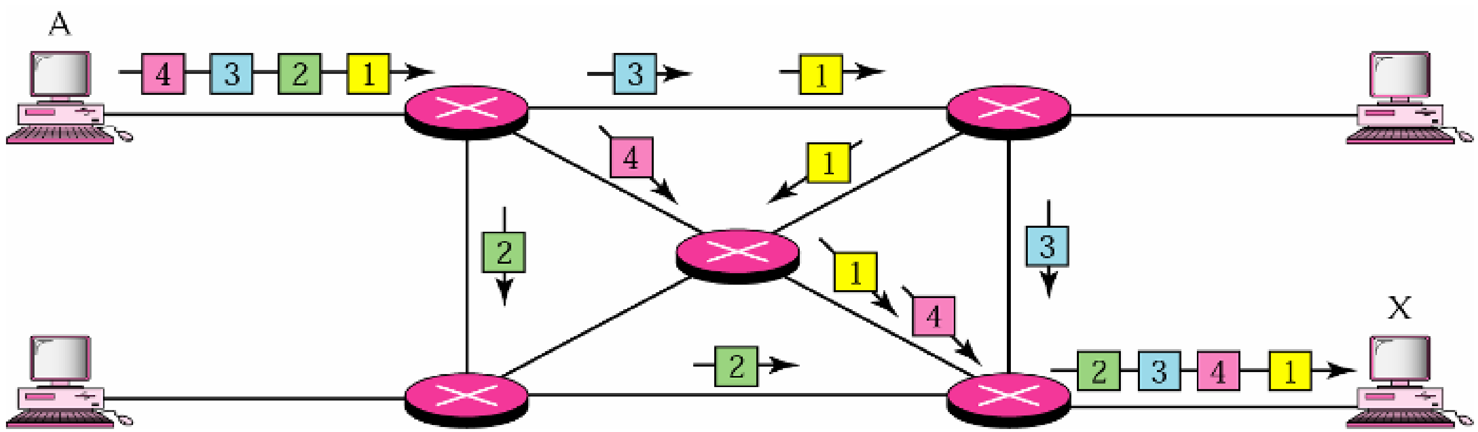
Overview

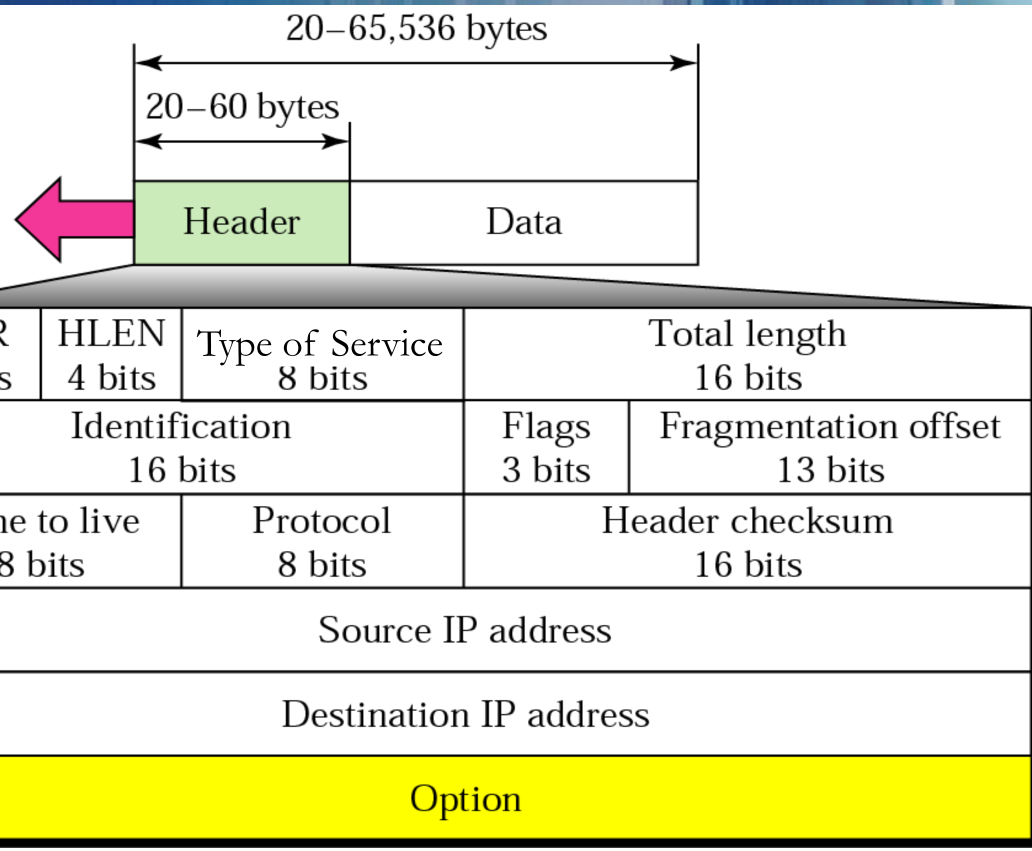
- Link Layer
- Network Layer
  - Addressing
  - Address Resolution (ARP)
  - Fragmentation
  - Intra-AS Routing
    - Distance Vector
    - Link State
  - Multicast Routing
  - IPv6
- Transport Layer
  - UDP
  - DNS

IP Service Model



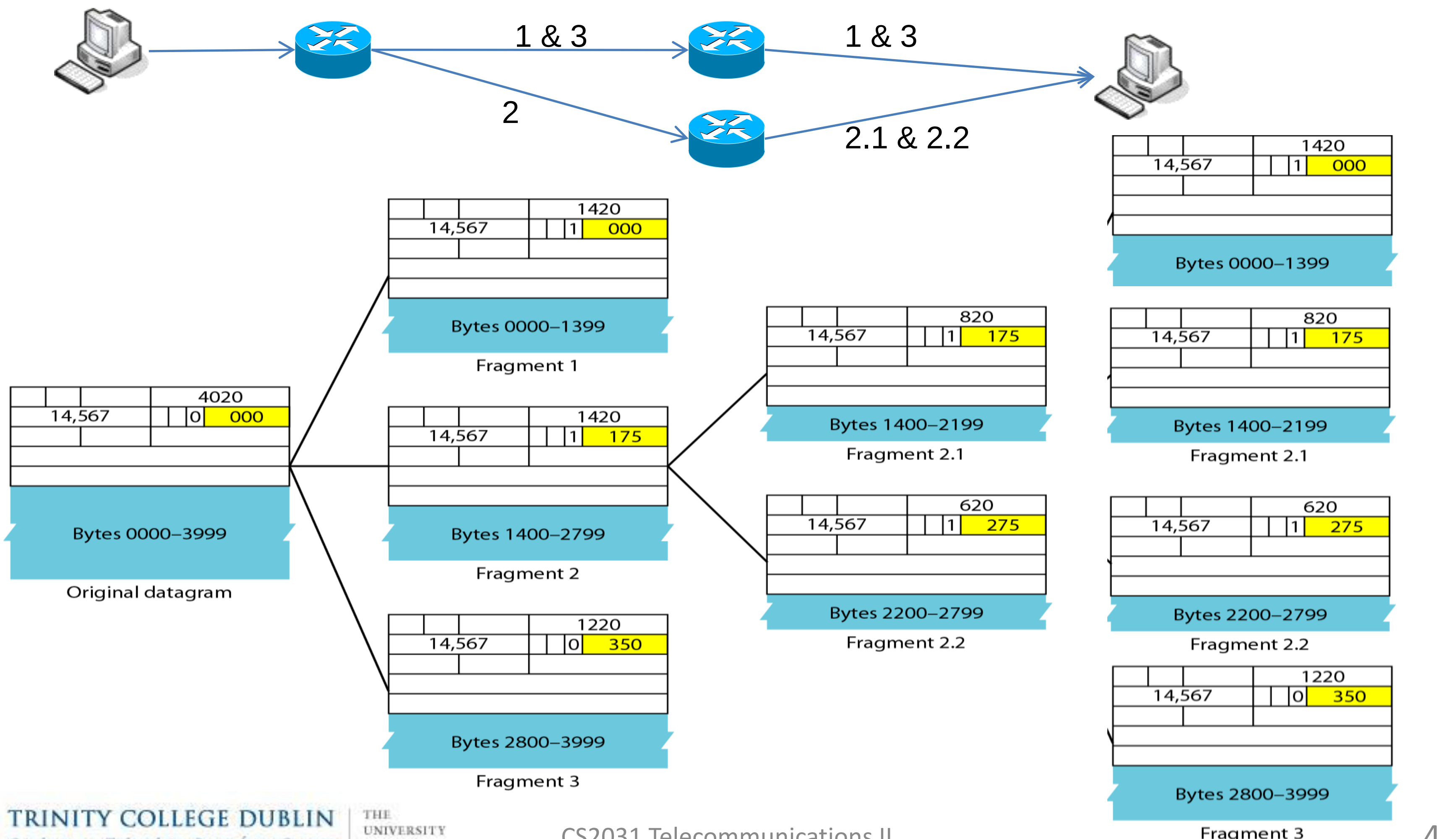
- Connection-less Communication
  - No state is kept about individual packets
- Order not guaranteed
- Best-effort delivery (unreliable service)
  - Packets may be lost
  - Packets may be delivered out of order
  - Duplicate copies of a packet may be delivered
  - Packets can be delayed for a long time

IP Datagram



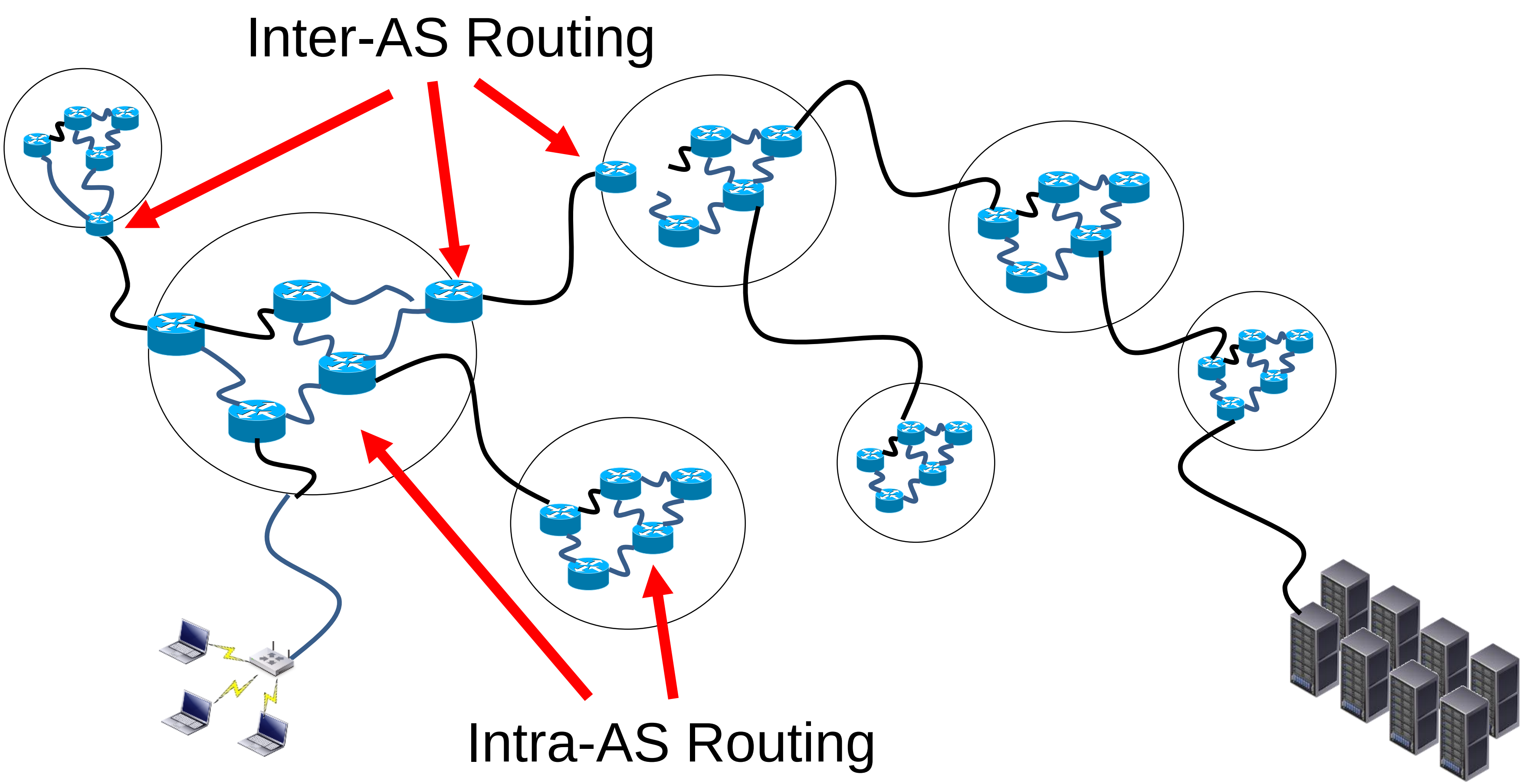
- The total length field defines the total length of the datagram including the header.

