EITF25 Internet--Techniques and Applications

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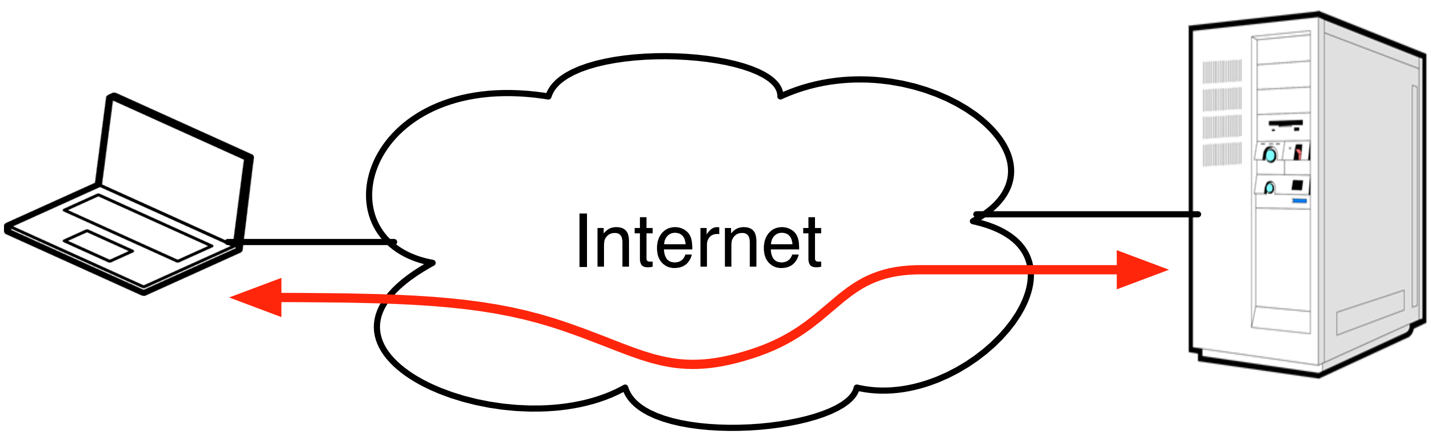
L6 Networking and IP

LUND UNIVERSITY

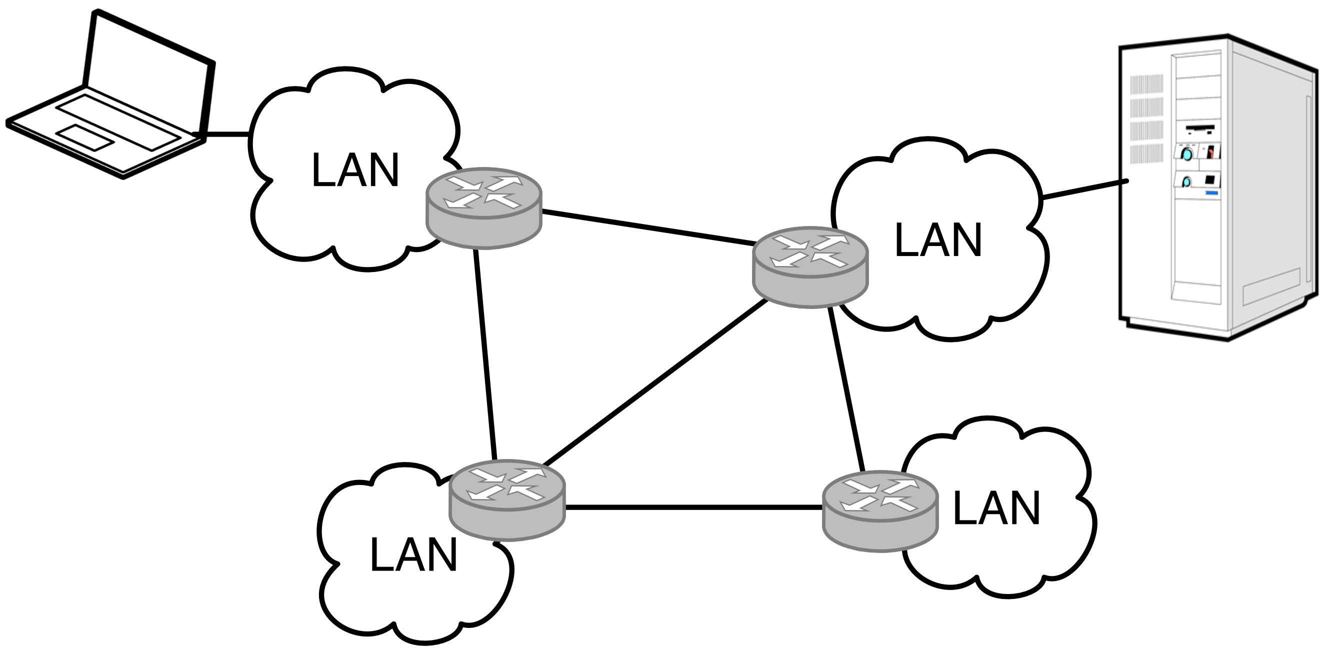
Data communication

In reality, the source and destination hosts are very seldom on the same network, for example web surf.



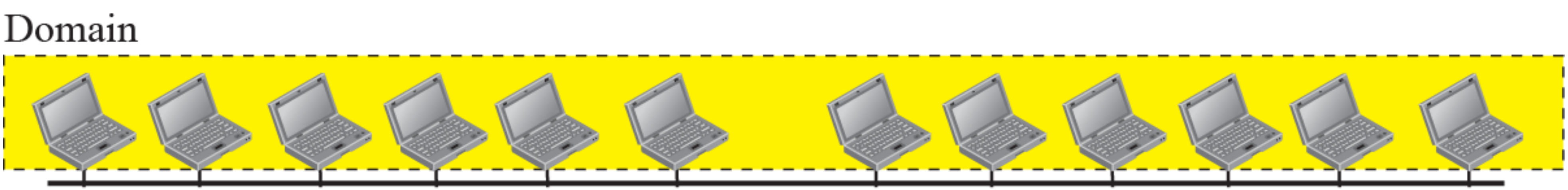
Internetworking

We need protocols and mechanisms for sending data across networks of different types.



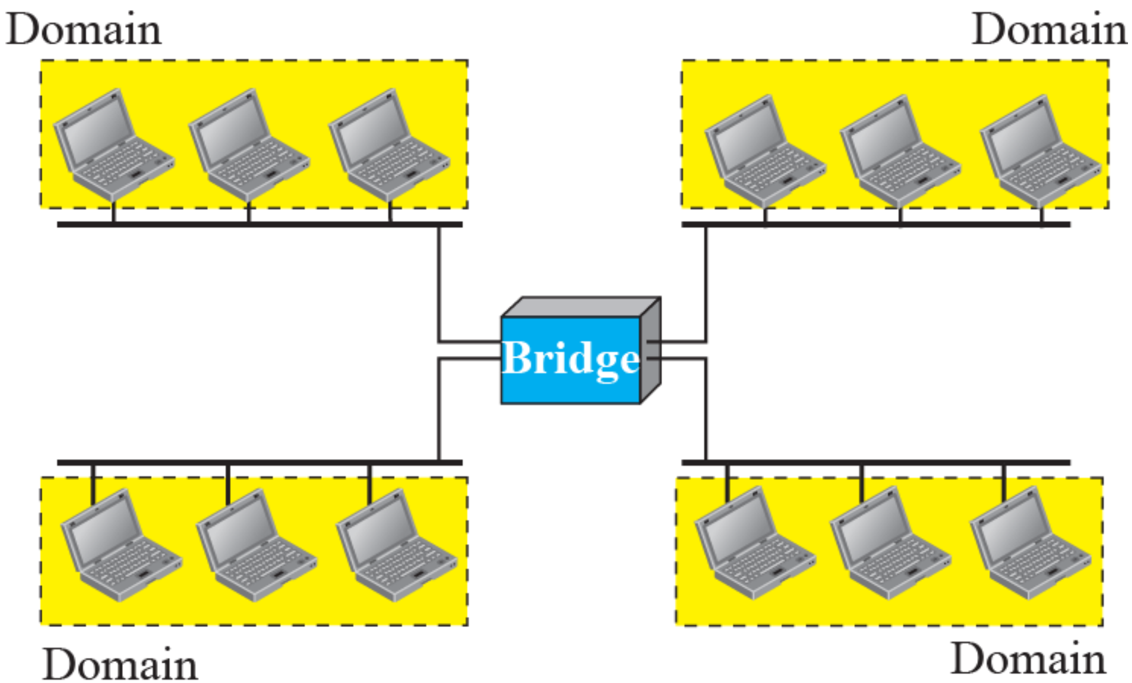
Collision domain

All hosts that share the same medium belong to a *collision domain*. This adds constraints on the size of the shared link.



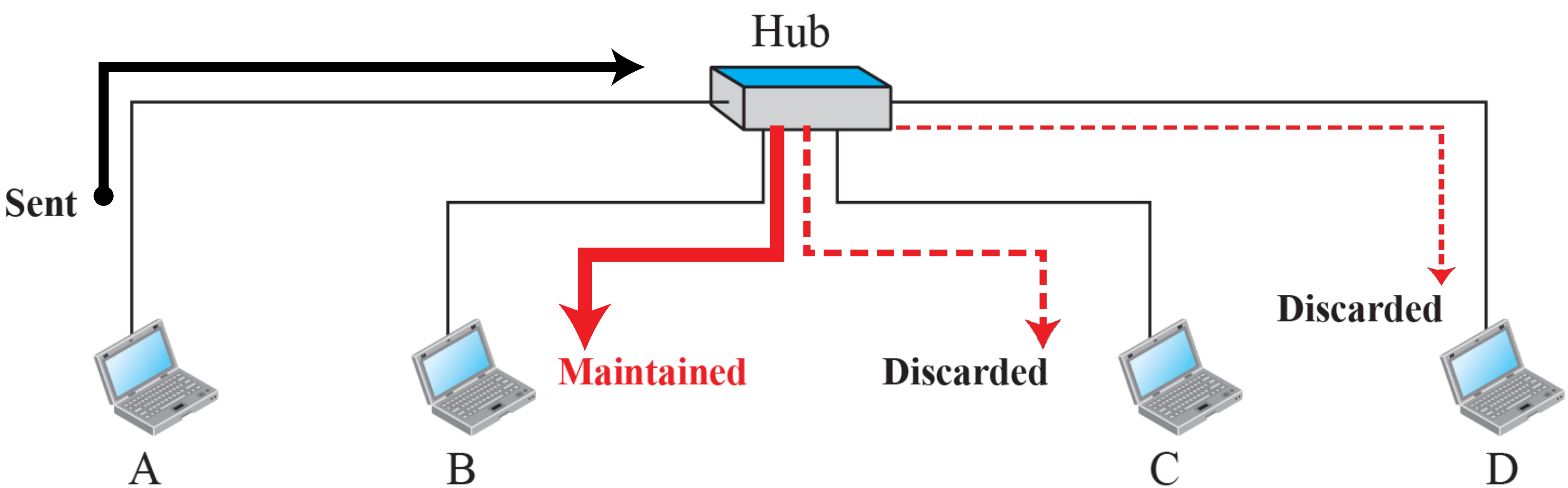
Bridges

Bridges separate the shared links into several collision domains. The bridge acts as a host on all links and can transfer packets between links.



Hubs

A hub transfers packets from an incoming link to all other links. It therefore works on the physical layer.

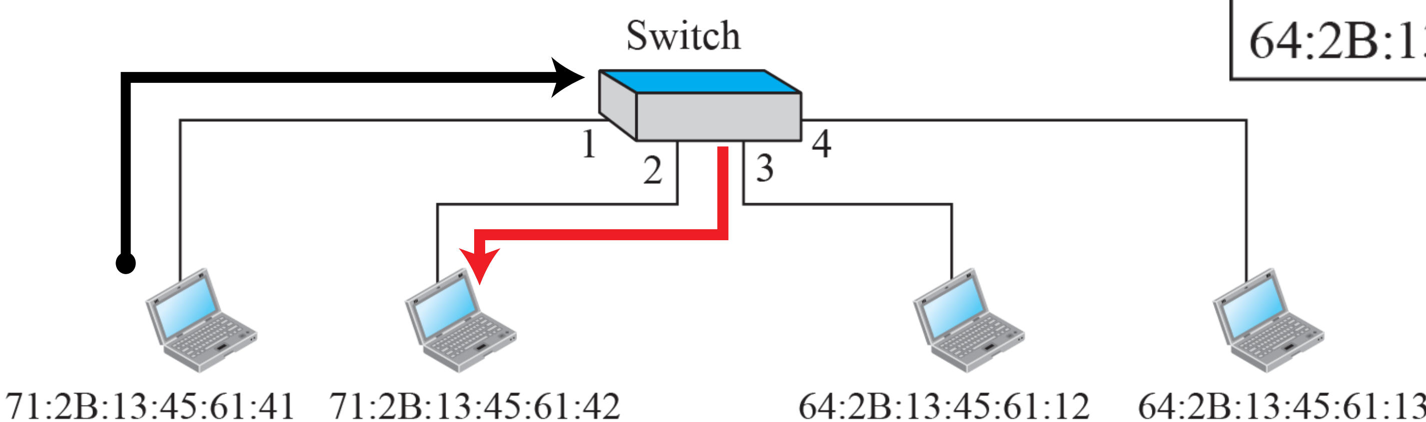


Basic principle for a switch

The switch keeps an address table for forwarding of packets. Addressing on layer 2.

