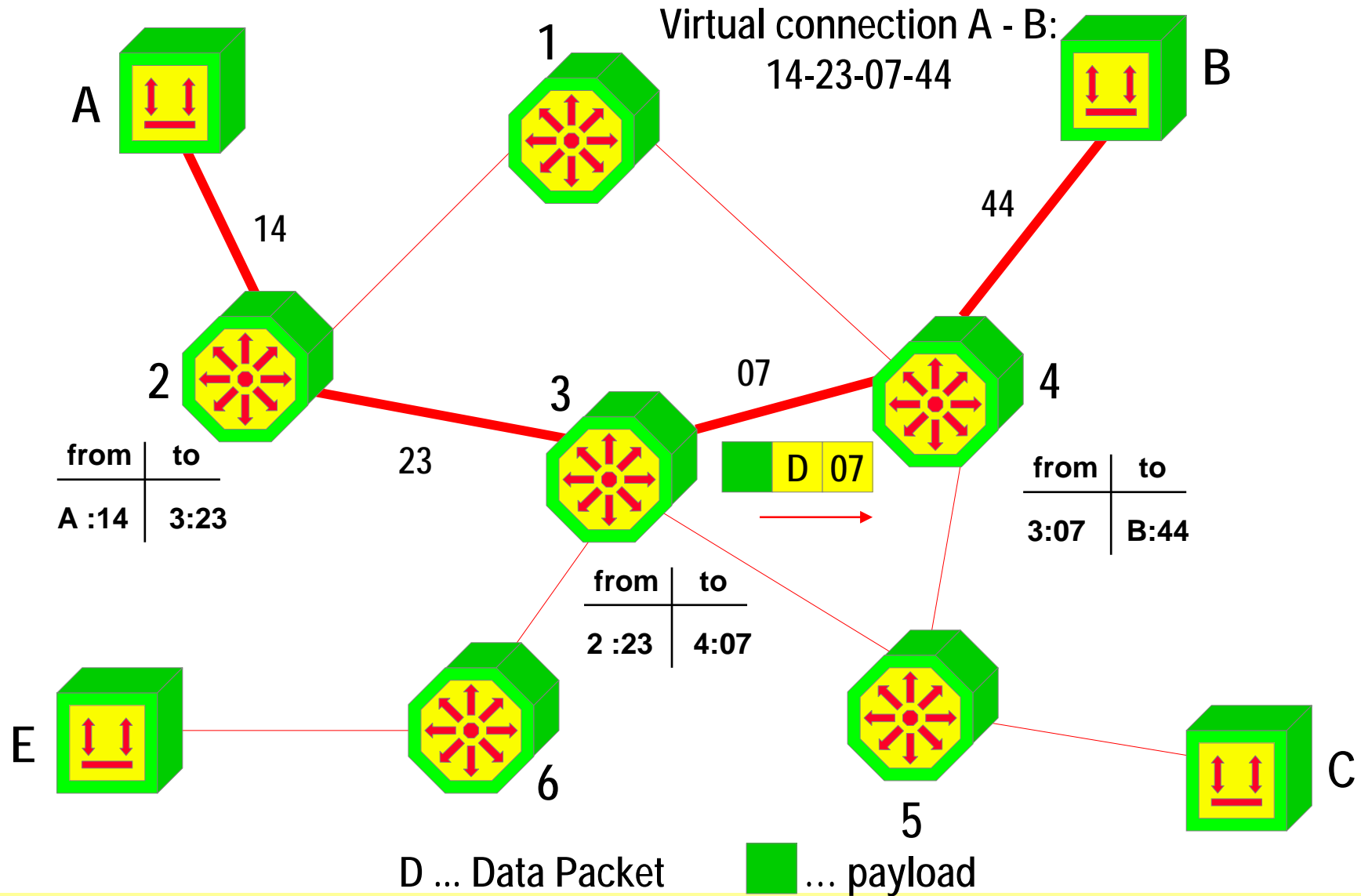


# Data Transfer 2

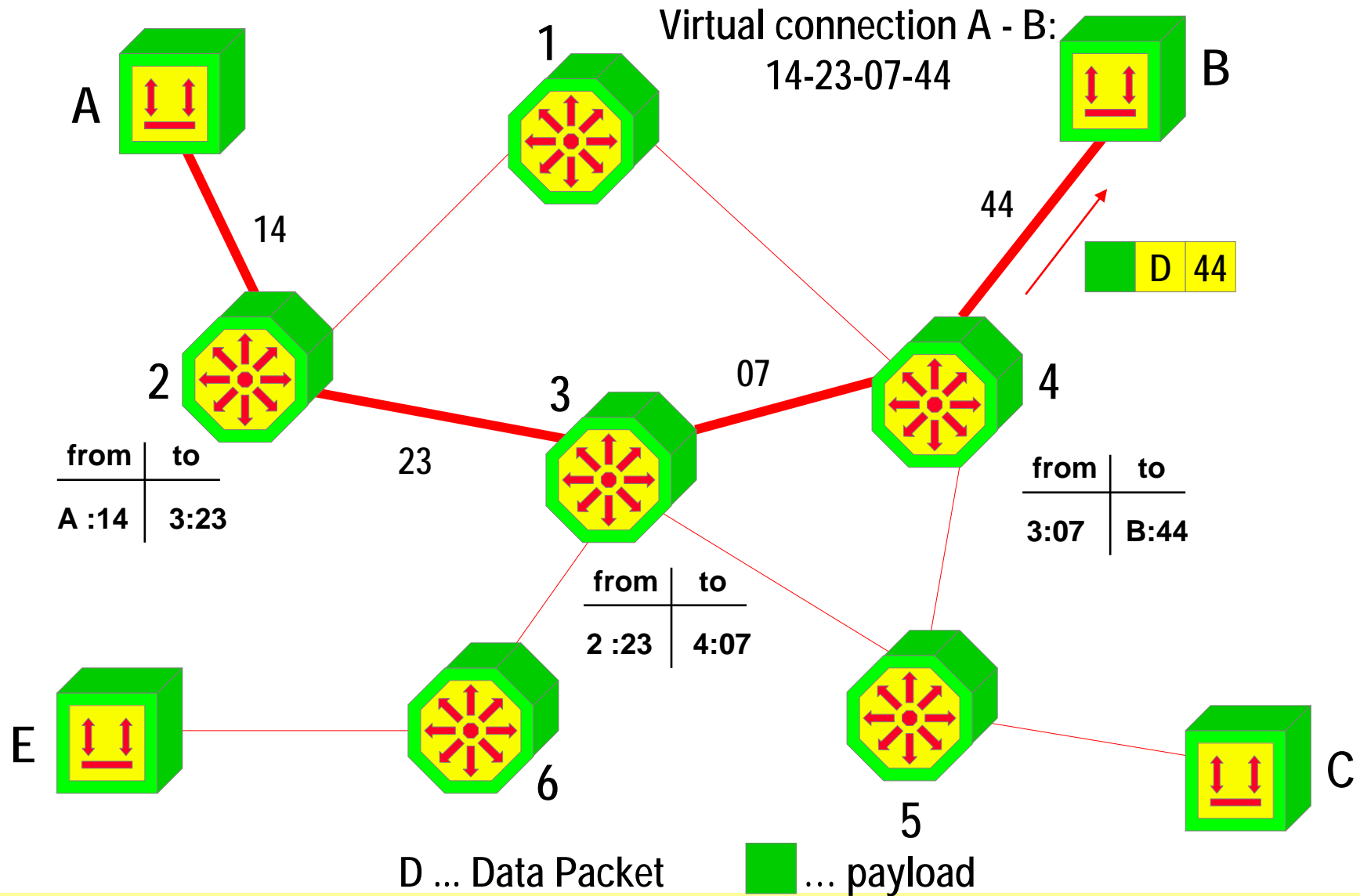




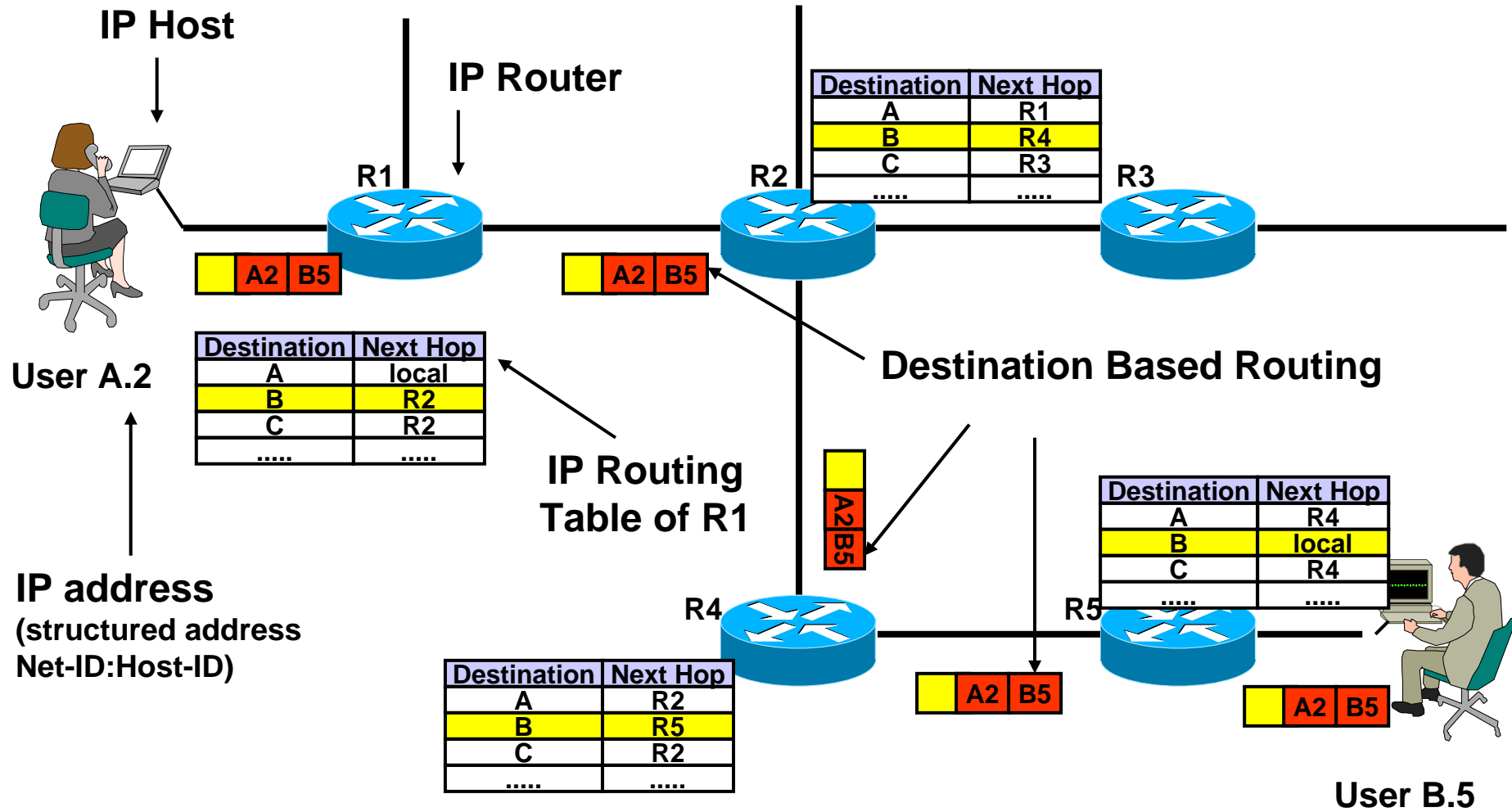
# Data Transfer 3



# Data Transfer 4



# IP Datagram Service



# IP Introduction (2)

---

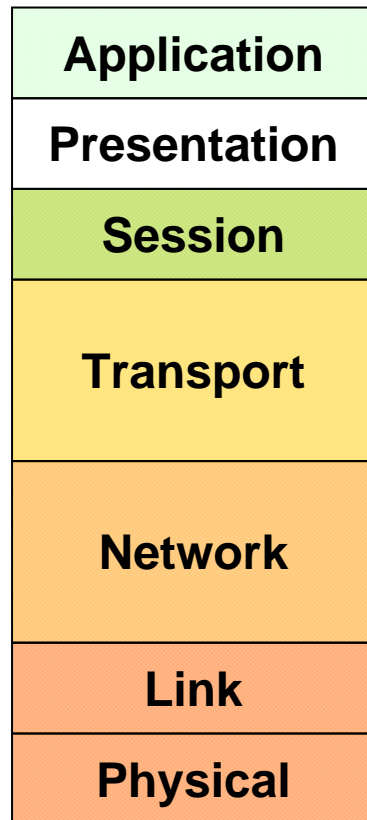


- **Shared responsibility**
