EITF25 – Internet: Technology and Applications

Internet Protocols
-1-
Network Layer

2015, Lecture 04

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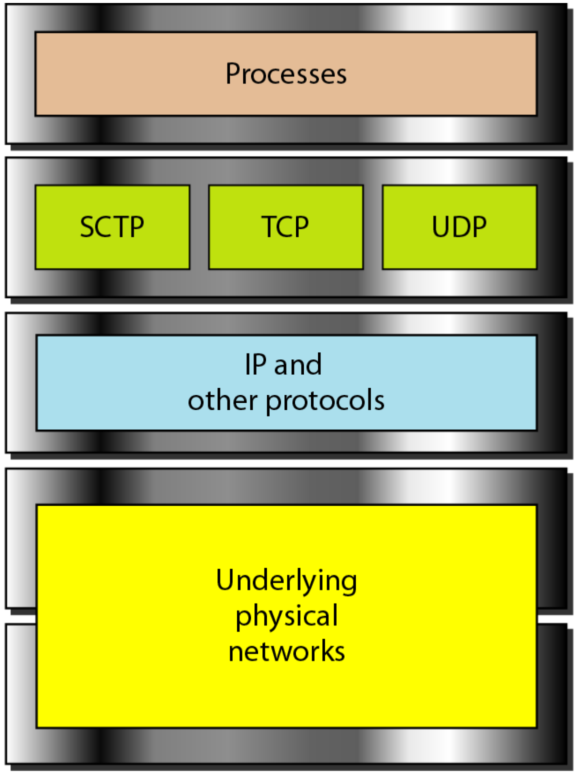
Previously on EITF25

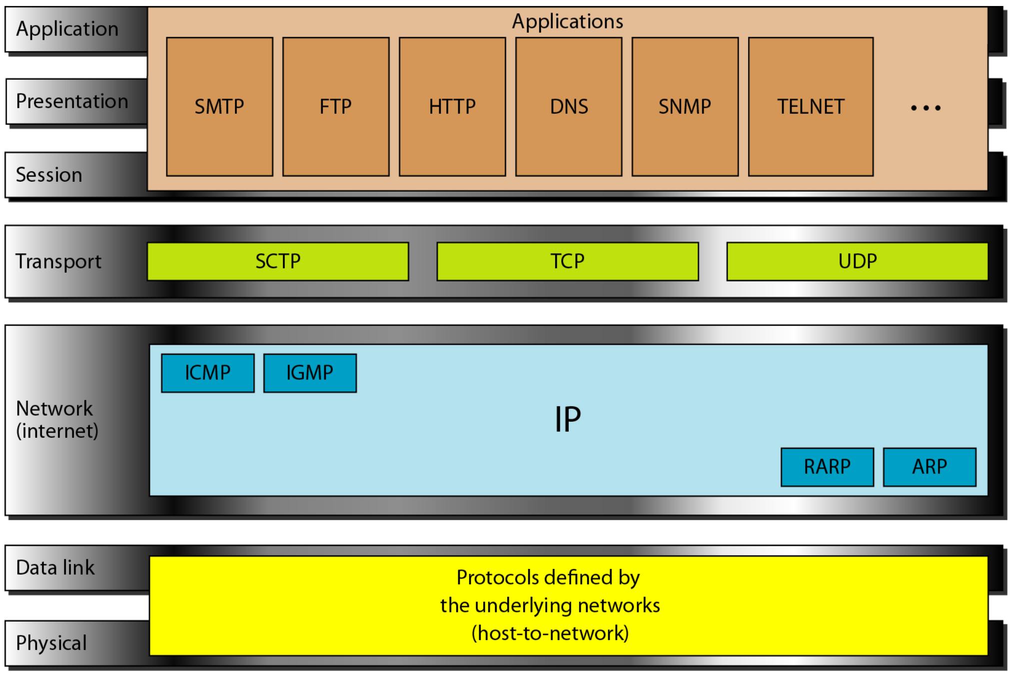
Medium Access Control Sublayer

- Access methods
  - Slotted ALOHA, CSMA/CD
- Ethernet
  - Evolution of local area networks
- Wireless LAN
  - Hidden terminal problem
  - CSMA/CA



Network layer

- Principles of digital communications
  - From electrical signals to bits to packets
- Using the physical infrastructure
  - Network access
- **Finding your way**
  - **Addressing, routing**
- Making use of it all
  - Applications



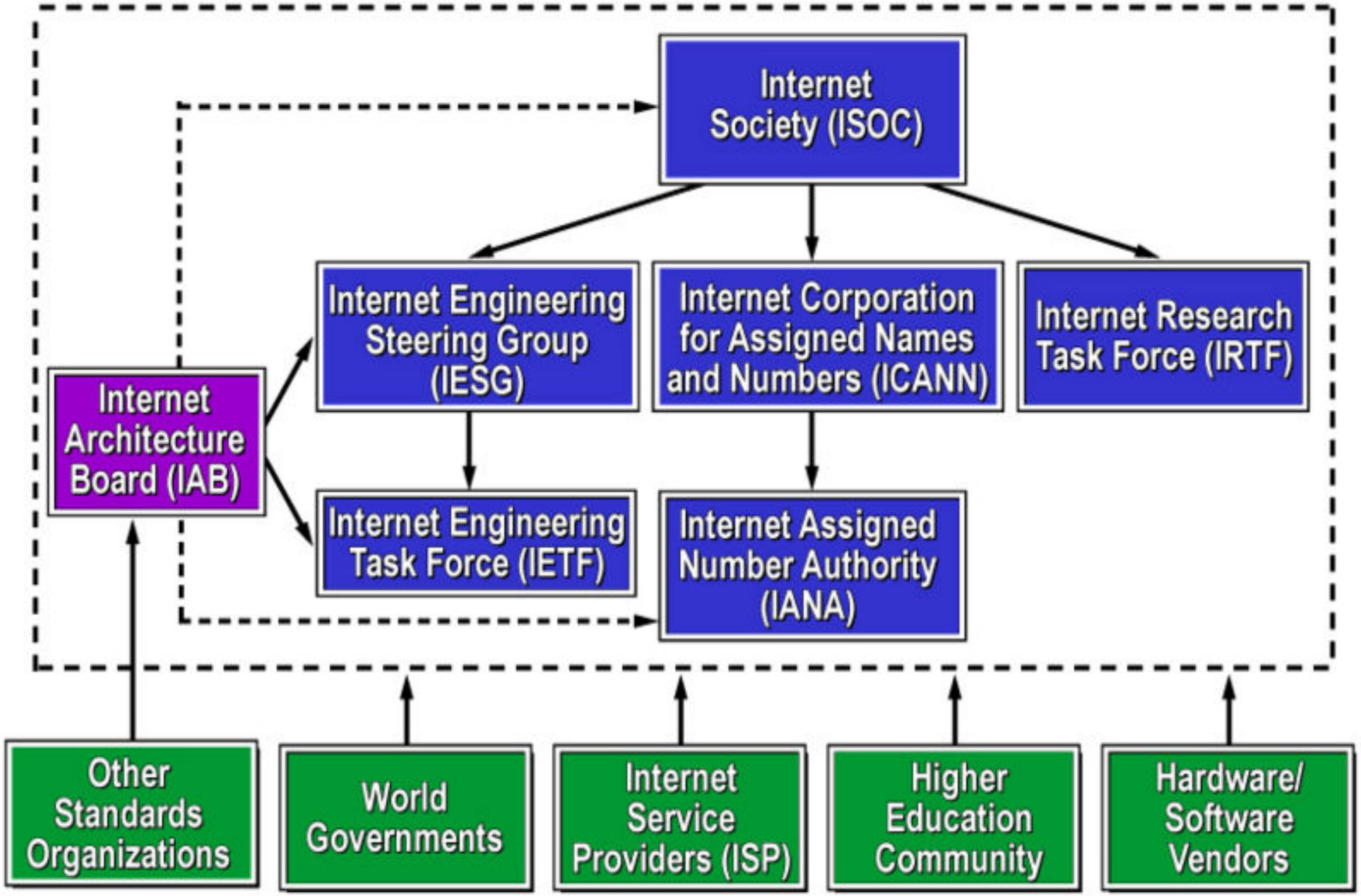
Today: Internet Protocols (1)

Network Layer

- Internetworking, routing
  [S1.5, S19.1][F18.1-2]
- Internet Protocol, v4 & v6
  [S14.1-4][F18.4-5, F19.1, F22.1-2]

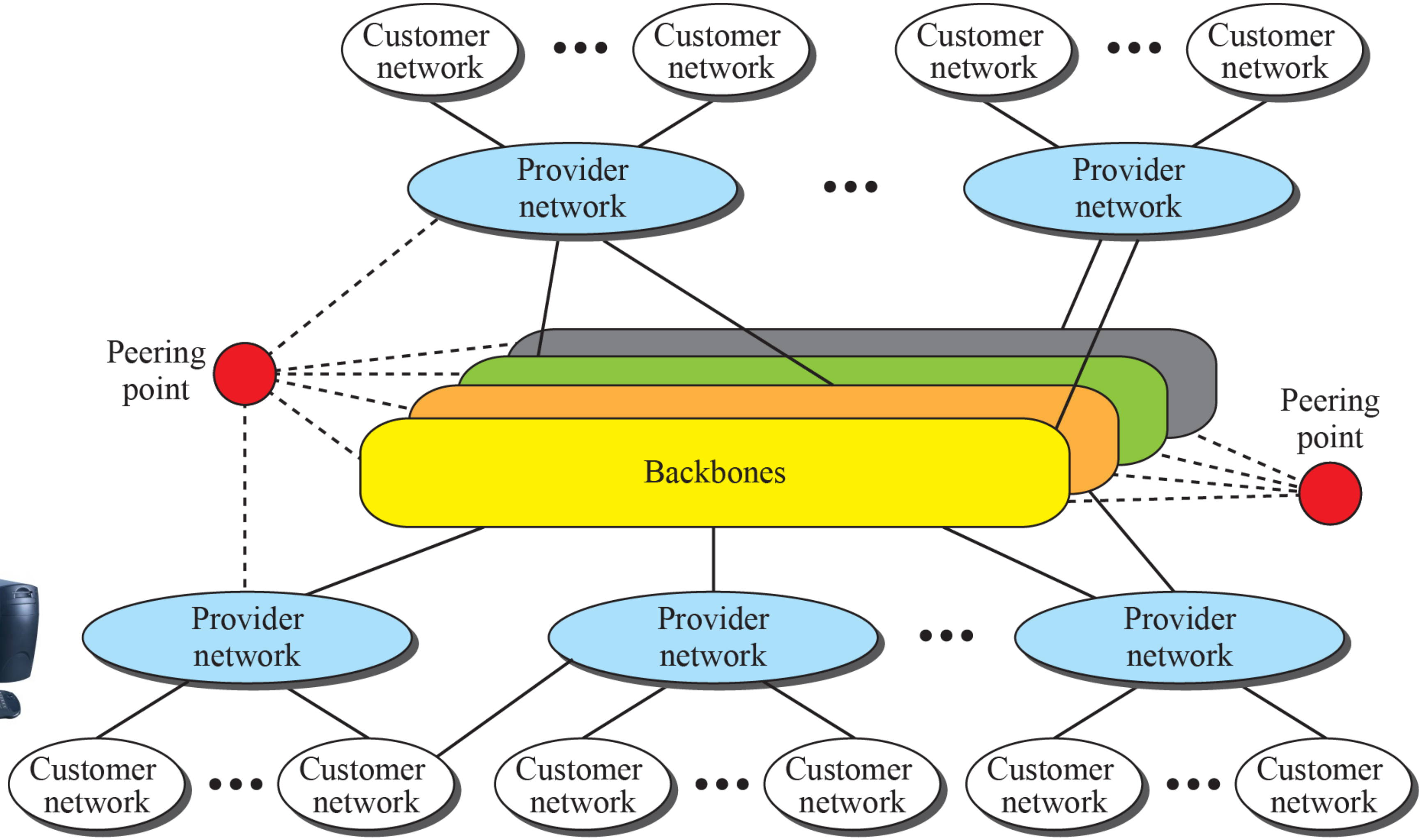
**[Kihl & Andersson: 6.1-3, 7.1-5, 7.8, 8.2]*