Switching table

Address	Port
71:2B:13:45:61:41	1
71:2B:13:45:61:42	2
64:2B:13:45:61:12	3
64:2B:13:45:61:13	4



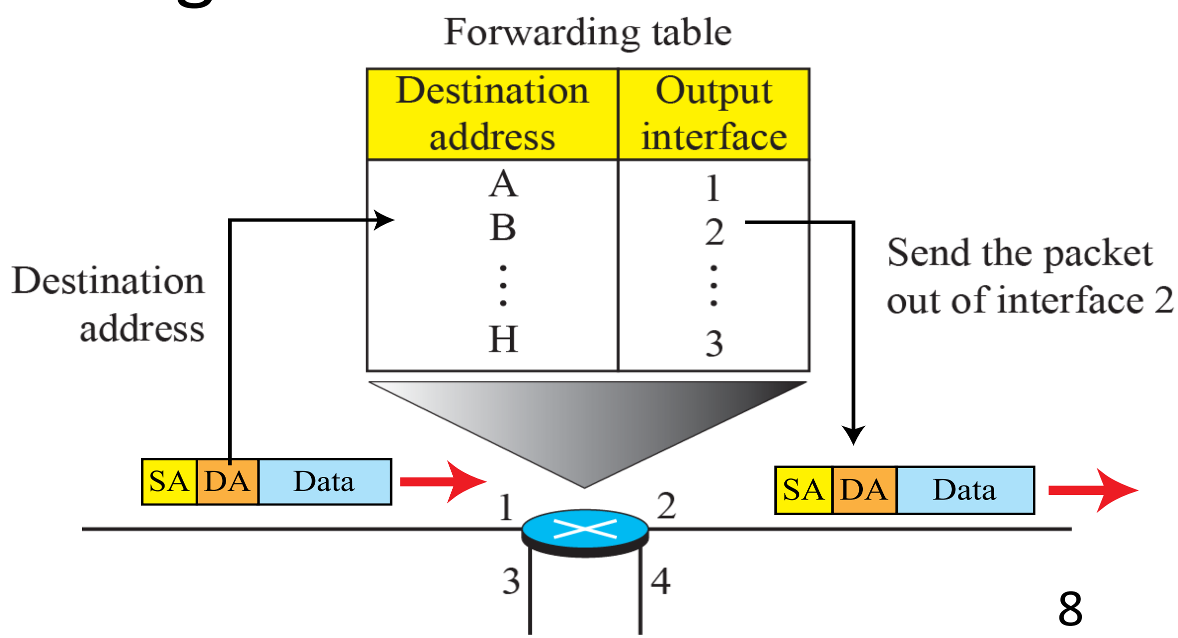
Router

Internetworking device

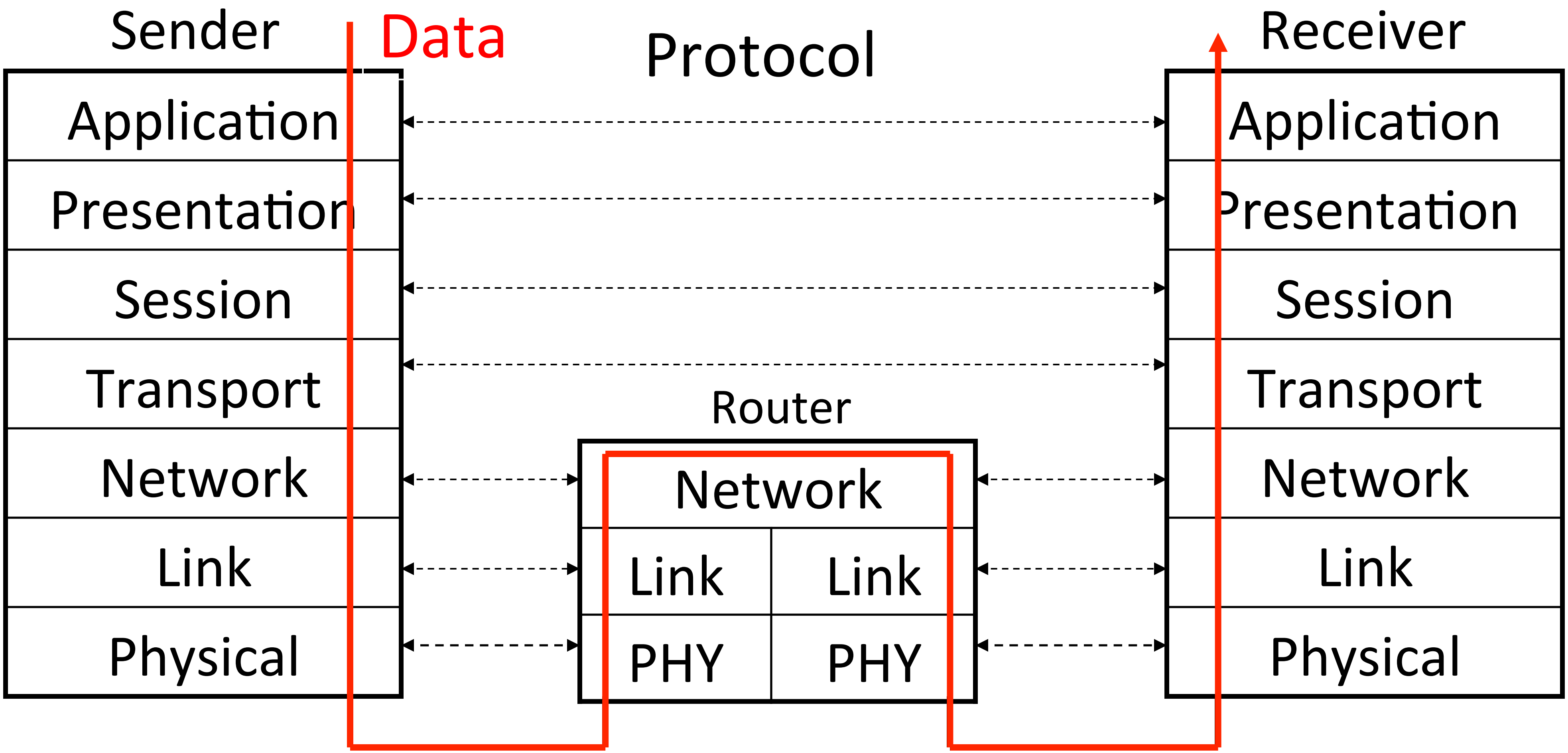
- Passes data packets between networks
- Checks ***Network*** addresses
- Uses Routing/forwarding tables

Two functions:

- Routing
- Forwarding



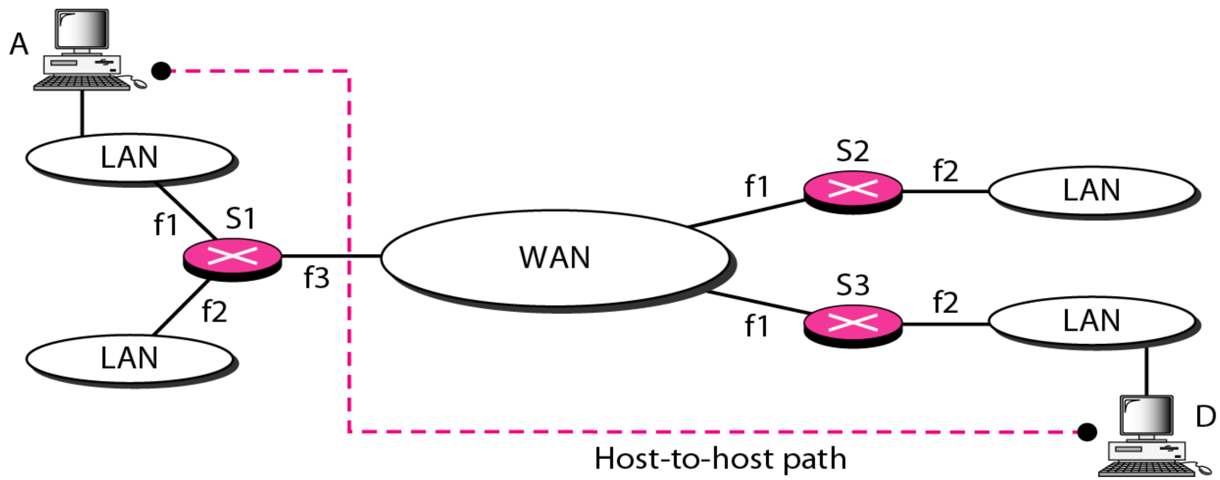
Router, logical layers



Network layer

L3

- end-to-end

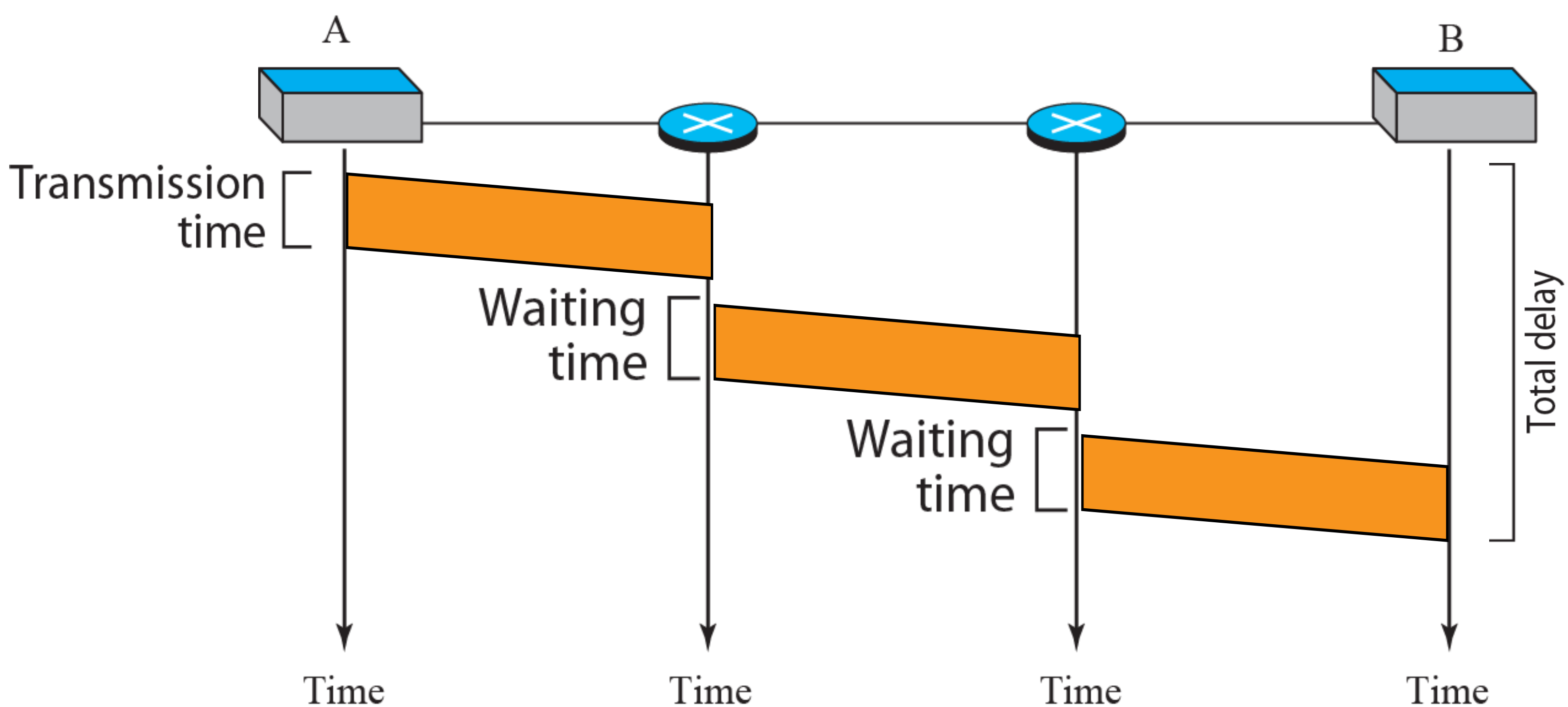


L2

- hop-by-hop

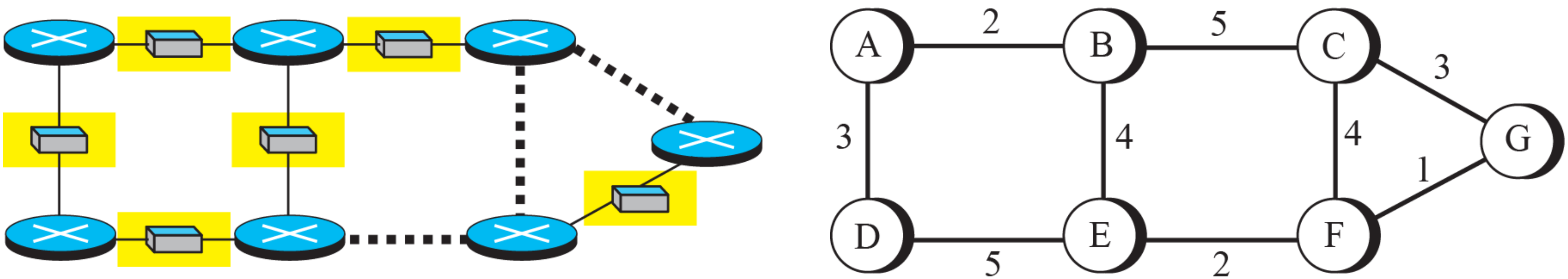
Transmission delay

Each router has buffers so that packets can be stored when waiting for service. The end-to-end transmission delay includes both waiting time and transmission time on links.



