Chapter 11

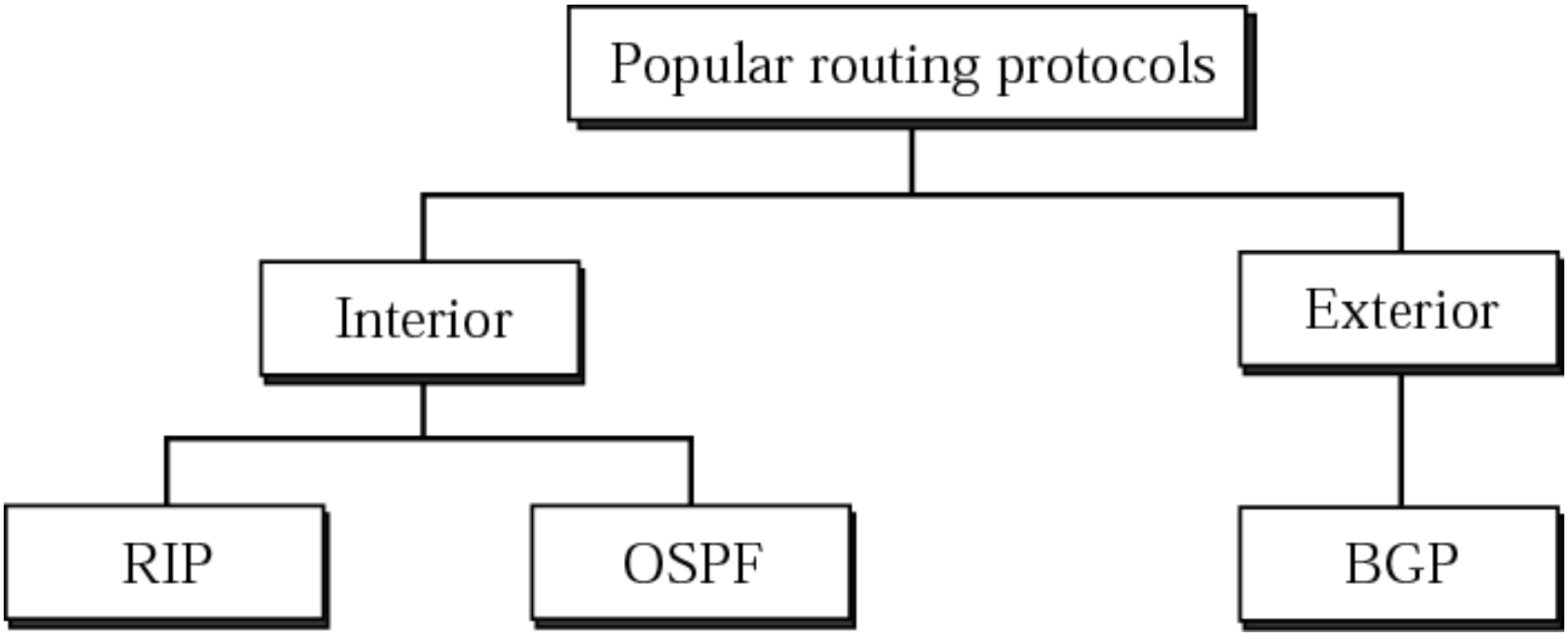
Routing Protocols (RIP, OSPF, BGP)

CONTENTS

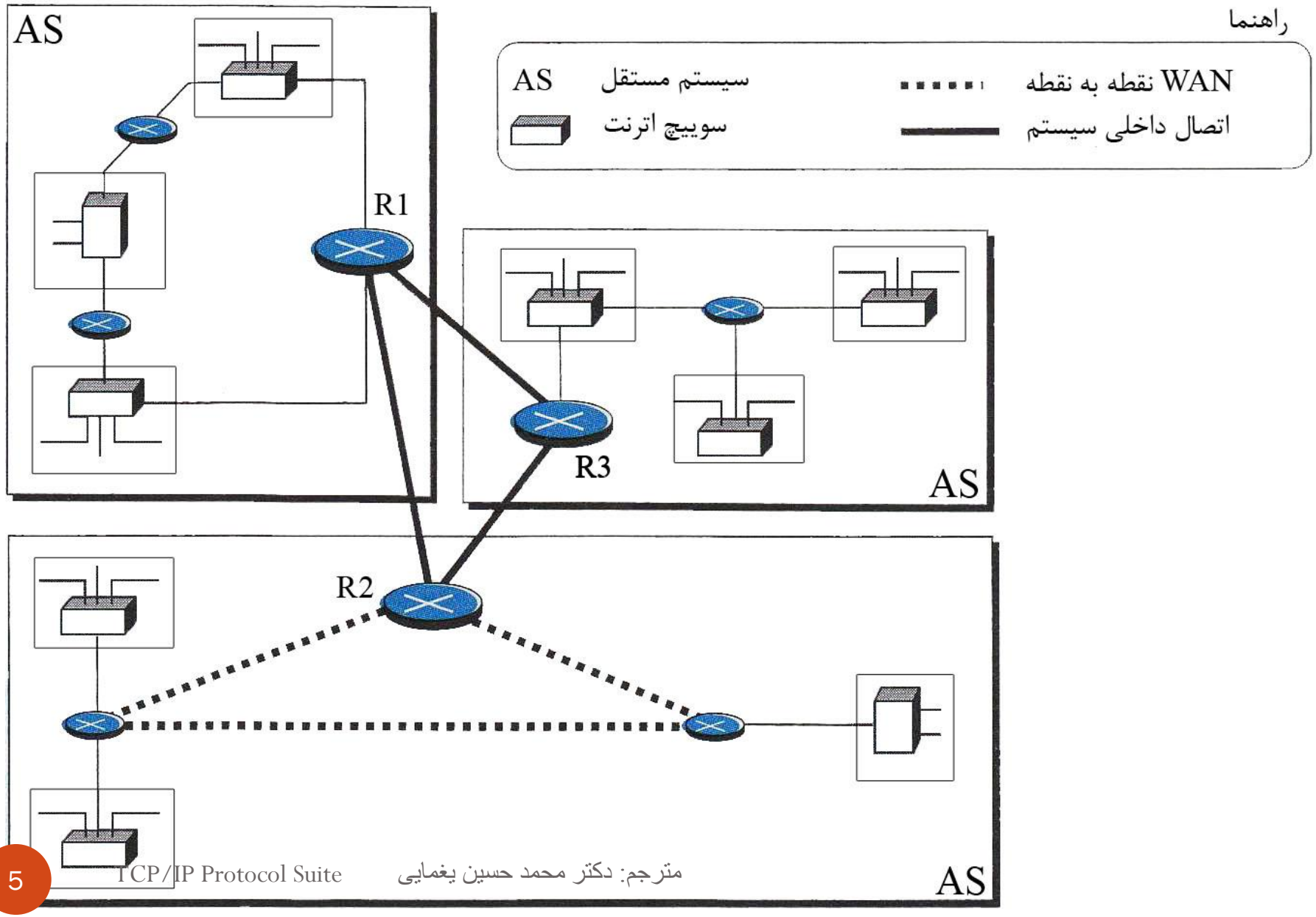
- **INTERIOR AND EXTERIOR ROUTING**
- **RIP**
- **OSPF**
- **BGP**