Fragmentation Example

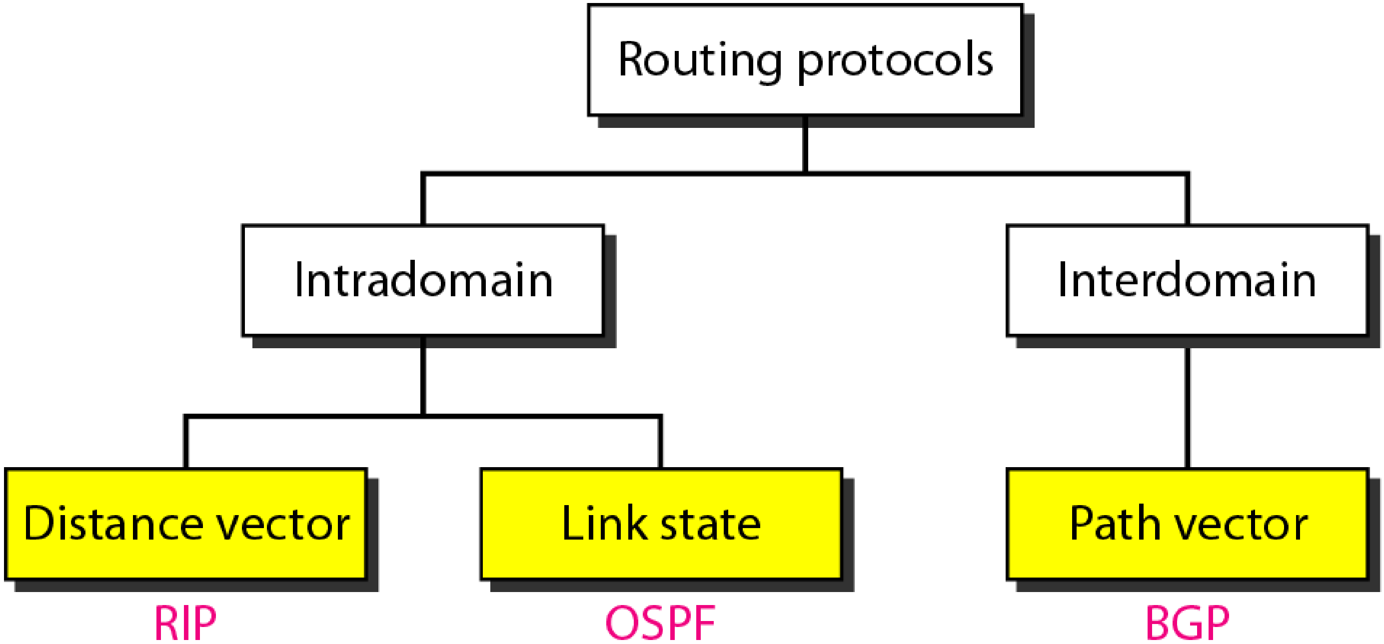


* Figure is courtesy of B. Forouzan

Internet = Network of Networks



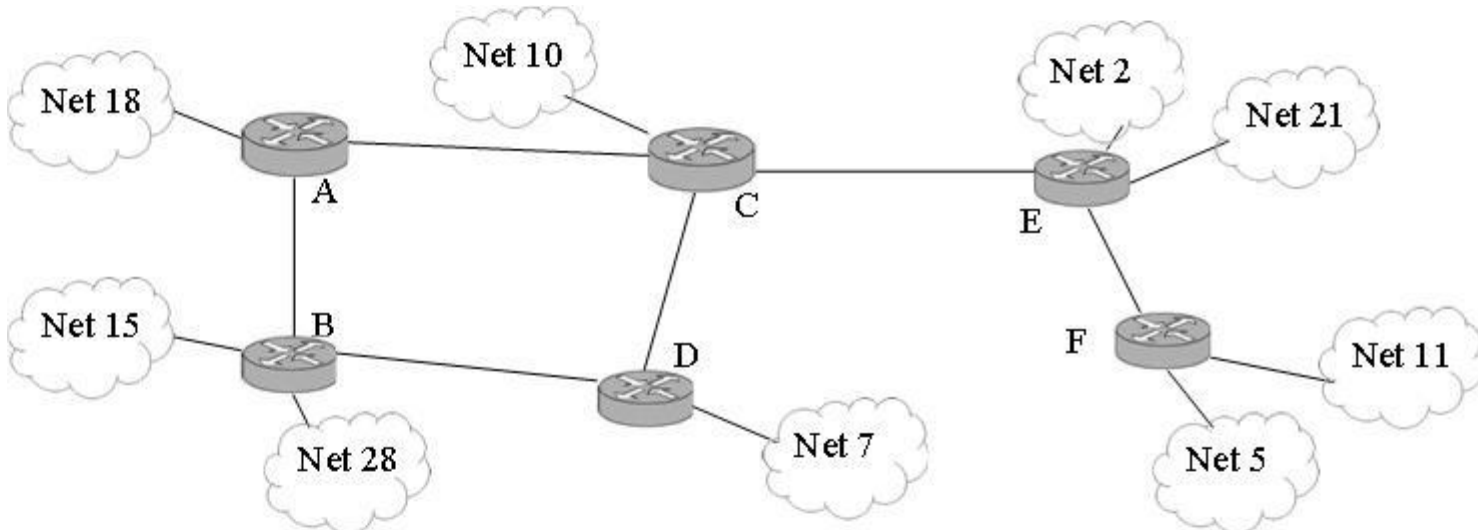
Routing Protocols



- Distance Vector routing
  - Routes propagate through exchange of routing tables
- Link State routing
  - Establish view of topology & run algorithm e.g. Dijkstra's Shortest-Path

* Figure is courtesy of B. Forouzan

Distance Vector Routing



A

Net18	1	-

B

Net15	1	-
Net28	1	-

C

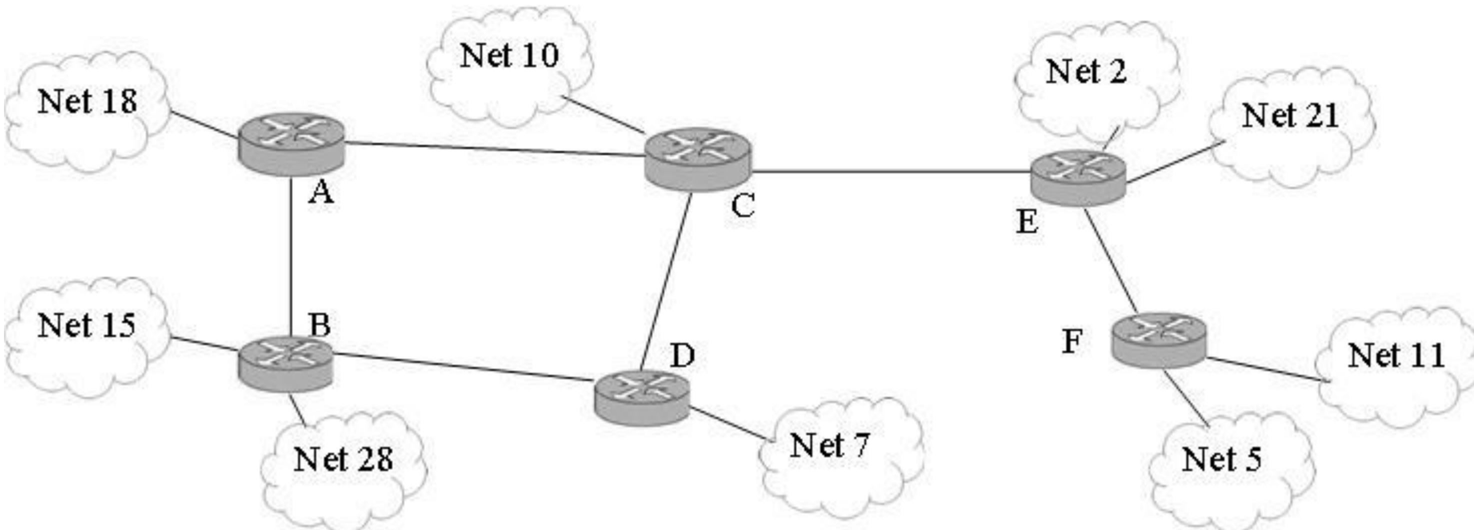
Net10	1	-

D

Net7	1	-

- Each router know the networks that are immediately connected to it

Distance Vector Routing



A

Net18	1	-
Net15	2	B
Net28	2	B
Net10	2	C

B

Net15	1	-
Net28	1	-
Net18	2	A
Net10	2	C

C

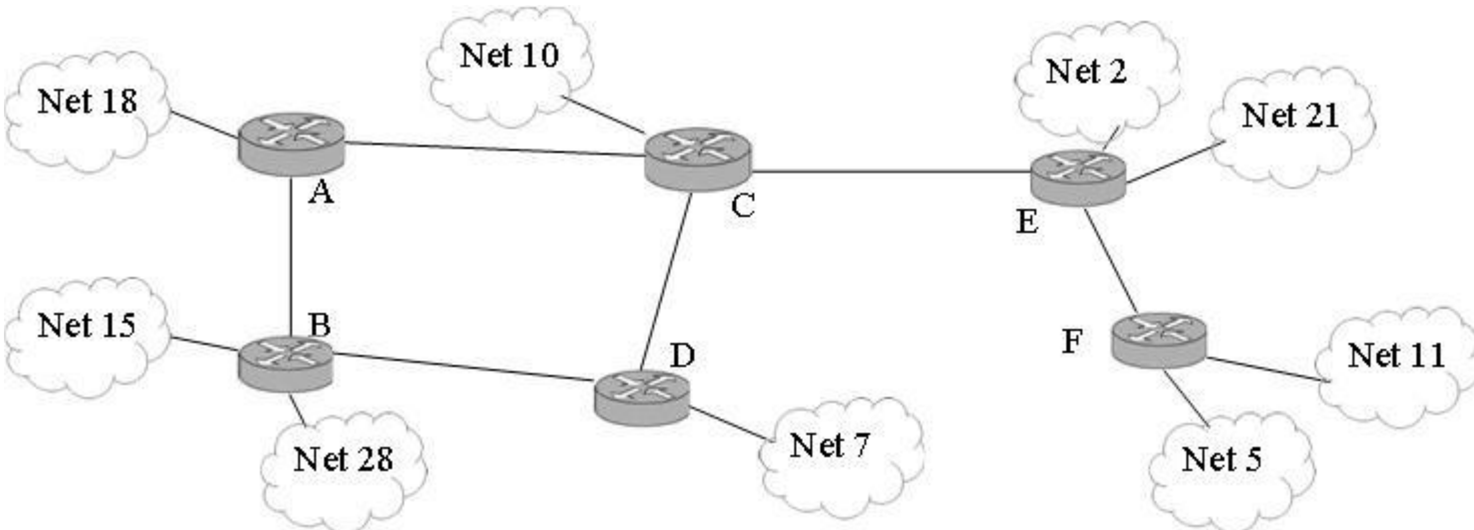
Net10	1	-
Net7	2	D
Net2	2	E
Net21	2	E

D

Net7	1	-
Net15	2	B
Net28	2	B
Net10	2	C

- Learning routes from neighbours
  - e.g. Node A incorporates information from Node B

Distance Vector: Example IV



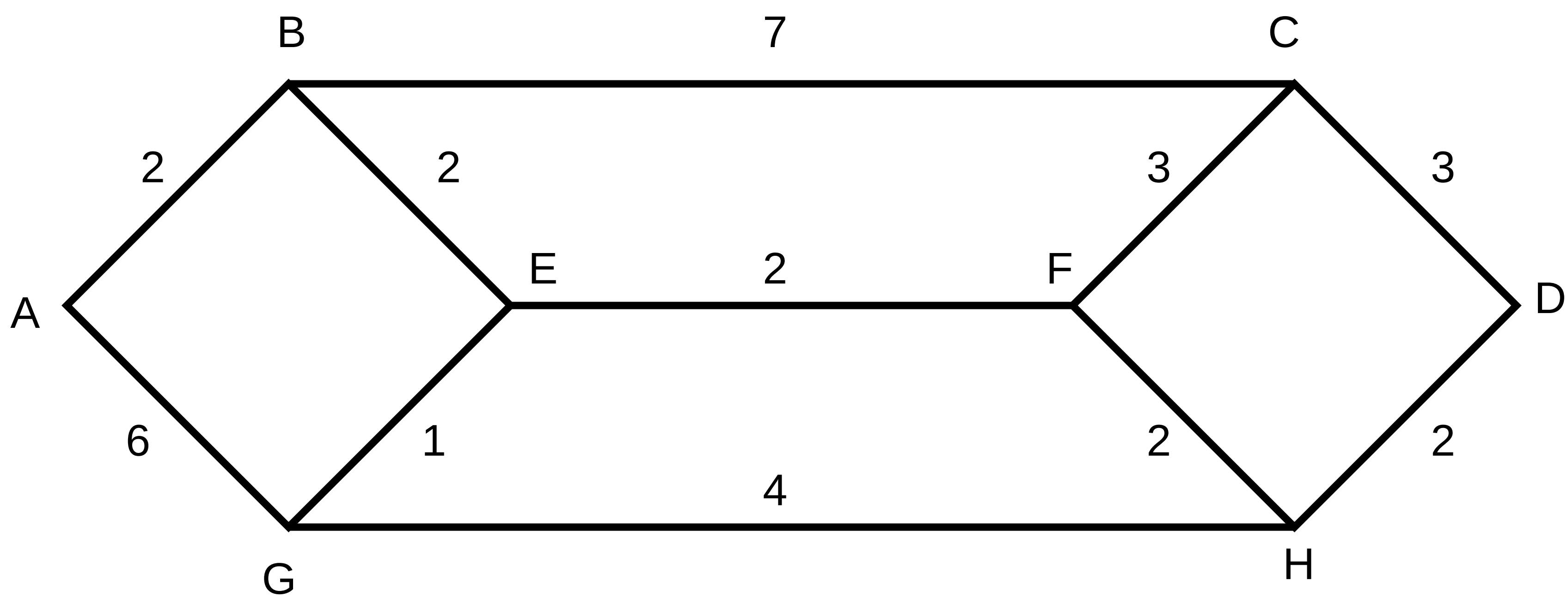
A

Net18	1	-
Net15	2	B
Net28	2	B
Net10	2	C
Net7	3	B
…	…	…
Net11	5	C
Net5	5	C

- Time require to build complete routing tables for all nodes
  – this is known as <u>convergence</u>