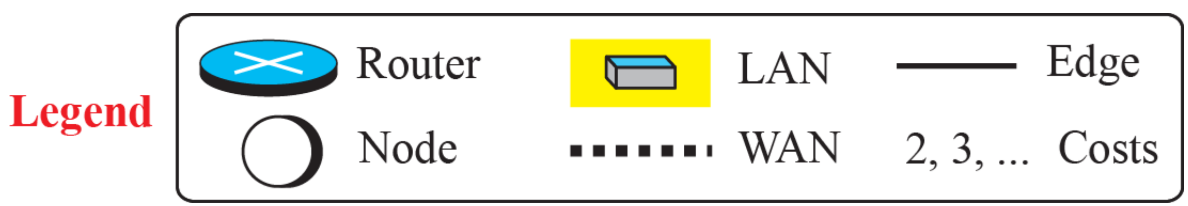
Routing algorithm

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



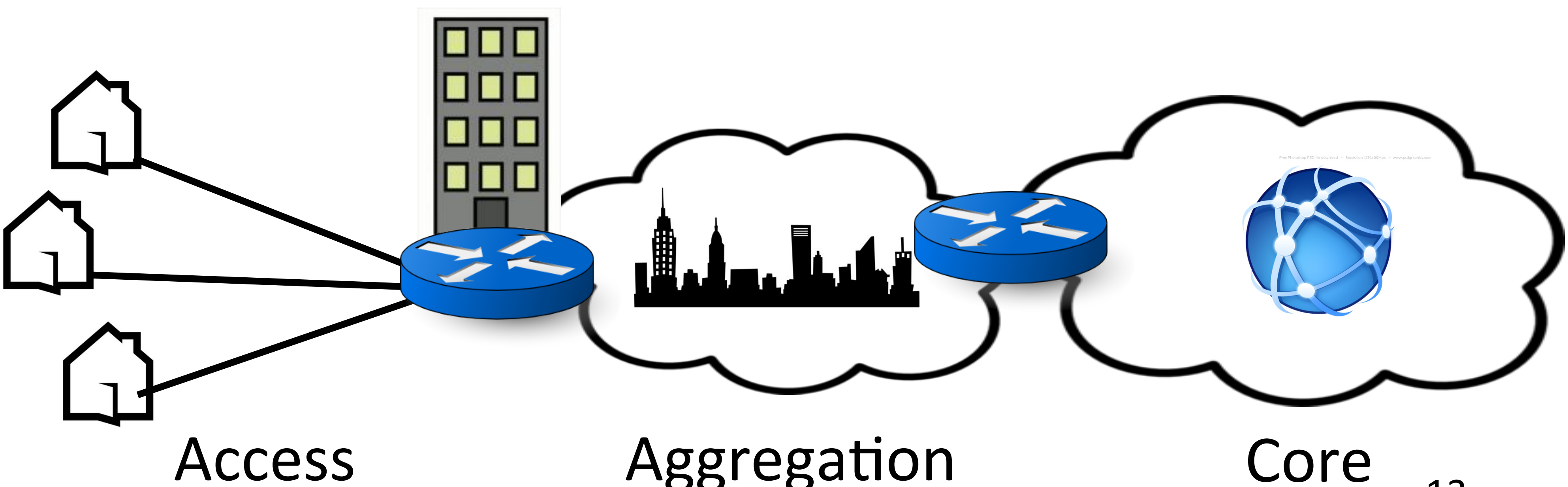
a. An internet

b. The weighted graph



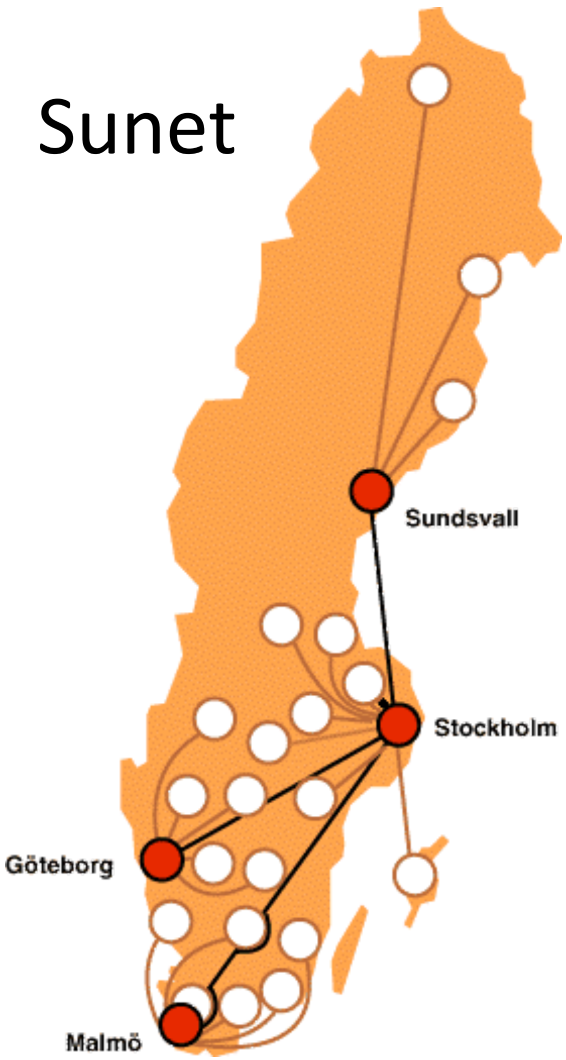
Network architecture

- Three stages of networks in Internet:
  - Access networks: close to the user, last mile
  - Aggregation network: aggregation of traffic from/to users
  - Backbone (core) networks: Internet highways

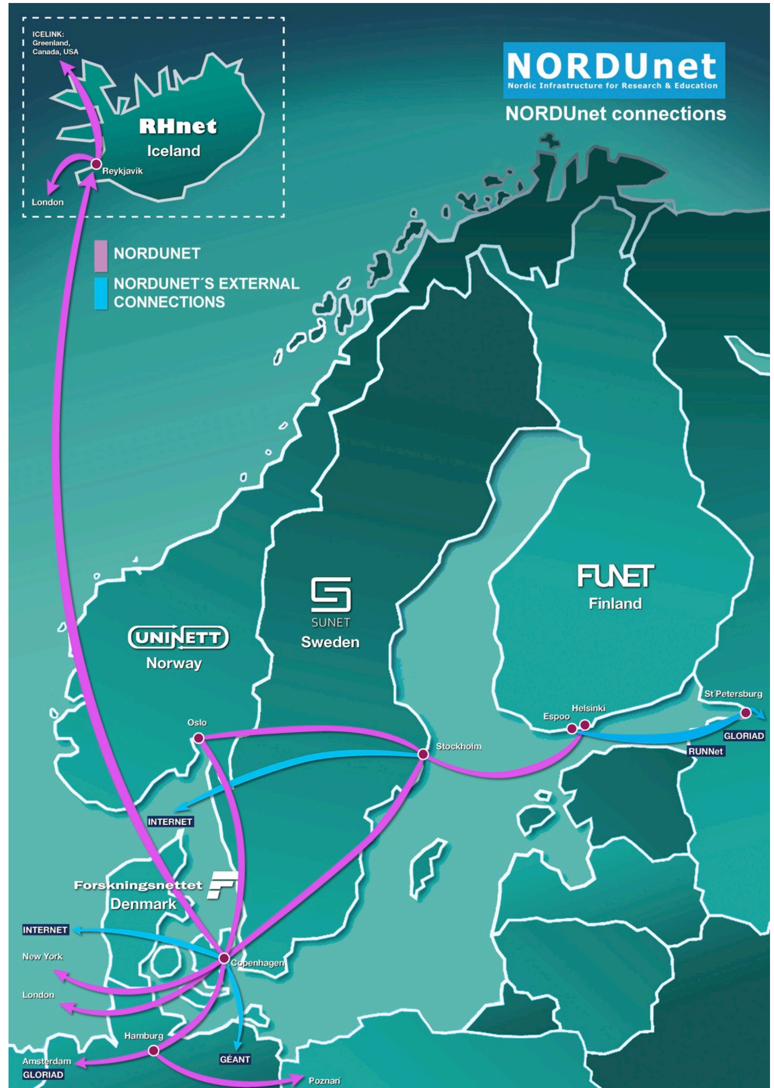


Core (university) network in Sweden

Sunet



Nordunet

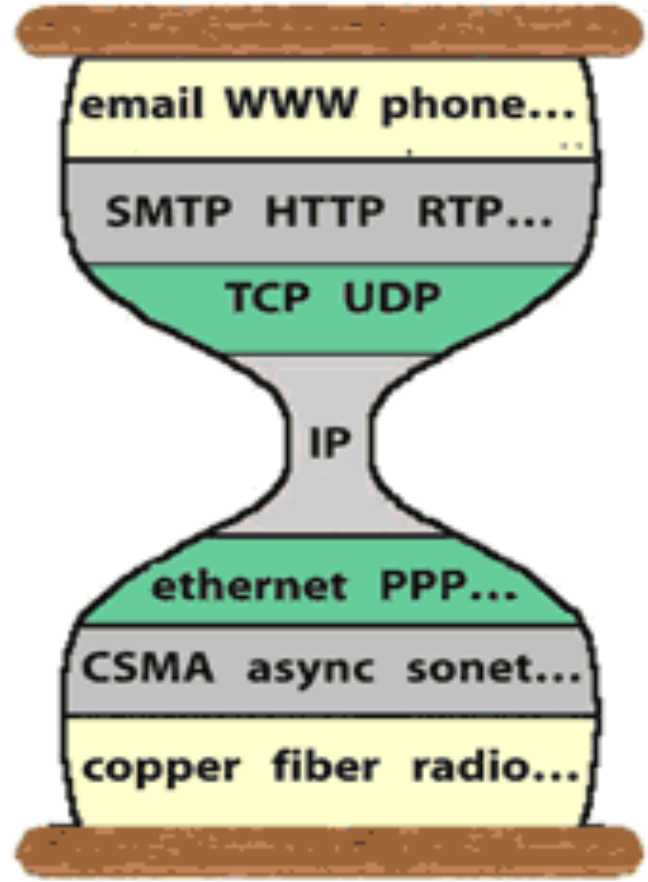


Network layer protocols

- 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*.