INTERIOR AND EXTERIOR ROUTING

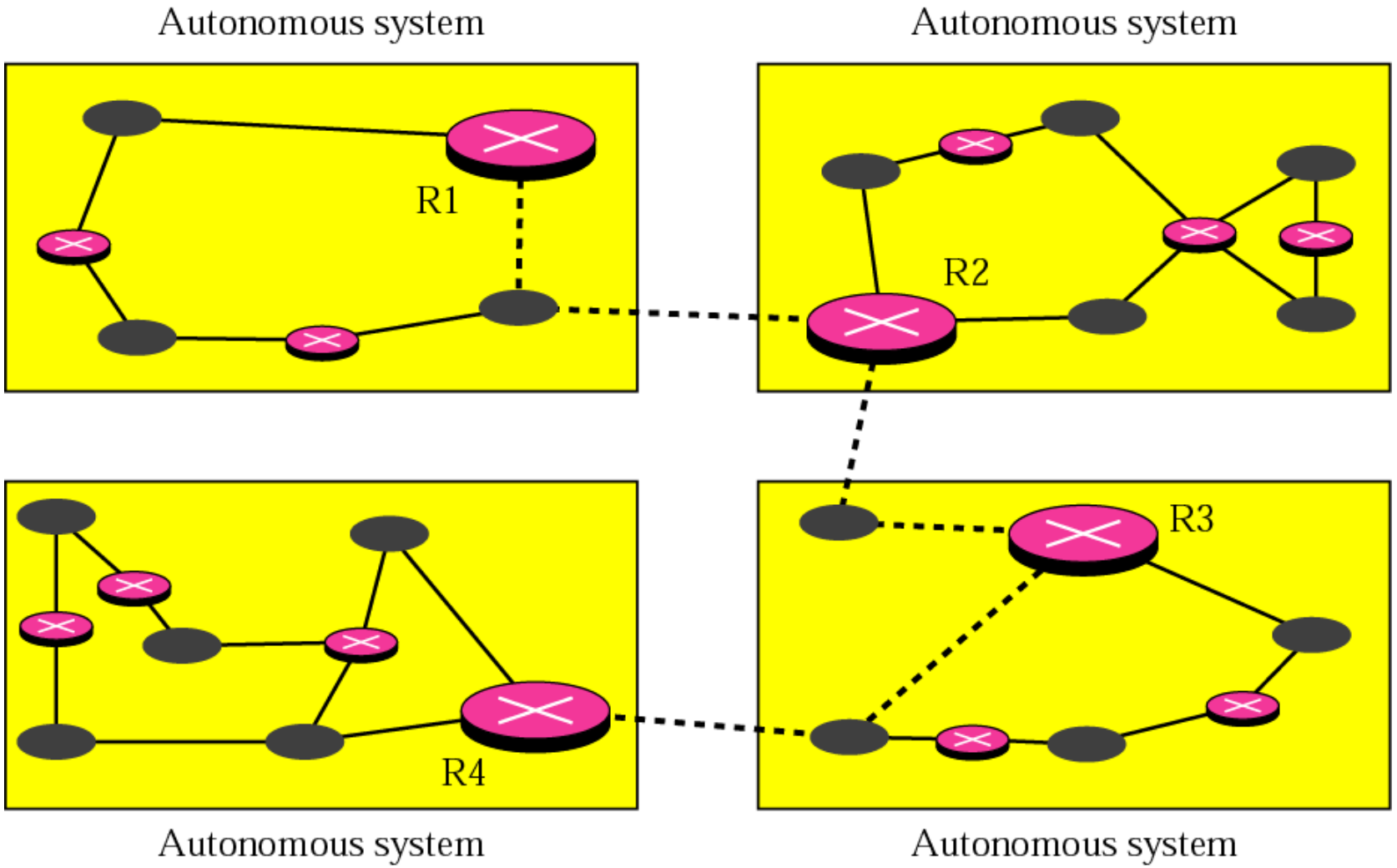
Popular routing protocols



Autonomous systems



Autonomous systems



مسیریابی بردار فاصله:
الگوریتم بلمن فورد

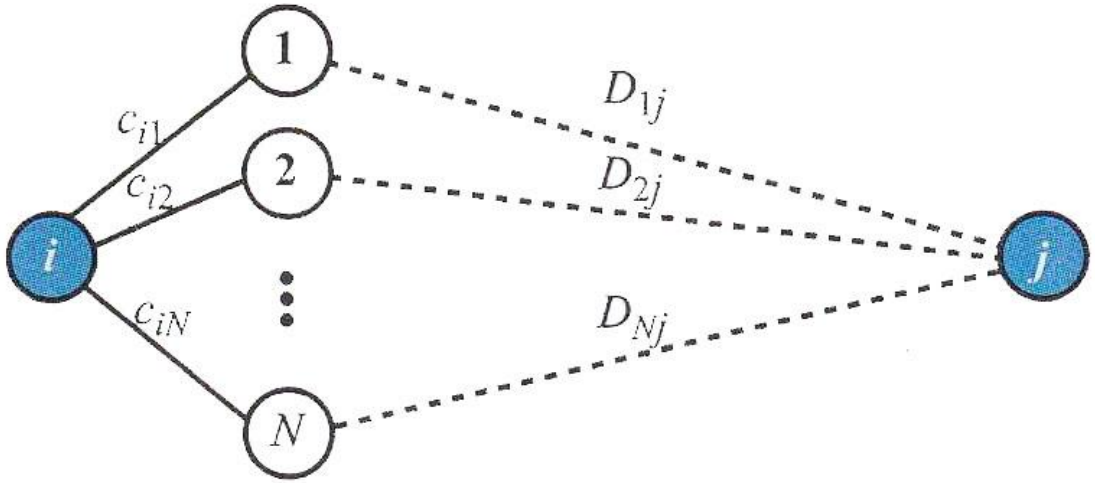
$$D_{ij} = \text{minimum}\ \{(c_{i1} + D_{1j}), (c_{i2} + D_{2j}), \ldots (c_{iN} + D_{Nj})$$

راهنما

Dij کوتاهترین فاصله بین i و j

cij هزینه بین i و j

N تعداد نودها



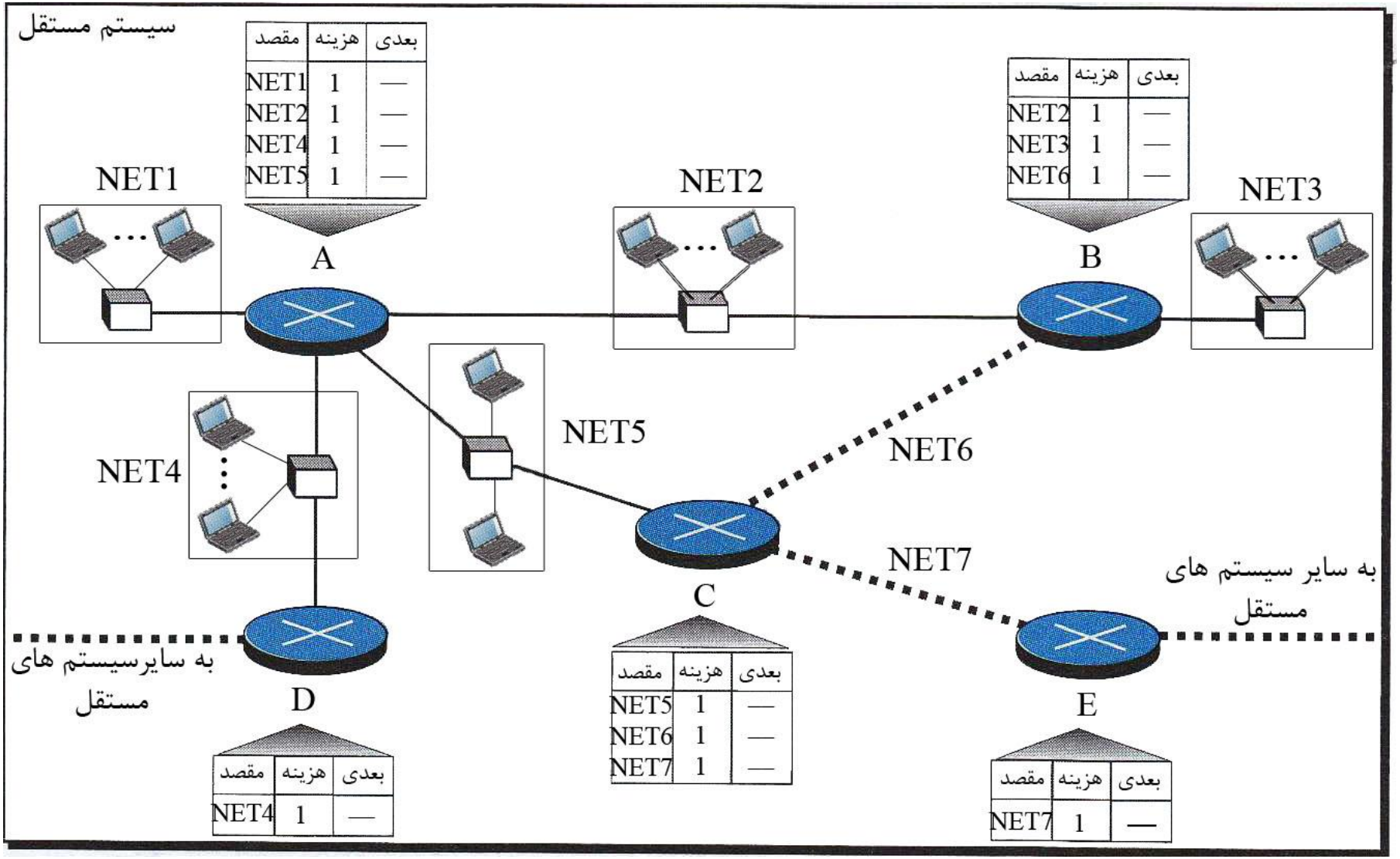
الگوریتم بلمن فورد

```
1   Bellman_Ford  ( )
2   {
3       // Initialization
4      for  (i=1 to N; for j=1 to N)
5      {
6           If  (i = = j)   D_ij = 0    c_ij = 0
7           else            D_ij = ∞    c_ij = cost between i and j
8       }
9       // Updating
10      repeat
11      {
12          for  (i = 1 to N; for j = 1 to N)
13          {
14              D_ij ← minimum [(c_i1 + D_1j)  …  (c_iN + D_Nj)]
15          } // end for
16      } // untile  (there was no change in previous iteraton)
17  } // end Bellman_Ford
```