Link State Routing

- View of complete topology
  - through broadcasts

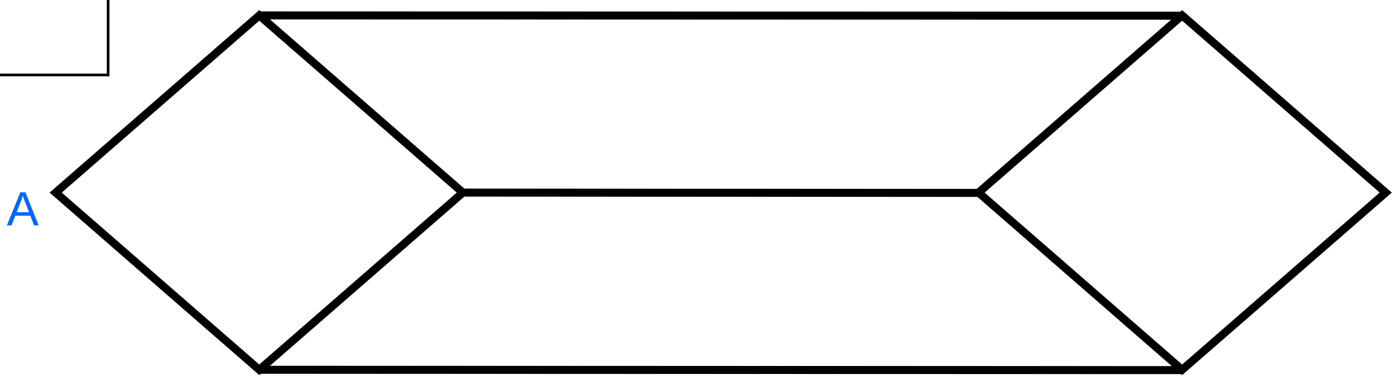


Dijkstra's Algorithm for Router A

Routing Table

Tentative Nodes

A	0	-



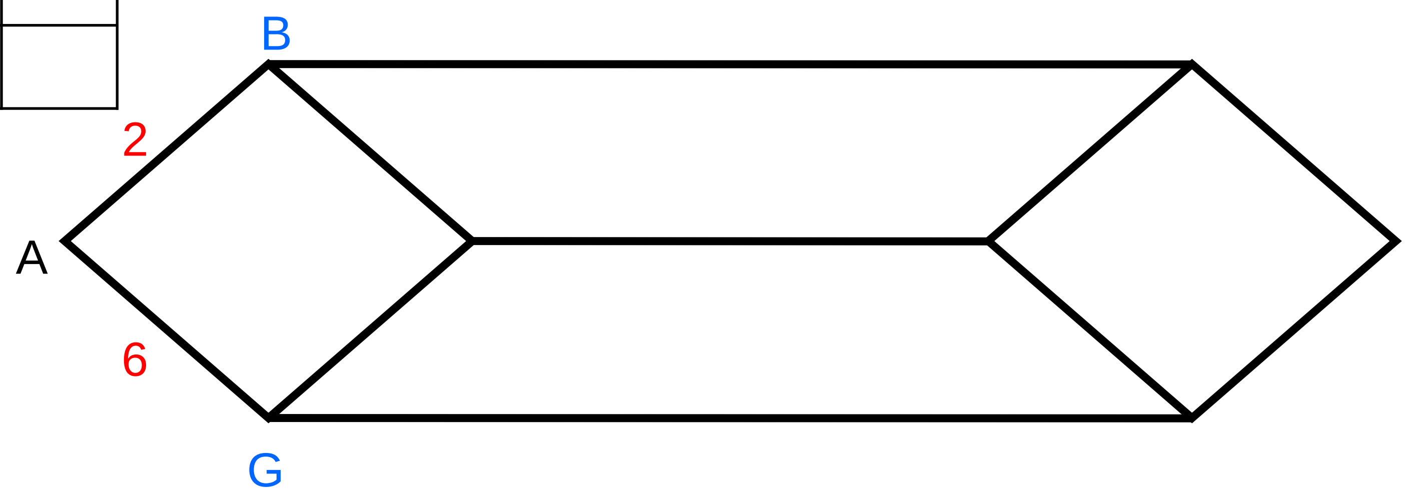
Dijkstra’s Algorithm for Router A

Routing Table

A	0	-

Tentative Nodes

B	2	A
G	6	A



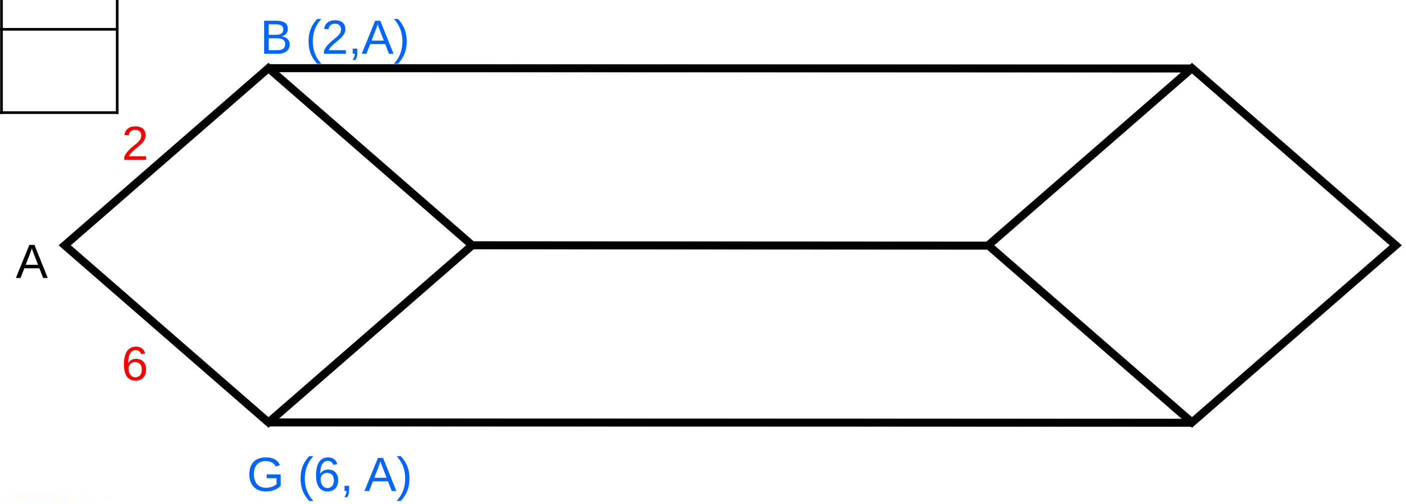
Dijkstra's Algorithm for Router A

Routing Table

A	0	-
B	2	A

Tentative Nodes

G	6	A



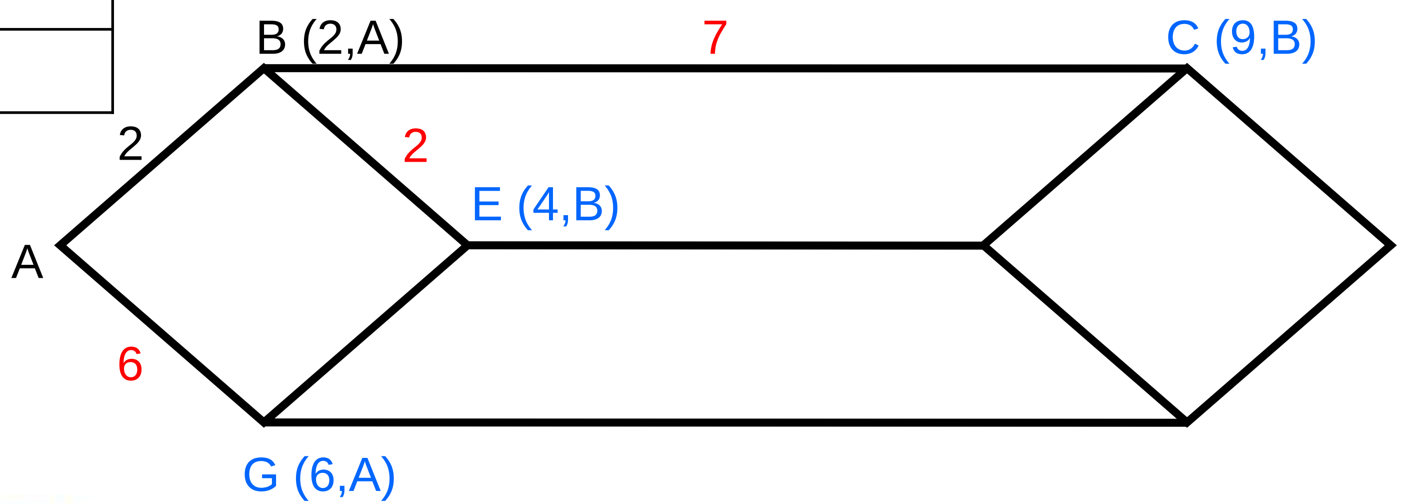
Example: Dijkstra's Algorithm

Routing Table

A	0	-
B	2	A

Tentative Nodes

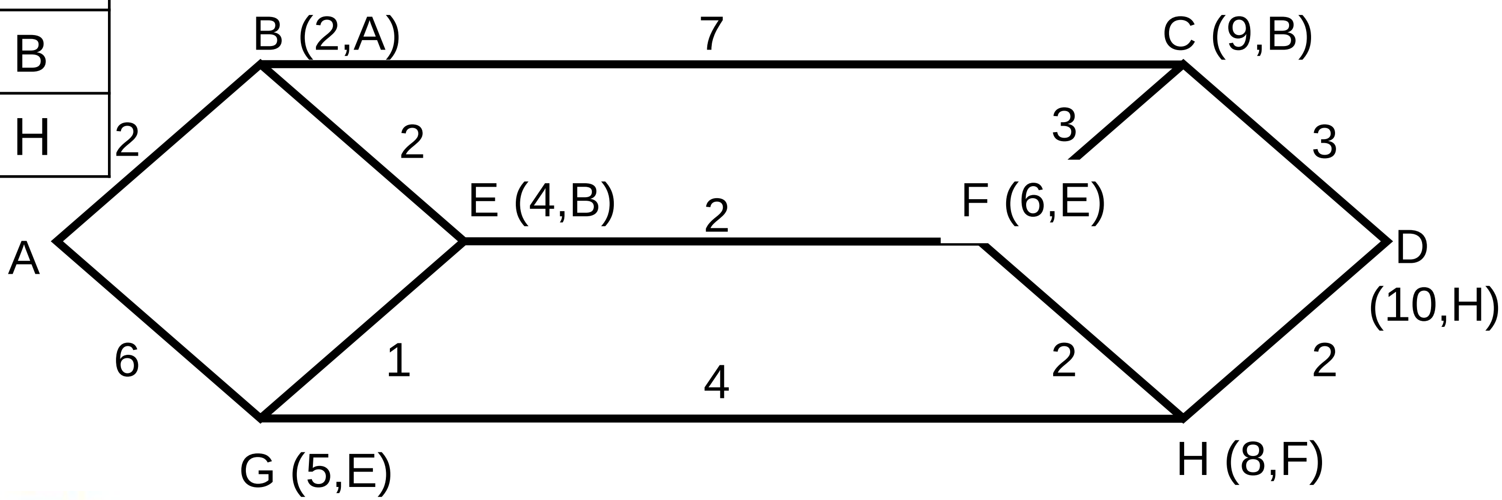
G	6	A
E	4	B
C	9	B



Example: Dijkstra's Algorithm

Routing Table

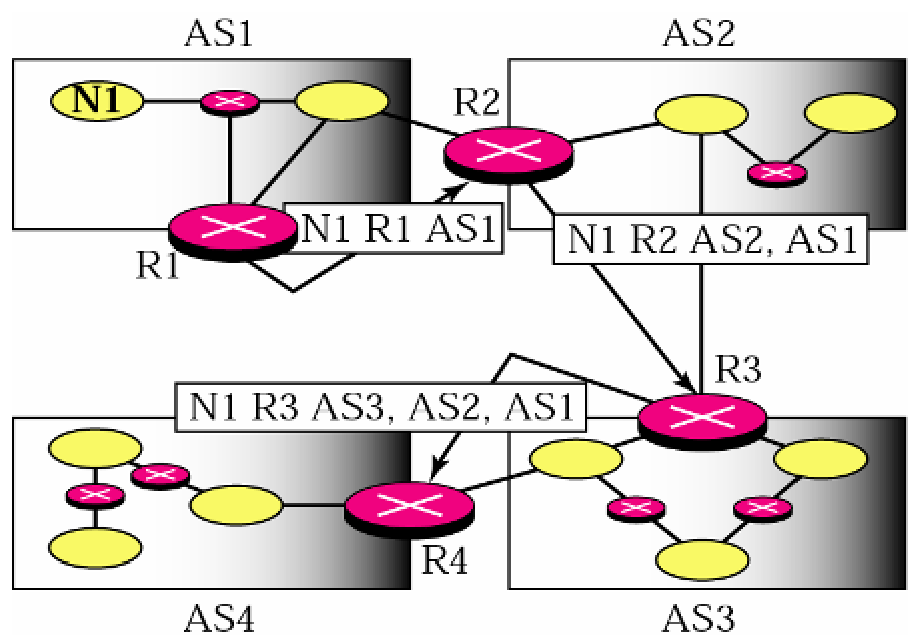
A	0	-
B	2	A
E	4	B
G	5	E
F	6	E
H	8	F
C	9	B
D	10	H



Border Gateway Protocol (BGP)

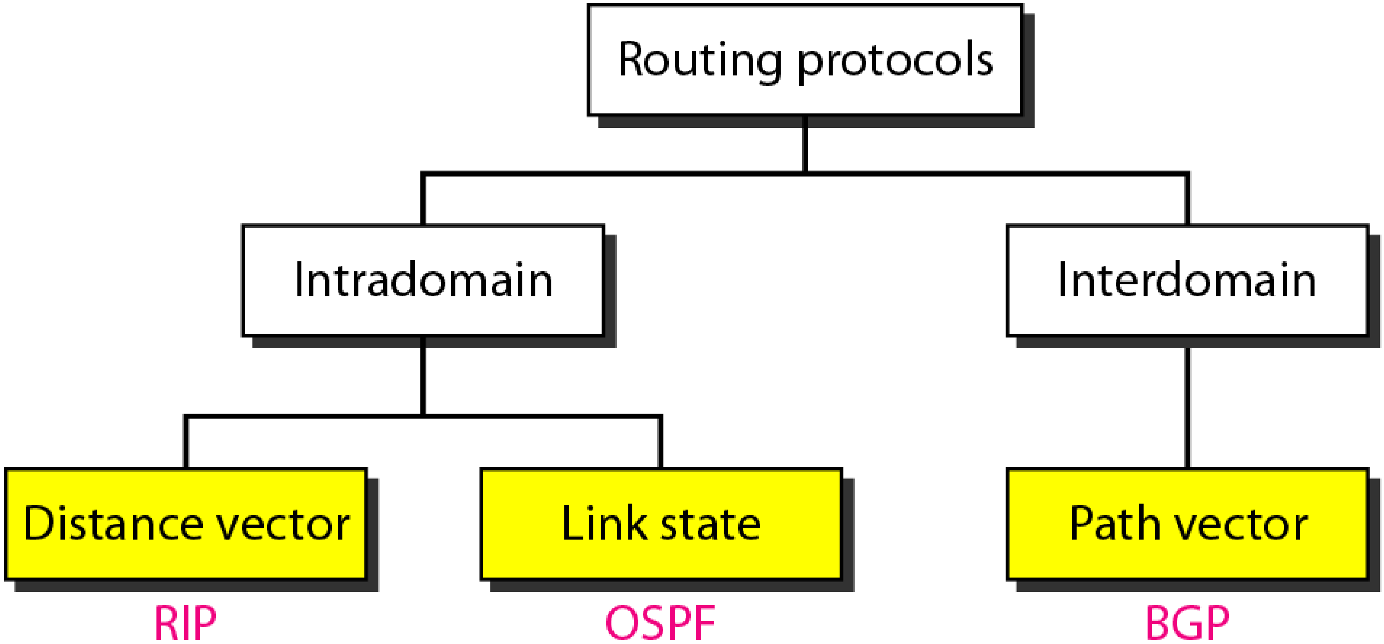
- Uses Path Vector Routing
- Advertisements include complete path to destination
- Router that forwards advertisement adds itself to the list
- Path can be checked for loops
- Policies are applied when incorporating new routes