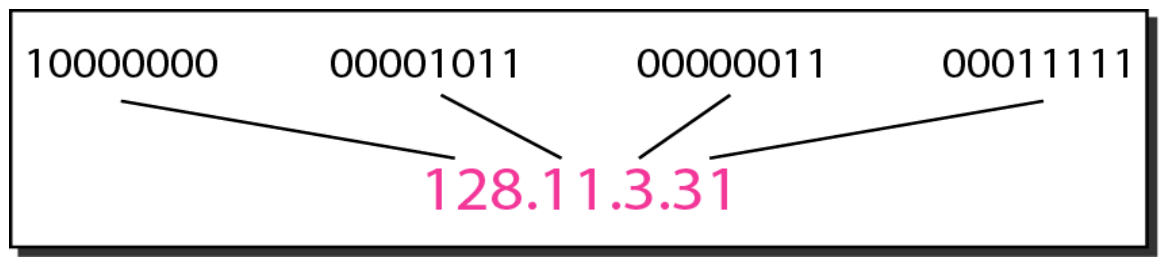
Internet

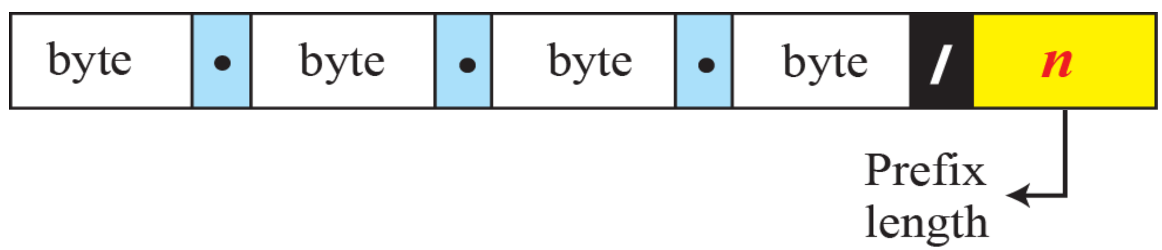
- All networks that are part of Internet have one thing in common:
- **They all use the same network protocol, *Internet Protocol (IP)*!**
- Sometimes illustrated with a hourglass.



IPv4 addresses

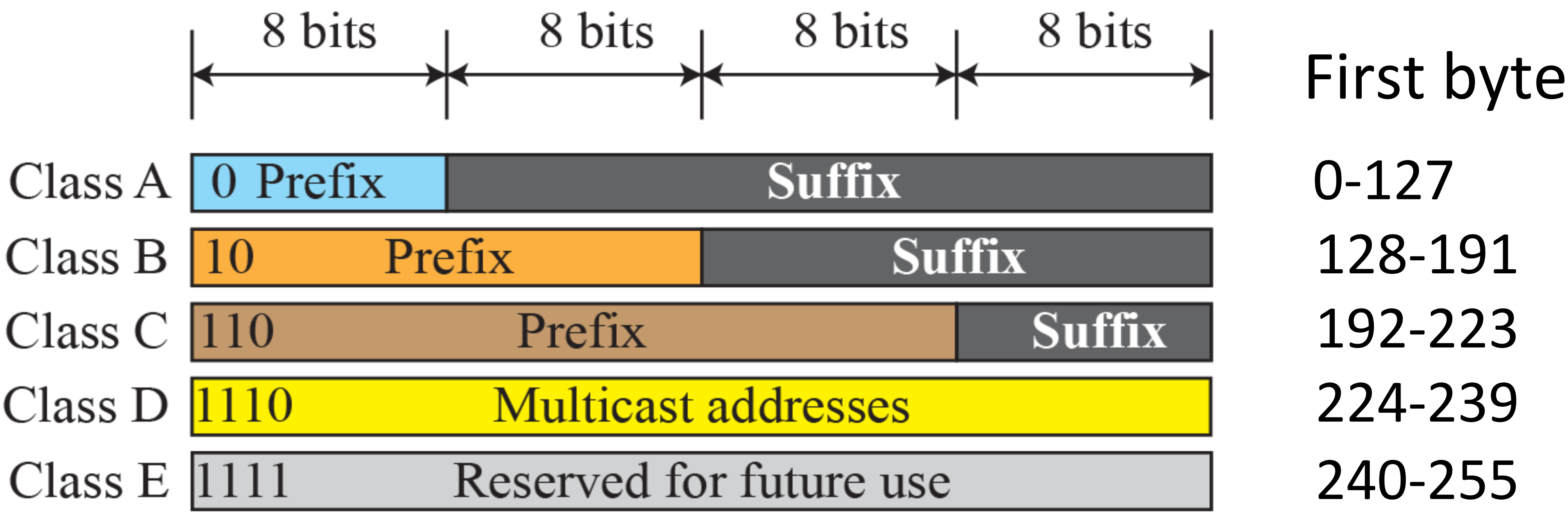
- 32 bits = 4 bytes
- $2^{32} = (2^8)^4 = 256^4 = 4\ 294\ 967\ 296$
- Classful vs. classless hierarchy
- Notations
  - Dotted decimal
  - Slash (CIDR)





Classful addressing

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



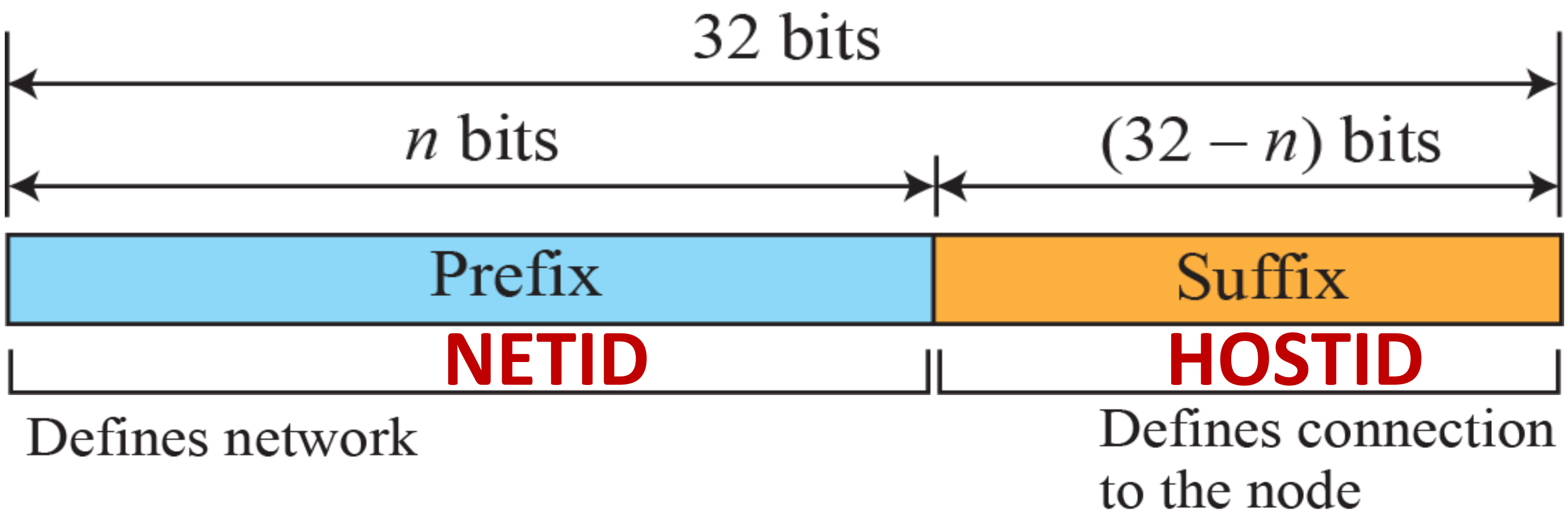
Organizations can only get addresses in one of the predefined blocks.

Address depletion

- Classful addressing defined as there were very few networks connected to the Internet.
- With the growth of Internet, the address classes did not 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
  - $N = 2^{32-n}$ *host addresses in network*



Classless addressing Example

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

	205	16	37	39
	11001101.	00010000.	00100101.	00100111
28	11111111.	11111111.	11111111.	11110000
	11001101.	00010000.	00100101.	00100000

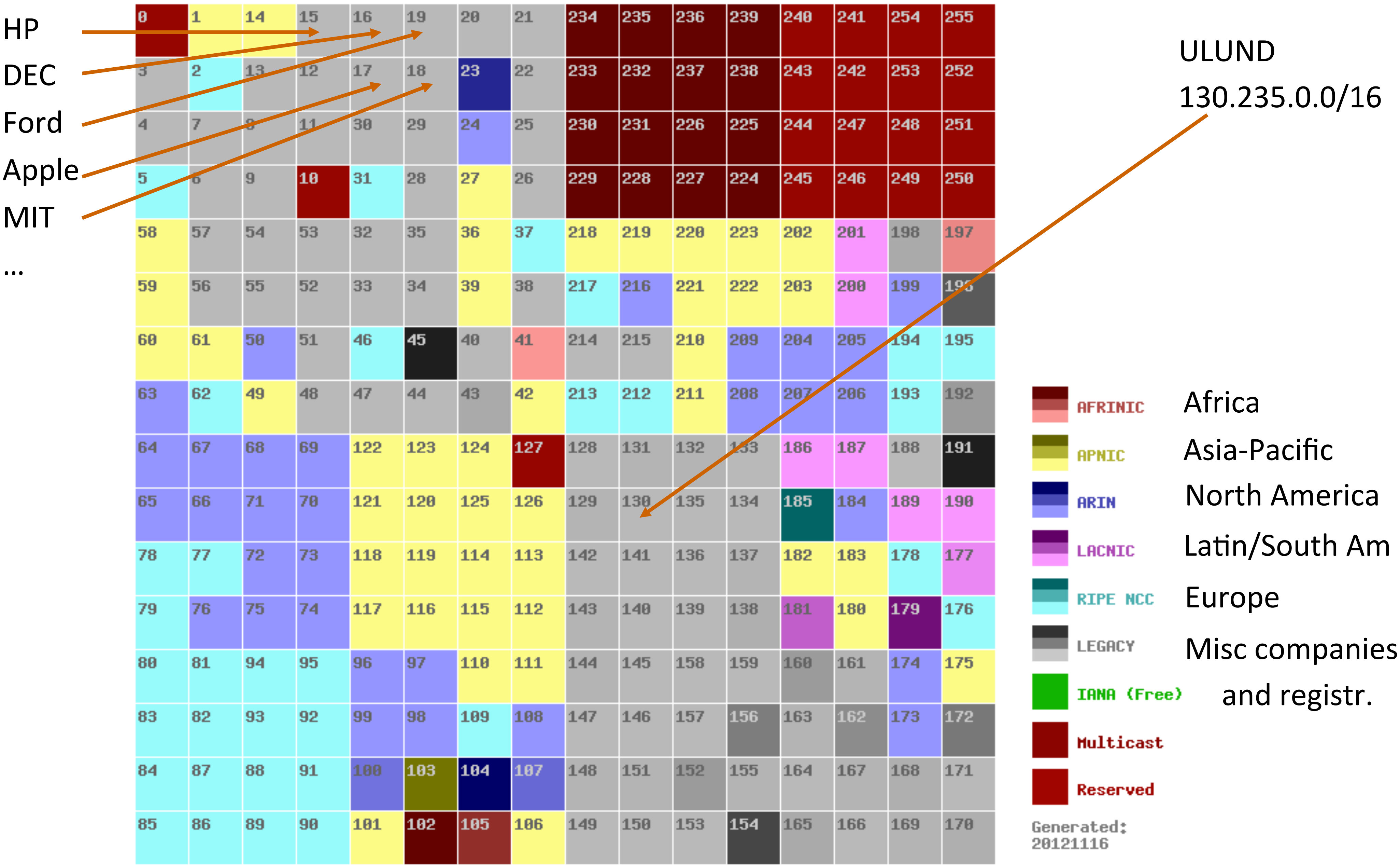
Address space

11001101.00010000.00100101.00100000 : 205.16.37.32

... ...