  - ◆ Both network and hosts must take care for delivery (!)
  - ◆ Routers deliver datagrams to remote hosts based on IP address
  - ◆ Hosts responsible for end-to-end control
- **End-to-end control relies on TCP**
  - ◆ Layer 4

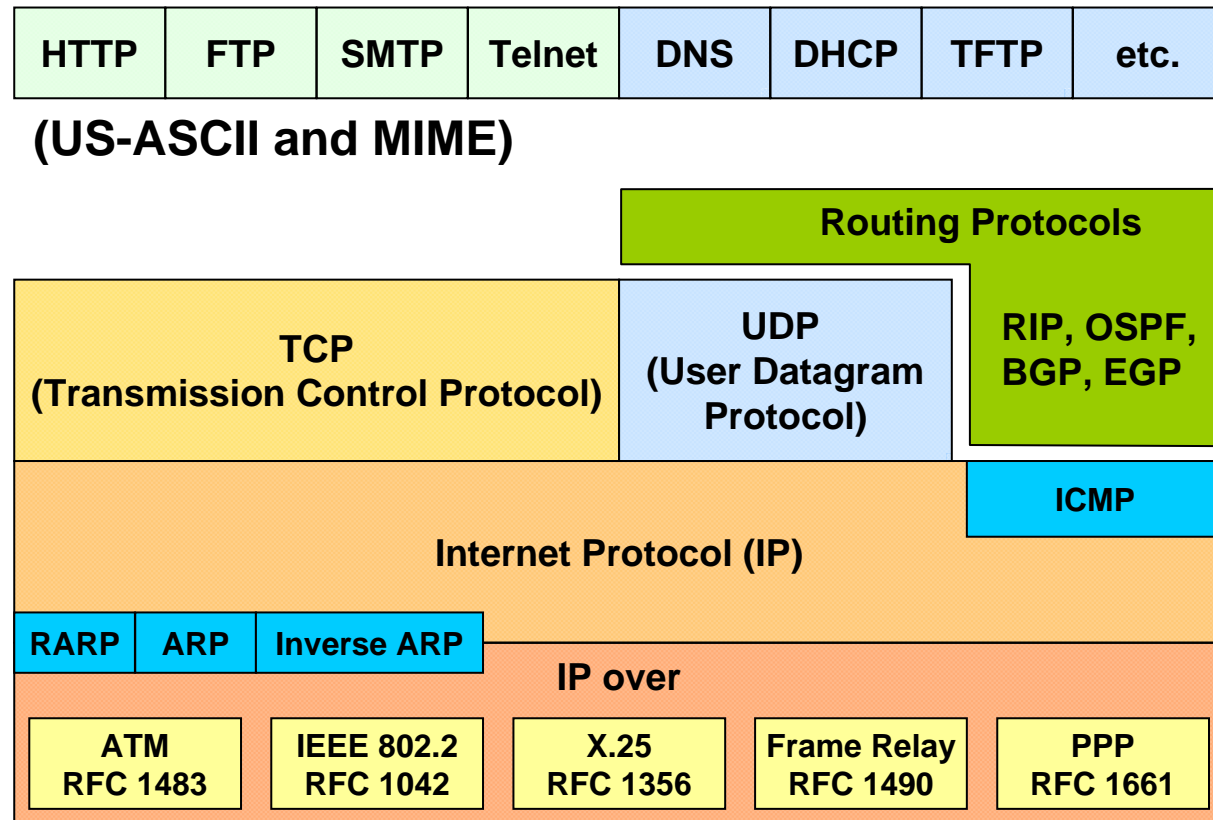
# IP Introduction (3)