Network	Next Router	Path
N01	R01	AS14, AS23, AS67
N02	R05	AS22, AS67, AS05, AS89
N03	R06	AS67, AS89, AS09, AS34
N04	R12	AS62, AS02, AS09



* Figure is courtesy of B. Forouzan

Routing Protocols

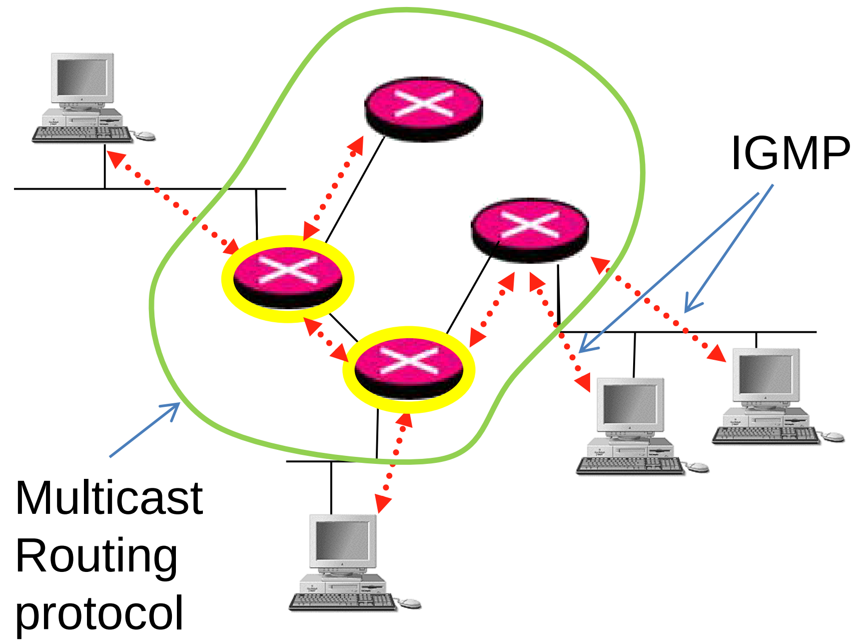


- Distance Vector routing
  - Routes propagate through exchange of routing tables
- Link State routing
  - Establish view of topology & run algorithm e.g. Dijkstra's Shortest-Path

* Figure is courtesy of B. Forouzan

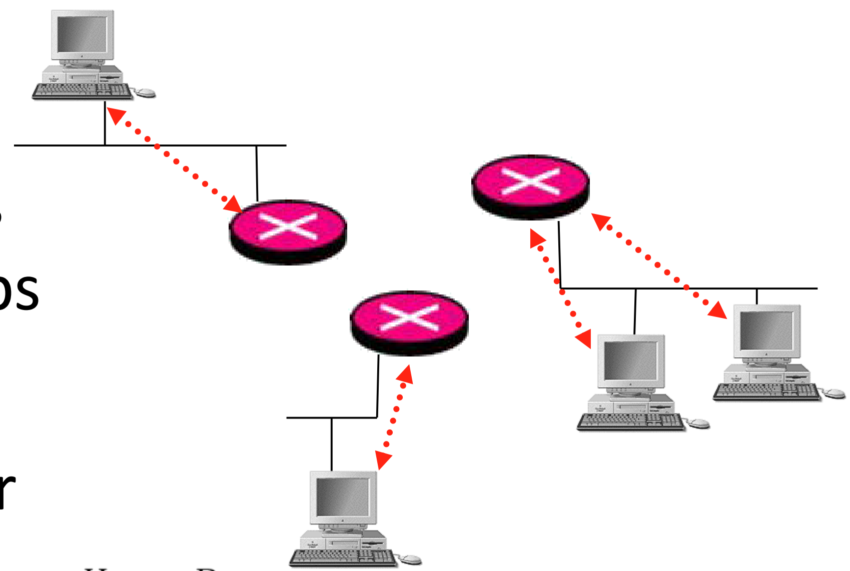
Multicast Overview

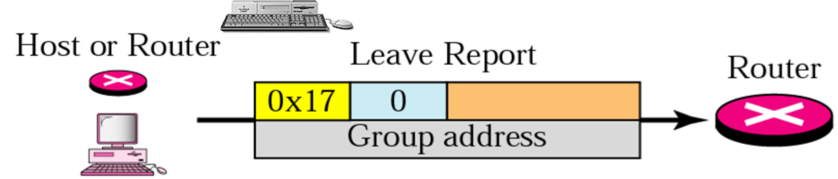
- 2-Layer Approach:
  - Endpoints and Routers:
    Internet Group Management Protocol (IGMP) between
    - Join & Leave –
  - Routers:
    Multicast Routing protocols
- Multicast Addresses:
  224.0.0.0 – 239.255.255.255
  or 224.0.0.0/4

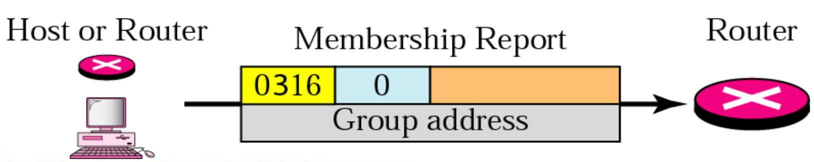


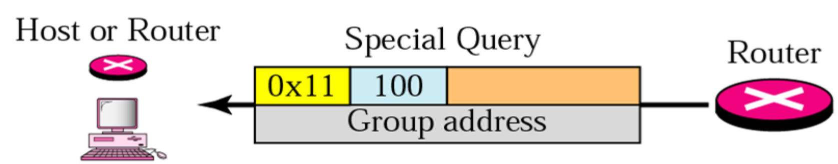
Internet Group Management Protocol (IGMP)

- Defines communication between hosts and router
- Specifies messages for hosts for joining and leaving groups
- Specifies query messages for routers

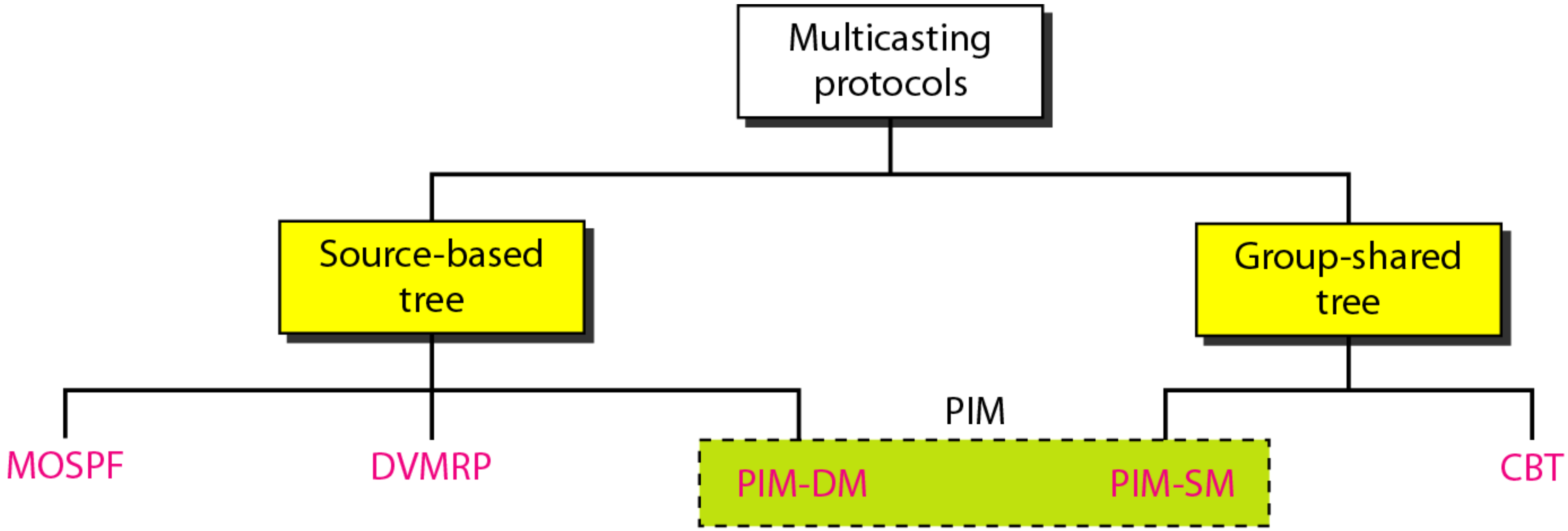








Multicast Routing Protocols



- Intra-AS
  - MOSPF
  - DVMRP
  - PIM
    - Sparse mode
    - Dense mode
- Inter-AS
  - MBGP + MSDP
  - BGMP + MASC

Summary: Multicast Routing

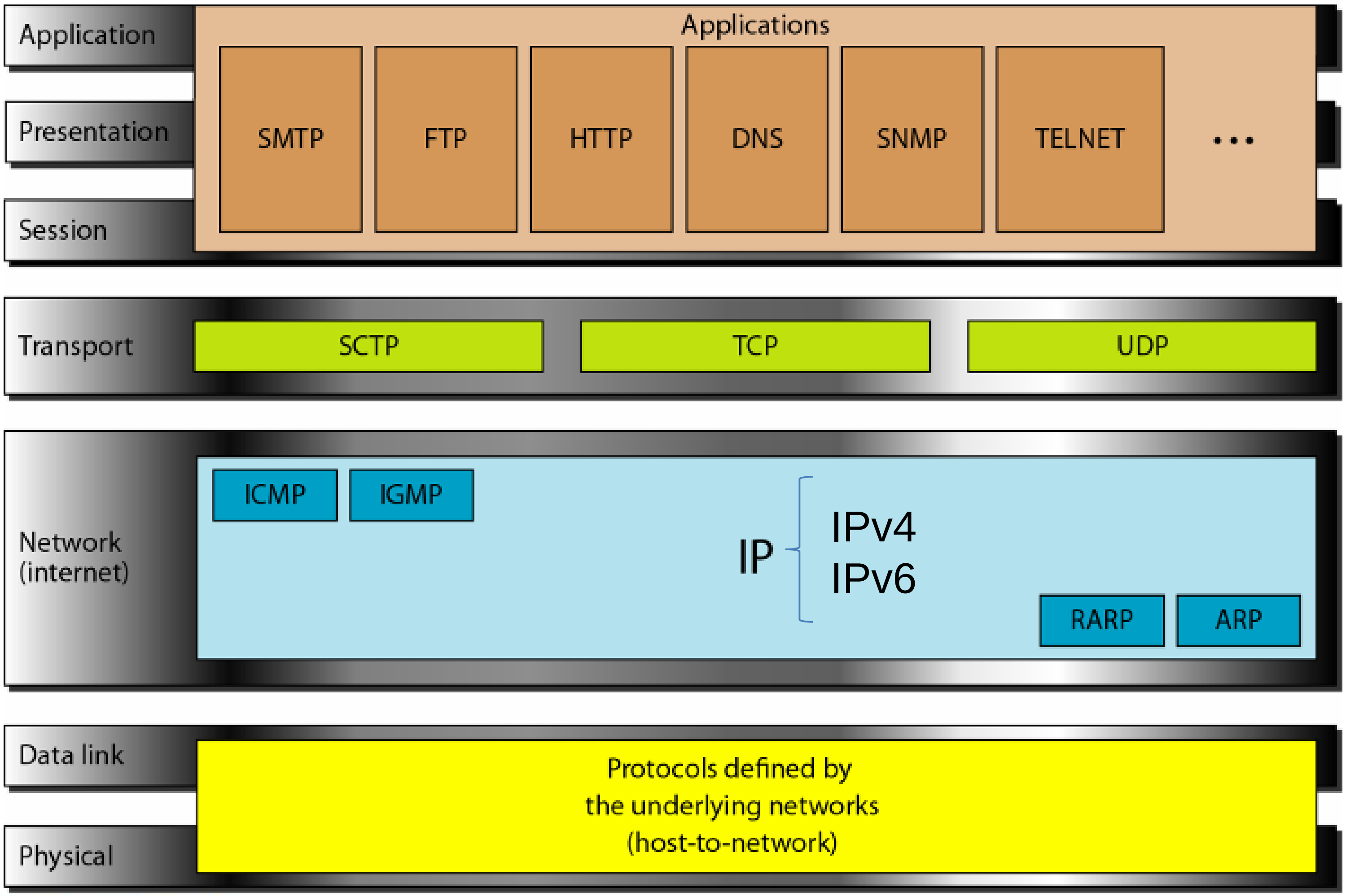
- Internet Group Management Protocol (IGMP)
  – Join&leave messages from hosts to routers

- Protocol Independent Multicast (PIM)
  – Dense Mode (DM)
    - Start from broadcast and get routers not interested to opt out
  – Sparse Mode (SM)
    - Start from rendezvous point and grow tree from there