Internet administration



Source: http://www.hill2dot0.com

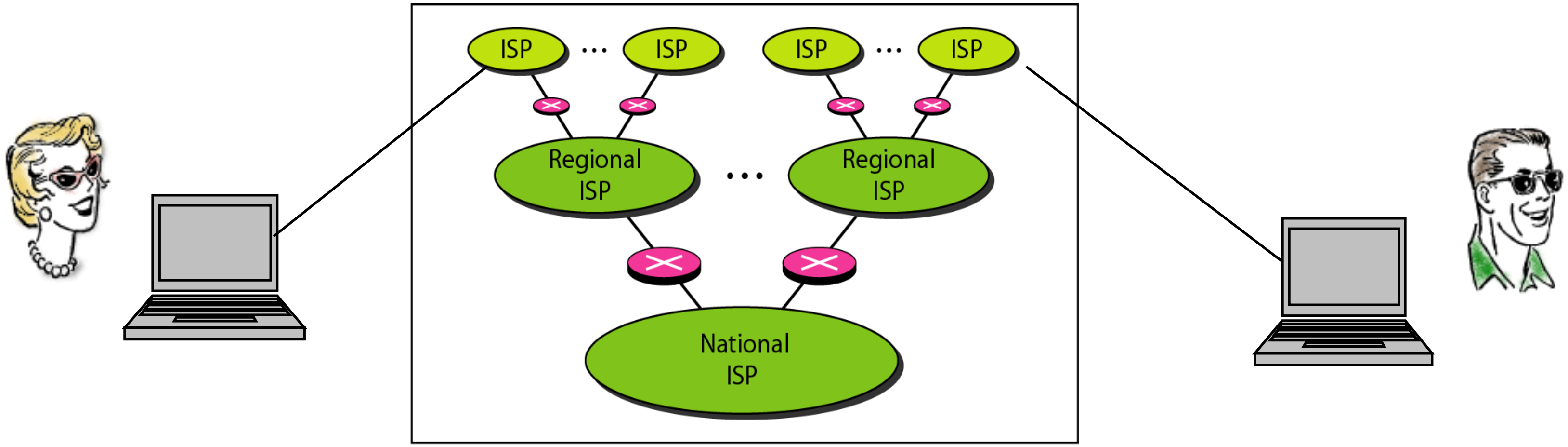
Internet hierarchy



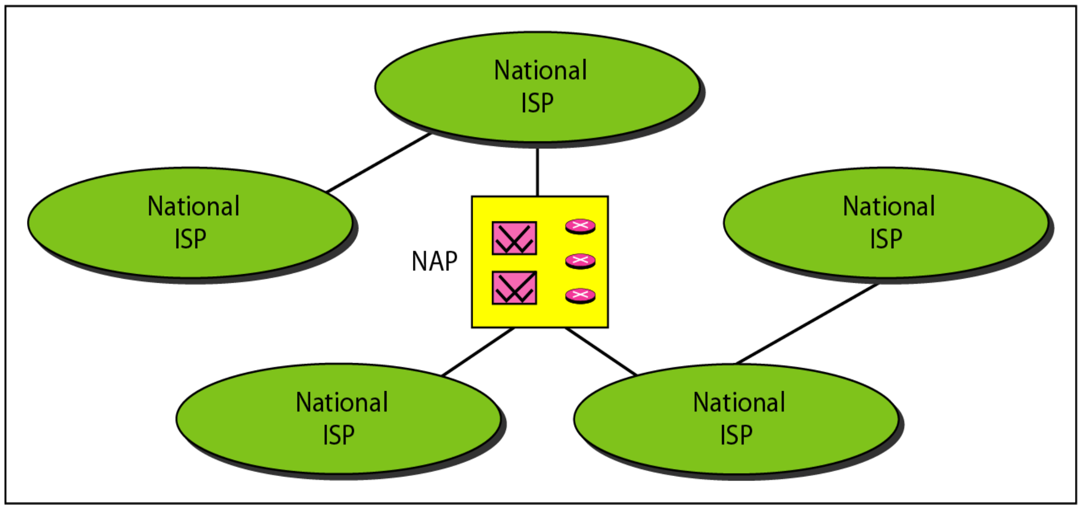
Network architecture

- Two types of networks in Internet
  - Backbone networks
  - Access networks
- Internet Service Providers (ISP)
  - Today, the access networks and some of the backbone networks are owned by private ISP.
- Network Access Points (NAP)
  - Switching stations providing connection between backbone networks