11001101.00010000.00100101.00101111 : 205.16.37.47

Map of IPv4


HP
DEC
Ford
Apple
MIT
…
ULUND
130.235.0.0/16
0 1 14 15 16 19 20 21 234 235 236 239 240 241 254 255
3 2 13 12 17 18 23 22 233 232 237 238 243 242 253 252
4 7 8 11 30 29 24 25 230 231 226 225 244 247 248 251
5 6 9 10 31 28 27 26 229 228 227 224 245 246 249 250
58 57 54 53 32 35 36 37 218 219 220 223 202 201 198 197
59 56 55 52 33 34 39 38 217 216 221 222 203 200 199 196
60 61 50 51 46 45 40 41 214 215 210 209 204 205 194 195
63 62 49 48 47 44 43 42 213 212 211 208 207 206 193 192
64 67 68 69 122 123 124 127 128 131 132 133 186 187 188 191
65 66 71 70 121 120 125 126 129 130 135 134 185 184 189 190
78 77 72 73 118 119 114 113 142 141 136 137 182 183 178 177
79 76 75 74 117 116 115 112 143 140 139 138 181 180 179 176
80 81 94 95 96 97 110 111 144 145 158 159 160 161 174 175
83 82 93 92 99 98 109 108 147 146 157 156 163 162 173 172
84 87 88 91 100 103 104 107 148 151 152 155 164 167 168 171
85 86 89 90 101 102 105 106 149 150 153 154 165 166 169 170
AFRINIC
Africa
APNIC
Asia-Pacific
ARIN
North America
LACNIC
Latin/South Am
RIPE NCC
Europe
LEGACY
Misc companies
and registr.
IANA (Free)
Multicast
Reserved
Generated:
20121116

Problems with IPv4

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

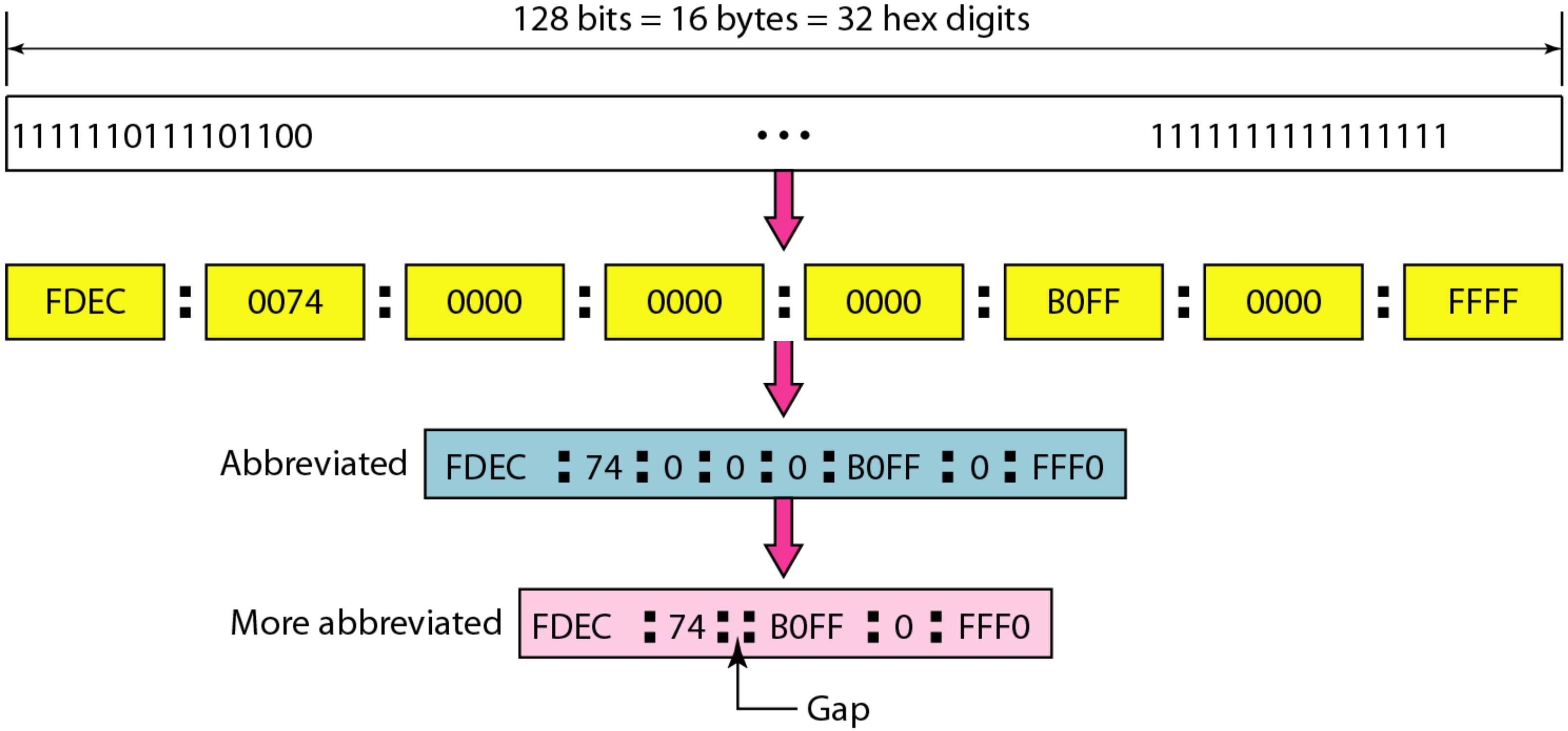
IPv6

Some advantages with IPv6

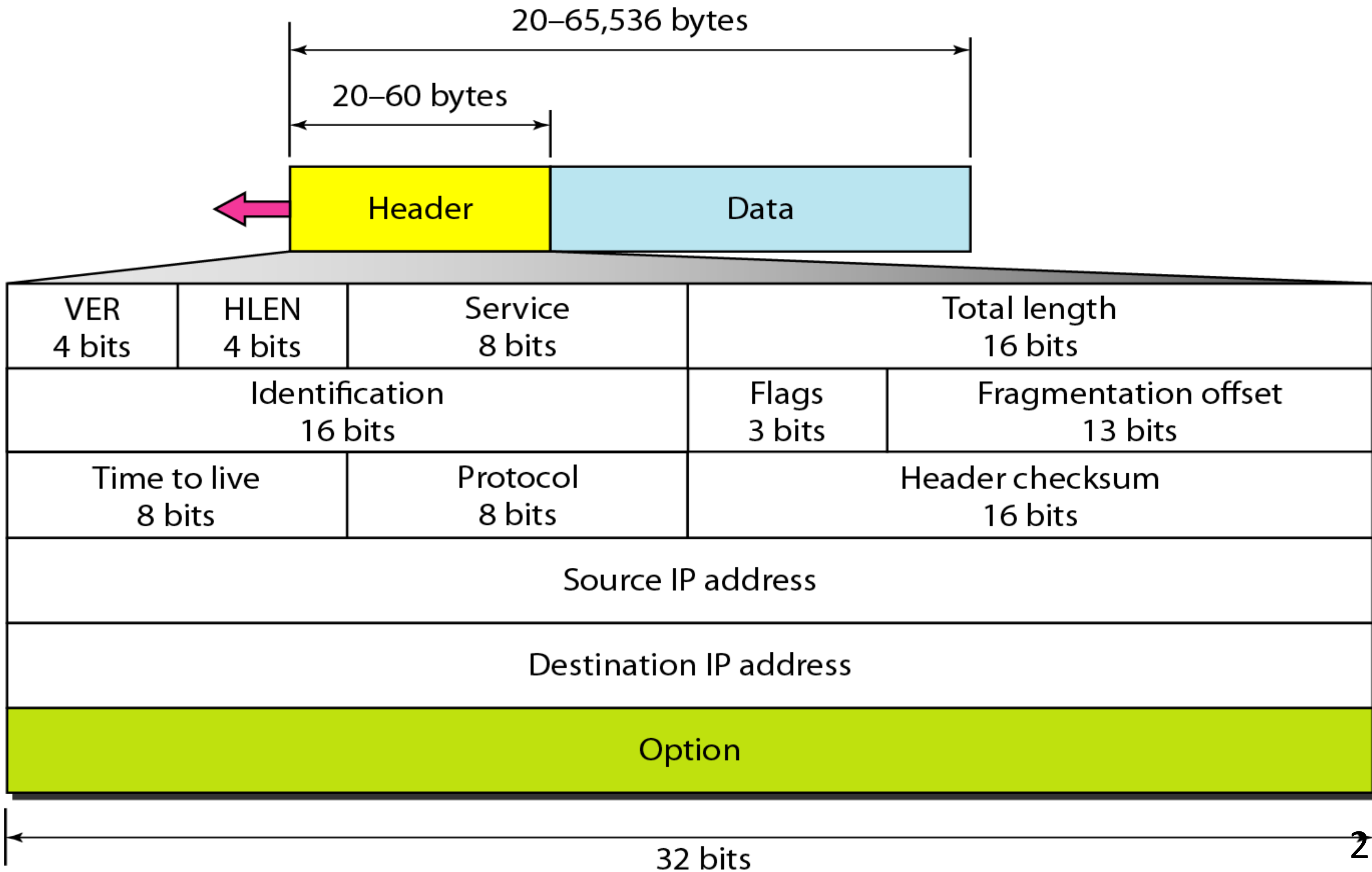
- **Larger address space:** 128 bit-long addresses.
- **Better header format:** base header has constant length (40 bytes). Options can be inserted when needed.
- **Support for more security:** Encryption and authentication options.
- **Support for real-time applications:** Special handling of datagram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

IPv6 addresses

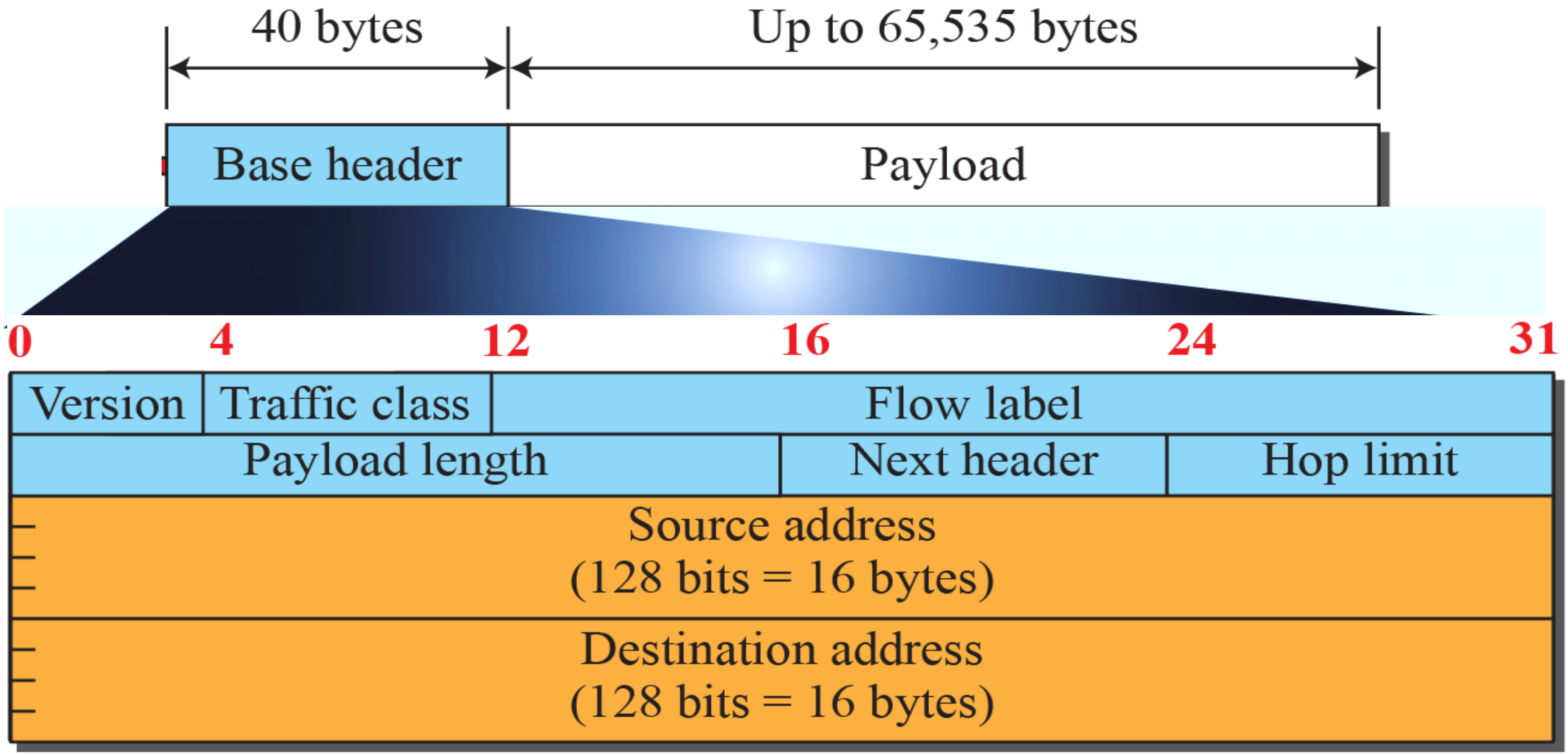
- 128 bits = 16 bytes
- $2^{128} = 3.4 \cdot 10^{38}$
- CIDR (/n-notation) same as IPv4