**OSI  
7 Layer Model**



**TCP/IP Protocol Suite**



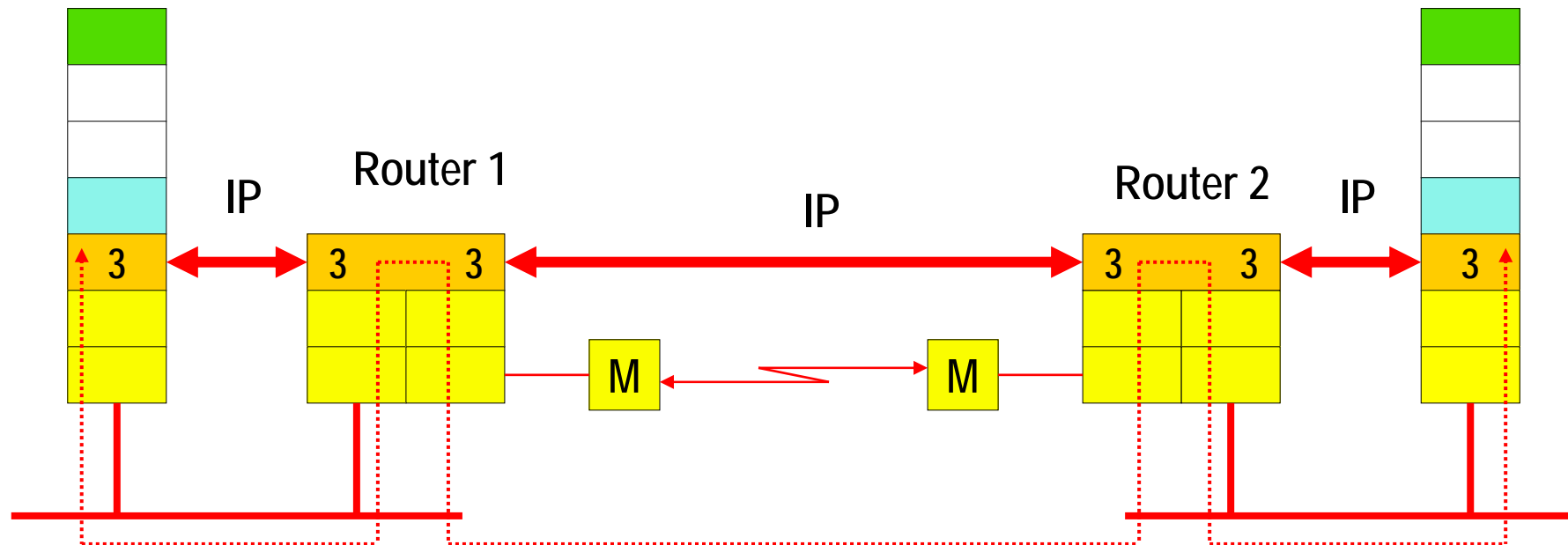
# IP and OSI Network Layer 3

Layer 3 Protocol = IP

Layer 3 Routing Protocols = RIP, OSPF, EIGRP, BGP

IP Host A

IP Host B



# 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**



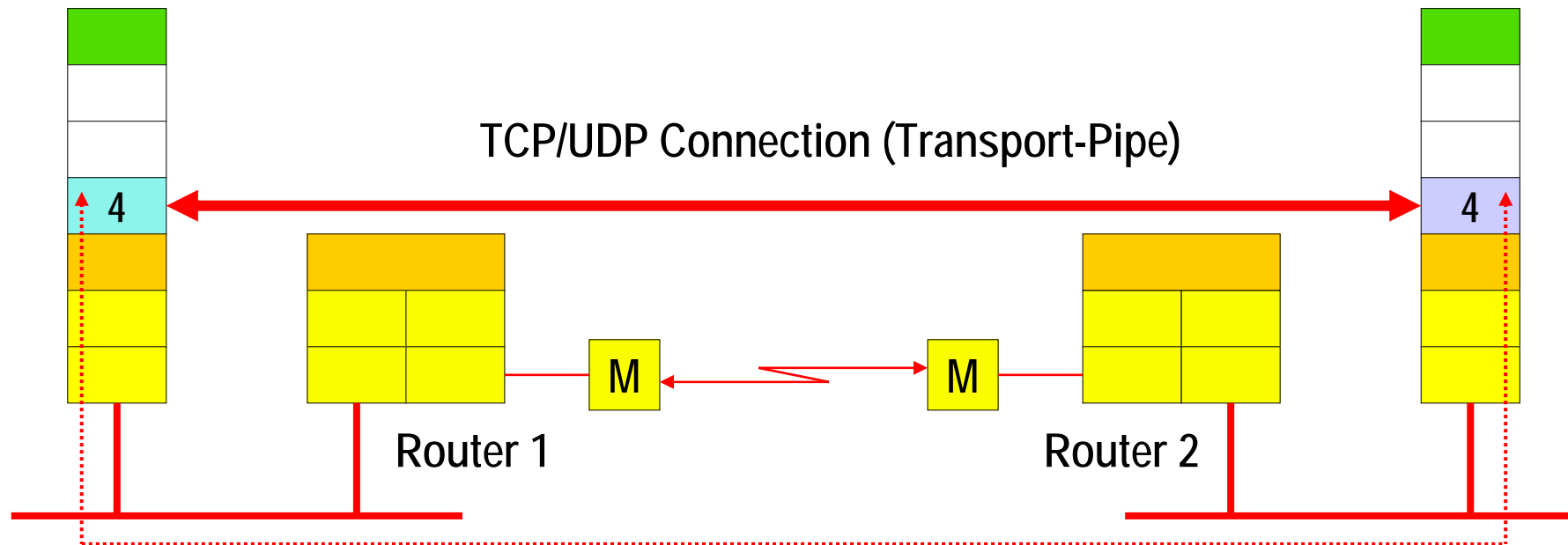
# TCP/UDP and OSI Transport Layer 4

Layer 4 Protocol = TCP (Connection-Oriented)

Layer 4 Protocol = UDP (Connectionless)

IP Host A

IP Host B



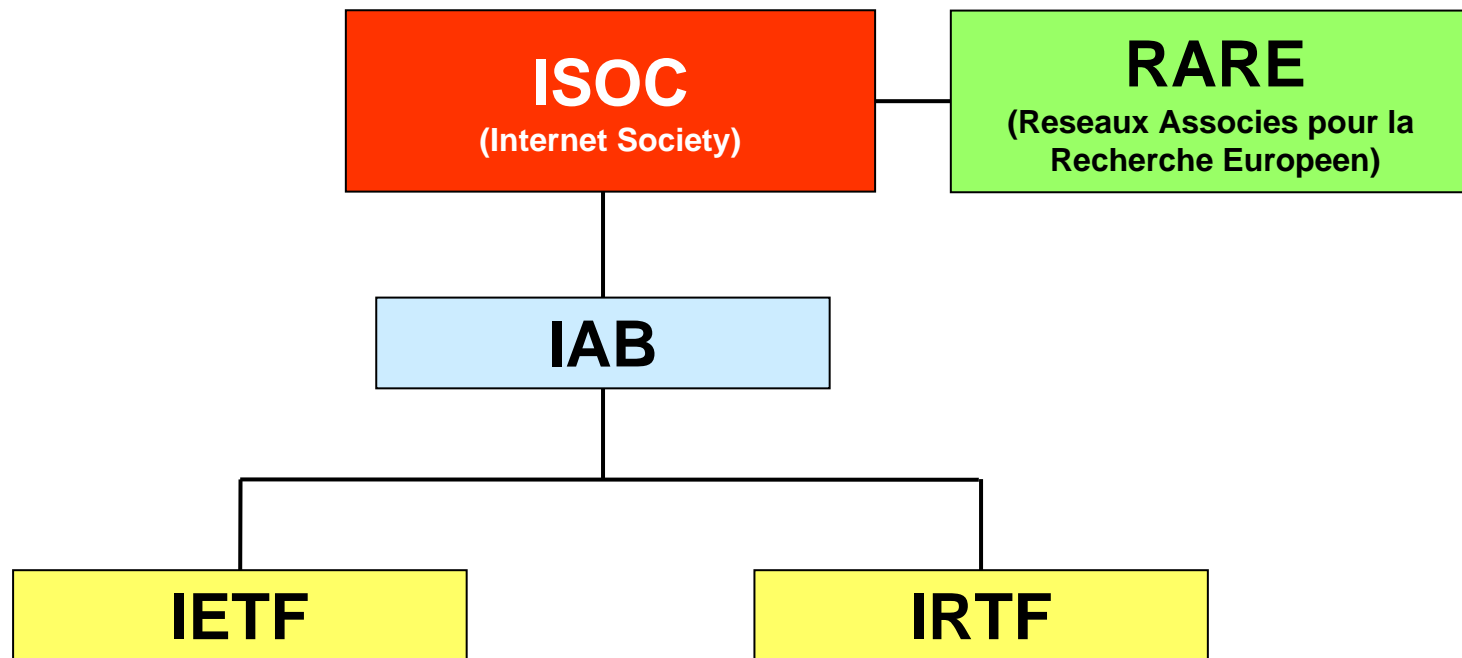
# IP Introduction (6)