Organisation of Internet



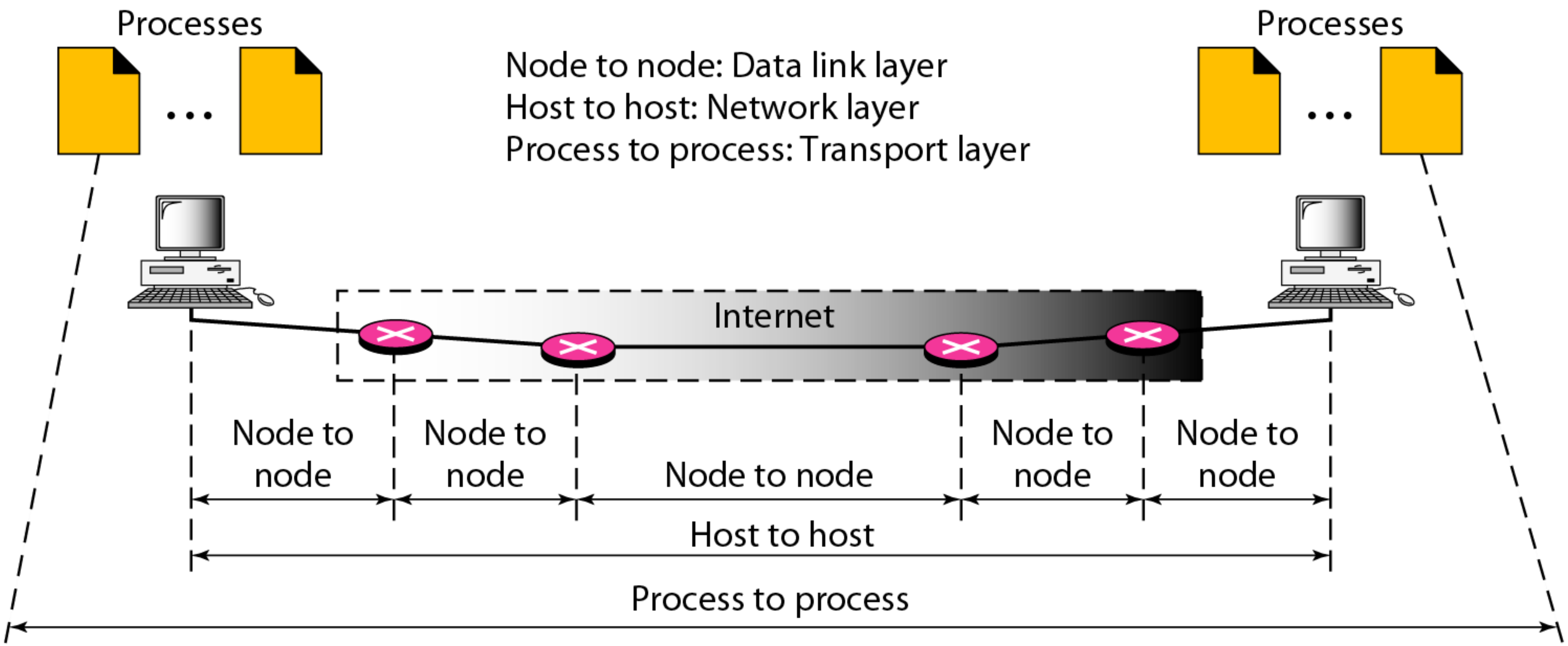
a. Structure of a national ISP



b. Interconnection of national ISPs

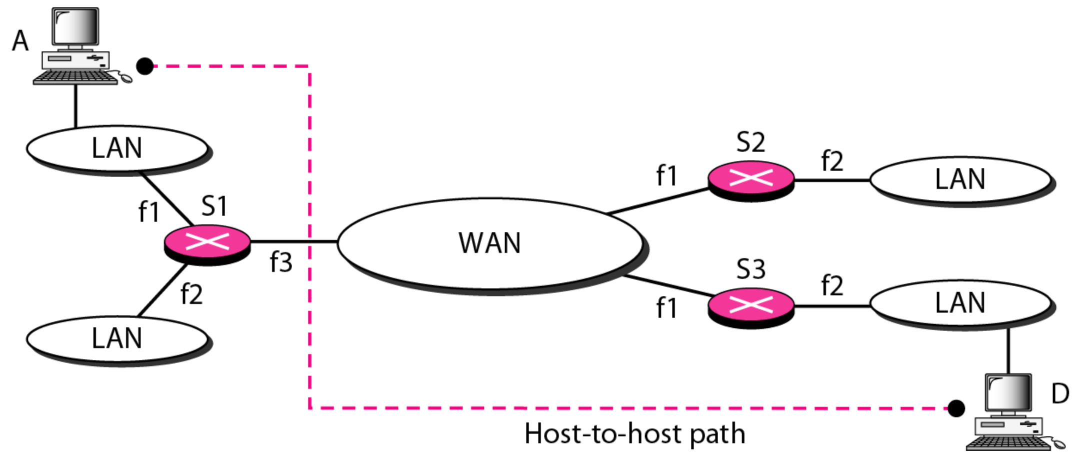
Host-to-host delivery

- Multiple applications even on the same host



Network layer

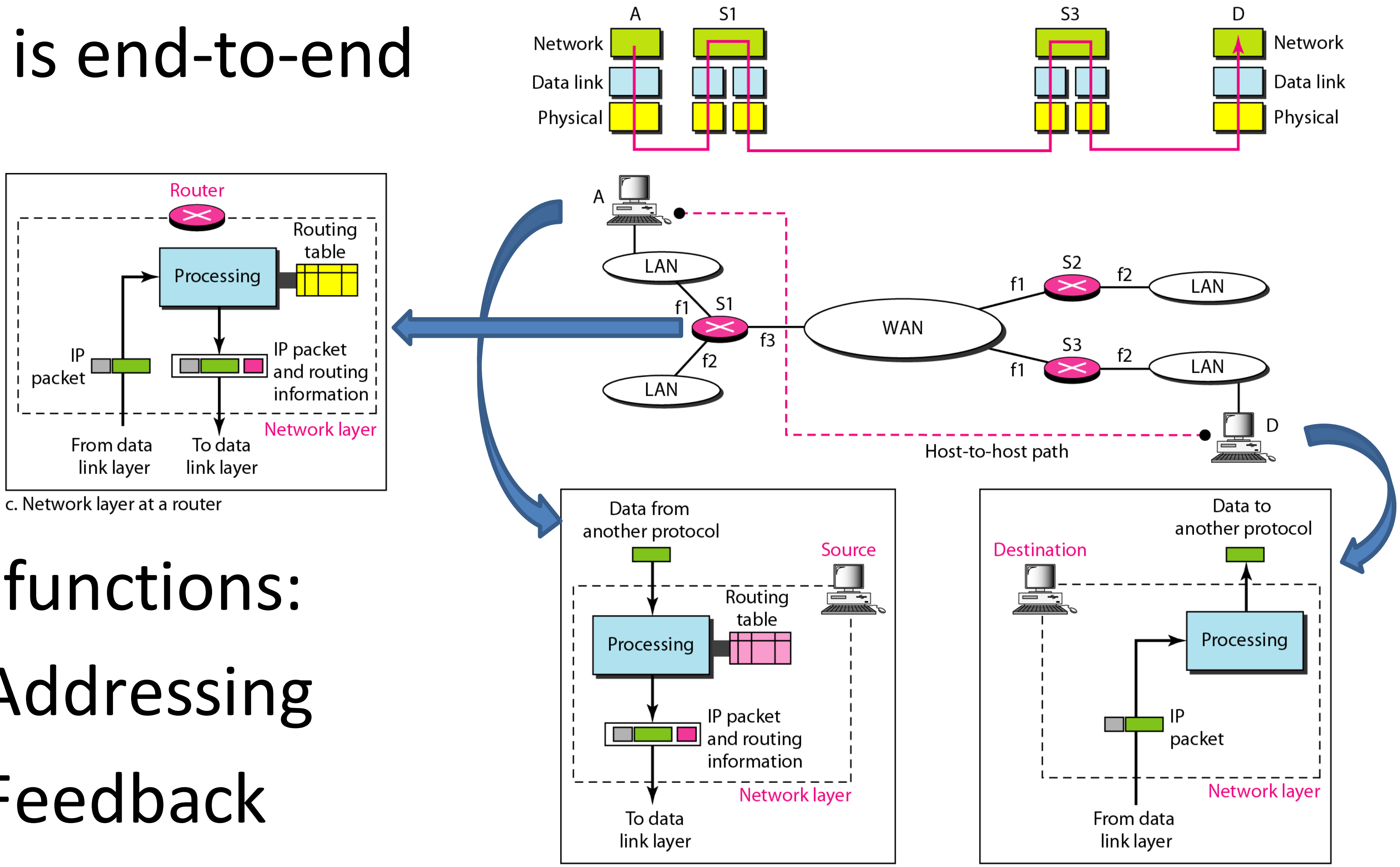
- L3
  - end-to-end



- L2
  - hop-by-hop

Network layer: Routing

- L3 is end-to-end



c. Network layer at a router

a. Network layer at source

b. Network layer at destination

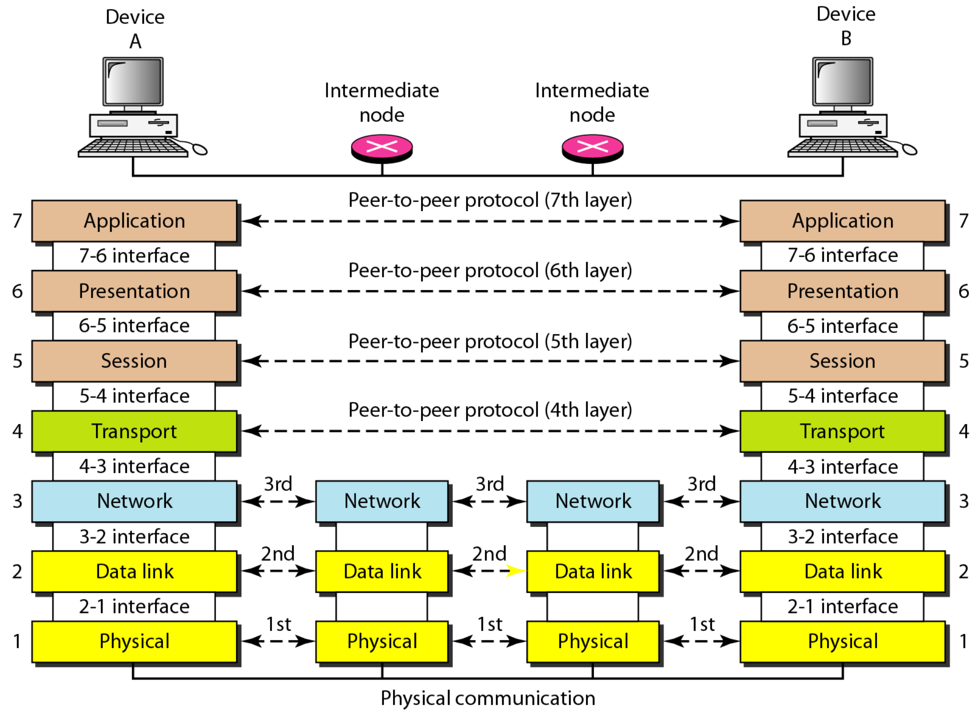
Two functions:

❶ Addressing

❷ Feedback

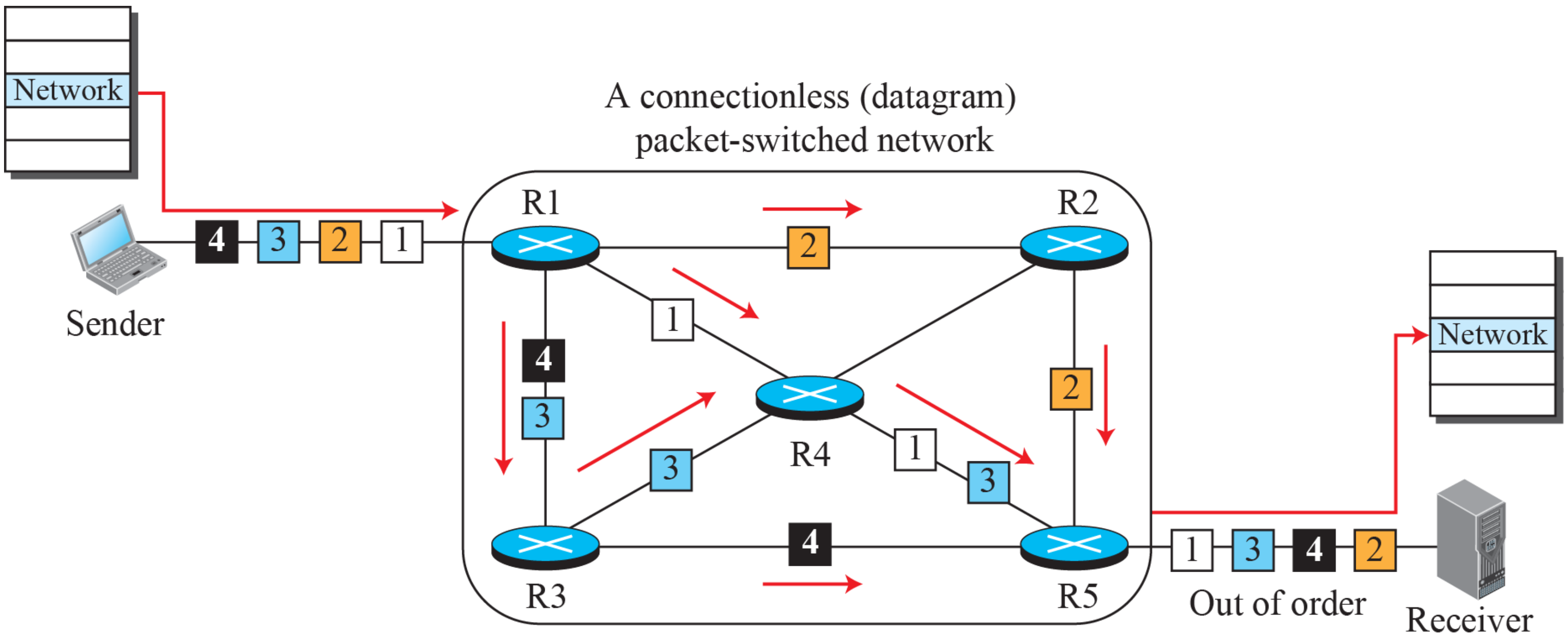
Routing

- Choosing the optimal path
  - Using a cost metric
- Sharing information
  - Central
  - Distributed
- Algorithms
  - Rules and procedures
  - Updates



Packet-switched routing

- Choosing the optimal path
  - Using a cost metric



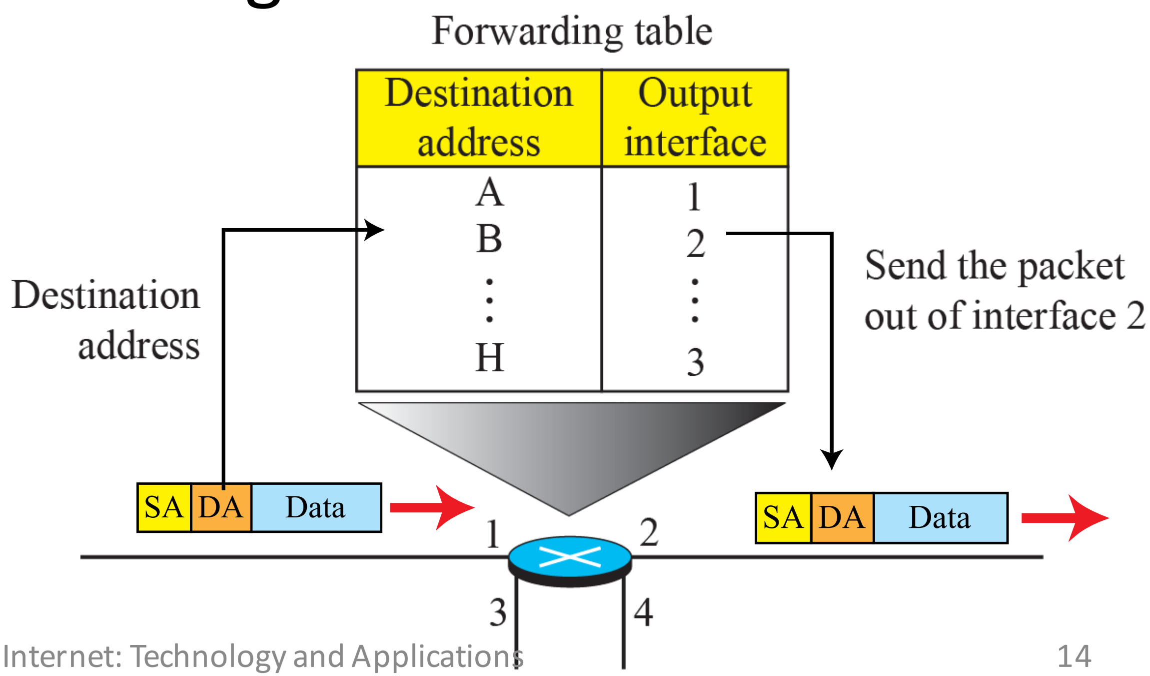
Router

- Internetworking device
  - Passes data packets between networks
  - Checks ***Network Layer*** addresses
  - Uses Routing/forwarding tables

Two functions:

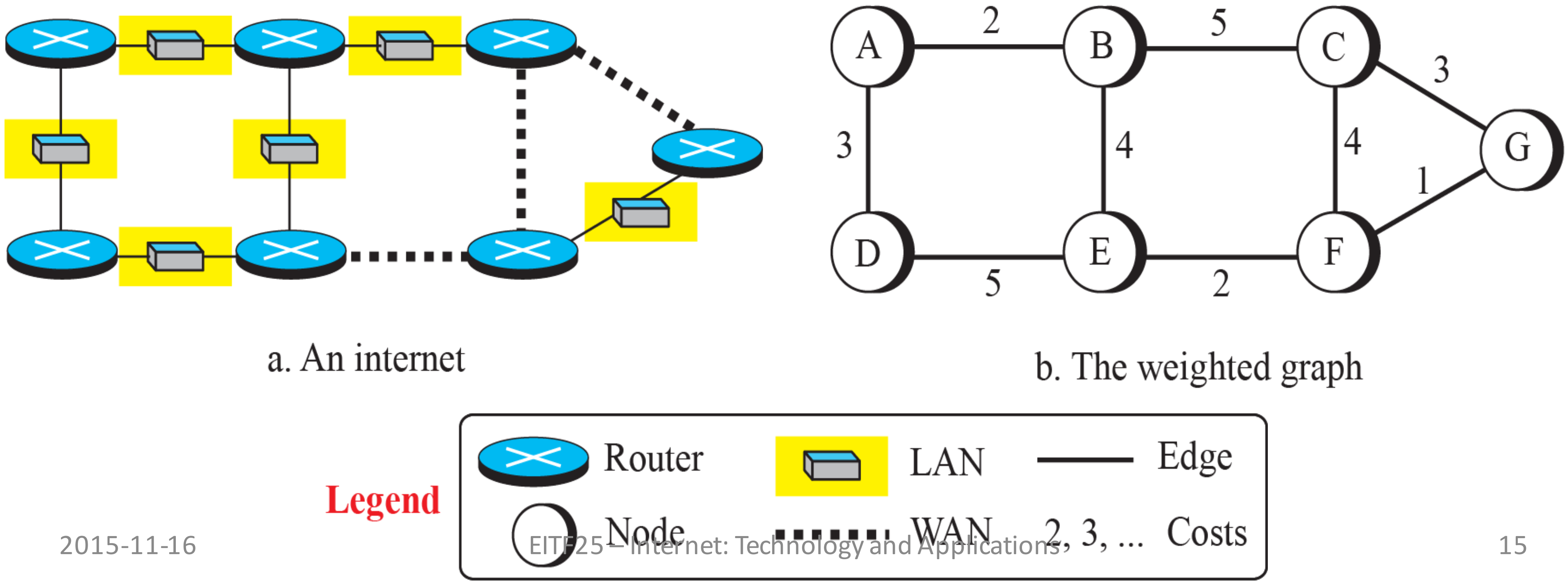
❶ Routing

❷ Forwarding



Routing algorithm

- Find route with least cost between source and destination.
- Update routing tables



a. An internet

b. The weighted graph

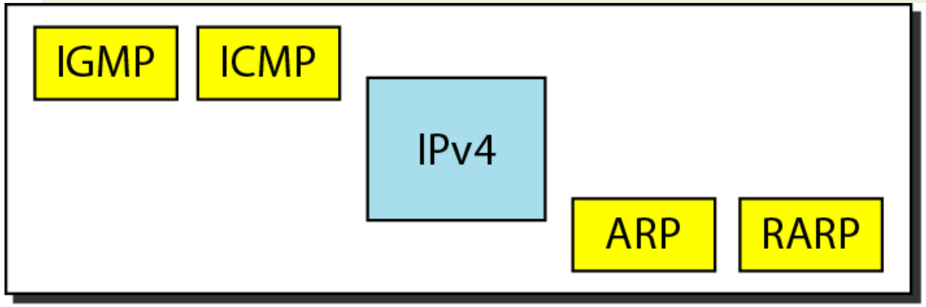
Network layer protocols

- We need a universal address system. This is called the *network address*.
- We need rules for data forwarding. This is called *routing*.
- We need entities connecting several networks together and forwarding data between them. These are called *routers*.