مسیریابی بردار فاصله

- در مسیریابی بردار فاصله معمولاً هزینه، تعداد پرش‌هاست.
  - بنابراین هزینه بین هر دو همسایه مقدار ۱ می‌گیرد.
- هر همسایه به محض دریافت اطلاعات از همسایگانش، باید جدول مسیریابی خود را بصورت همزمان به روز-رسانی کند.
- پس از اینکه یک مسیریاب، جدول مسیریابی خود را به روز رسانی نمود، باید نتایج را به همسایگانش ارسال نماید تا آن‌ها نیز جدول مسیریابی خود را به روز رسانی نمایند.
- هر مسیریاب باید حداقل سه بخش از اطلاعات را برای هر مسیر نگهداری کند:
  - شبکه مقصد، هزینه و پرش بعدی. ردیف i در جدول مسیریابی Table_i بصورت سه ستون در ردیف i نشان داده می‌شود:
    - $\text{Table}_i.\text{dest}, \text{Table}i.\text{cost}, \text{Table}i.\text{next}$
- با مراجعه به اطلاعات هر مسیر دریافتی از یک همسایه مانند R، دو بخش از اطلاعات که شامل مقصد و هزینه می‌باشد بدست می‌آید: R.cost و R.dest. اطلاعات شامل پرش بعدی نمی‌باشد؛ چرا که، آدرس مبدأ فرستنده است.

مثال


سیستم مستقل
مقصد هزینه بعدی
NET1 1 —
NET2 1 —
NET4 1 —
NET5 1 —
A
NET1
NET2
NET3
مقصد هزینه بعدی
NET2 1 —
NET3 1 —
NET6 1 —
B
NET4
NET5
NET6
NET7
C
مقصد هزینه بعدی
NET5 1 —
NET6 1 —
NET7 1 —
به سایر سیستم های مستقل
به سایرسیستم های مستقل
D
مقصد هزینه بعدی
NET4 1 —
E
مقصد هزینه بعدی
NET7 1 —

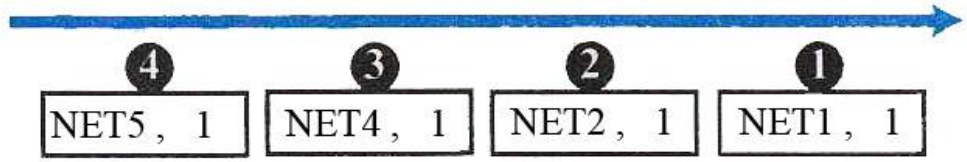
تغییرات در جدول مسیریابی B

مقصد	هزینه	بعدی
NET1	1	---
NET2	1	---
NET4	1	---
NET5	1	---

A

مقصد	هزینه	بعدی
NET2	1	---
NET3	1	---
NET6	1	---

B



جدول مسیریابی B

مقصد	هزینه	بعدی
NET1	2	A
NET2	1	---
NET3	1	---
NET6	1	---

پس از دریافت رکورد ۱

جدول مسیریابی B

مقصد	هزینه	بعدی
NET1	2	A
NET2	1	---
NET3	1	---
NET6	1	---

پس از دریافت رکورد ۲

جدول مسیریابی B

مقصد	هزینه	بعدی
NET1	2	A
NET2	1	---
NET3	1	---
NET4	2	A
NET6	1	---

پس از دریافت رکورد ۳

جدول مسیریابی B

مقصد	هزینه	بعدی
NET1	2	A
NET2	1	---
NET3	1	---
NET4	2	A
NET5	2	A
NET6	1	---

پس از دریافت رکورد ۴

جدول نهایی مسیریاب ها

A

مقصد	هزینه	بعدی
NET1	1	---
NET2	1	---
NET3	2	B
NET4	1	---
NET5	1	---
NET6	2	C
NET7	2	C

B

مقصد	هزینه	بعدی
NET1	2	A
NET2	1	---
NET3	1	---
NET4	2	A
NET5	2	A
NET6	1	---
NET7	2	C

C

مقصد	هزینه	بعدی
NET1	2	A
NET2	2	A
NET3	2	B
NET4	2	A
NET5	1	---
NET6	1	---
NET7	1	---