---

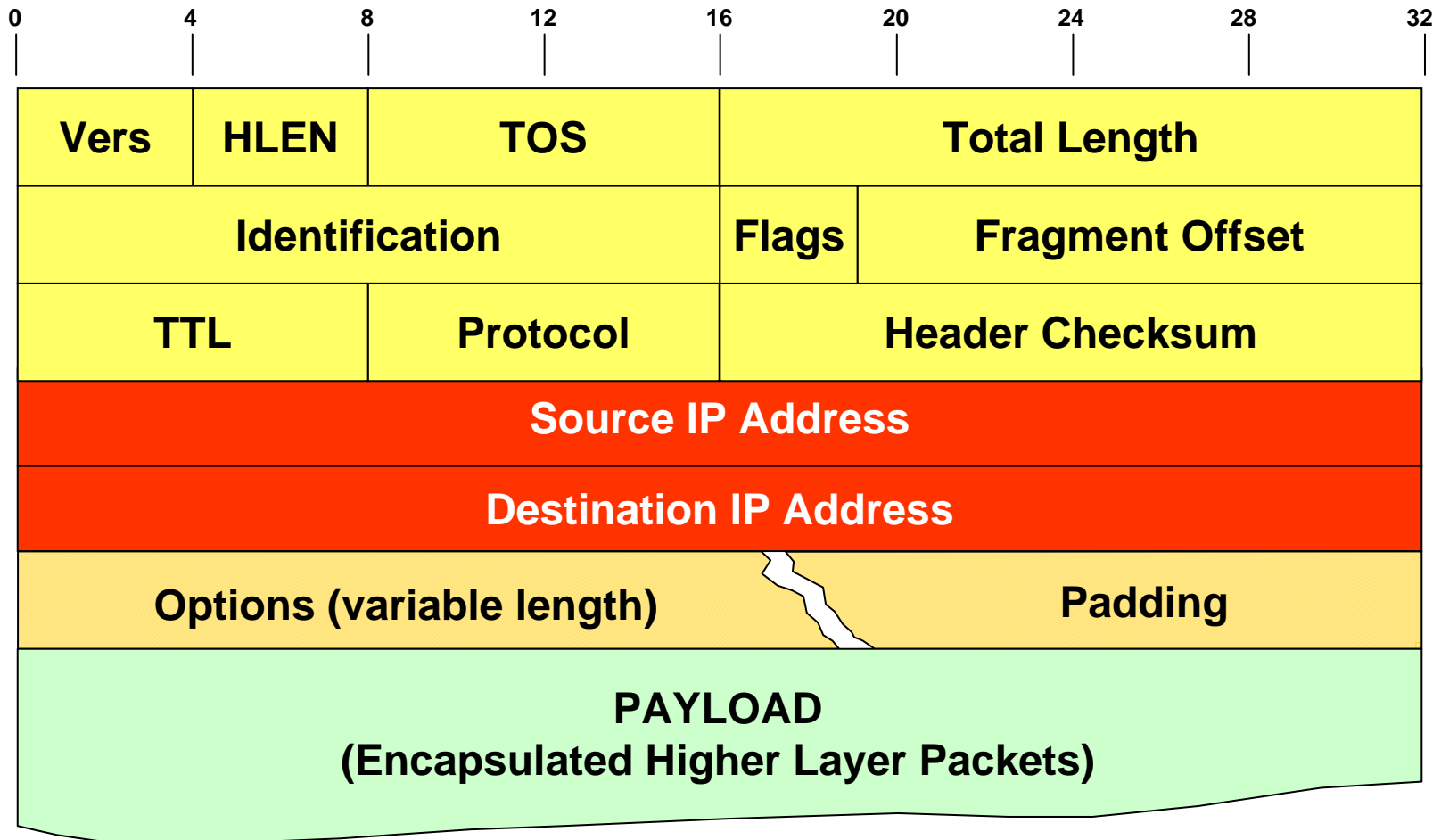


- **Request for Comments (RFCs)**
  - ◆ **De facto standards for the Internet**
  - ◆ **Initially posted by snail mail**
  - ◆ **IETF (Internet Engineering Task Force) reviews and confirms them**
  - ◆ **RFCs are numbered in sequence of publishing**
  - ◆ **Everybody may write an RFC (!)**

# Internet Organizations



# The IP Header (Address Fields)



# The IP Address

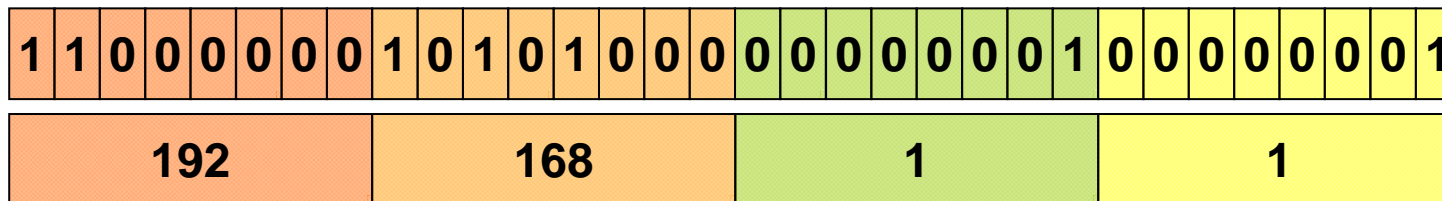


- **Dotted Decimal Notation**

Binary IP Address: 110000001010100000000100000001

Decimal Value: 3232235777

Decimal Representation *per byte*:



→ **192 . 168 . 1 . 1**

# IP Address Classes

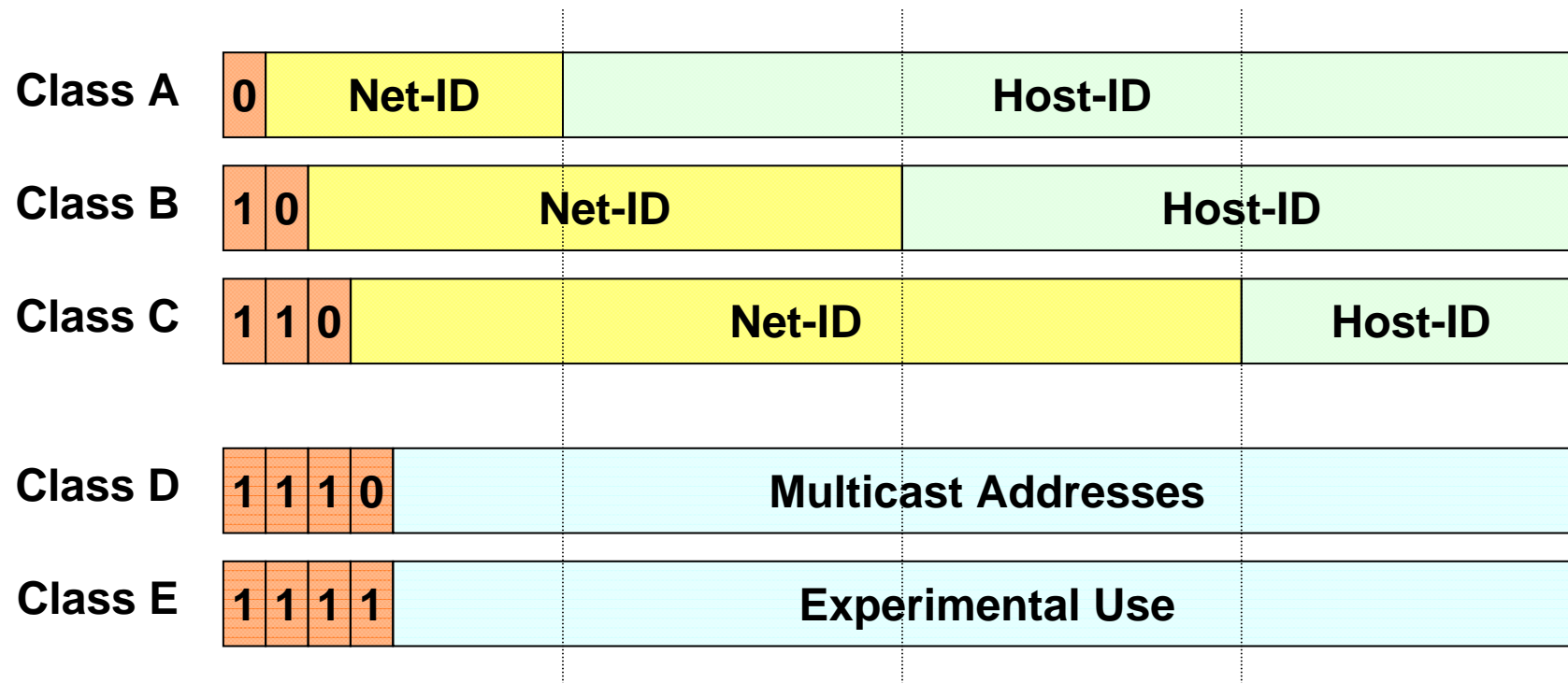


- **Net-ID? Host-ID?**
- **5 Classes defined!**
  - ◆ **A (1-127)**
  - ◆ **B (128-191)**
  - ◆ **C (192-223)**
  - ◆ **D (224-239, Multicast)**
  - ◆ **E (240-254, Experimental)**
- **Classes define number of address-bits for net-id**