Internet Protocol

IPv4

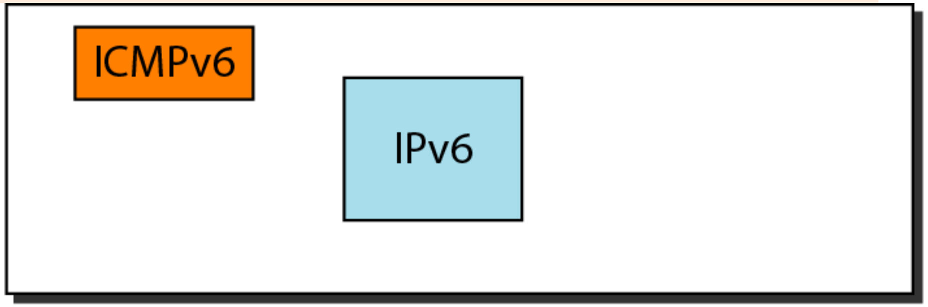
- Addressing scheme
  - Hierarchy
  - Configuration
  - Lookup
- Datagram format



Network layer in version 4

IPv6

- Larger address space
- Better header format
  - Extendible
  - More secure
- Support for QoS



Network layer in version 6

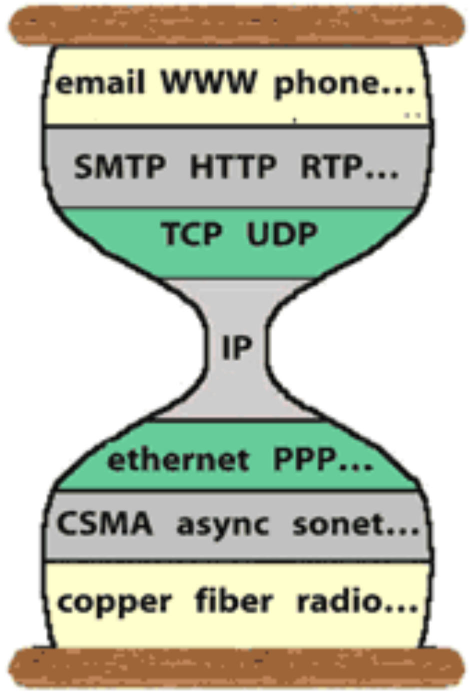
Internet

- All networks that are part of Internet have one thing in common:

  They all use the same network protocol, ***Internet Protocol (IP)***!
- They do not need to use the same link protocols, which means that all kinds of networks can be part of Internet.
- The protocol framework for Internet is called ***the TCP/IP model***.

TCP/IP model

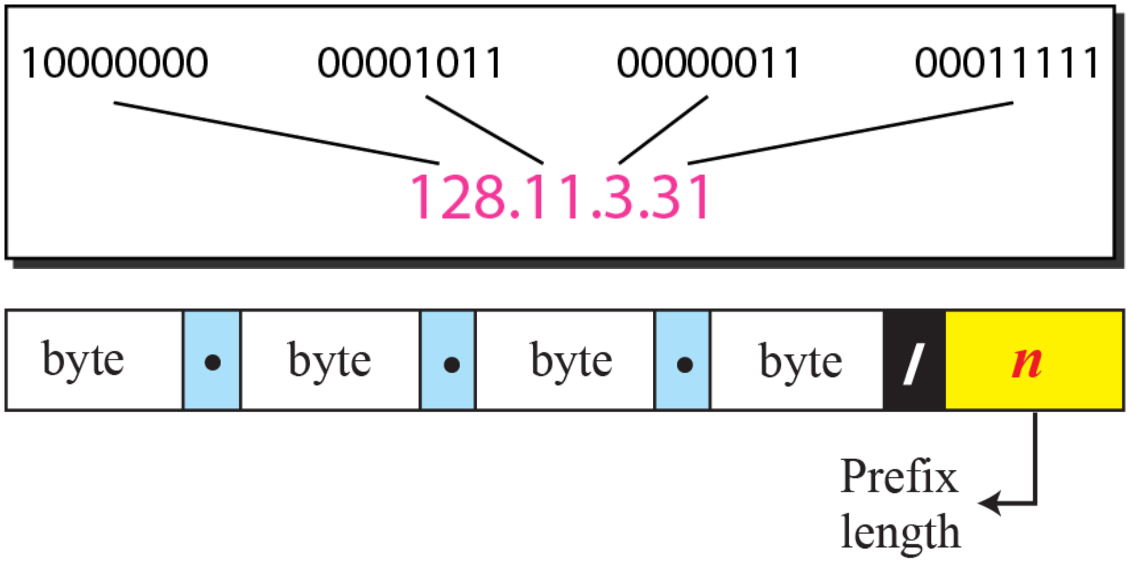
- Sometimes illustrated with a hourglass.
- IP can be used on all types of networks
- This has made Internet what it is today.



IPv4 addresses

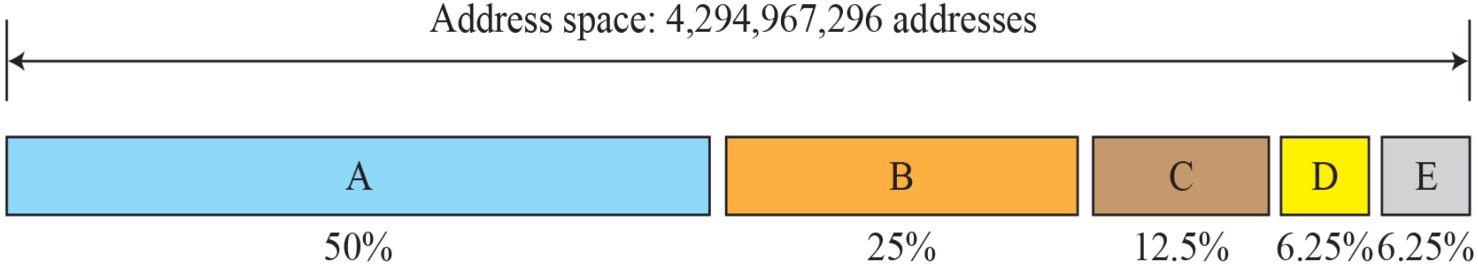
- 32 bits = 4 bytes
- $2^{32} = (2^8)^4 = 256^4 = 4\ 294\ 967\ 296$
- Classful vs. classless hierarchy

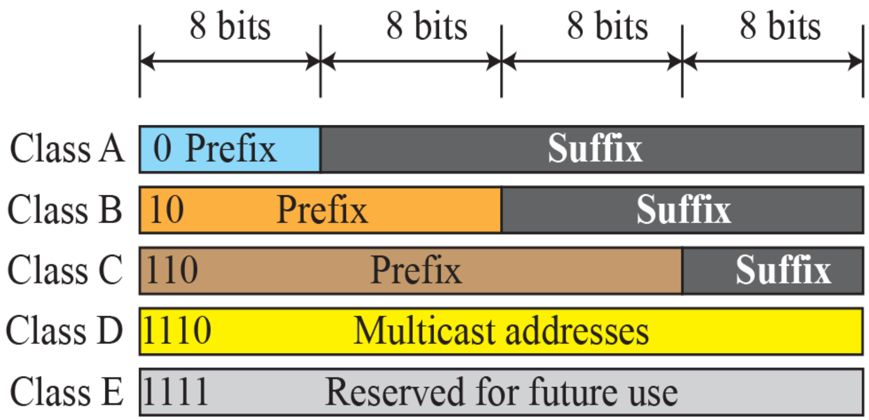
- Notations
  - Dotted decimal
  - Slash (CIDR)



Classful addressing

- Five address classes defined: A, B, C, (D and E)





Class	Prefixes	First byte
A	n = 8 bits	0 to 127
B	n = 16 bits	128 to 191
C	n = 24 bits	192 to 223
D	Not applicable	224 to 239
E	Not applicable	240 to 255

Classful addressing

- Organizations can only get addresses in one of the predefined blocks.

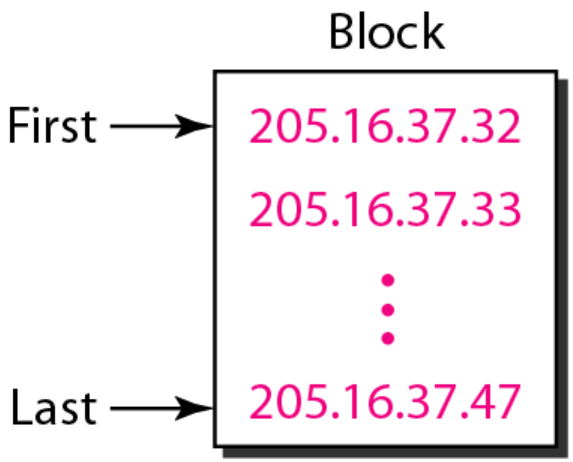
Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast

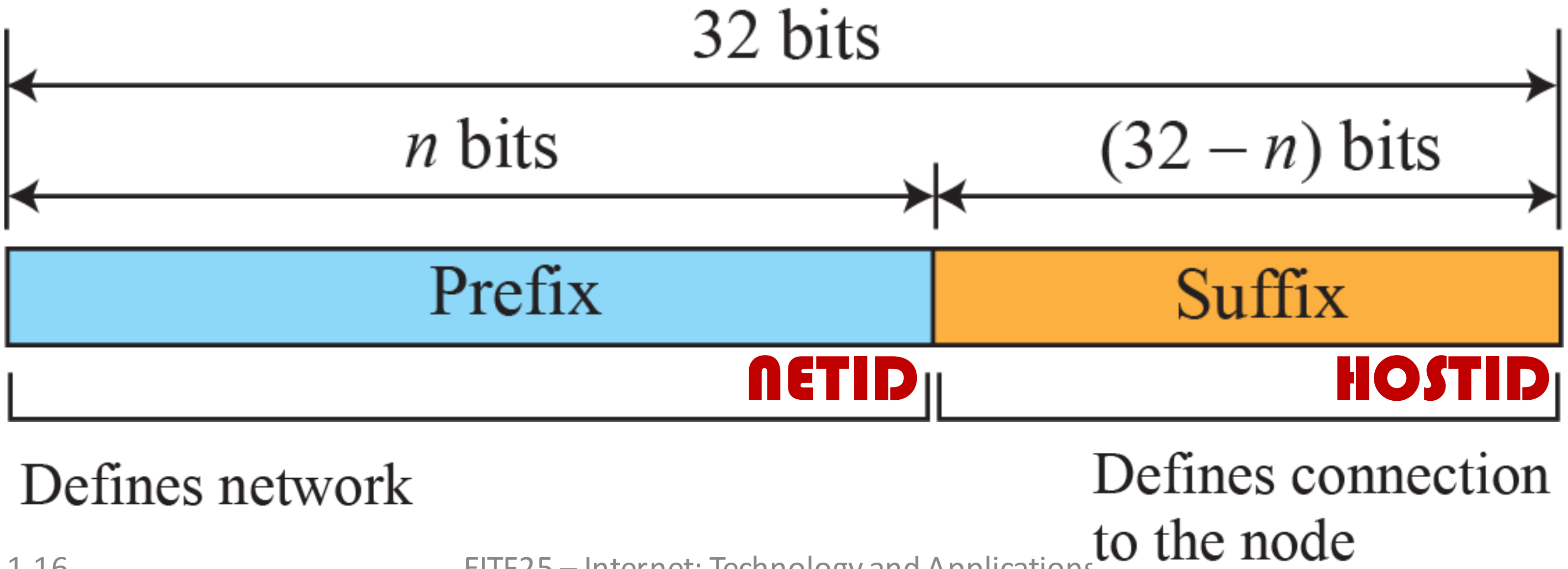
Address depletion

- Classful addressing defined as there were very few networks connected to the Internet.
- With the growth of Internet, the address classes didn’t match the reality.
- Subnetting and supernetting was introduced.
  - Class A and B address blocks divided into subnets.
  - Several Class C address blocks combined into larger blocks called supernets.