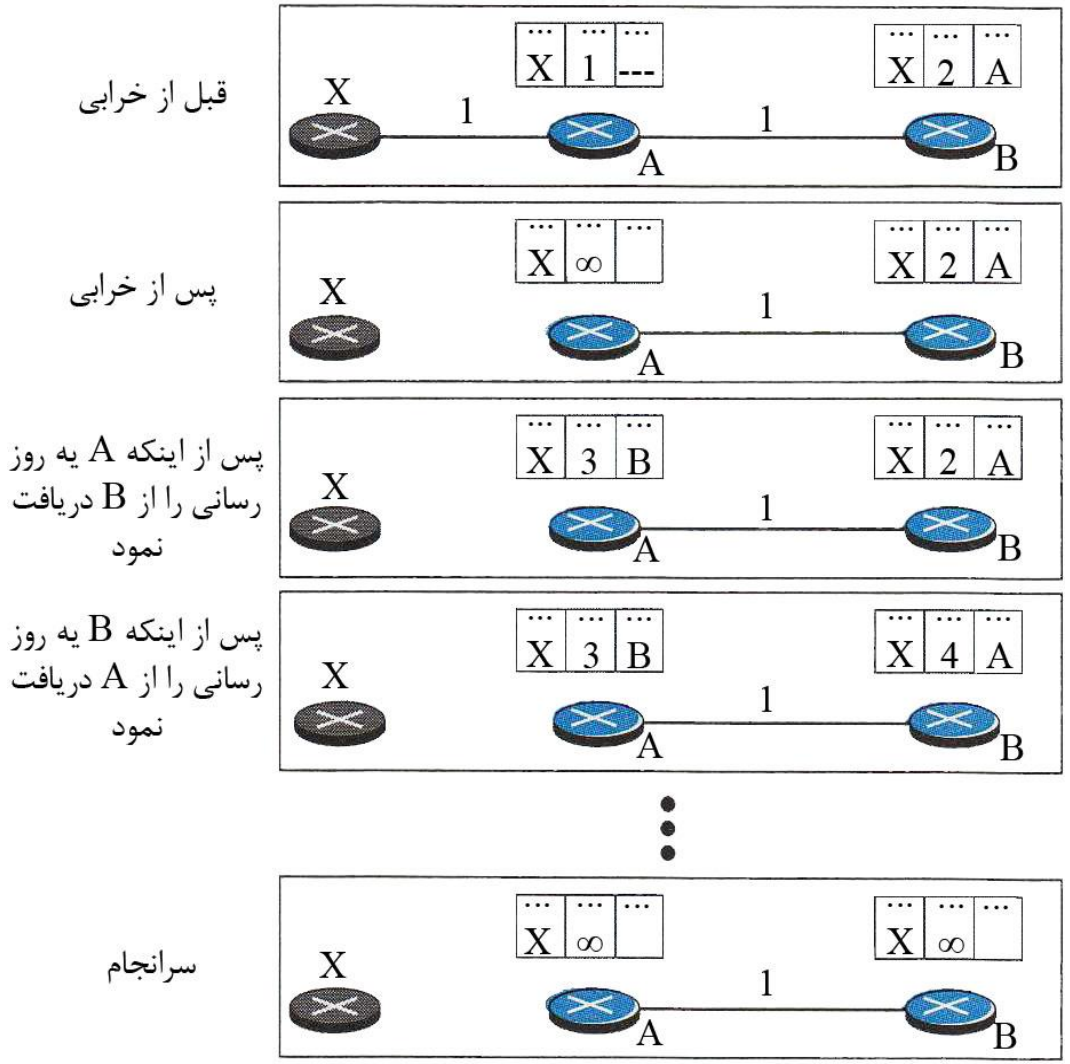
D

مقصد	هزینه	بعدی
NET1	2	A
NET2	2	A
NET3	3	A
NET4	1	---
NET5	1	A
NET6	3	A
NET7	3	A

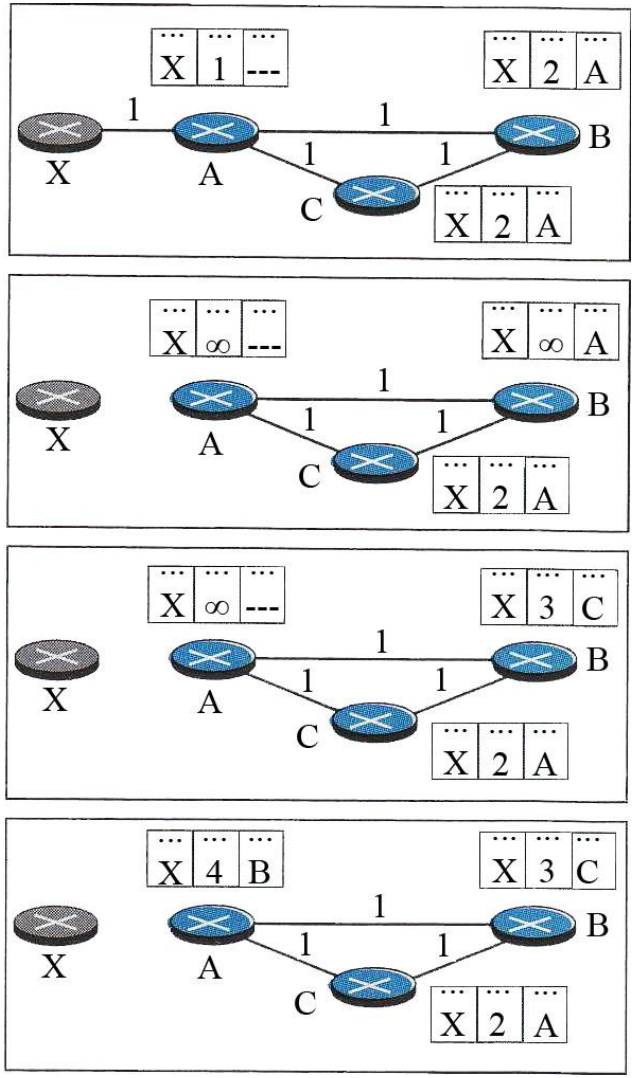
E

مقصد	هزینه	بعدی
NET1	3	C
NET2	3	C
NET3	3	C
NET4	3	C
NET5	2	C
NET6	2	C
NET7	1	---

حلقه دو نودی


قبل از خرابی
X 1 ---
X 2 A
X
1
1
A
B
پس از خرابی
X ∞
X 2 A
X
1
A
B
پس از اینکه A یه روز رسانی را از B دریافت نمود
X 3 B
X 2 A
X
1
A
B
پس از اینکه B یه روز رسانی را از A دریافت نمود
X 3 B
X 4 A
X
1
A
B
سرانجام
X ∞
X ∞
X
1
A
B