CS2031
Telecommunications II

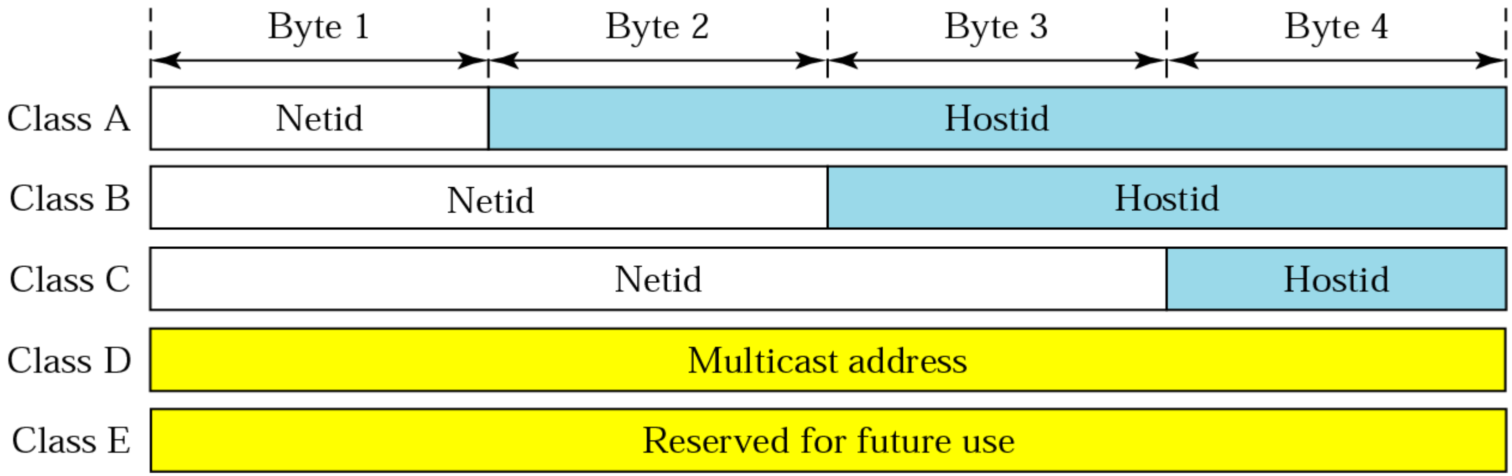
IPv6

Protocols in the OSI Model



* Figure is courtesy of B. Forouzan

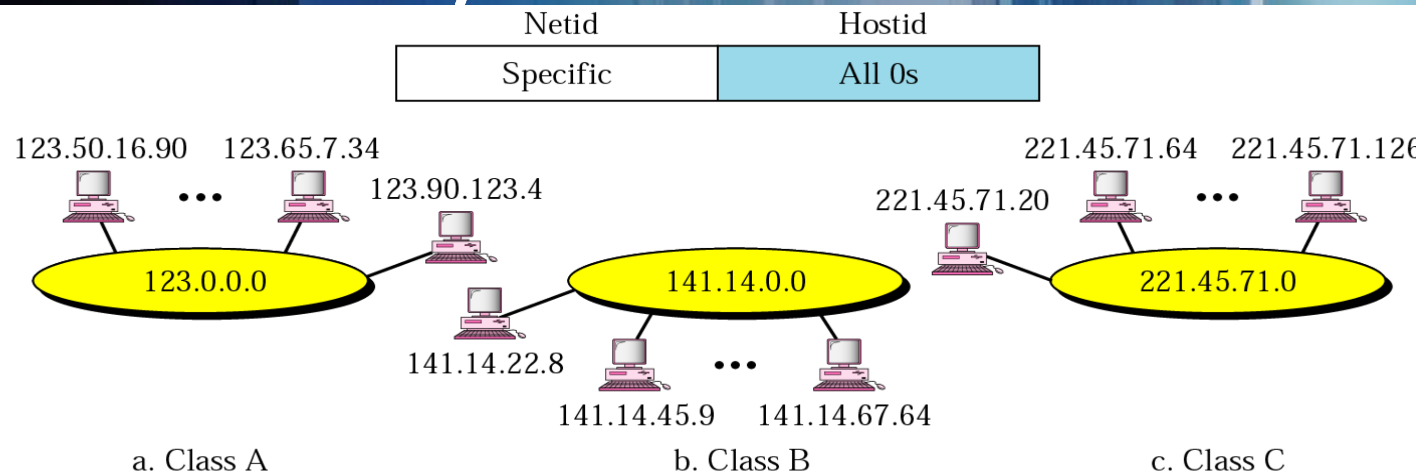
Classful Addresses



- Class A (international organisations)
  - 126 networks with 16,277,214 hosts each
- Class B (large companies)
  - 16,384 networks with 65,354 hosts each
- Class C (smaller companies)
  - 2,097,152 networks with 254 hosts each

* Figure is courtesy of B. Forouzan

Inefficiency of Classful Addresses



- Classful Addresses:

Class	Networks	Addresses
A	126	16,777,214
B	16,382	65,534
C	2,097,152	254

- Inefficient use of Hierarchical Address Space
  - Class C with 2 hosts (2/254 = 0.78% efficient)
  - Class B with 256 hosts (256/65534 = 0.39% efficient)

* Figure is courtesy of B. Forouzan

Why IPv6? (Current Business Reasons)

2002 ☺

- Demand from particular regions
  - Asia, EU
  - technical, geo-political, and business reasons
  - demand is now
- Demand for particular services
  - cellular wireless (especially 3GPP standards)
  - Internet gaming (e.g., Sony Playstation 2)
  - use is >= 1.5 years away (but testbeds needed now)
- Potential move to IPv6 by Microsoft?
  - IPv6 included in Windows XP, but not enabled by default
  - to be enabled by default in next major release of Windows
  - use is >= 1.5 years away

*Text is courtesy of S. Deering

Why IPv6? (Theoretical Reasons)

- Only compelling reason: **more IP addresses!**
  - For billions of new users (Japan, China, India,…)
  - For billions of new devices (mobile phones, cars, appliances,…)
  - For always-on access (cable, xDSL, ethernet-to-the-home,…)
  - For applications that are difficult, expensive, or impossible to operate through NATs (IP telephony, peer-to-peer gaming, home servers,…)
  - To phase out NATs to improve the robustness, security, performance, and manageability of the Internet

*Text is courtesy of S. Deering

How Was The Address Size Chosen?

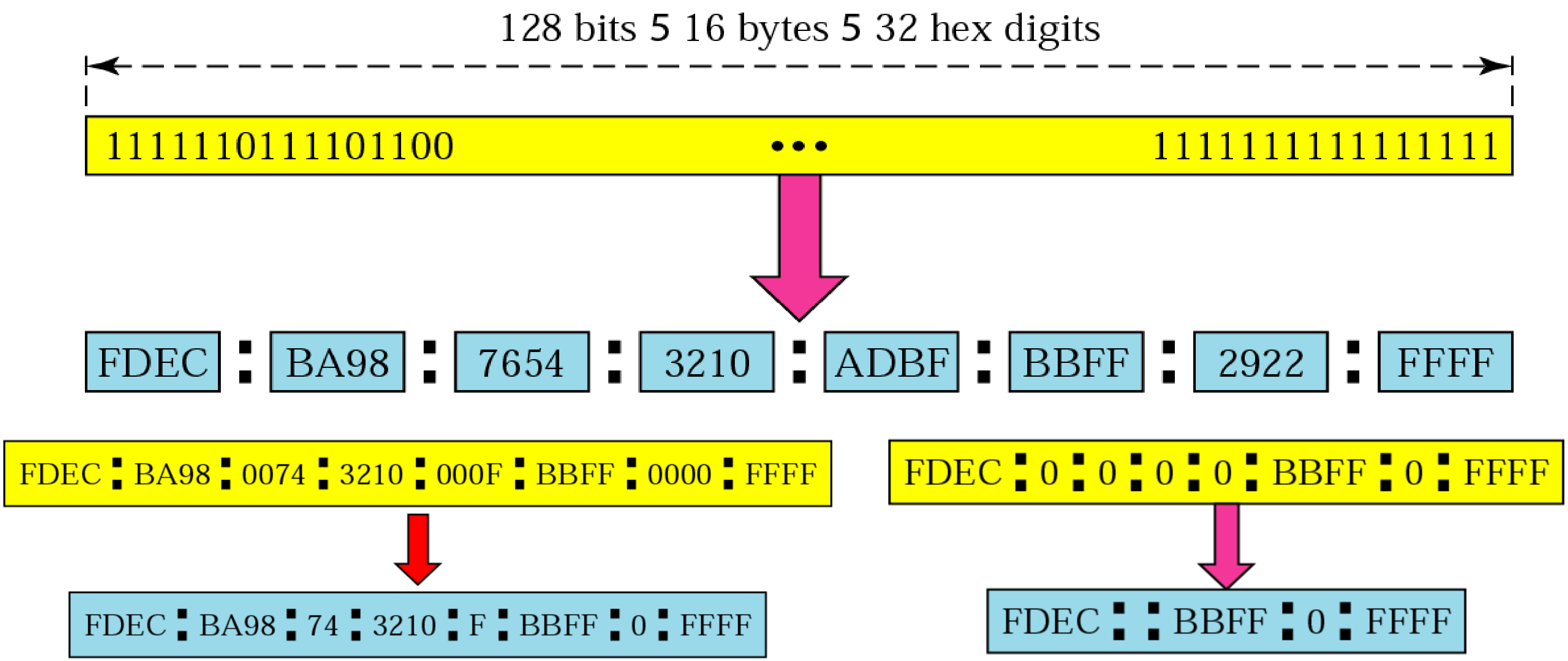
- Proposal: Fixed-length, 64-bit addresses
  - Minimizes growth of per-packet header overhead
  - Efficient for software processing
- Proposal: Variable-length, up to 160 bits
  - Compatible with OSI NSAP addressing plans
  - Big enough for auto-configuration using IEEE 802 addresses
  - Could start with addresses shorter than 64 bits & grow later
- Settled on fixed-length, 128-bit addresses

  (**340,282,366,920,938,463,463,374,607,431,768,211,456** in all!)
  - ~1500 addresses/sqft of the earths surface

*Text is courtesy of S. Deering

IPv6 Address

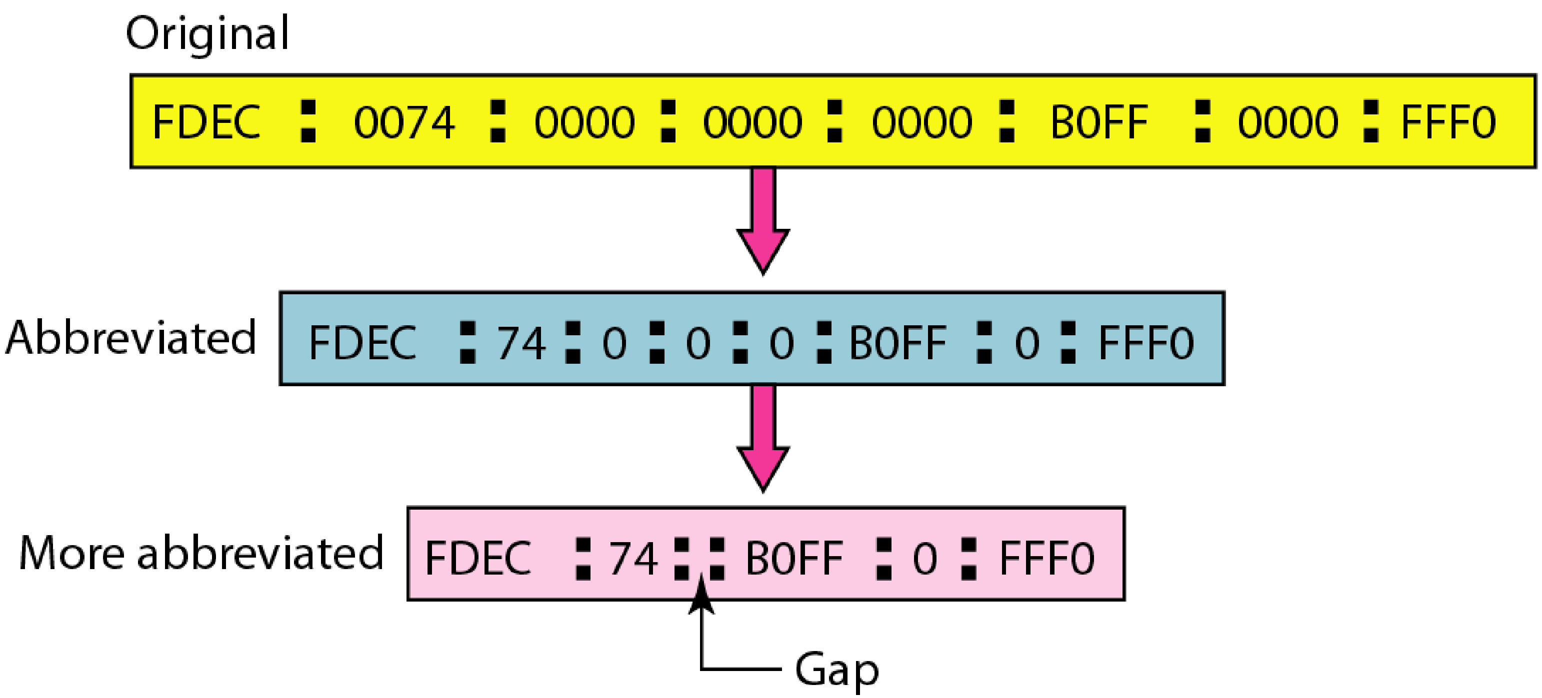
- Standard representation is set of eight 16-bit values separated by colons