Classless addressing

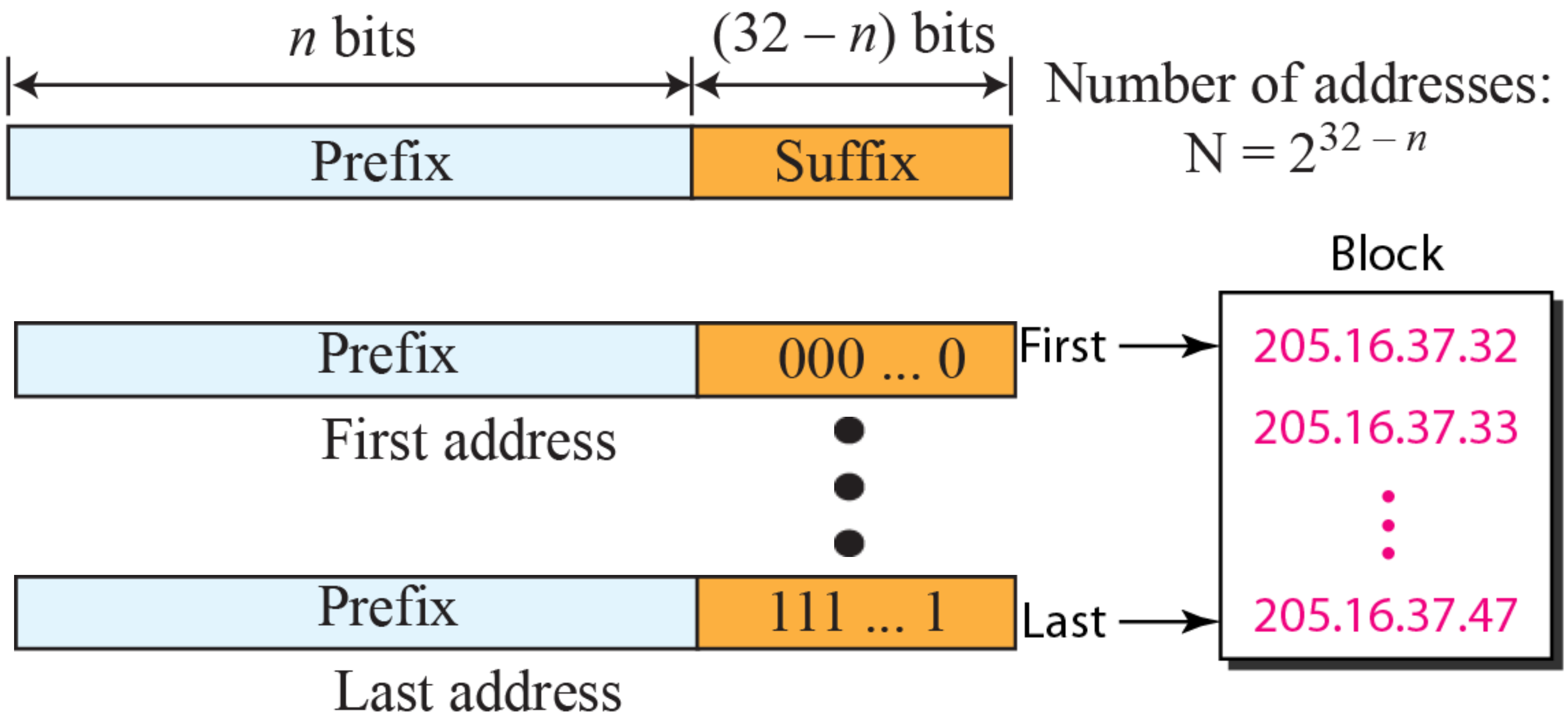
- Addresses in blocks
  - Block size power of 2
  - $N = 2^{32-n}$
  - First address divisible by N





Exercise: Classless addressing

- CIDR = slash notation with mask ***/n***
- 205.16.37.39/28

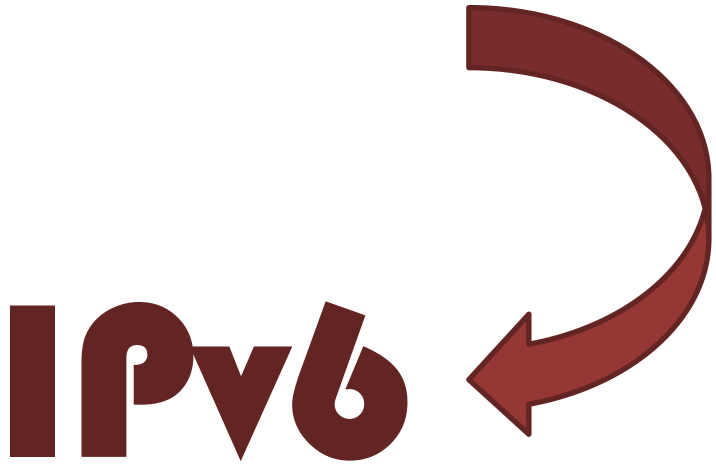


See you in 15' :)

- After the break
  - IPv6
  - Fragmentation
  - Forwarding, ARP

Problems with IPv4

- Address space too small
- Not designed for real-time applications
- No support for encryption and authentication

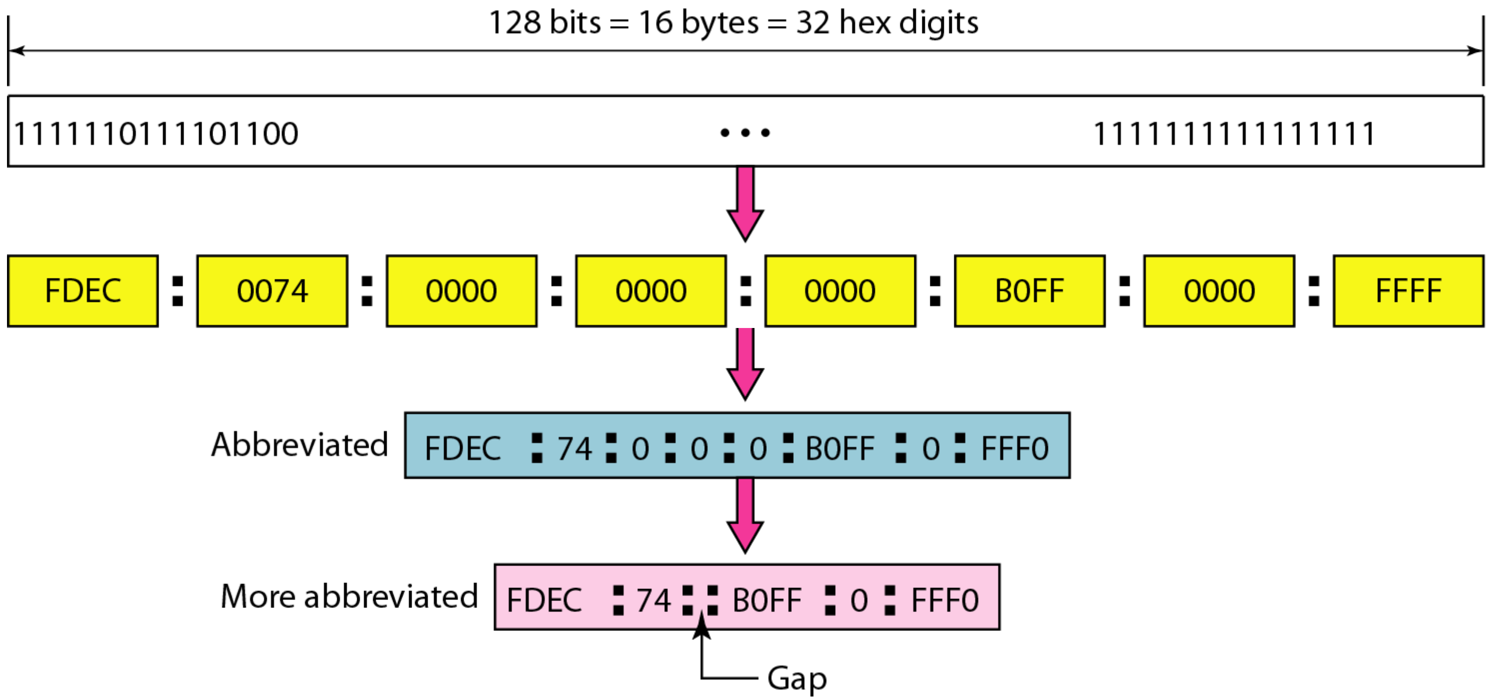


Some advantages with IPv6

- **Larger address space:** 128 bit-long addresses.
- **Better header format:** base header has constant length (40 bytes). Options can be inserted when needed.
- **Support for more security:** Encryption and authentication options.
- **Support for real-time applications:** Special handling of datagram can be requested.

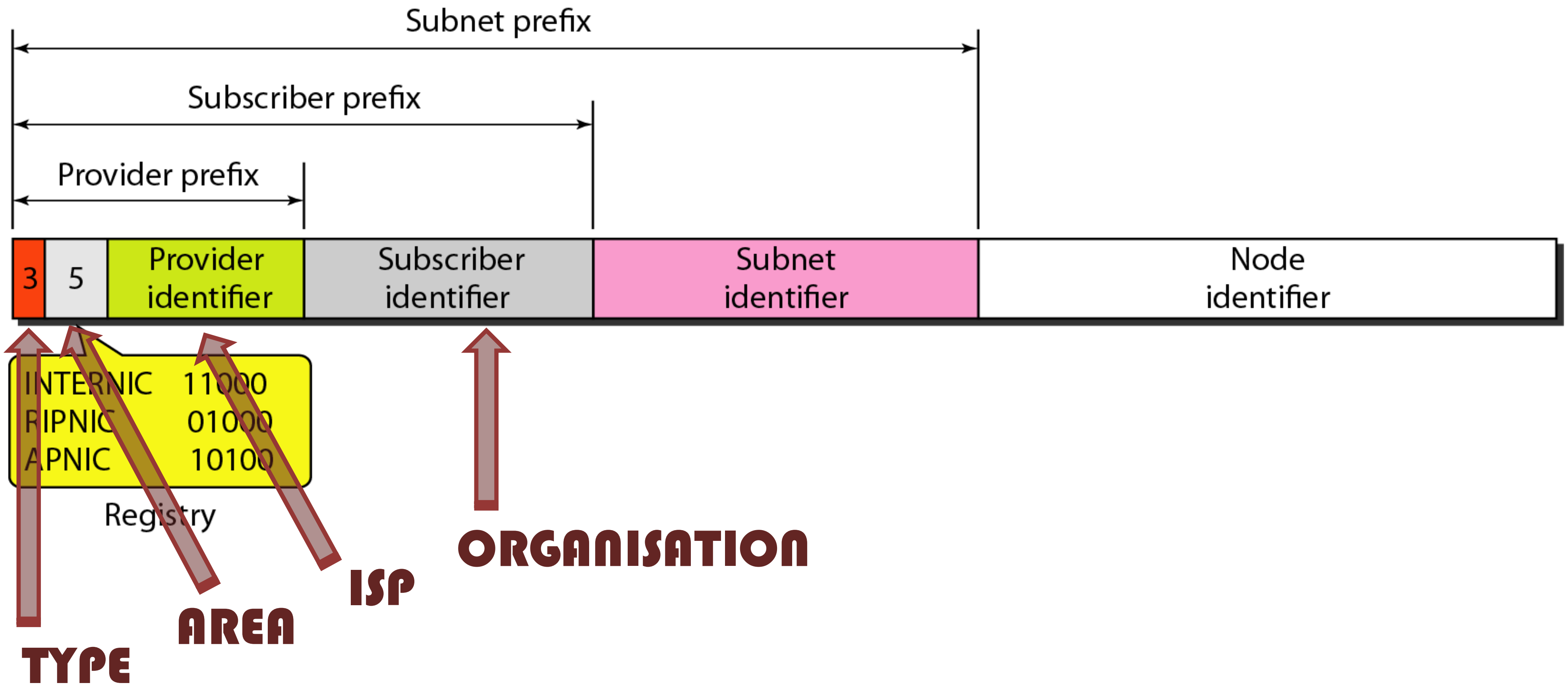
IPv6 addresses

- 128 bits = 16 bytes
- $2^{128} = 2^{32} \cdot 2^{96} > 3 \cdot 10^{35}$
- Notations