ناپایداری سه نودی

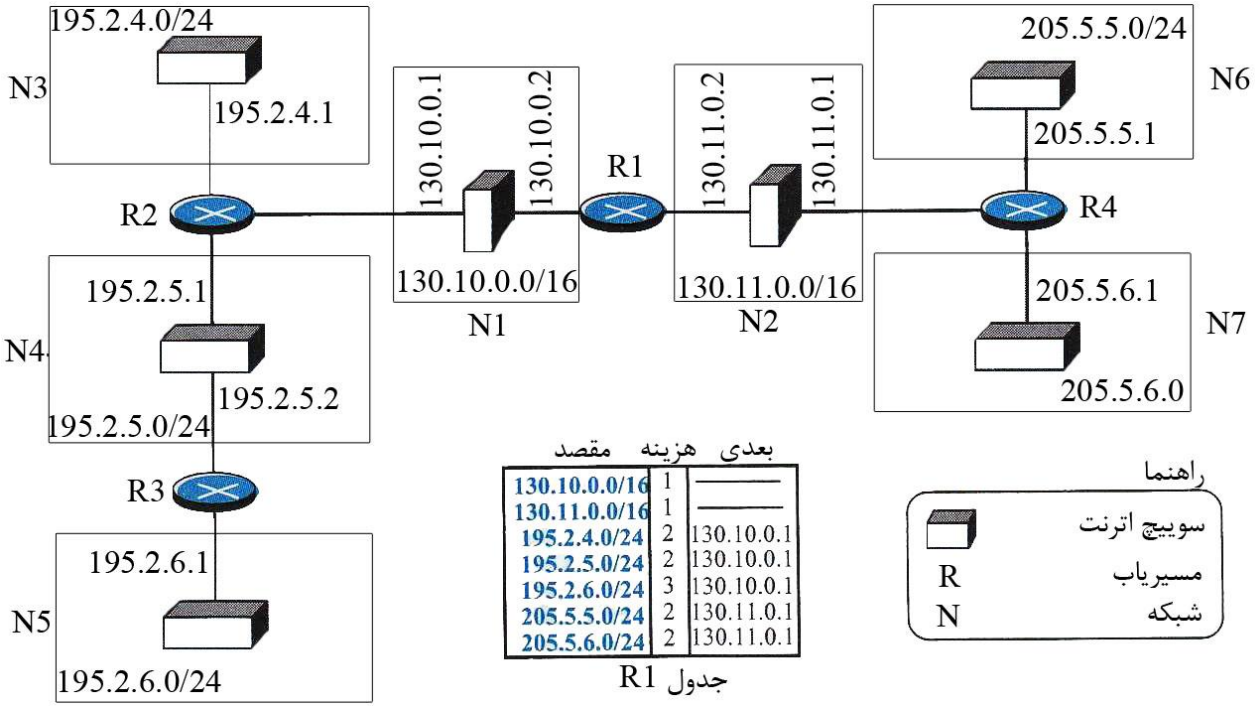


RIP: Routing Information Protocol

RIP: Routing Information Protocol

- مقصد در جدول مسیریابی یک شبکه است؛ یعنی اولین ستون جدول، آدرس شبکه را مشخص می‌کند.
- RIP از معیار بسیار ساده‌ای بنام فاصله استفاده می‌کند.
- فاصله بر حسب تعداد لینک‌هایی است که باید برای رسیدن به مقصد طی شوند.
  - بنابراین متریک مورد استفاده در RIP، تعداد پرش می‌باشد.
- ۱۶ به عنوان بینهایت تعریف می‌شود؛ به این معنی که در سیستم مستقلی که از RIP استفاده می‌کند، هر مسیر نمی‌تواند بیش از ۱۵ پرش داشته باشد.
- ستون پرش بعدی، آدرس مسیریابی را نشان می‌دهد که بسته باید به آن فرستاده شود تا به مقصد برسد.

نمونه ای از یک دامنه که از RIP استفاده می‌کند



جدول R1

مقصد	هزینه	بعدی
130.10.0.0/16	1	———
130.11.0.0/16	1	———
195.2.4.0/24	2	130.10.0.1
195.2.5.0/24	2	130.10.0.1
195.2.6.0/24	3	130.10.0.1
205.5.5.0/24	2	130.11.0.1
205.5.6.0/24	2	130.11.0.1

جدول R2

مقصد	هزینه	بعدی
130.10.0.0/16	1	———
130.11.0.0/16	2	130.10.0.2
195.2.4.0/24	1	———
195.2.5.0/24	1	———
195.2.6.0/24	2	195.2.5.2
205.5.5.0/24	3	130.10.0.2
205.5.6.0/24	3	130.10.0.2