* Figure is courtesy of B. Forouzan

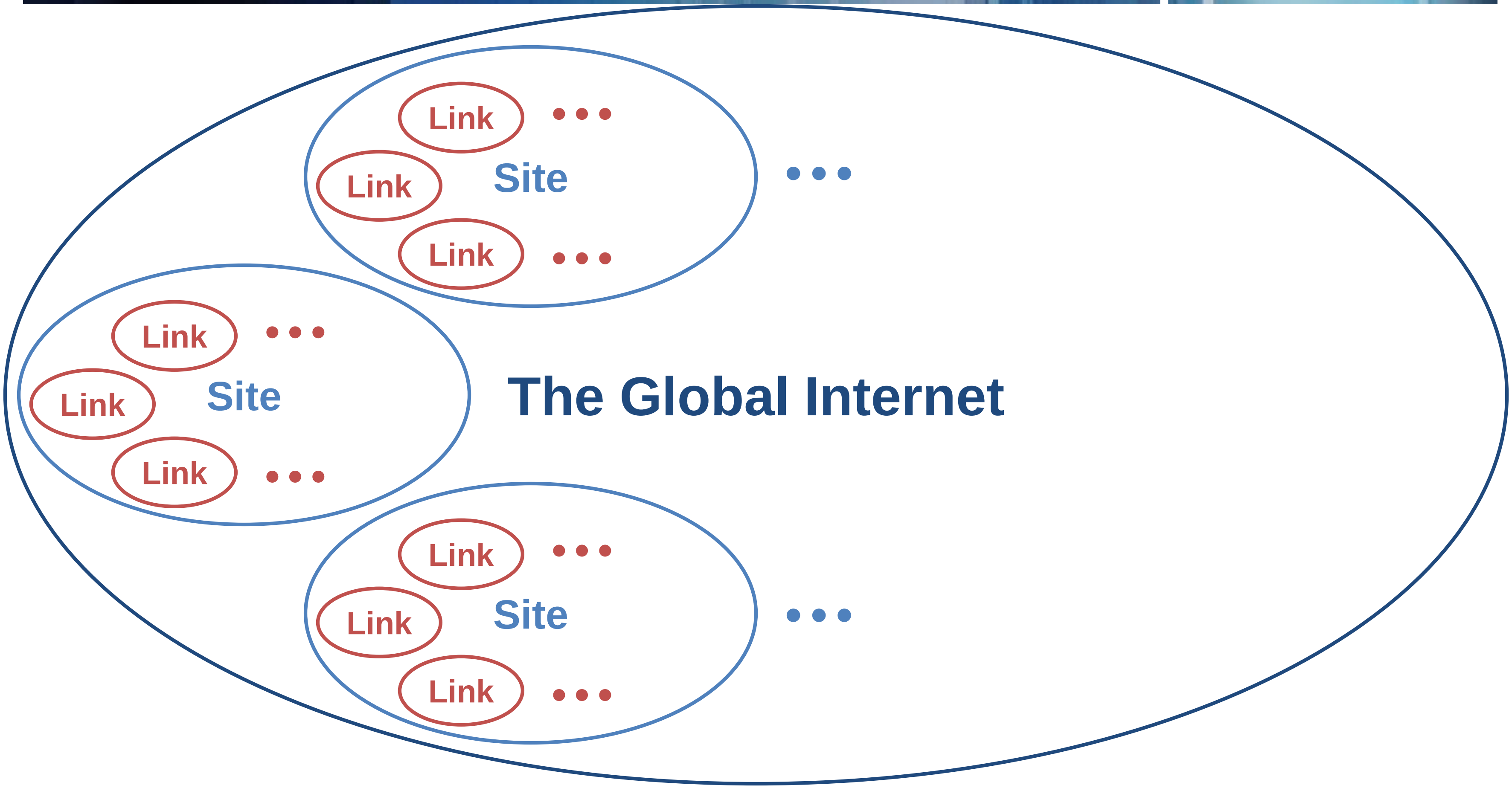
Address Abbreviation

- Sequences of zeros can be replaced with series of colons



* Figure is courtesy of B. Forouzan

Address Zones and Scopes



Each oval is a different zone; different colors indicate different scopes

Non-Global Unicast Addresses

- Link-local unicast addresses are meaningful only in a single link zone, and may be re-used on other links

1111111010	0	interface ID
10 bits	54 bits	64 bits

- Site-local unicast addresses are meaningful only in a single site zone, and may be re-used in other sites

1111111011	0	subnet ID	interface ID
10 bits	38 bits	16 bits	64 bits

64-bit EUI Address

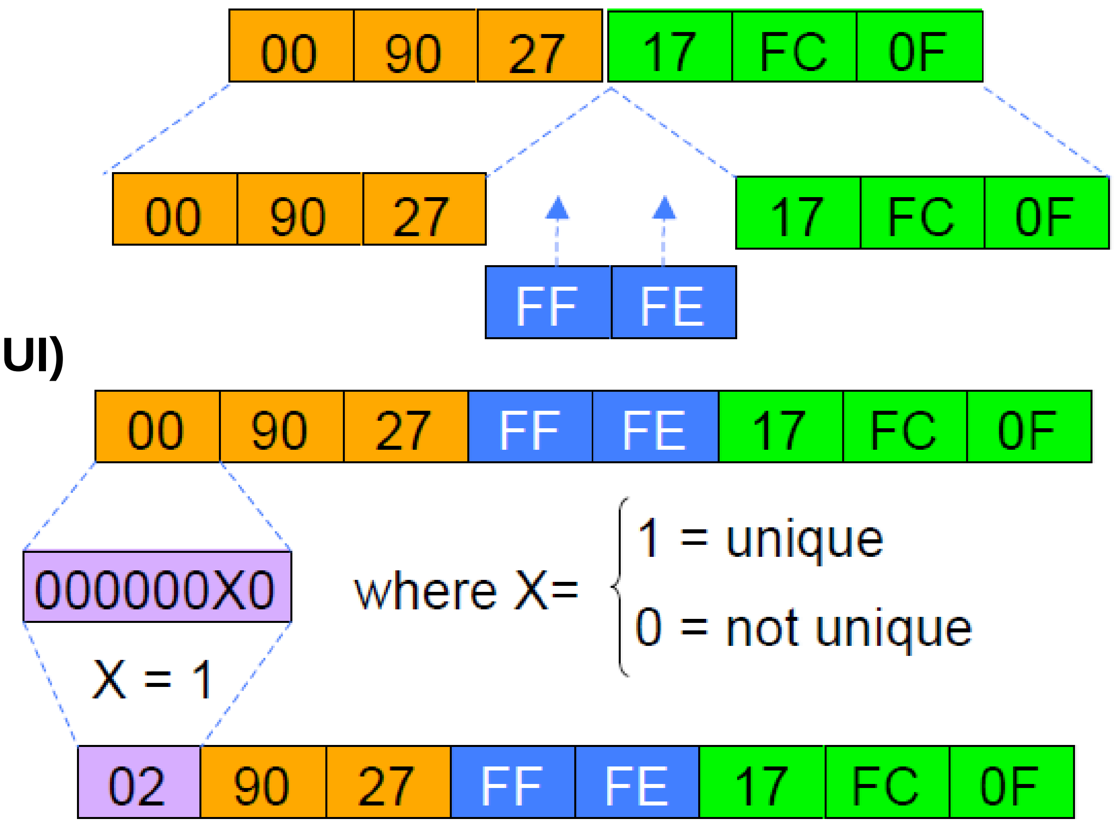
Ethernet MAC address (48 bits)

Extended Unique Identifier (EUI)

64 bits version

Uniqueness of the MAC

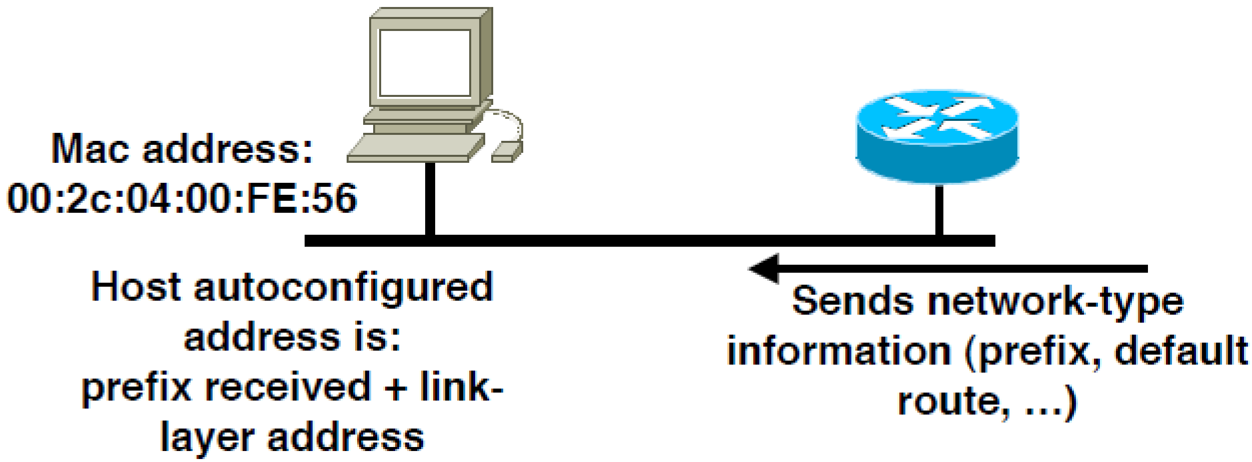
Eui-64 address



- EUI-64 address is formed by inserting FFFE and OR’ing a bit identifying the uniqueness of the MAC address

* Figure is courtesy of P. Smith, Cisco

IPv6 Autoconfiguration



- Client sends router solicitation (RS) messages
- Router responds with router advertisement (RA)
  This includes prefix and default route
- Client configures its IPv6 address by concatenating prefix received with its EUI-64 address

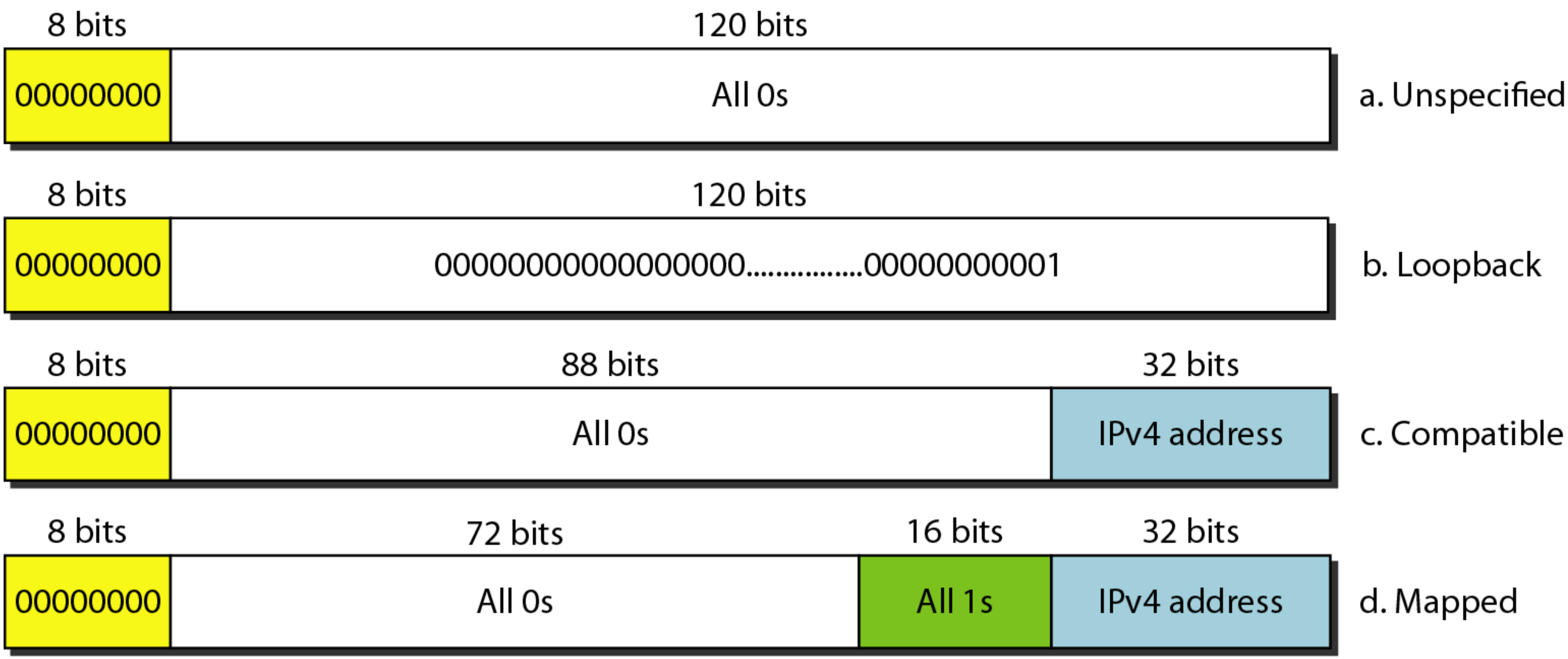
Multicast Addresses

8 bits	4	4	112 bits
11111111	Flag	Scope	Group ID

- Low-order flag indicates permanent / transient group; three other flags reserved
- Scope field:
  - 1 - interface-local (for multicast loopback)
  - 2 - link-local (same as unicast link-local)
  - 3 - subnet-local
  - 4 - admin-local
  - 5 - site-local (same as unicast site-local)
  - 8 - organization-local
  - B - community-local
  - E - global (same as unicast global)
  - (all other values reserved)

* Figure is courtesy of B. Forouzan

Reserved Addresses



* Figure is courtesy of B. Forouzan

Different Types of Addresses

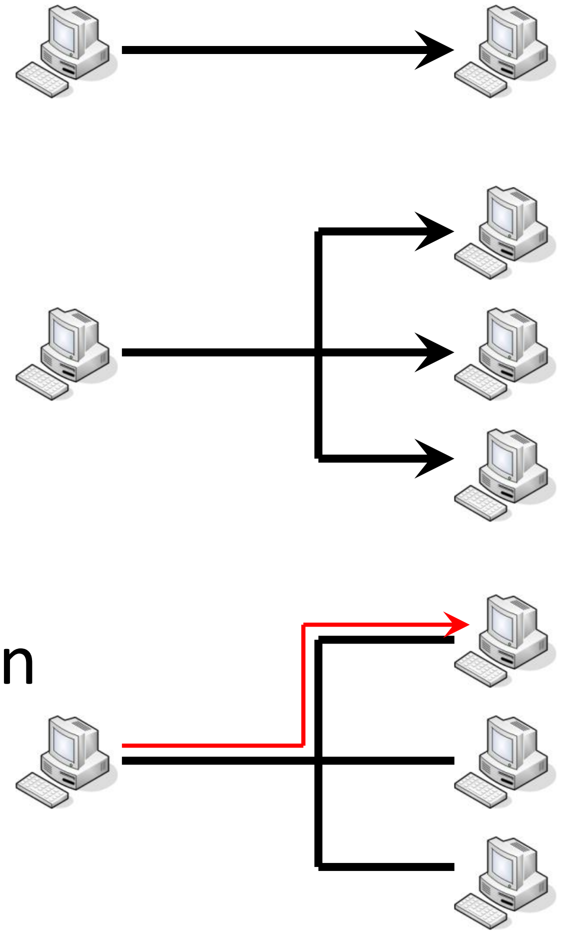
Type	Binary	Hex
Unspecified	000…0	::/128
Loopback	000…1	::1/128
Global Unicast Address	0010	2000::/3
Link Local Unicast Address	1111 1110 10	FE80::/10
Unique Local Unicast Address	1111 1100 1111 1101	FC00::/7
Multicast Address	1111 1111	FF00::/8