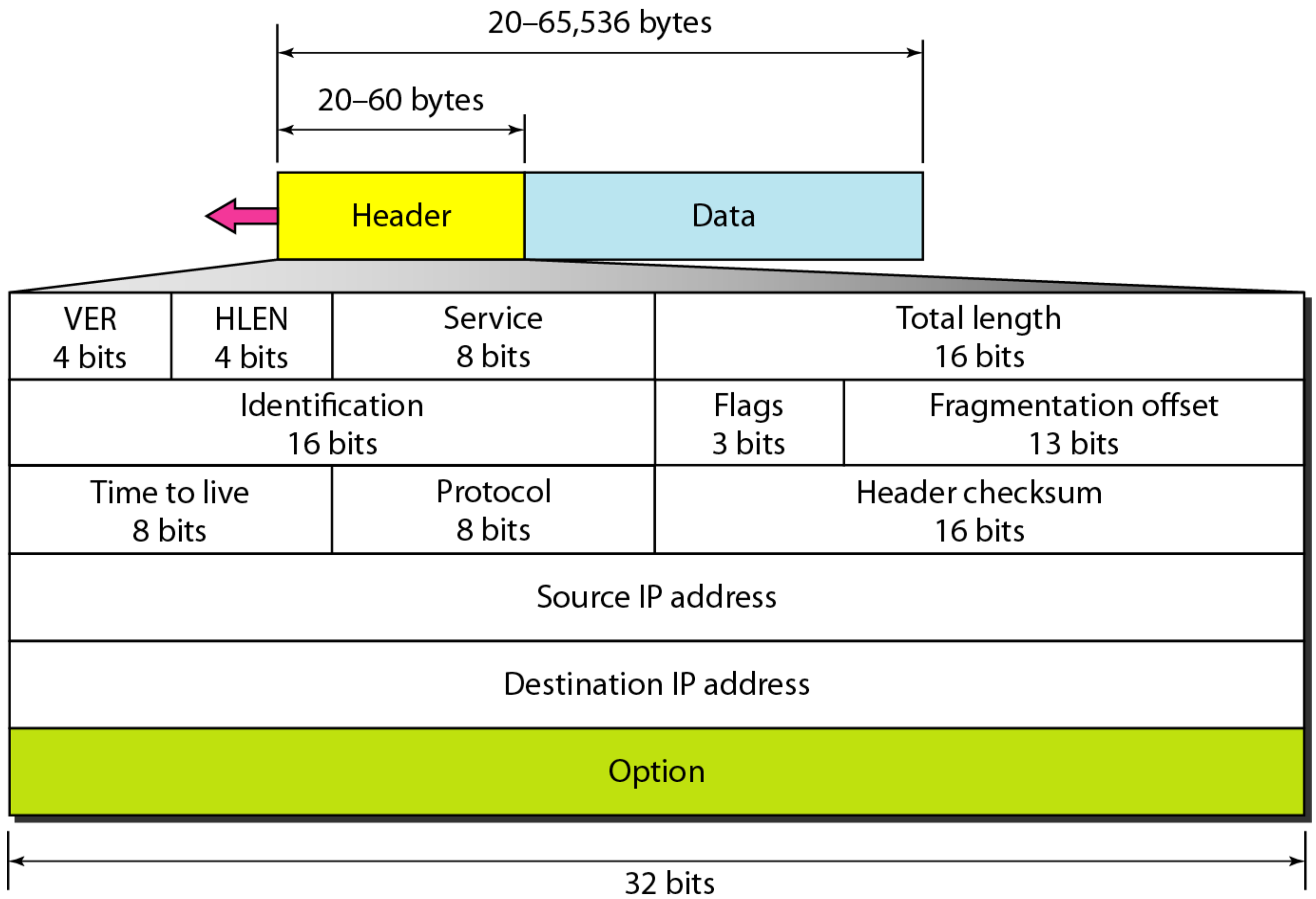


Global unicast addresses

- Identify individual computers

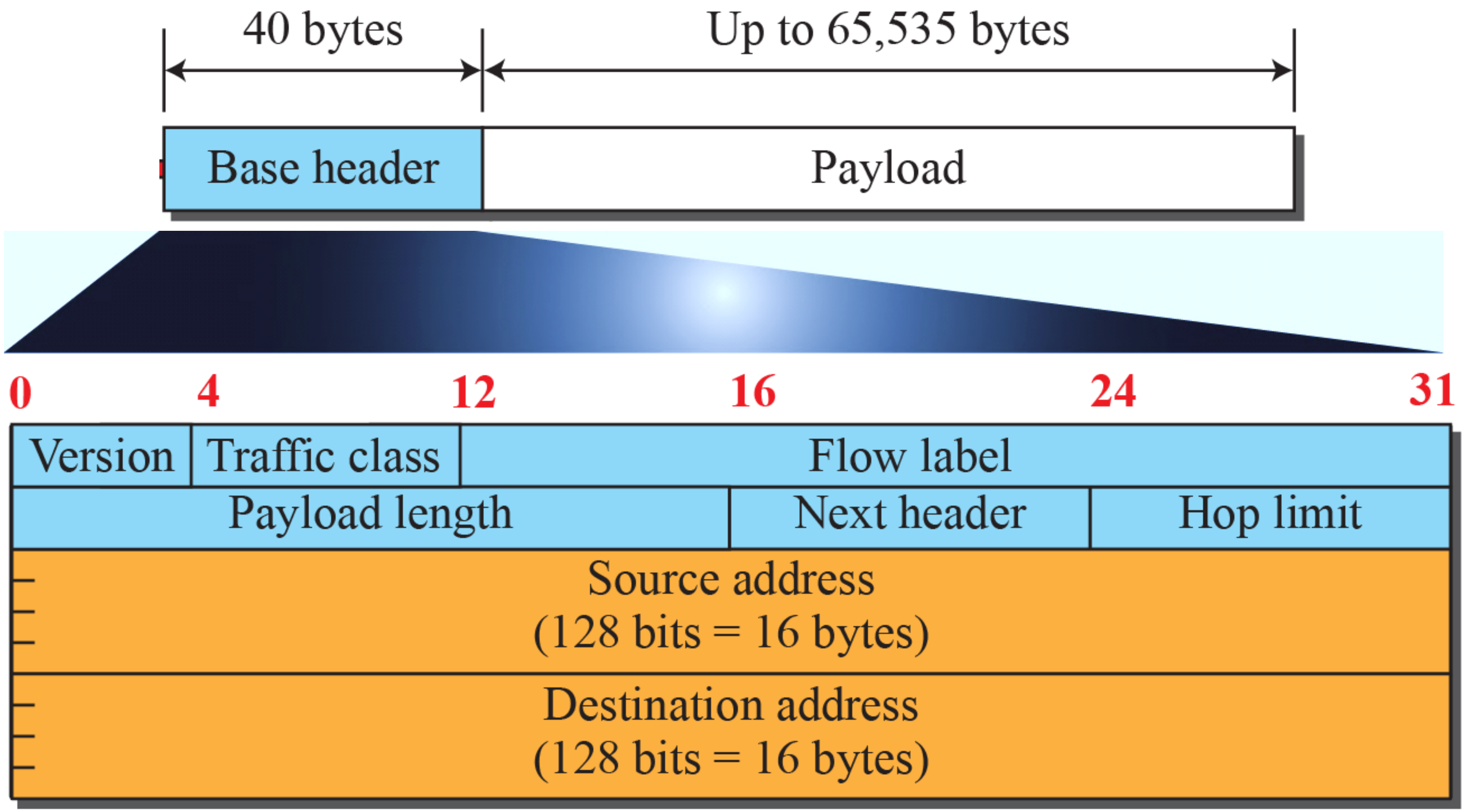


IPv4 datagram

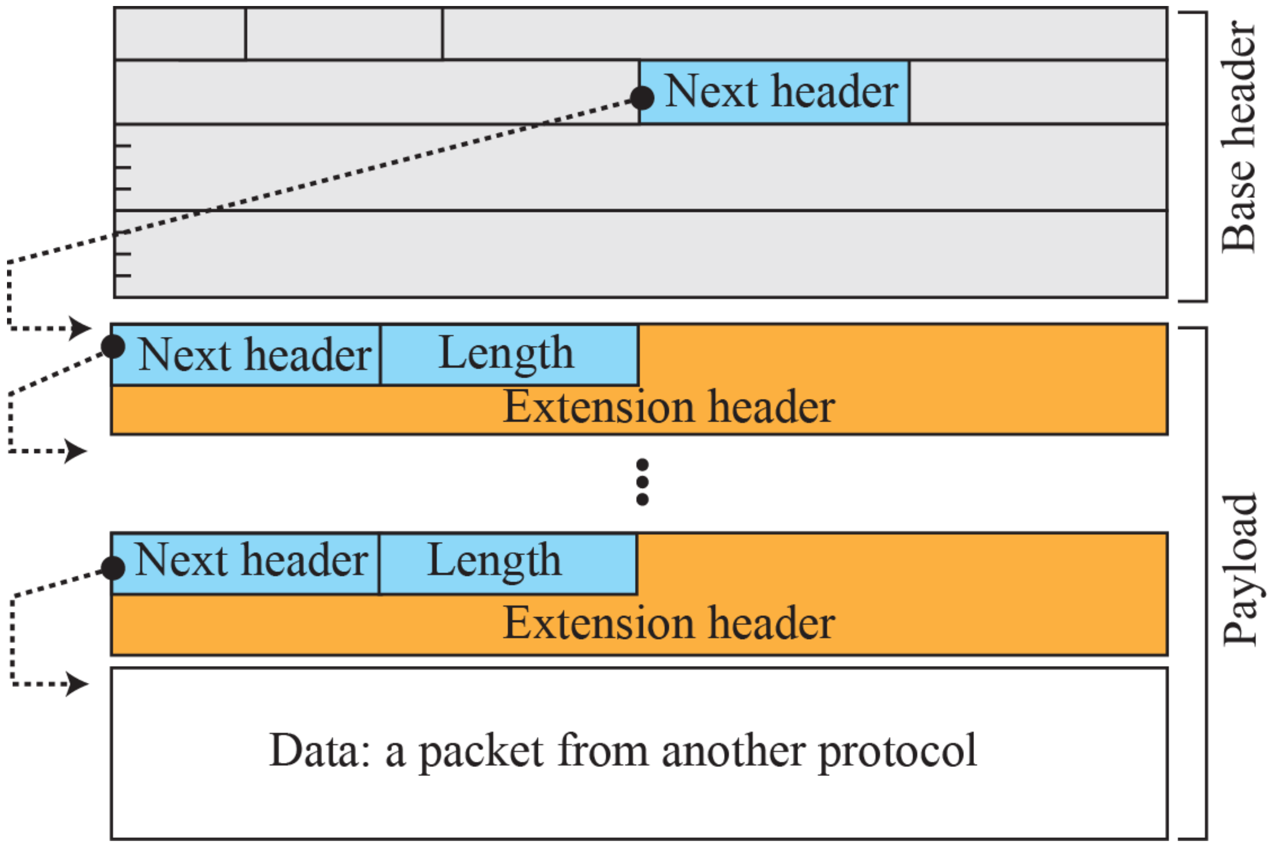


IPv6 datagram

- Simpler base header, flexible for extensions



IPv6 extension headers



Some next-header codes

00: Hop-by-hop option
02: ICMPv6
06: TCP
17: UDP
43: Source-routing option
44: Fragmentation option
50: Encrypted security payload
51:Authentication header
59: Null (no next header)
60: Destination option

Traffic Classes → Packet priorities

- 0 .. 7
  - Congestion controlled

Priority	*Meaning*
0	No specific traffic
1	Background data
2	Unattended data traffic
3	Reserved
4	Attended bulk data traffic
5	Reserved
6	Interactive traffic
7	Control traffic

- 8 .. 15
  - Non-congestion controlled

Priority	*Meaning*
8	Data with greatest redundancy
. . .	. . .
15	Data with least redundancy

IPv6 and QoS

Flow label

- Identification of a stream
  - TCP sessions
  - Virtual connections
- Processing
  - Flow label table
  - Forwarding table
- Routing
  - Algorithms still necessary
  - But not run for every packet!

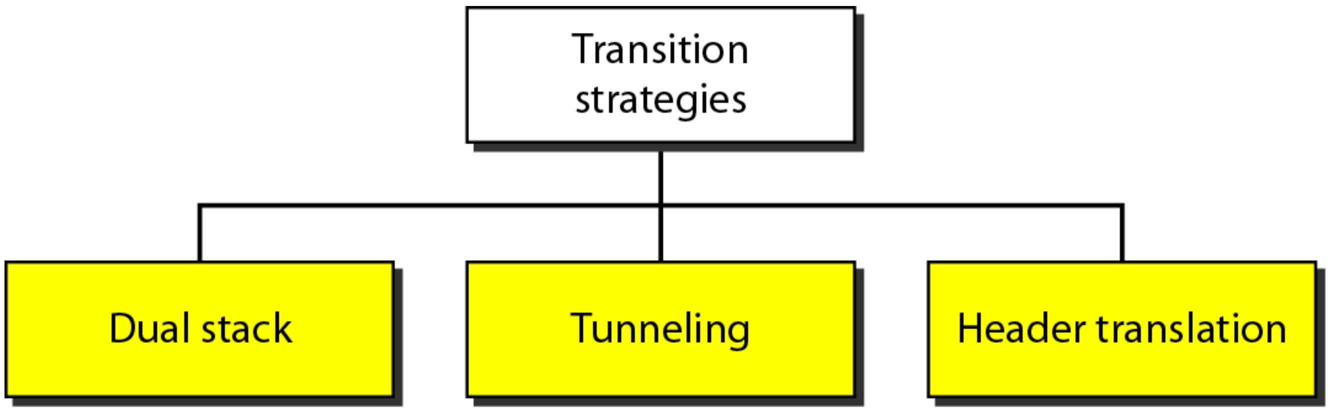
CROSS-LAYER?