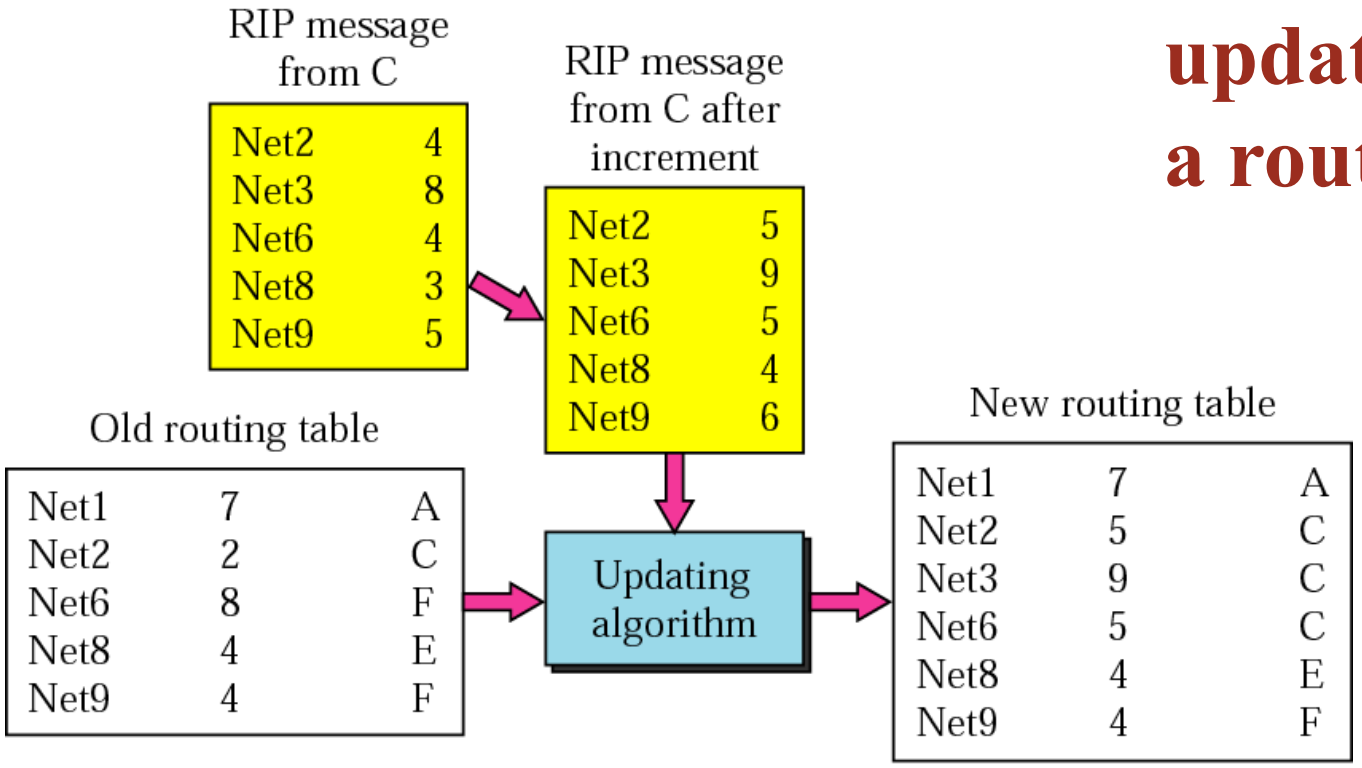
جدول R3

مقصد	هزینه	بعدی
130.10.0.0/16	2	195.2.5.1
130.11.0.0/16	3	195.2.5.1
195.2.4.0/24	2	195.2.5.1
195.2.5.0/24	1	———
195.2.6.0/24	1	———
205.5.5.0/24	4	195.2.5.1
205.5.6.0/24	4	195.2.5.1

جدول R4

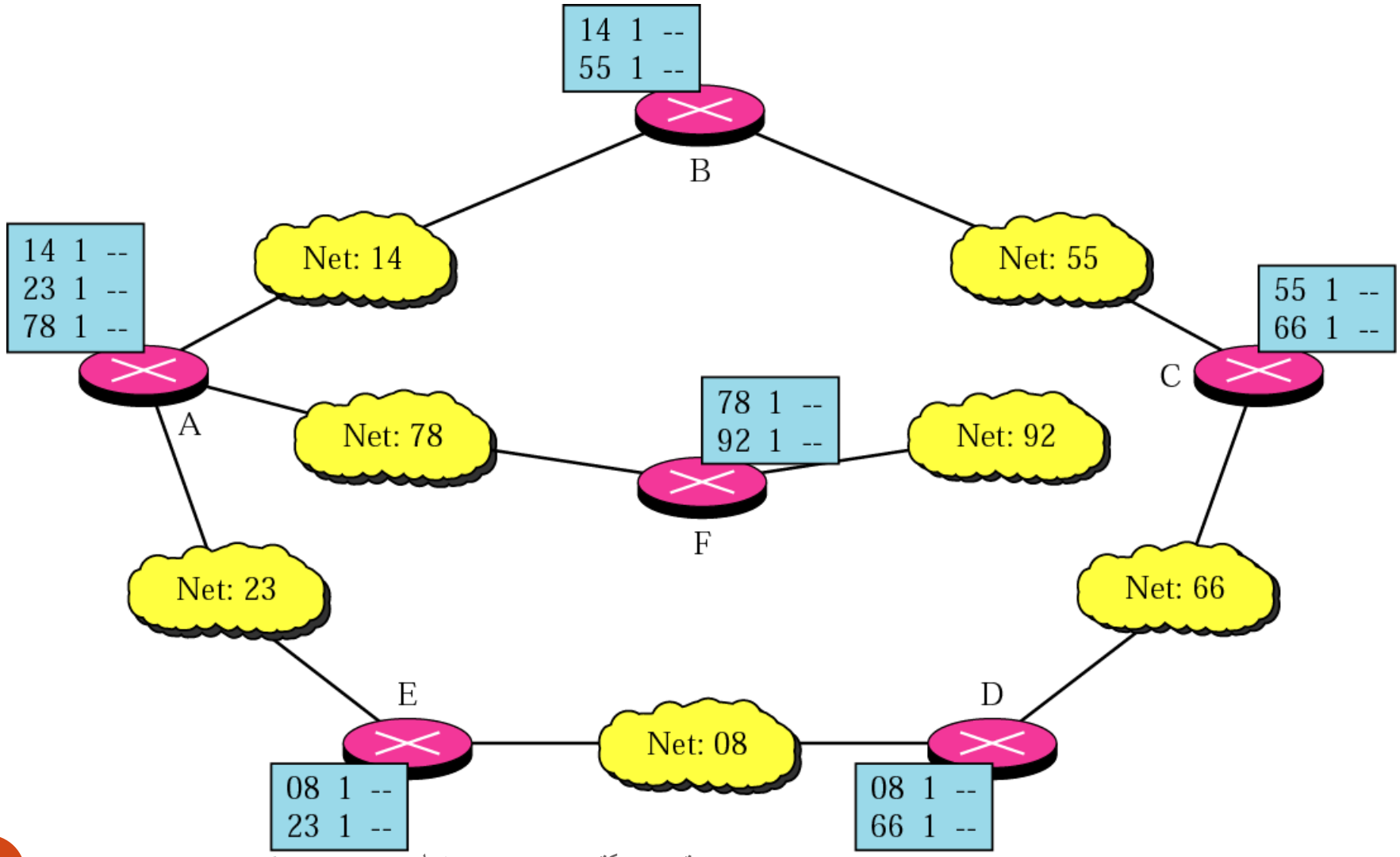
مقصد	هزینه	بعدی
130.10.0.0/16	2	130.11.0.2
130.11.0.0/16	1	———
195.2.4.0/24	3	130.11.0.2
195.2.5.0/24	3	130.11.0.2
195.2.6.0/24	4	130.11.0.2
205.5.5.0/24	1	———
205.5.6.0/24	1	———