IPv4 datagram



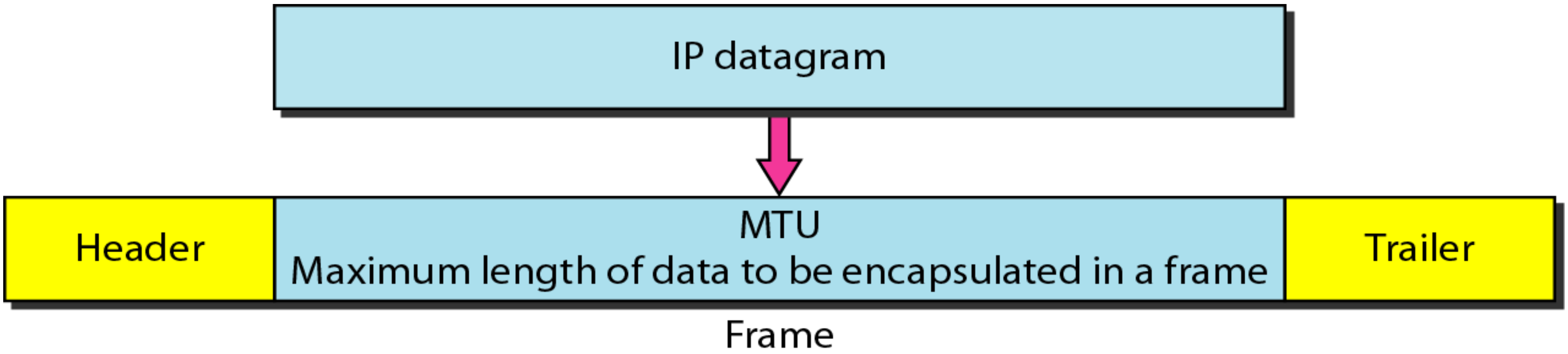
IPv6 datagram



Transition: IPv4 → IPv6

- Cannot happen overnight
  - Too many independent systems
  - Economic cost
  - IPv4 address space lasted longer than expected
- Coexisence needed
  - Dual stack
  - Tunneling
  - Header translation

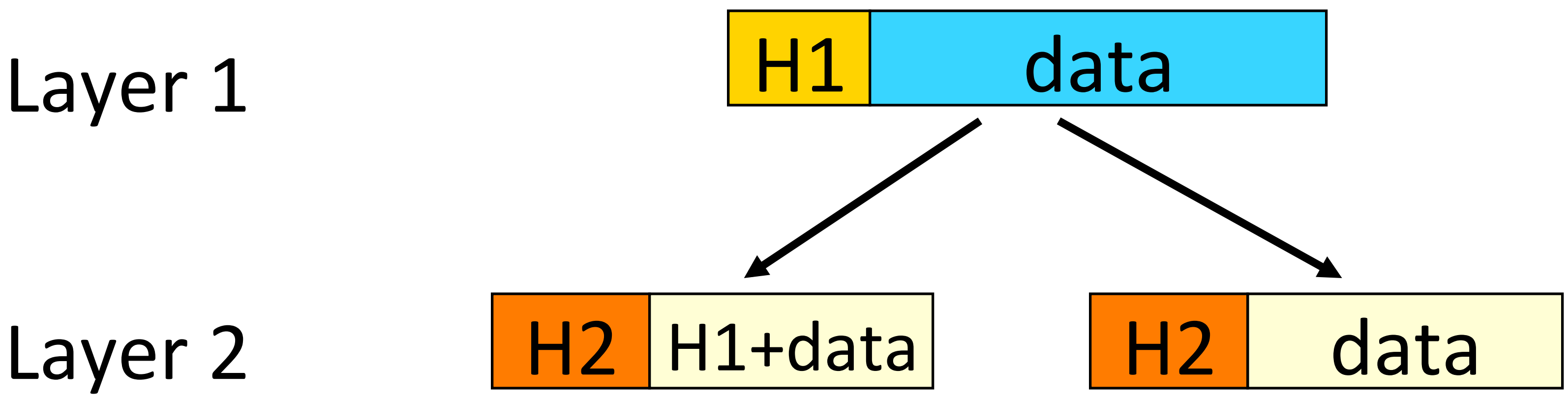
Maximum datagram size



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

If data from an upper layer cannot fit in one data packet, the data is fragmented (according to some prespecified rules)

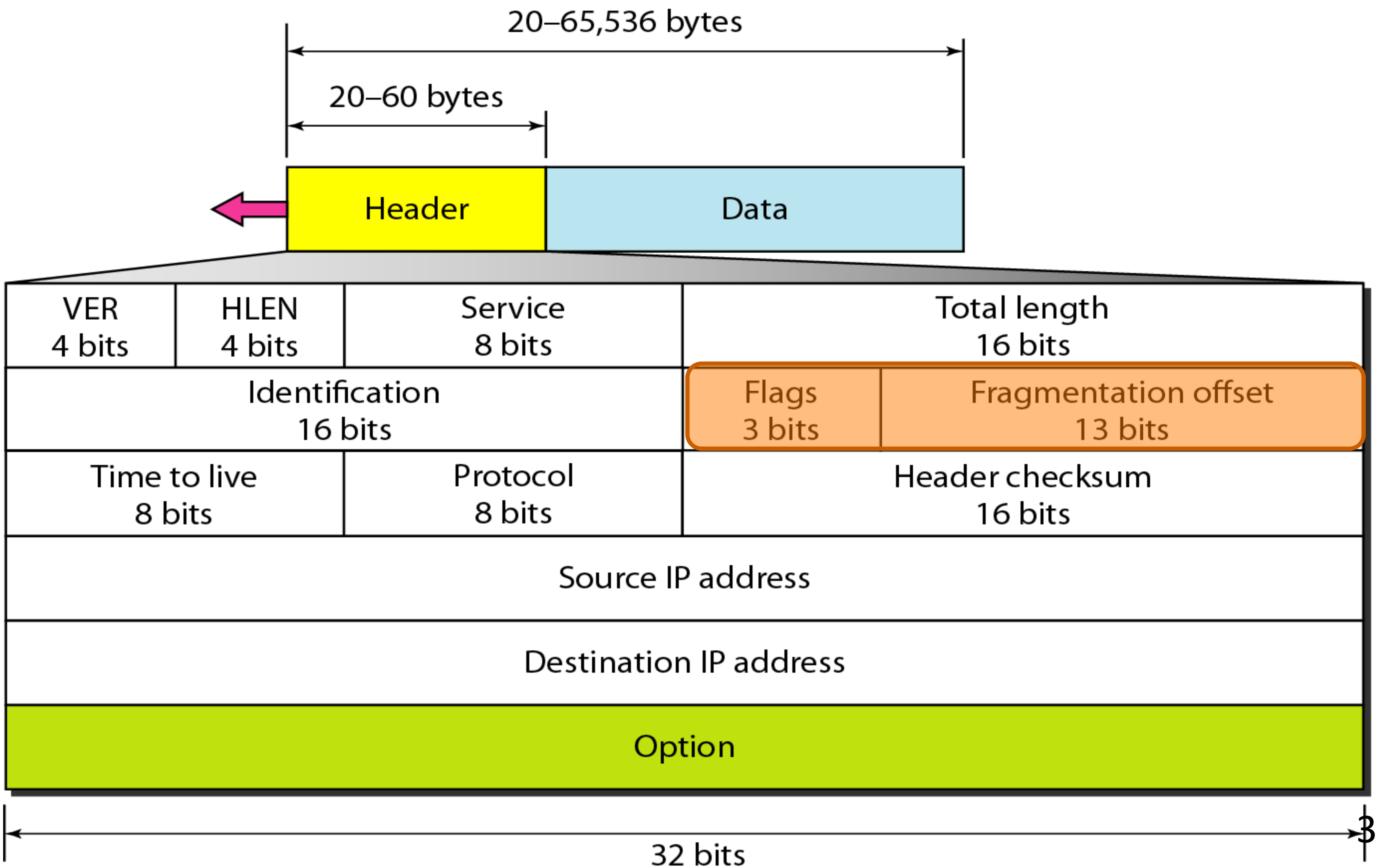


Fragmentation

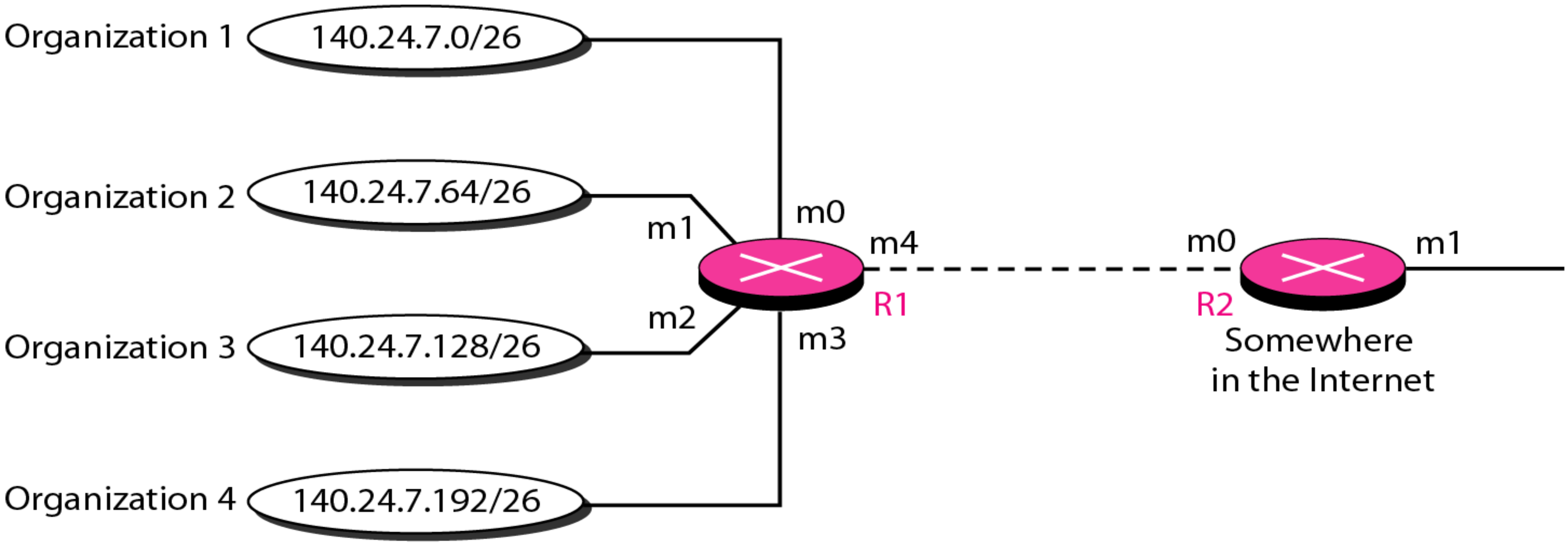
- IPv4
  - Performed by the router meeting the problem
- IPv6
  - Performed by the source router only
- Defragmentation by destination host

D: Do not fragment
M: More fragments

Fragmentation field (IPv4)



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

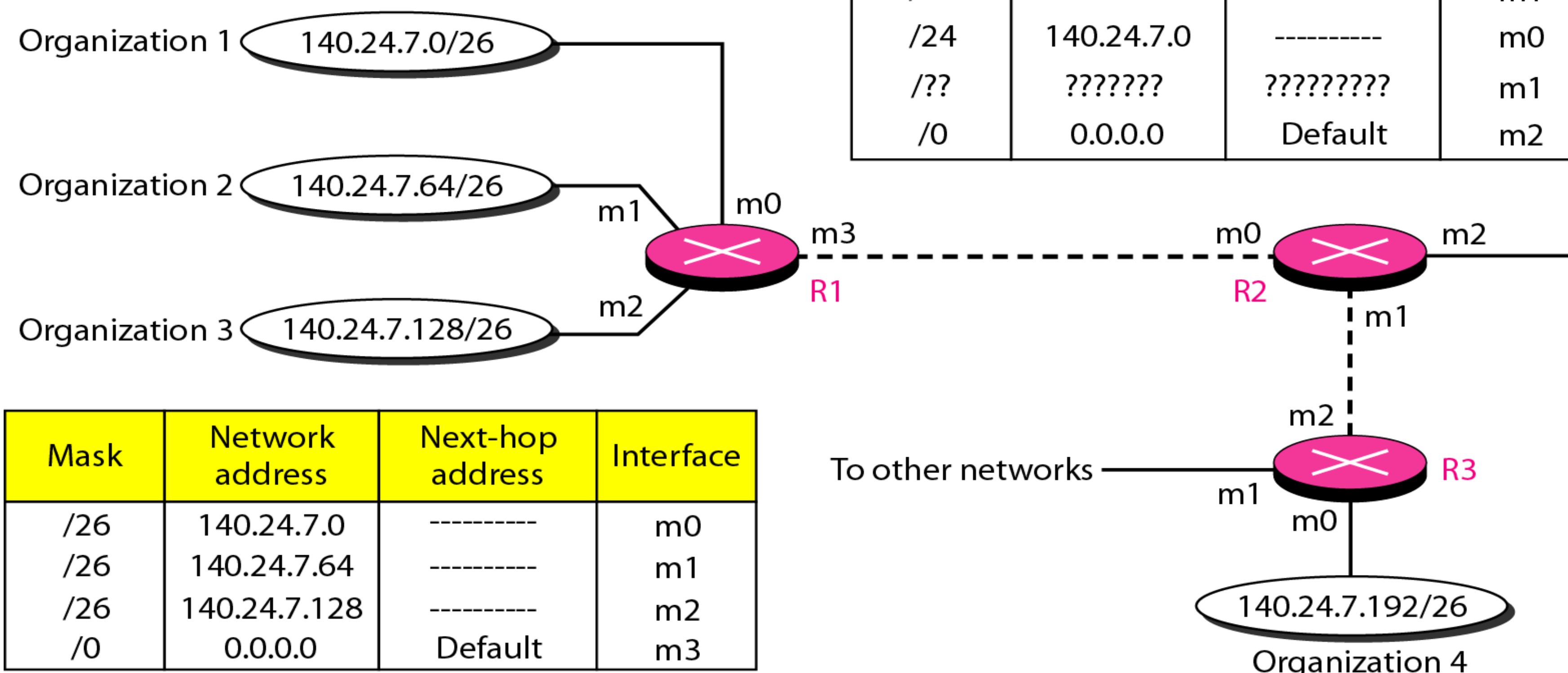
Mask	Network address	Next-hop address	Interface
/24	140.24.7.0	----------	m0
/0	0.0.0.0	Default	m1