# 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**)

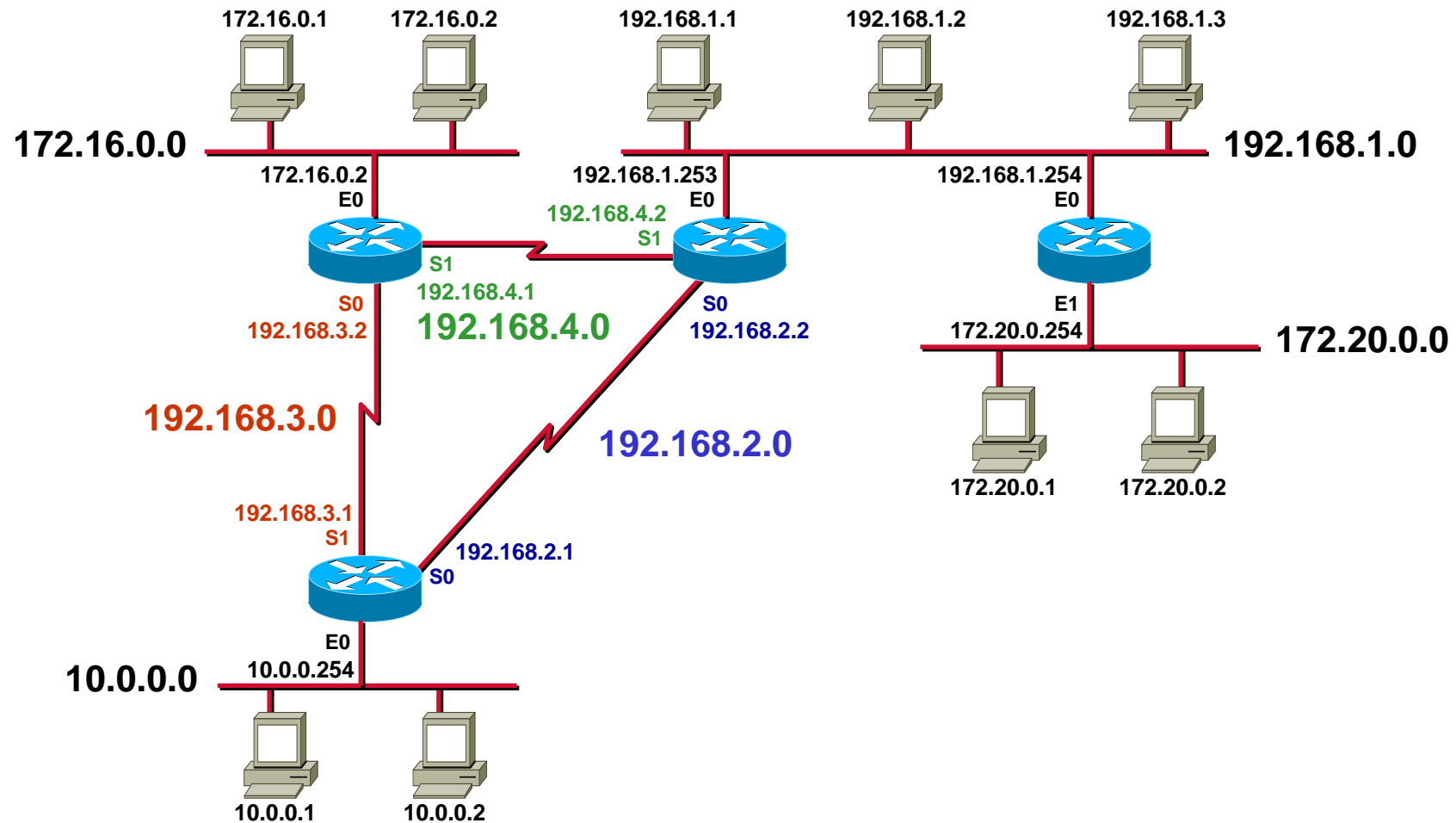


# Reserved Addresses

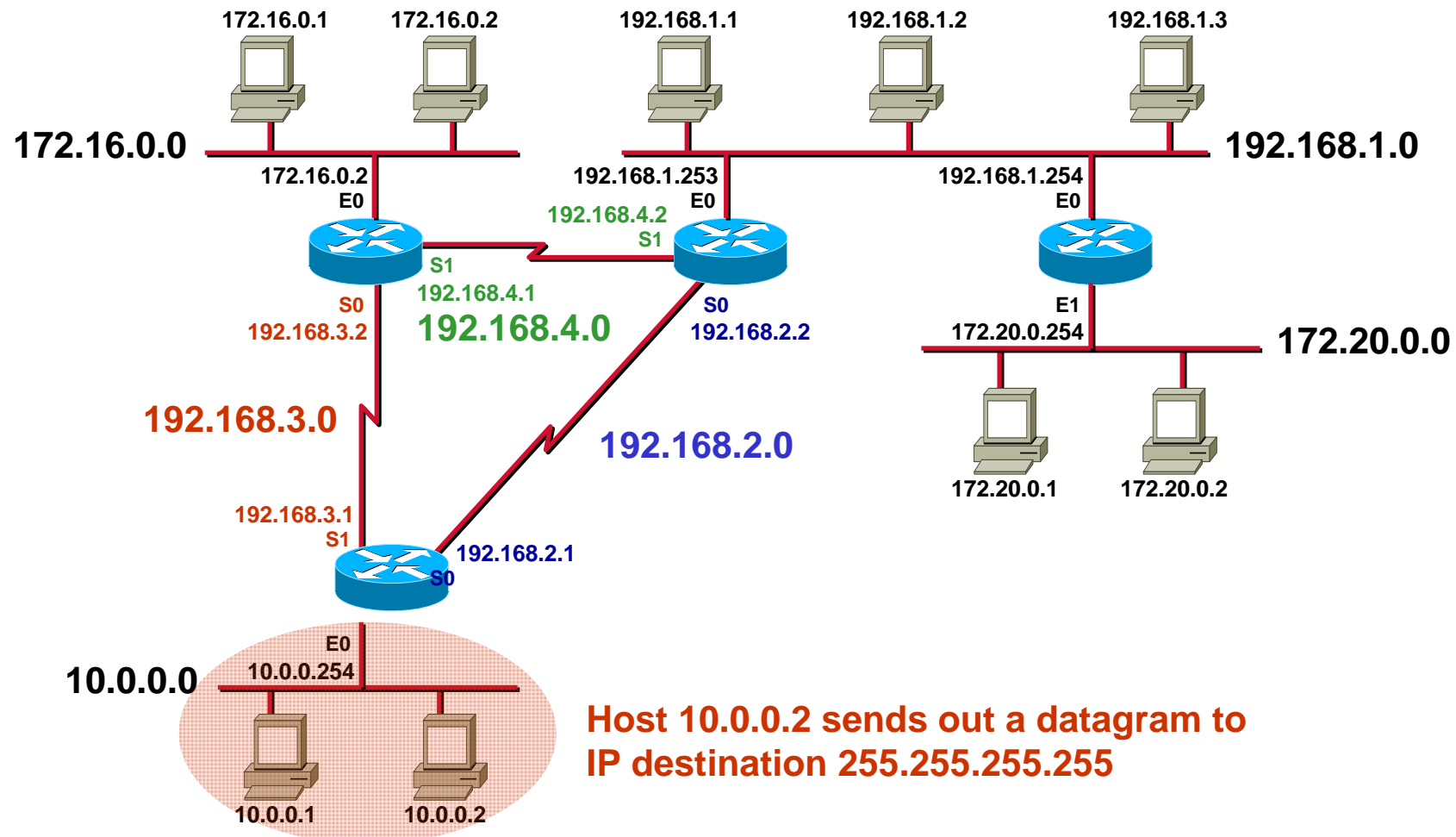


- Address range for **private use**
  - ◆ 10.0.0.0 - 10.255.255.255
  - ◆ 172.16.0.0 - 172.31.255.255
  - ◆ 192.168.0.0 - 192.168.255.255
- RFC 1918
- Network 127.x.x.x is reserved for "Loopback"