Traffic class

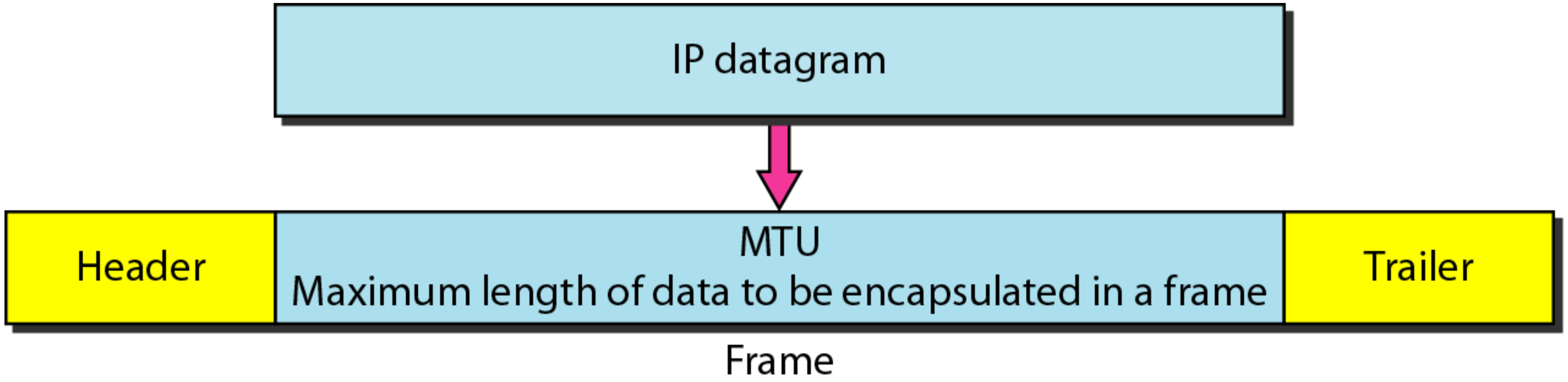
- Classification of packets
  - Queueing schemes
  - Relation to delay
- TCP vs. UDP
  - Congestion-controlled
  - Non-congestion-controlled
- Other protocols
  - RTP
  - RSVP

Transition: IPv4 → IPv6

- Cannot happen overnight
  - Too many independent systems
  - Economic cost
  - IPv4 address space lasted longer than expected
- Coexisence needed



Maximum datagram size



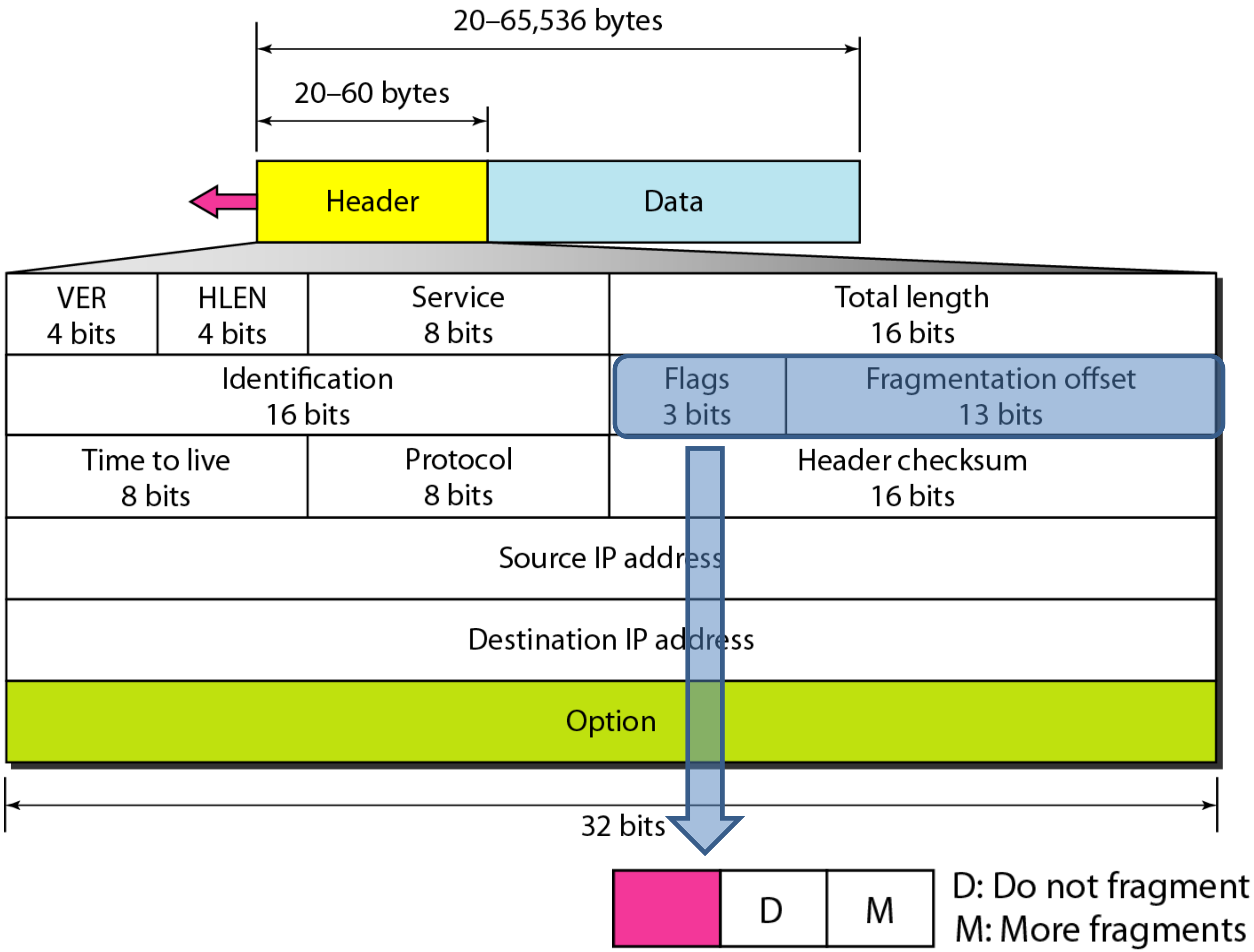
Protocol	*MTU*
Hyperchannel	65,535
Token Ring (16 Mbps)	17,914
Token Ring (4 Mbps)	4,464
FDDI	4,352
Ethernet	1,500
X.25	576
PPP	296

Fragmentation

- Needed when IP datagram size > MTU
- IPv4
  – Performed by the router meeting the problem
- IPv6
  – Performed by the source router only
- Defragmentation by destination host