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



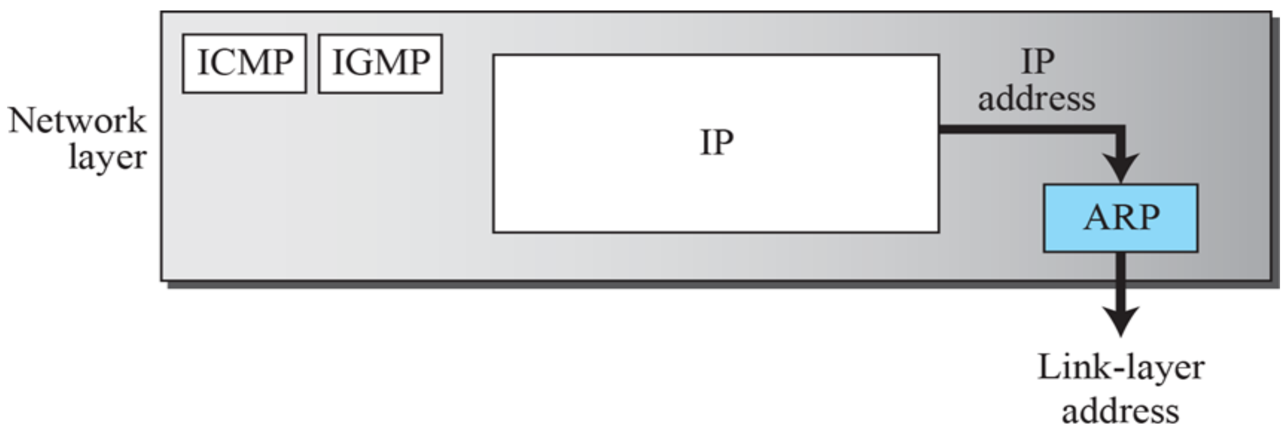
Mask	Network address	Next-hop address	Interface
/26	140.24.7.0	----------	m0
/26	140.24.7.64	----------	m1
/26	140.24.7.128	----------	m2
/0	0.0.0.0	Default	m3

Routing table for R1

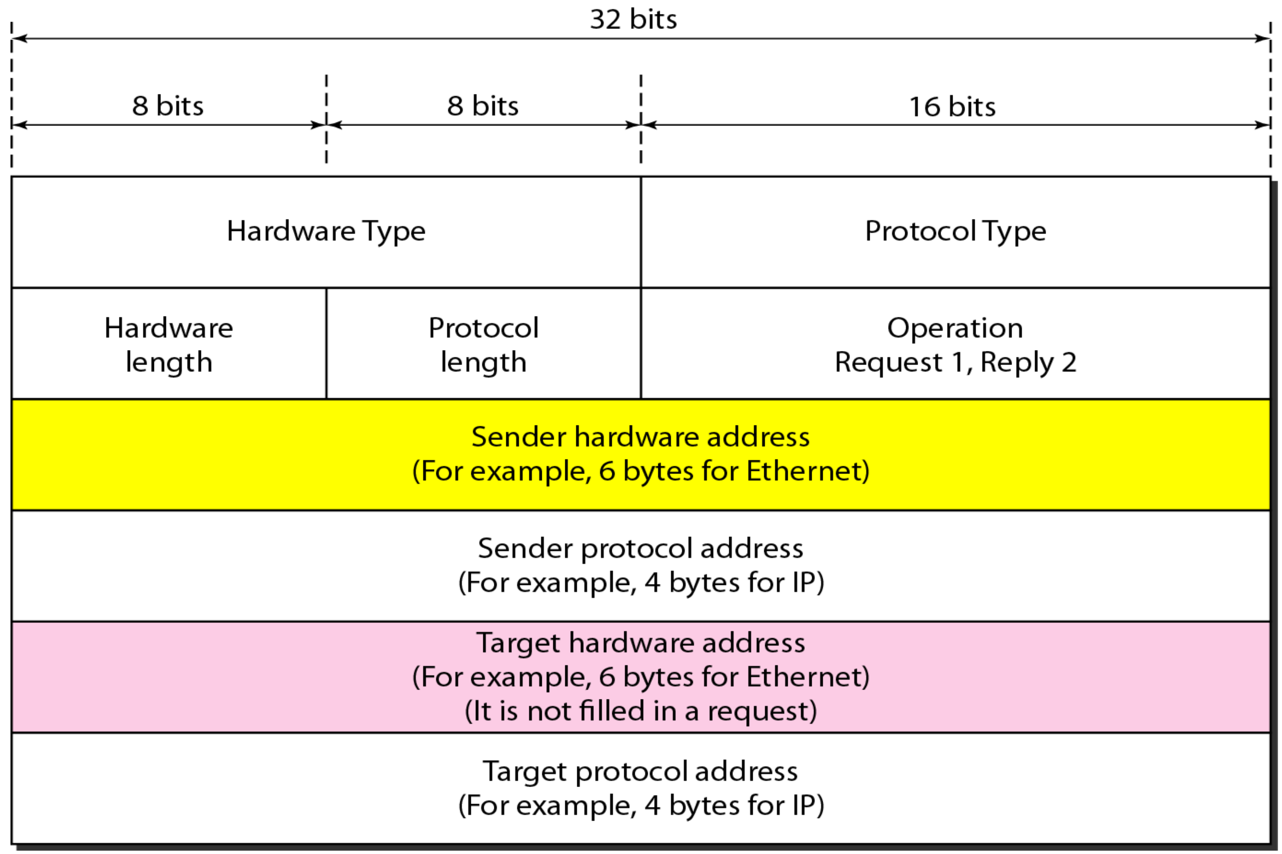
Mask	Network address	Next-hop address	Interface
/26	140.24.7.192	----------	m0
/??	???????	?????????	m1
/0	0.0.0.0	Default	m2

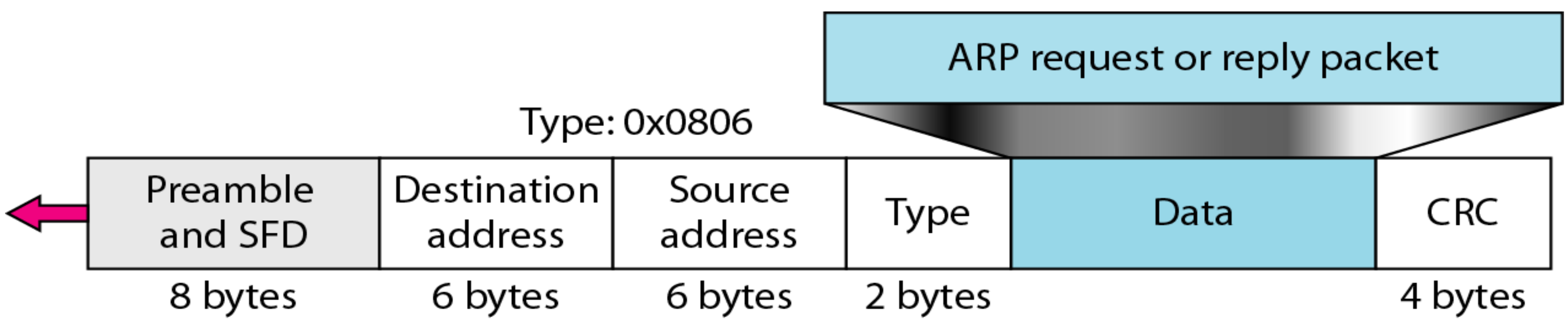
Address Resolution Protocol (ARP)

- Mapping of IP addresses to MAC addresses
- Internet
  - Network of networks connected by routers
- Routers/hosts need information
  - Logical (IP) → physical (MAC)



ARP packet


32 bits
8 bits
8 bits
16 bits
Hardware Type
Protocol Type
Hardware length
Protocol length
Operation Request 1, Reply 2
Sender hardware address (For example, 6 bytes for Ethernet)
Sender protocol address (For example, 4 bytes for IP)
Target hardware address (For example, 6 bytes for Ethernet) (It is not filled in a request)
Target protocol address (For example, 4 bytes for IP)

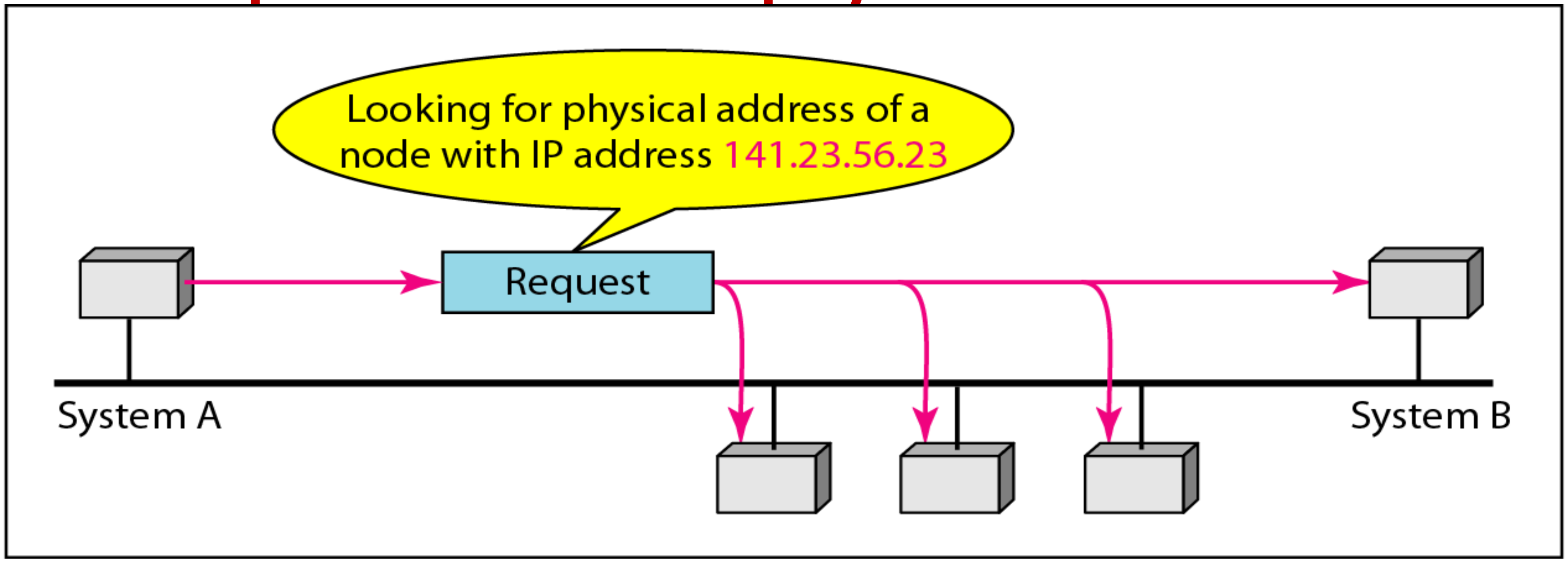

ARP request or reply packet
Type: 0x0806
Preamble and SFD
Destination address
Source address
Type
Data
CRC
8 bytes
6 bytes
6 bytes
2 bytes
4 bytes