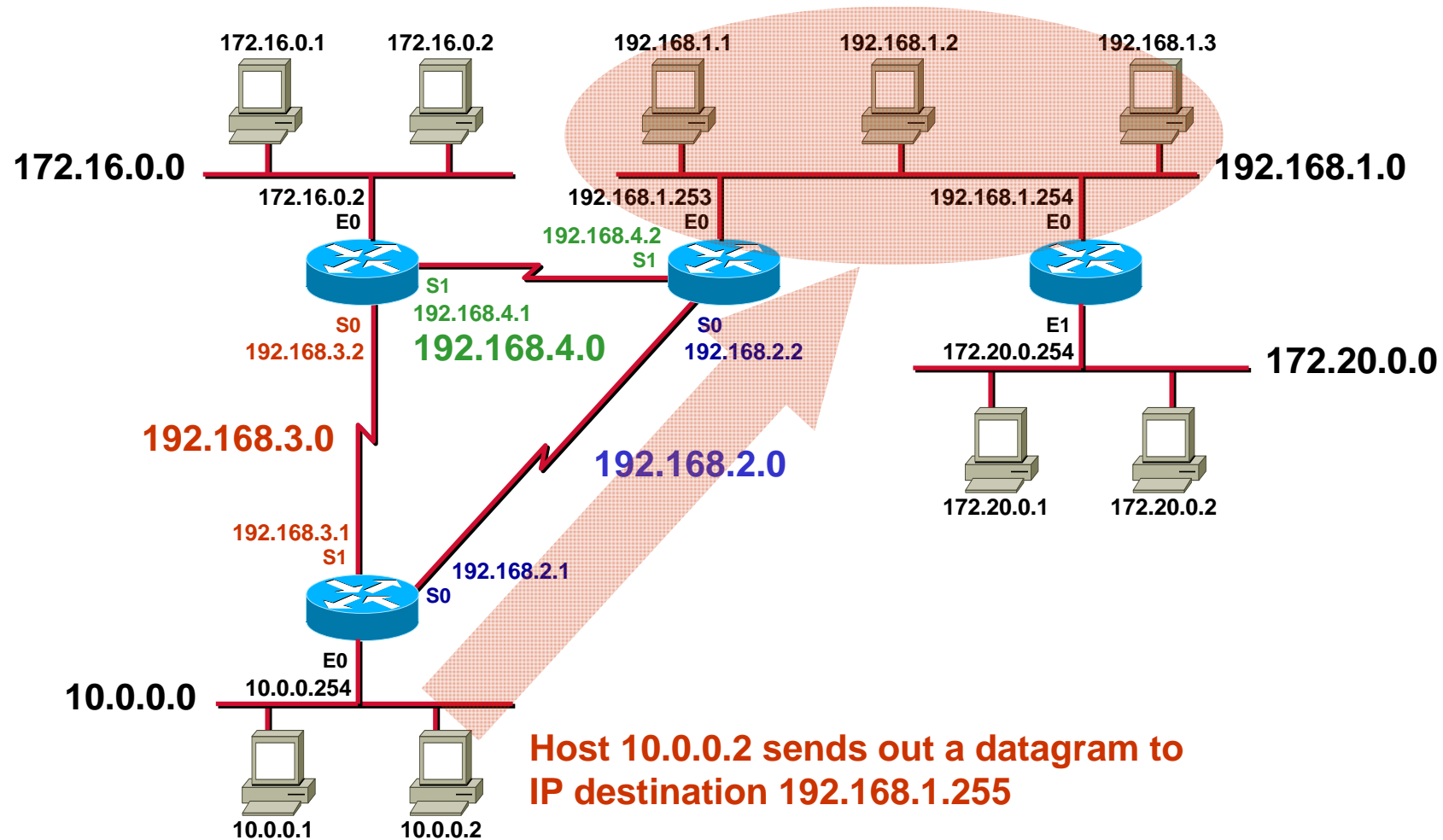
# Addressing Example



# IP Limited Broadcast



# IP Directed Broadcast



# Classful Address Waste



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

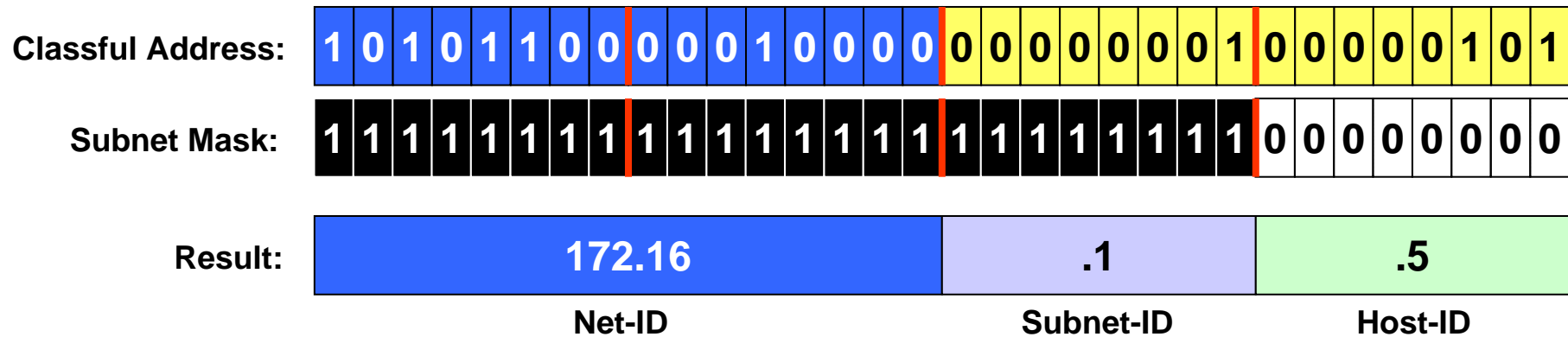
Network Number Statistics, April 1992 (Source: RFC 1335)

- **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



Class B Address: 172.16.1.5, Subnet Mask: 255.255.255.0



Alternative (newer) notation: 172.16.1.5 /24

# Subnet Zero / Subnet Broadcast



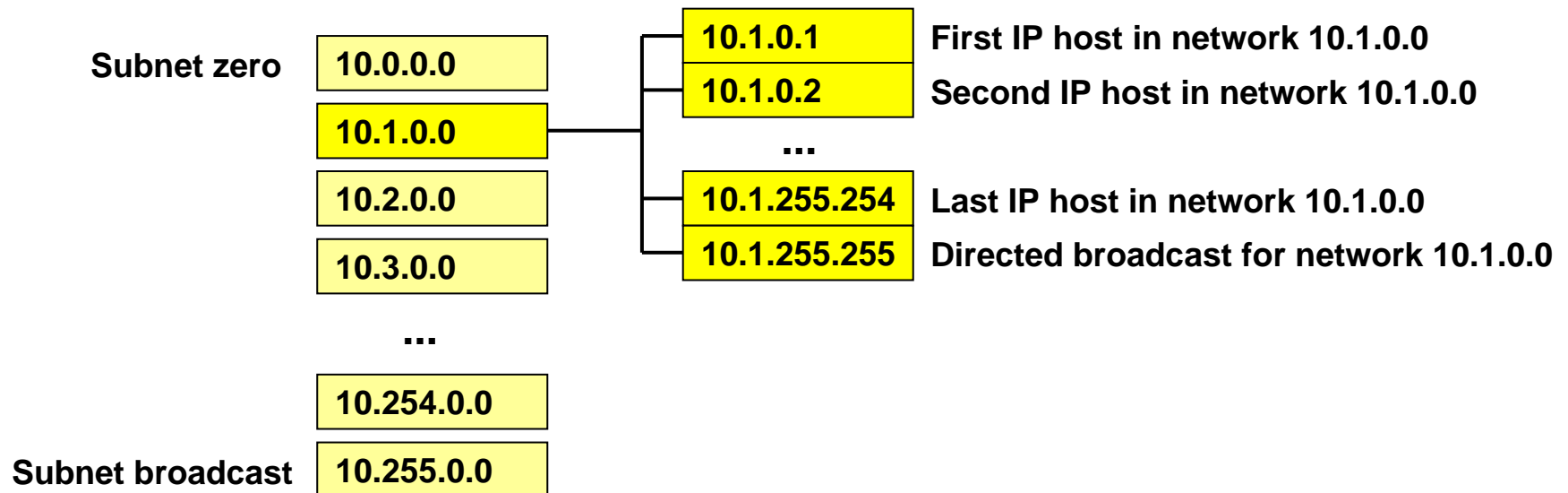
- **Consider network 10.0.0.0**
  - ◆ Is it a class A net "10" ?
  - ◆ Or do we have a subnet "10.0" ?
- **Consider broadcast 10.255.255.255**
  - ◆ Is it a directed broadcast for the whole net 10 ?
  - ◆ Or only for the subnet 10.255 ?
- **Subnet zero and subnet broadcast can be ambiguous!**