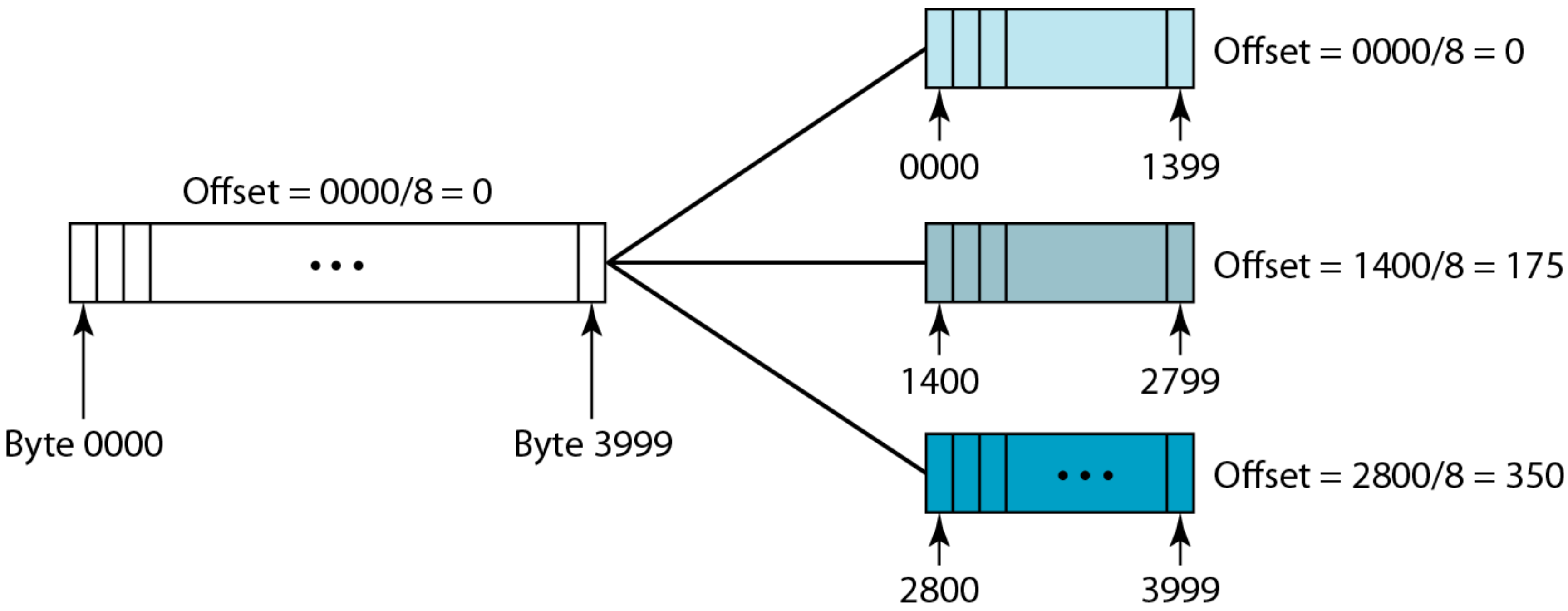
D: Do not fragment
M: More fragments

Fragmentation field

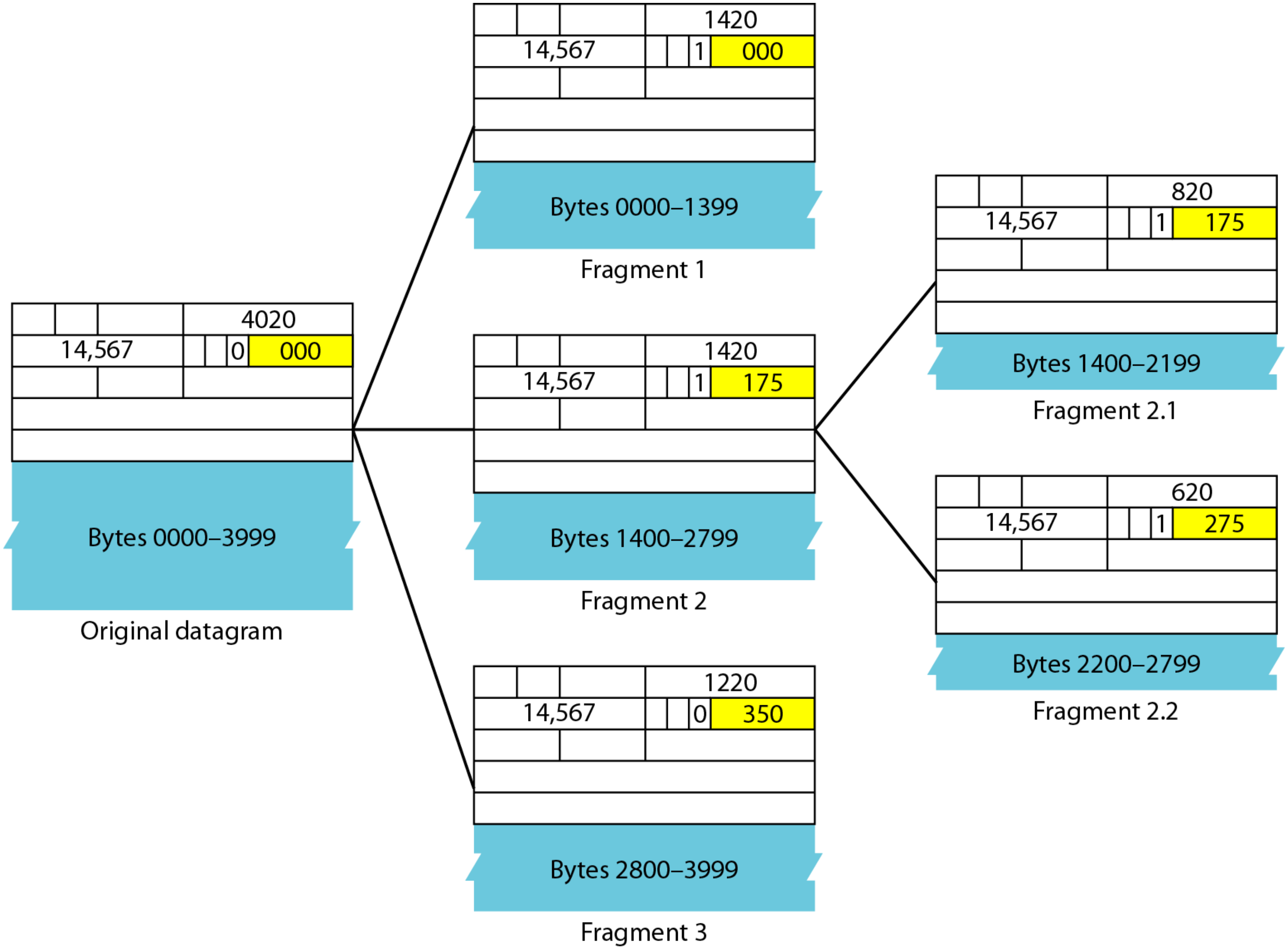


Fragmentation offset

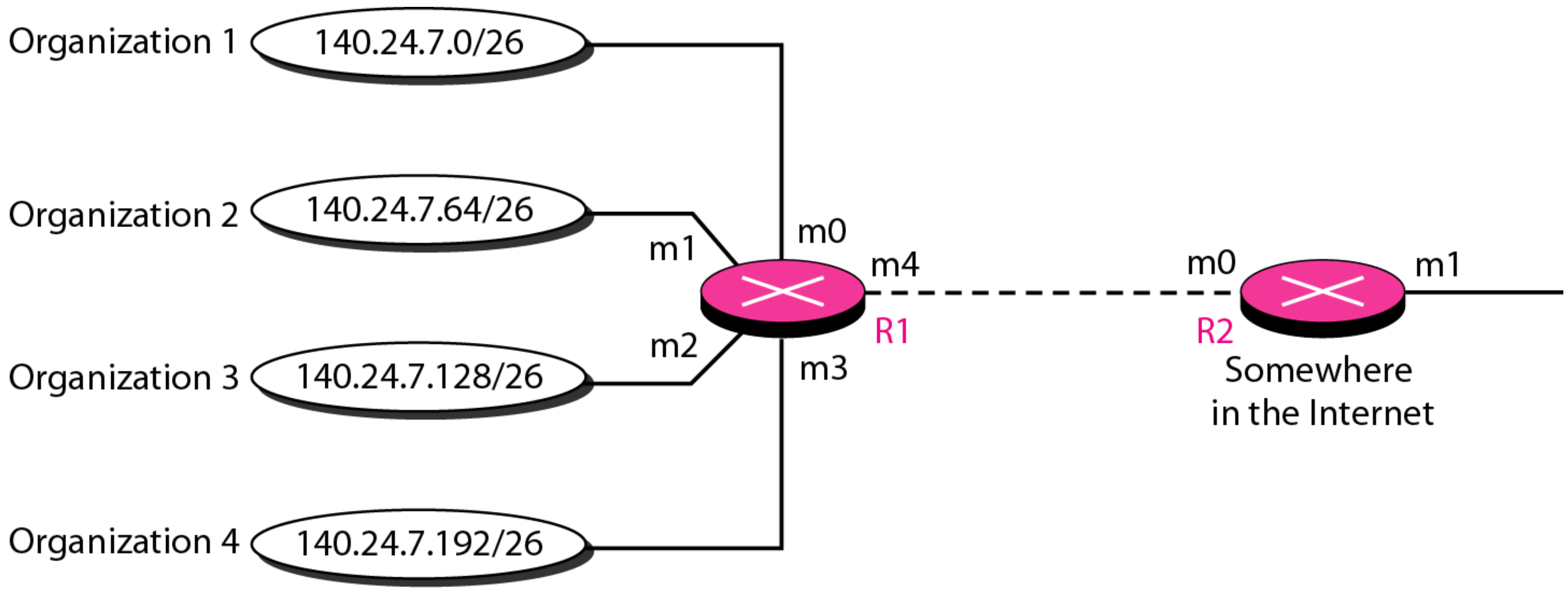
- Relative location of fragments
- 13 bits < 16 bits → /8



Fragmentation example



Forwarding: Address aggregation



Mask	Network address	Next-hop address	Interface
/26	140.24.7.0	----------	m0
/26	140.24.7.64	----------	m1
/26	140.24.7.128	----------	m2
/26	140.24.7.192	----------	m3
/0	0.0.0.0	Default	m4

Routing table for R1

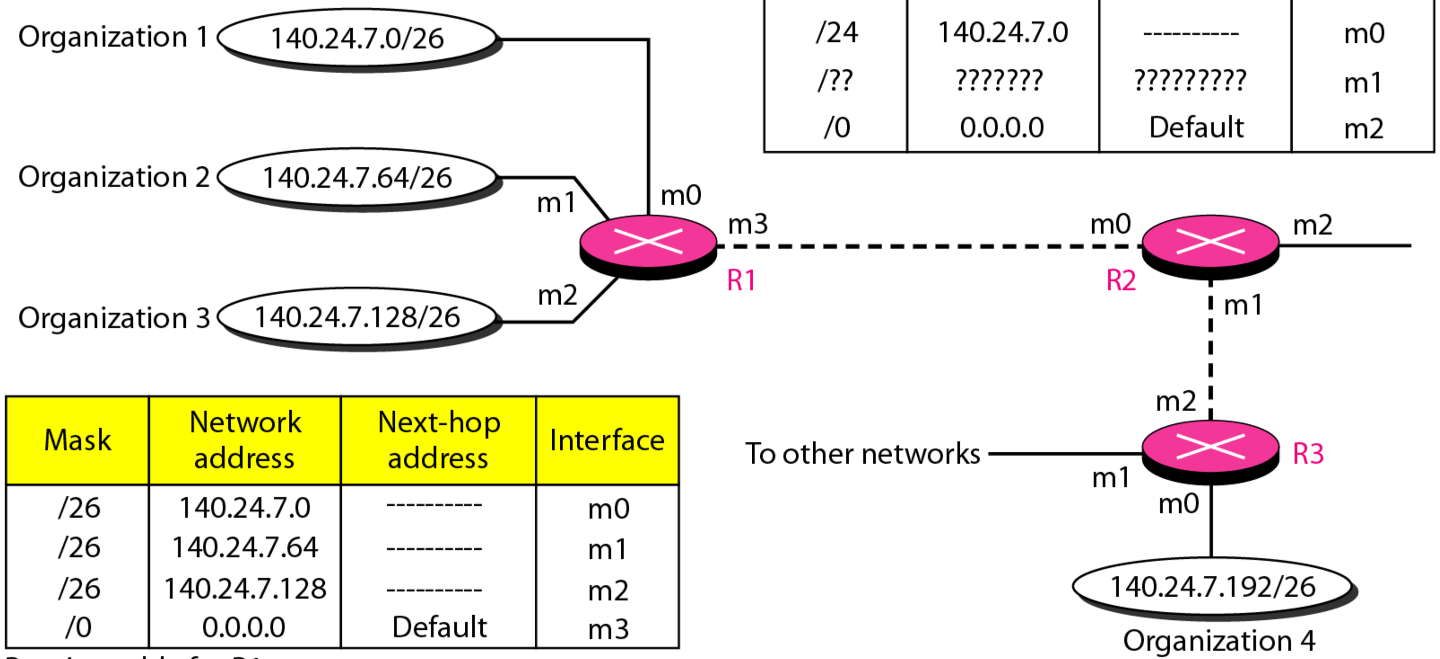
Mask	Network address	Next-hop address	Interface
/24	140.24.7.0	----------	m0
/0	0.0.0.0	Default	m1

Routing table for R2

Forwarding: Longest mask matching

Routing table for R2

Mask	Network address	Next-hop address	Interface
/26	140.24.7.192	----------	m1
/24	140.24.7.0	----------	m0
/??	???????	?????????	m1
/0	0.0.0.0	Default	m2



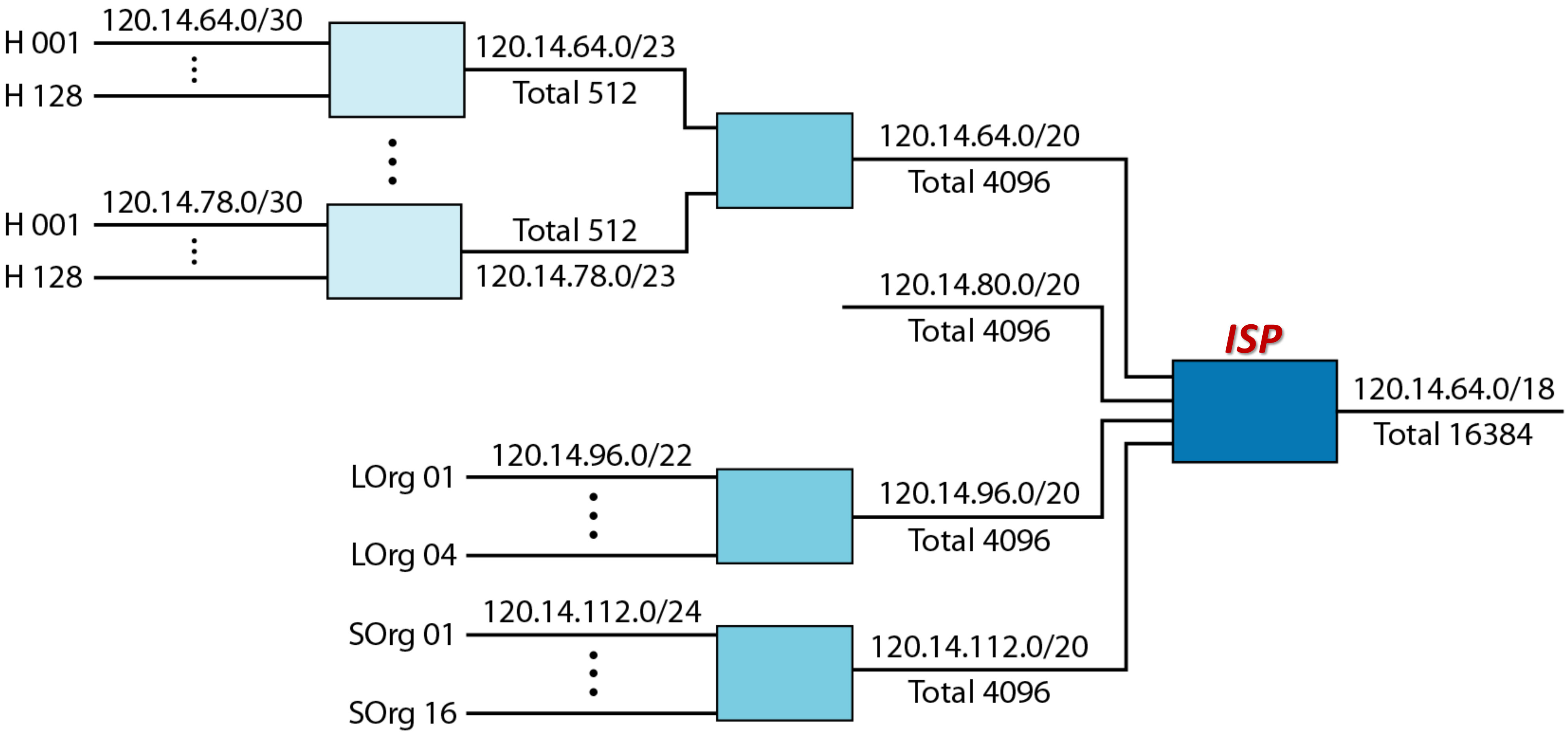
Mask	Network address	Next-hop address	Interface
/26	140.24.7.0	----------	m0
/26	140.24.7.64	----------	m1
/26	140.24.7.128	----------	m2
/0	0.0.0.0	Default	m3

Routing table for R1

Mask	Network address	Next-hop address	Interface
/26	140.24.7.192	----------	m0
/??	???????	?????????	m1
/0	0.0.0.0	Default	m2

Routing table for R3

Forwarding: Hierarchical routing



Summary: Internet Protocols (1)

- Internet architecture, internetworking
  - End-to-end principle, routing
- Internet Protocol
  - Addressing, datagram format
  - IPv4 vs IPv6
  - Fragmentation
  - Forwarding