ARP operation

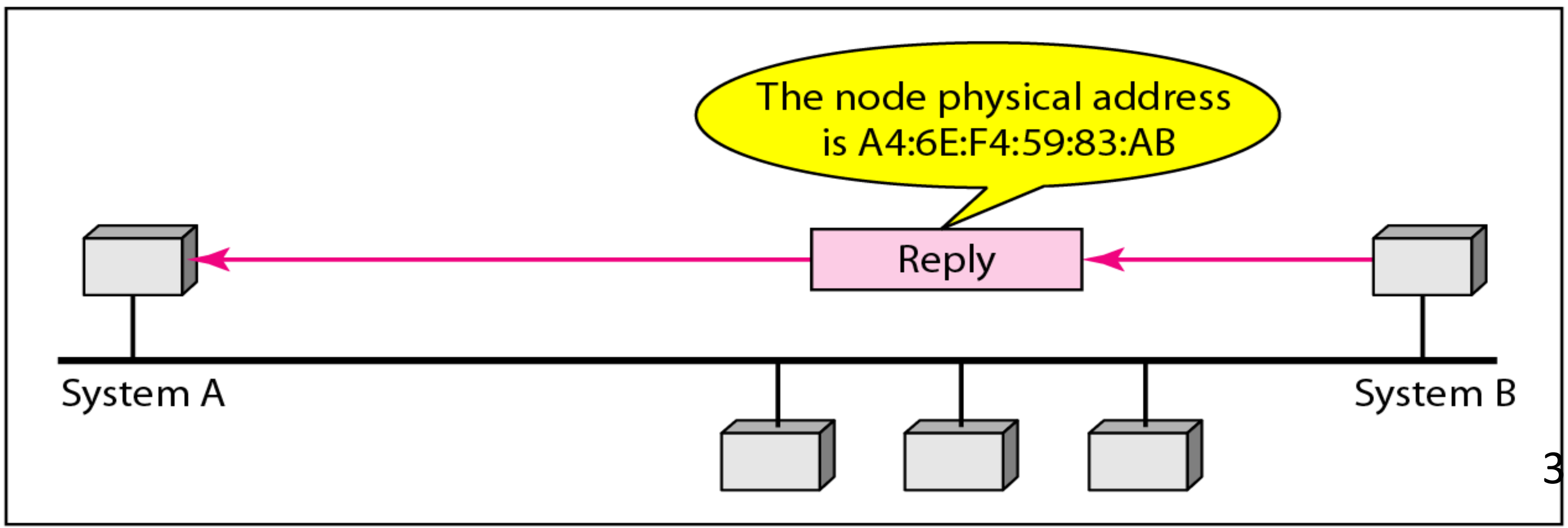
- ARP query broadcast every time a host/router needs a MAC address
- Intended host answers with an ARP response
- ARP cache (table) used to store MAC/IP pairs

- Some IP addresses known from start
  - Default gateway (router) → ”rest of Internet”
  - DNS server

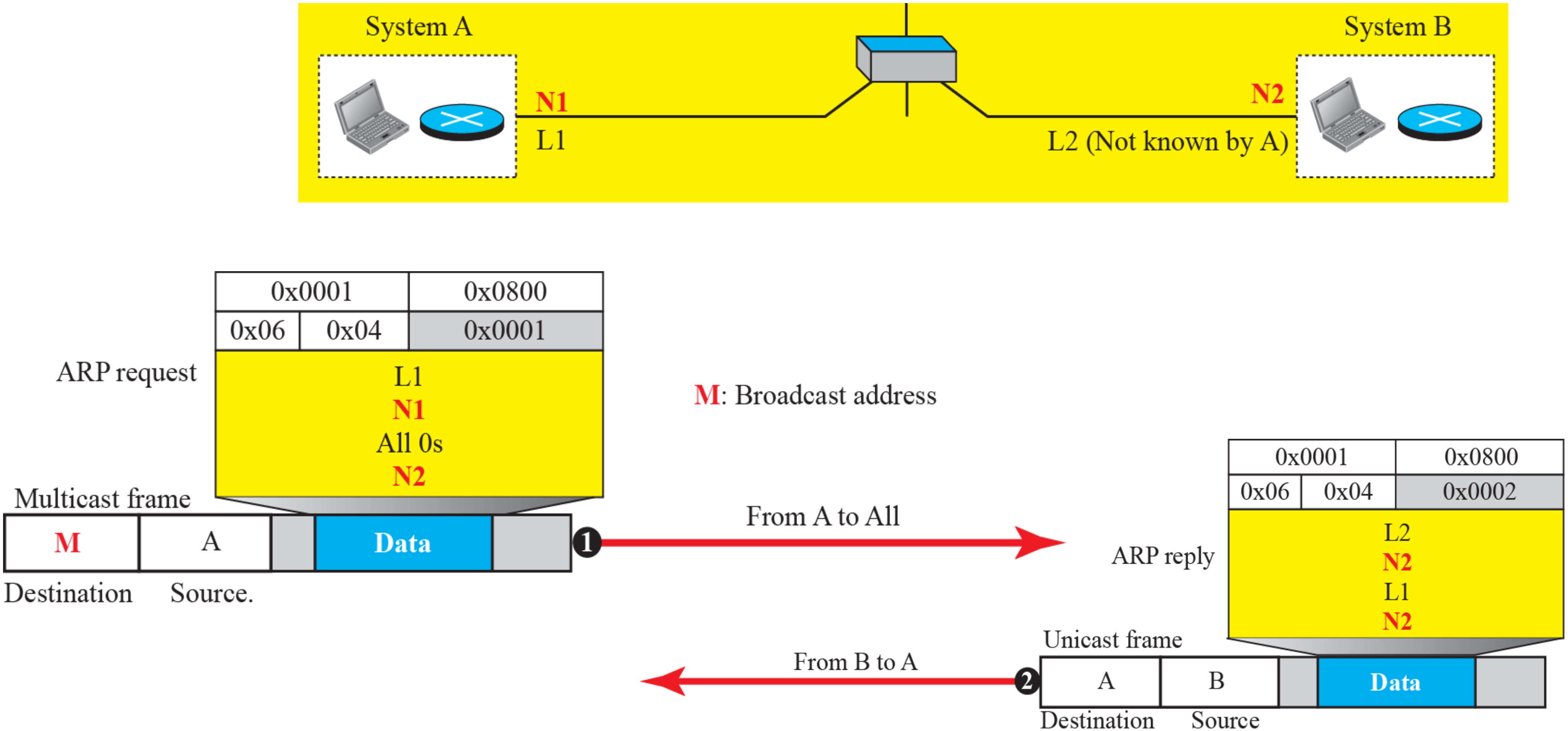
ARP request and reply



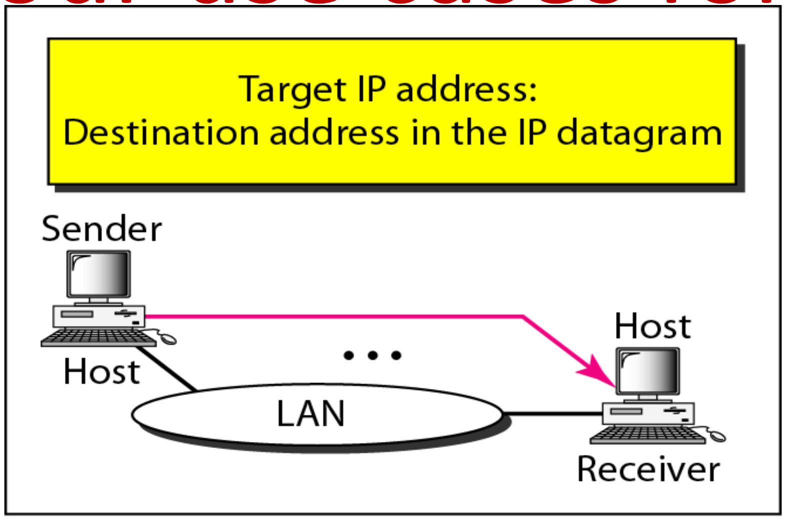
a. ARP request is broadcast



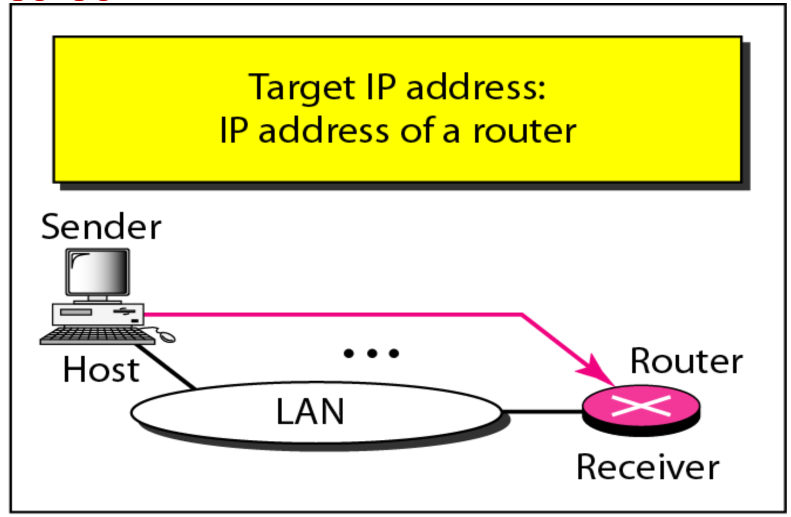
ARP example


System A
System B
N1
L1
N2
L2 (Not known by A)
0x0001
0x0800
0x06
0x04
0x0001
ARP request
L1
N1
All 0s
N2
M: Broadcast address
Multicast frame
M
A
Data
Destination
Source.
From A to All
1
0x0001
0x0800
0x06
0x04
0x0002
ARP reply
L2
N2
L1
N2
Unicast frame
From B to A
2
A
B
Data
Destination
Source

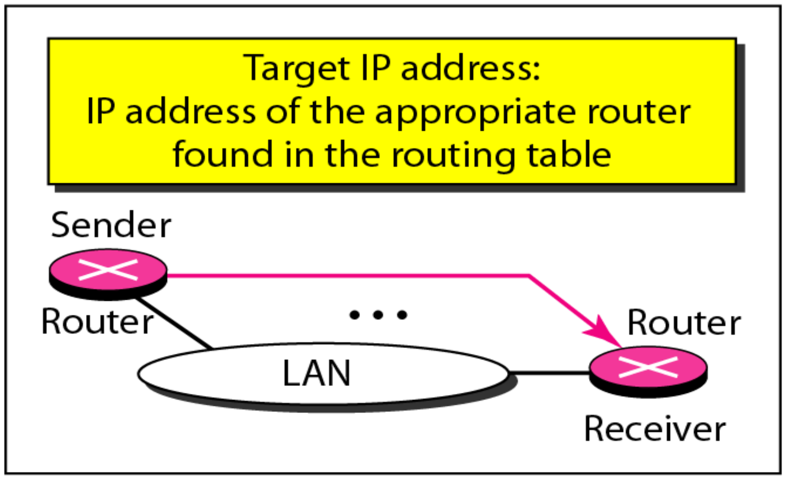
Four use cases for ARP



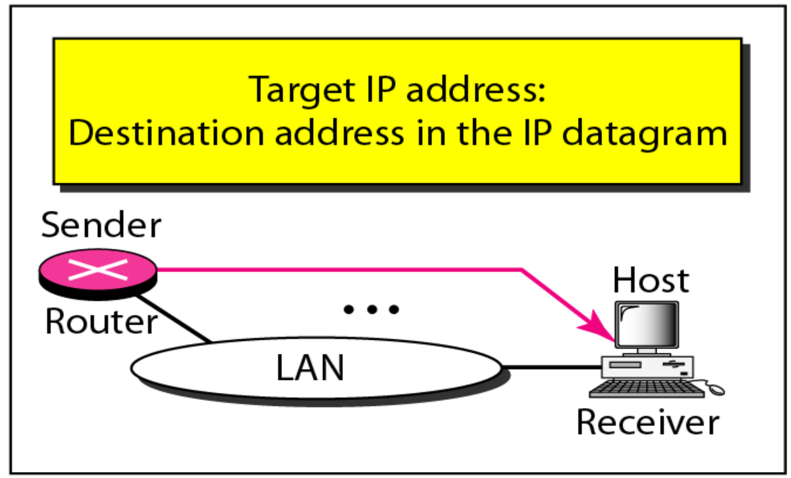
Case 1. A host has a packet to send to another host on the same network.



Case 2. A host wants to send a packet to another host on another network.
It must first be delivered to a router.



Case 3. A router receives a packet to be sent to a host on another network. It must first be delivered to the appropriate router.



Case 4. A router receives a packet to be sent to a host on the same network.