# 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:



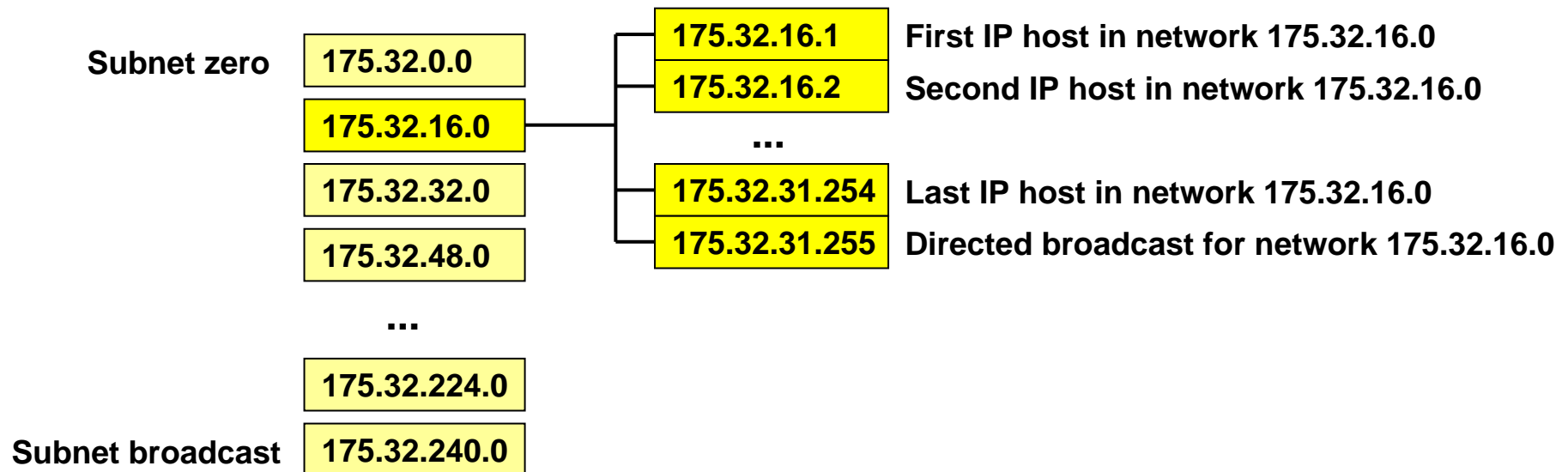


# Subnet Example 2



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

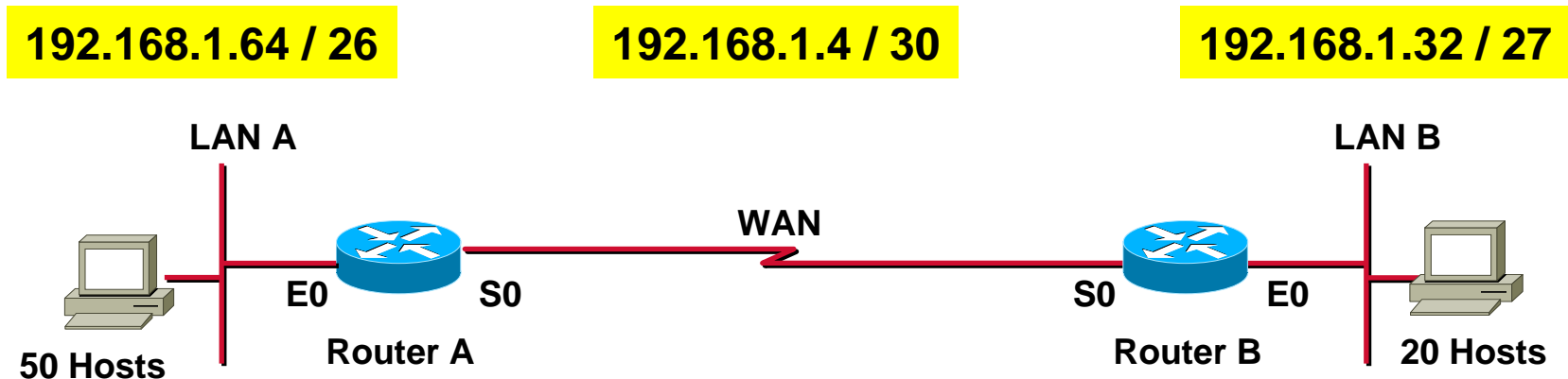
- 1) That is: 175.32.0.0 with 255.255.240.0 or 175.32.0.0/20
- 2) Resulting subnetworks:



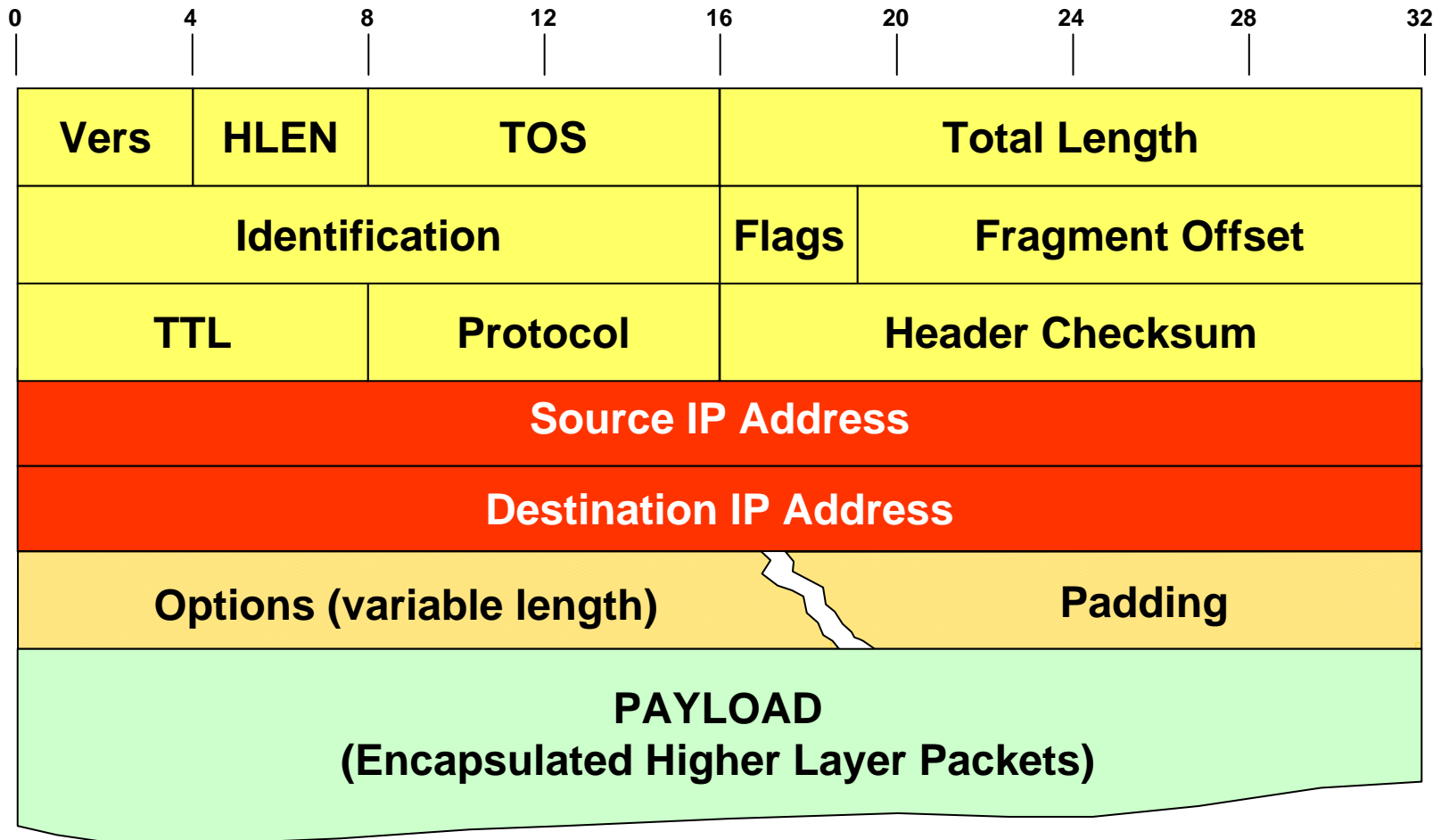
# Variable Length Subnetting (VLSM)



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



# The IP Header (Other Important Fields)



- **Version**

- Version of the IP protocol
- Current version is 4
- Useful for testing or for migration to a new version, e.g. "IP next generation" (IPv6)

- **HLEN**

- Length of the header in 32 bit words
- Different header lengths result from IP options
  - HLEN 5 to 15 = 20 to 60 octets

- **Total Length**

- Total length of the IP datagram (header + data) in octets
- If fragmented: length of fragment
- Datagram size max. = 65535 octets
- Each host has to accept datagram's of at least 576 octets
  - either as a complete datagram or for reassembly

- **Protocol**

- Indicates the higher layer protocols
  - Examples are: 1 (ICMP), 6 (TCP), 8 (EGP), 14(GRE),17 (UDP), 51 (IPsec AH), 50 (IPsec ESP), 89 (OSPF) etc.
- 100 different IP protocol types are registered so far