* Figure is courtesy of P. Smith, Cisco

Many Addresses

- An interface on an IPv6 node can, and usually will, have many addresses
  - Link-Local
  - Site-Local
  - Auto-configured 6to4
  - Solicited-Node Multicast
  - All-Nodes Multicast
  - Global anonymous
  - Global published

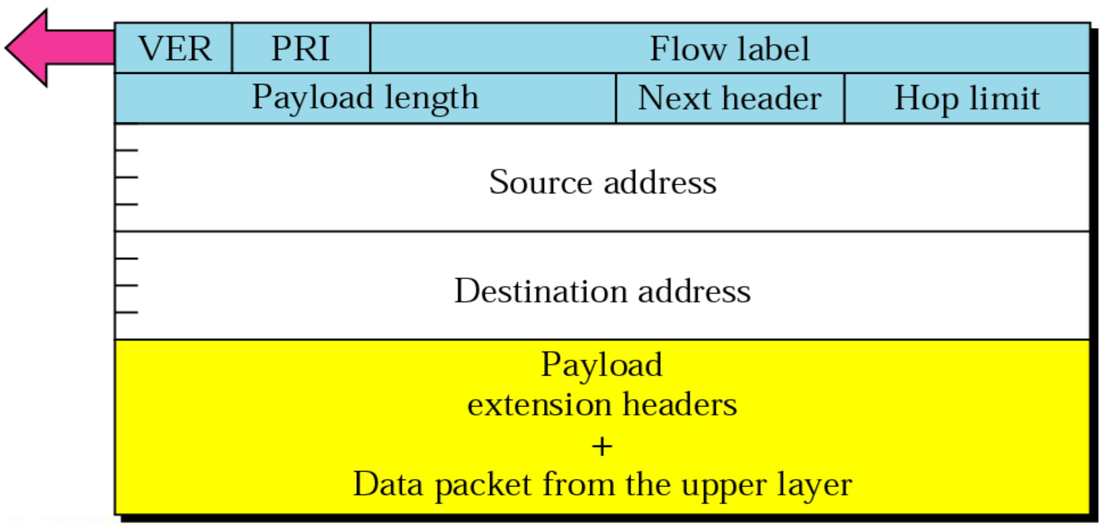
Communication Types



- Unicast
  - One-to-one communication
- Multicast
  - One-to-many communication
- Anycast
  - One-to-nearest communication
  - Delivered to any one interface

IPv6 Header

- Fixed length of all fields, header length irrelevant
- Remove Header Checksum – other layers are responsible
- No hop-by-hop fragmentation – fragment offset irrelevant
  - MTU discovery before sending or minimum MTU=1280
- Extension headers – next header type
- Basic Principle: Routers along the way should do minimal processing

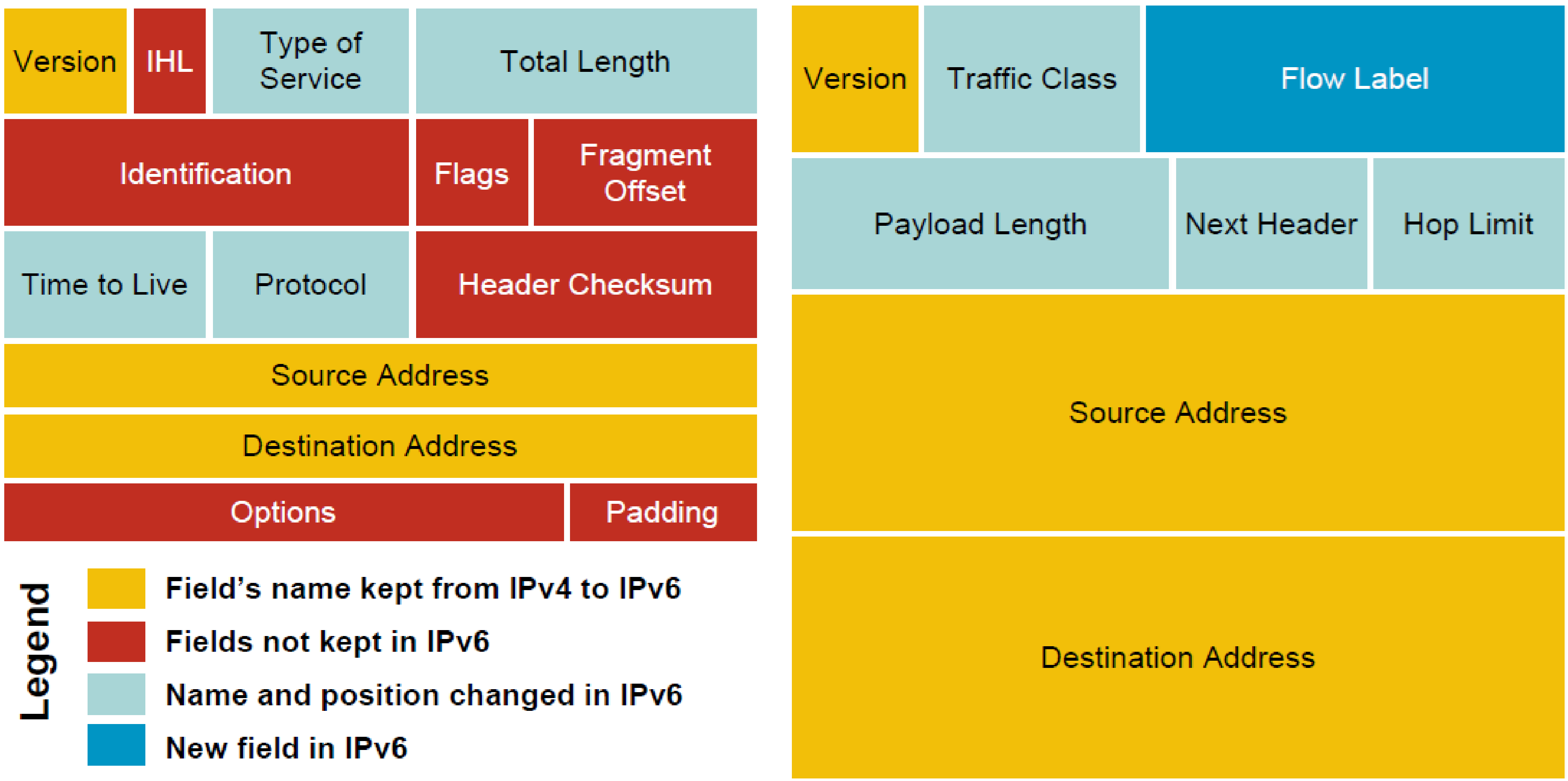


* Figure is courtesy of B. Forouzan

Header Comparison

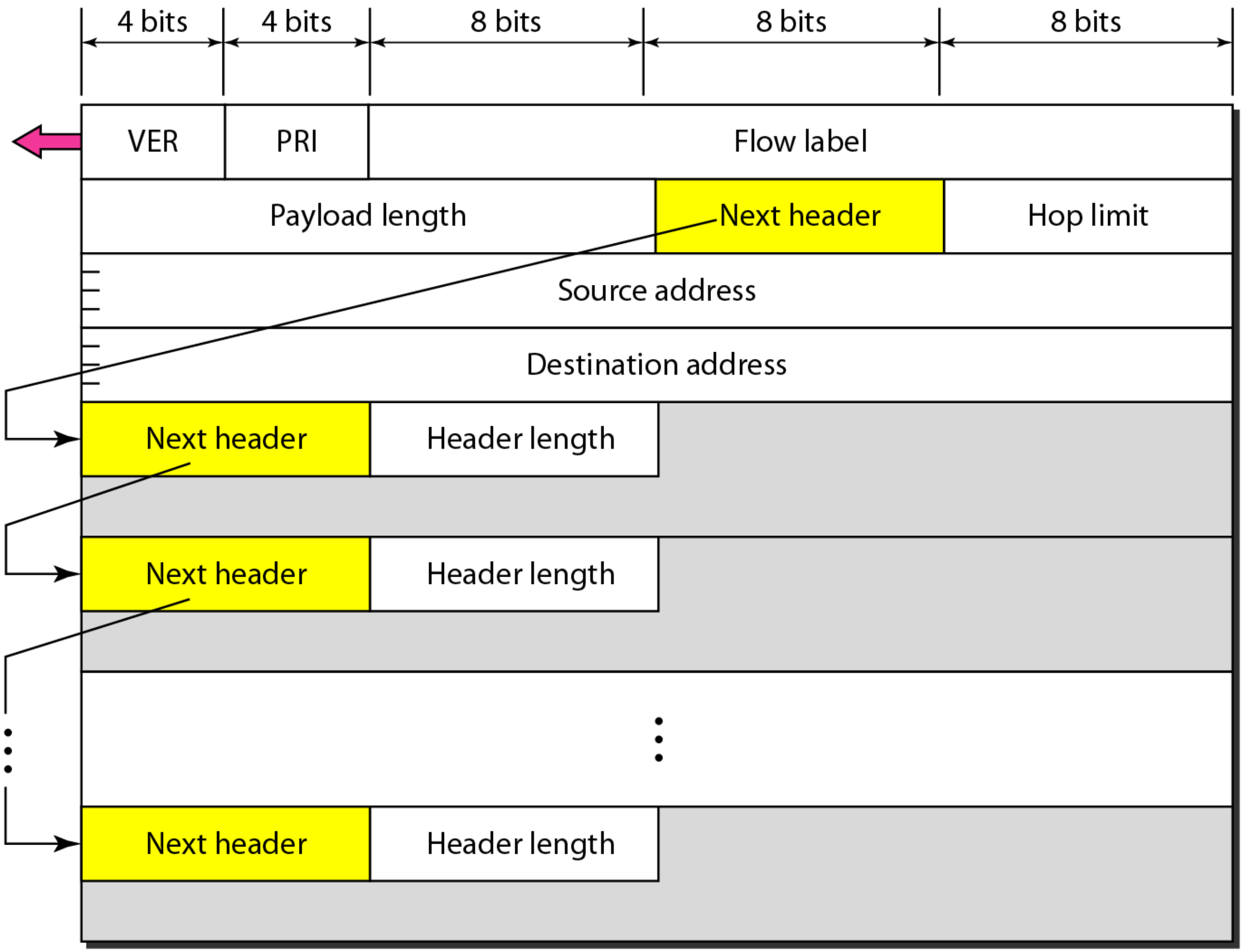
IPv4 Header

IPv6 Header



* Figure is courtesy of P. Smith, Cisco

Extension Headers



* Figure is courtesy of B. Forouzan

Extension Headers

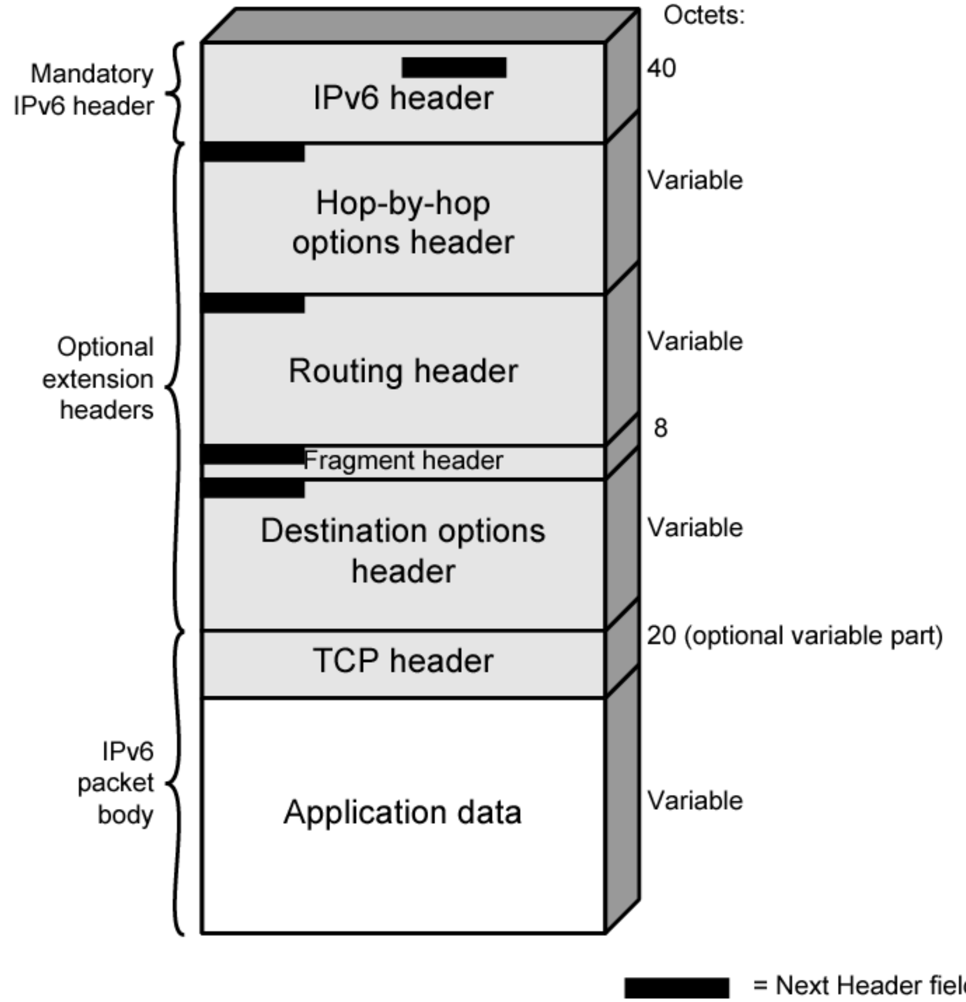
- Hop-by-Hop Options
  - Require processing at each router
- Routing
  - Similar to v4 source routing
- Fragment
- Authentication
- Encapsulating security payload
- Destination options
  - For destination node

Extension header	Description
Hop-by-hop options	Miscellaneous information for routers
Destination options	Additional information for the destination
Routing	Loose list of routers to visit
Fragmentation	Management of datagram fragments
Authentication	Verification of the sender's identity
Encrypted security payload	Information about the encrypted contents