- **Source IP Address**

- IP address of the source (sender) of a datagram

- **Destination IP Address**

- IP address of the receiver (destination) of a datagram

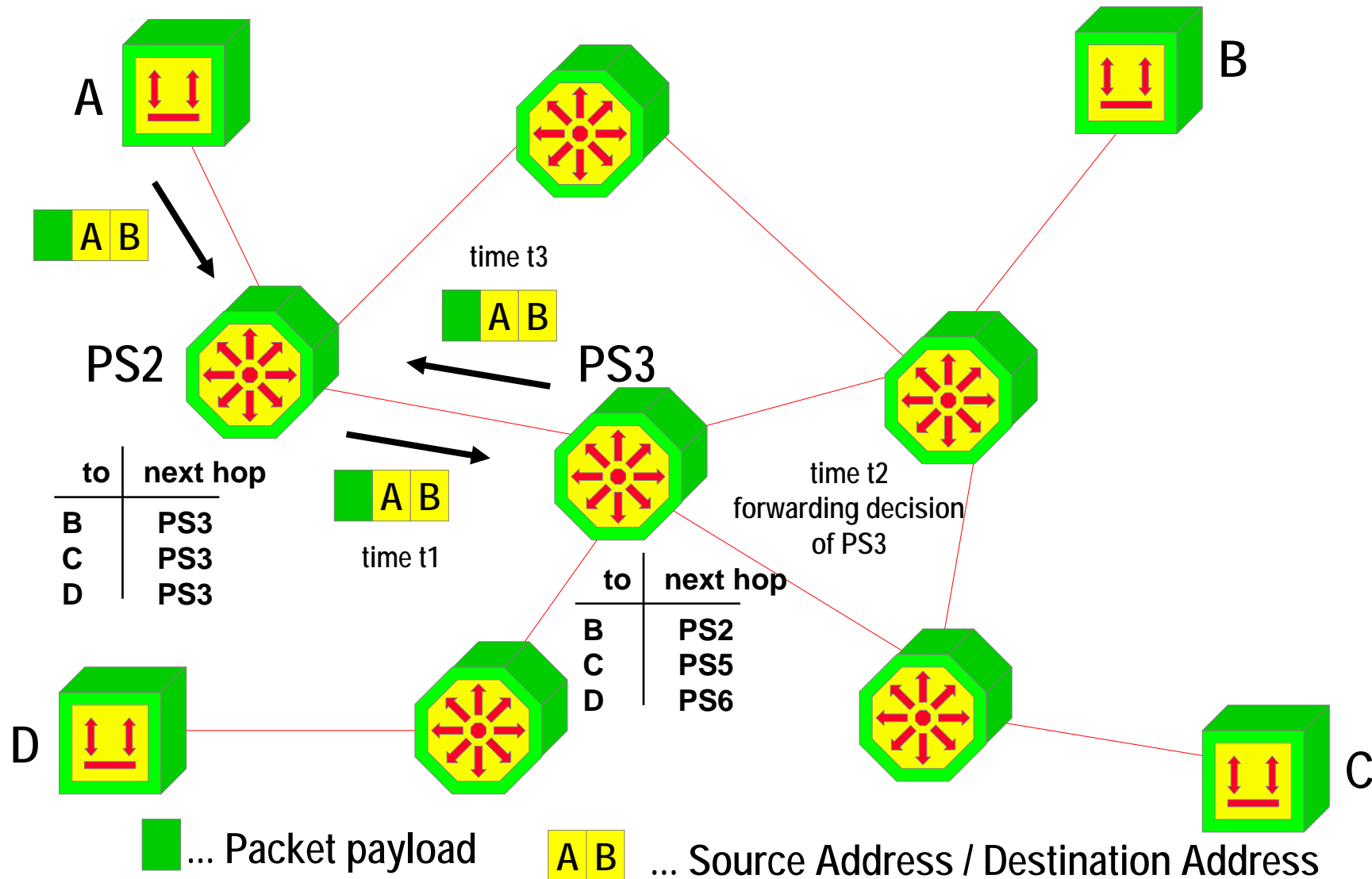
- **Pad**

- "0"-octets to fill the header to a 32 bit boundary

- **TTL Time To Live**

- Limits the lifetime of a datagram in the network (Units are seconds, range 0-255)
- Is set by the source to a starting value. 32 to 64 are common values, the current recommended value is 64 (RFC1700)
- Every router decrements the TTL by the processing/waiting time. If the time is less than one second, TTL is decremented by one ("TTL = hop count").
- If TTL reaches 0, the datagram (fragment) is discarded.
- An end system can use the remaining TTL value of the first arriving fragment to set the reassembly timer.

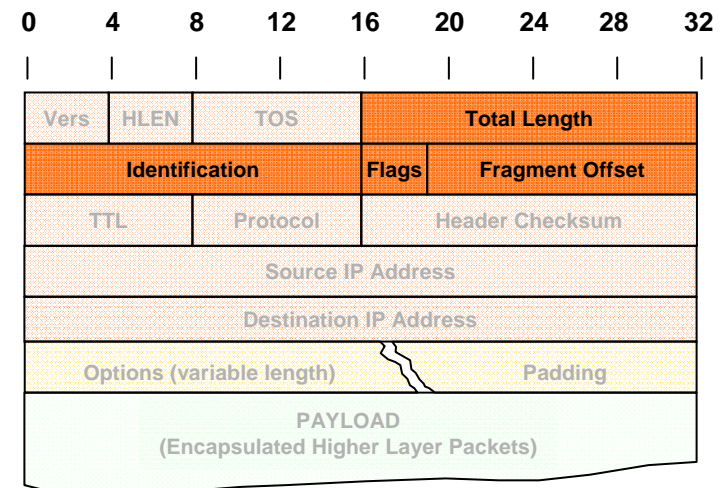
# IP datagram forwarding needs a kill-mechanism to overcome inconsistent routing tables



# 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



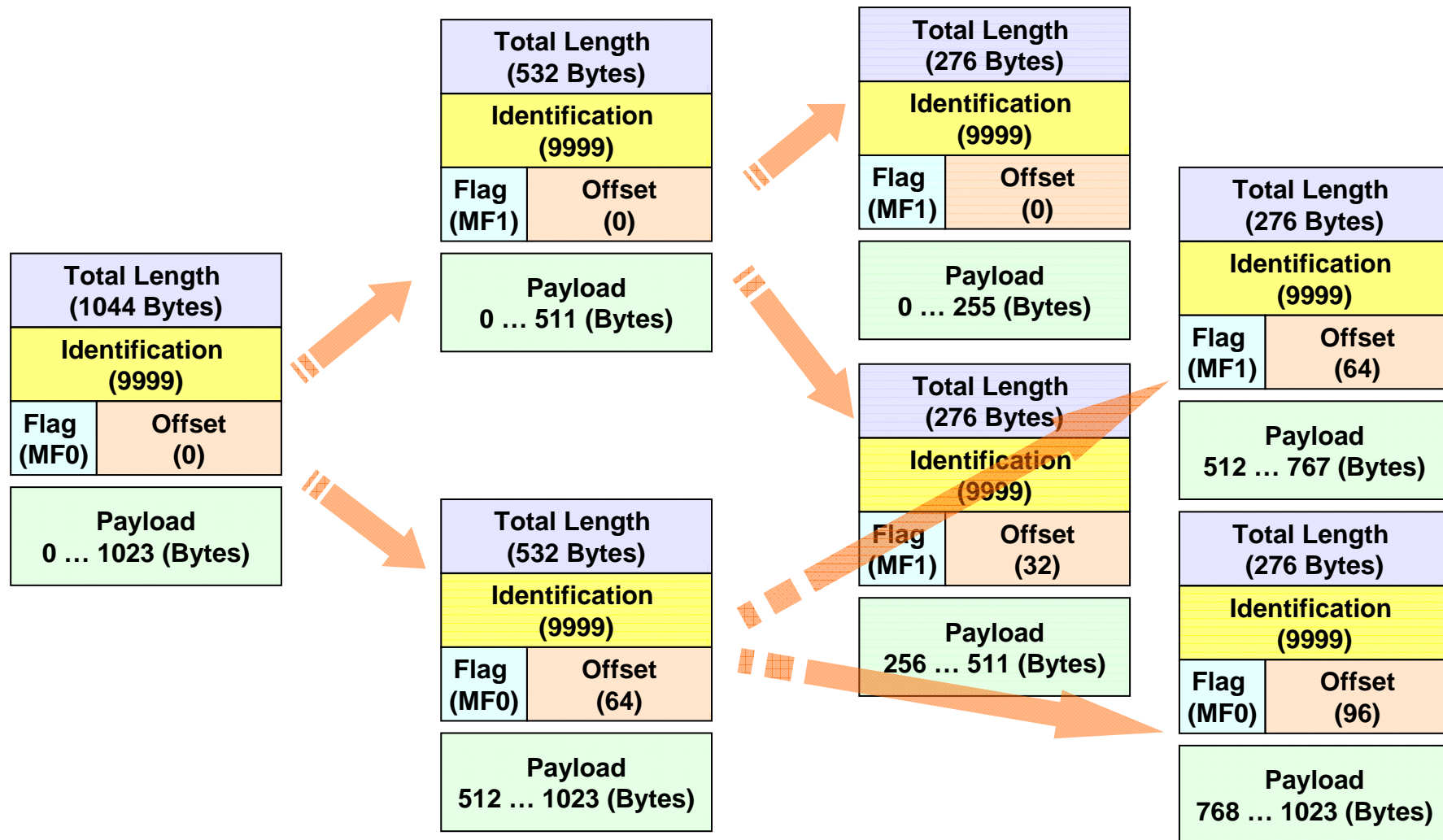


# IP Fragmentation (2)



- **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  $\neq$  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)**