* Figure is courtesy of A. Tanenbaum

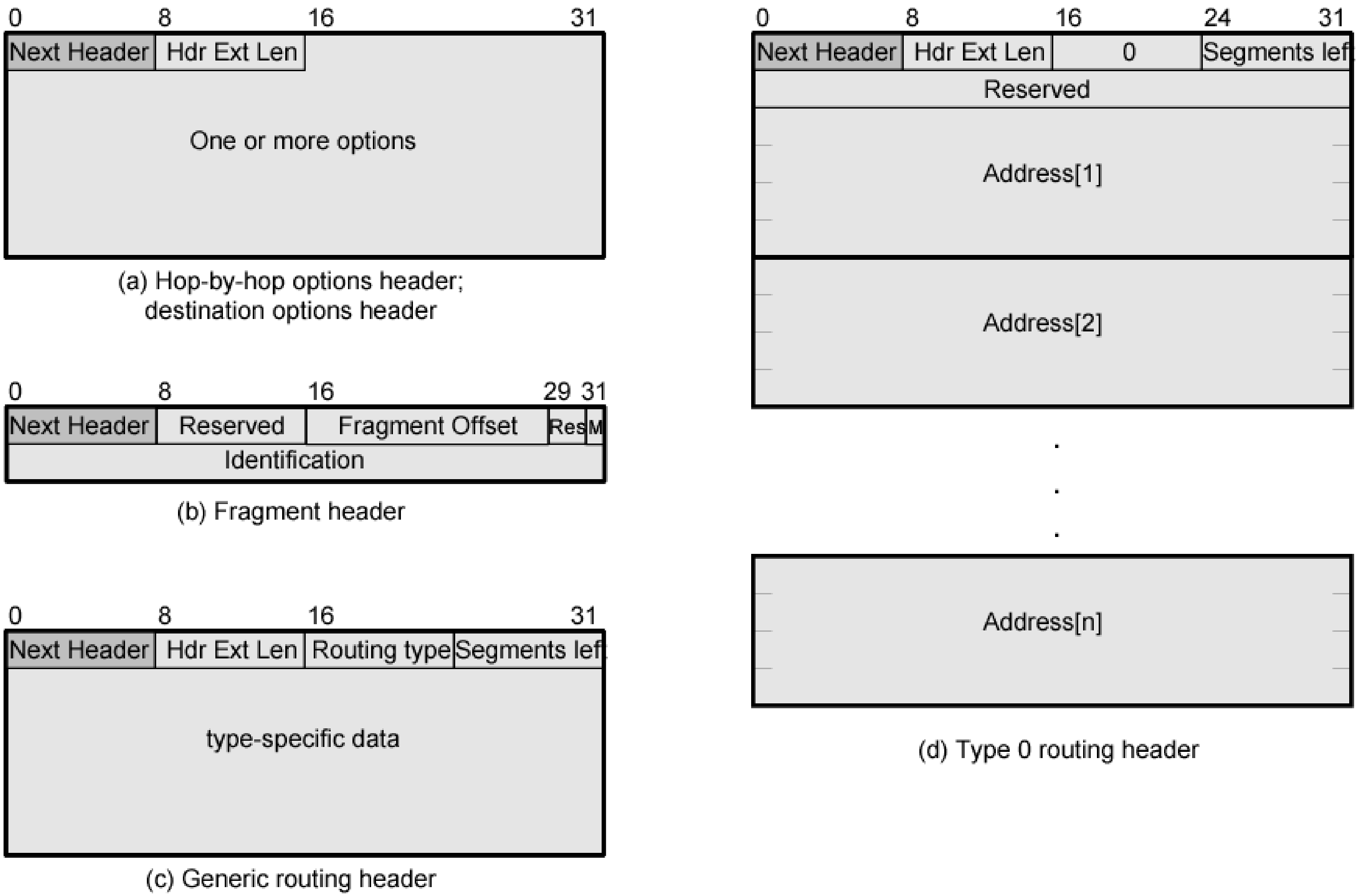
IPv6 Structure

- Every additional header is identified by “next header” field
  - including TCP and UDP header



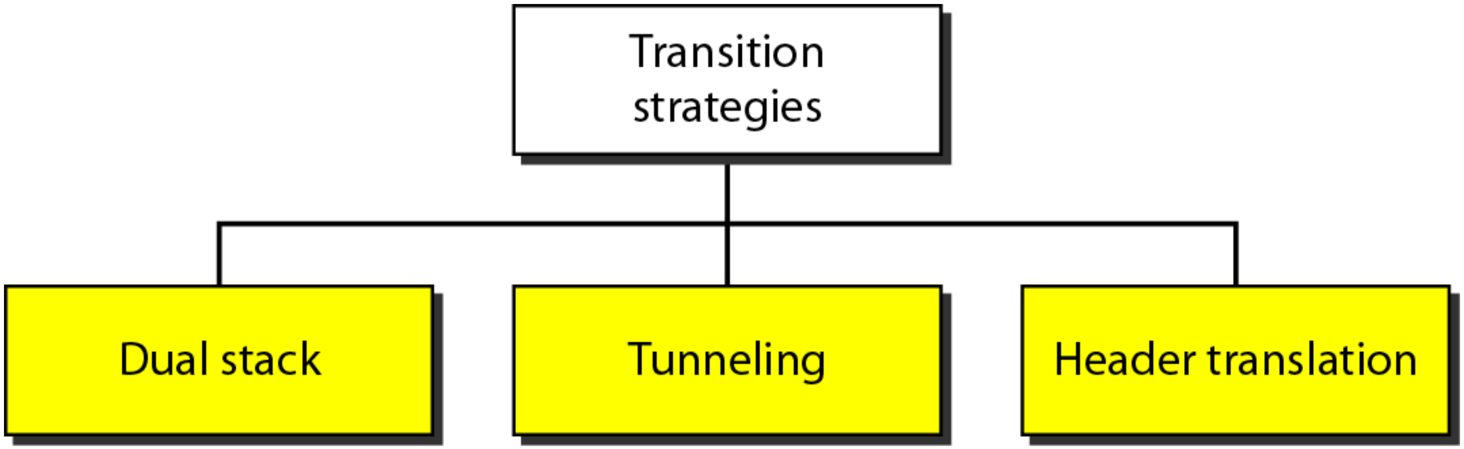
* Figure is courtesy of W. Stallings

IPv6 Extension Headers



* Figure is courtesy of W. Stallings

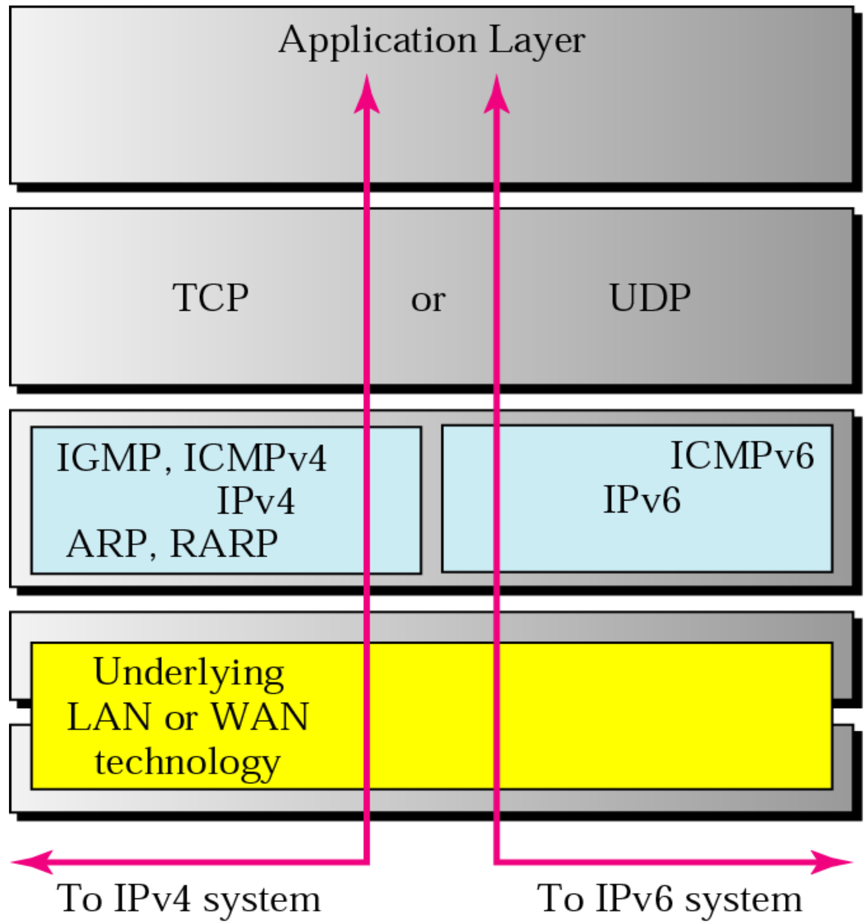
Transition from IPv4 to IPv6



* Figure is courtesy of B. Forouzan

IPv4-IPv6 Transition

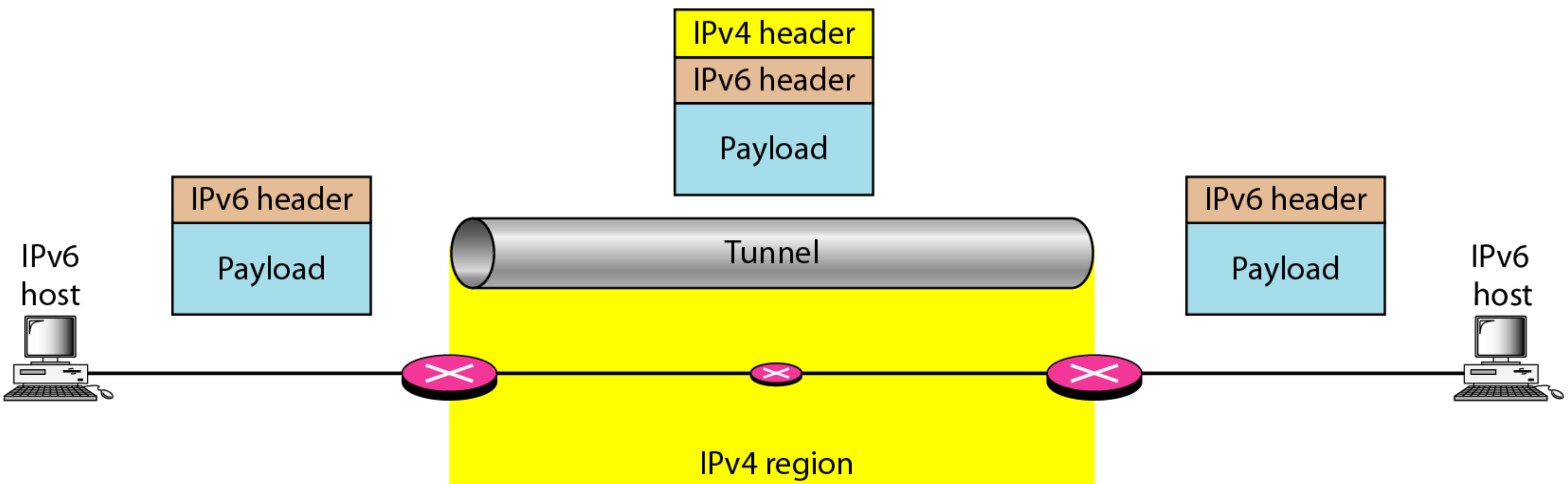
- Dual-Stack
  - Stack implements support for both IPv4 and IPv6
  - Allow IPv4 and IPv6 to co-exist in the same devices and networks



* Figure is courtesy of B. Forouzan

Tunneling

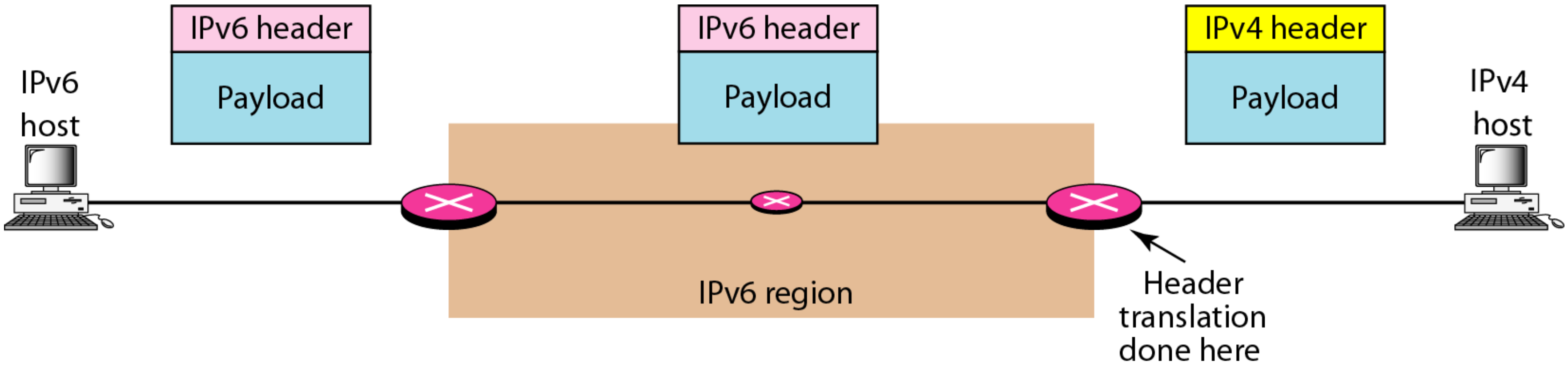
- Encapsulate IPv6 in IPv4 traffic
- Avoid order dependencies when upgrading hosts, routers, or regions



* Figure is courtesy of B. Forouzan

Header Translation

- Headers are translated into other format at “gateway”
- Allow IPv6-only devices to communicate with IPv4-only devices



* Figure is courtesy of B. Forouzan

Summary: IPv6

- Longer addresses: 128 bit
- Simpler, fixed-sized header

- Types of communication
  - Unicast
  - Multicast
  - Anycast

- Extension headers
  - Hop-by-Hop Options, Routing, Fragmentation, Authentication

- Techniques for transition
  - Dual-Stack
  - Tunneling
  - Translation


That's all folks
Telecomms II