Example of updating a routing table

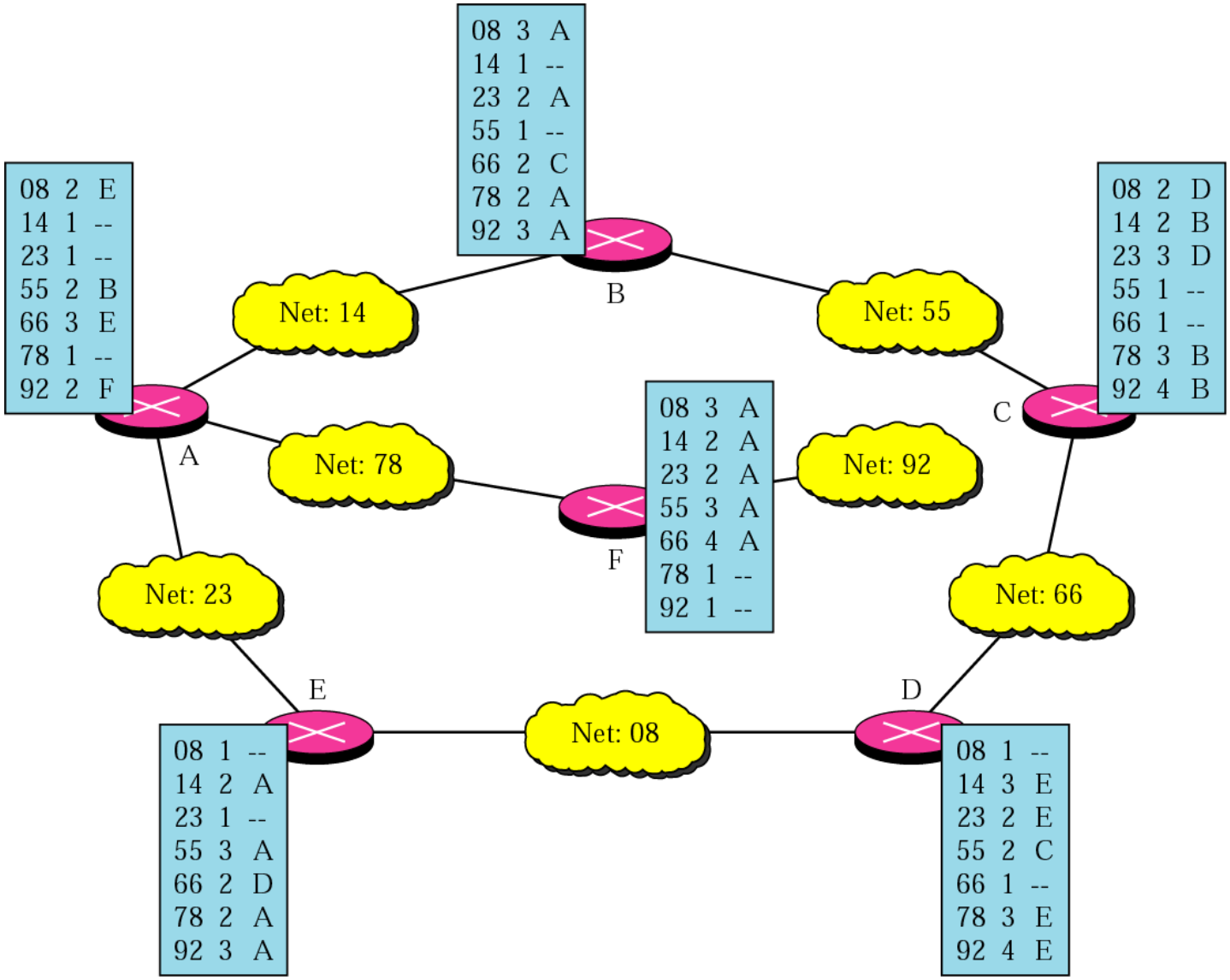


Net1: No news, do not change
Net2: Same next hop, replace
Net3: A new router, add
Net6: Different next hop, new hop count smaller, replace
Net8: Different next hop, new hop count the same, do not change
Net9: Different next hop, new hop count larger, do not change

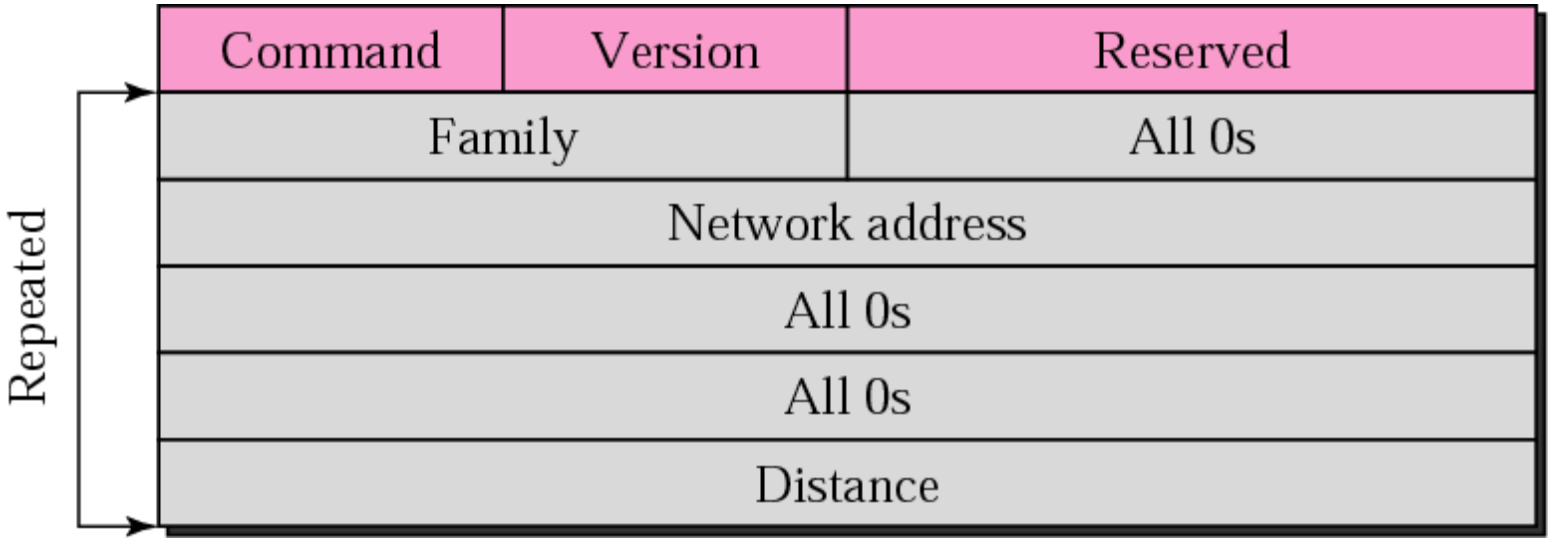
Initial routing tables in a small autonomous system



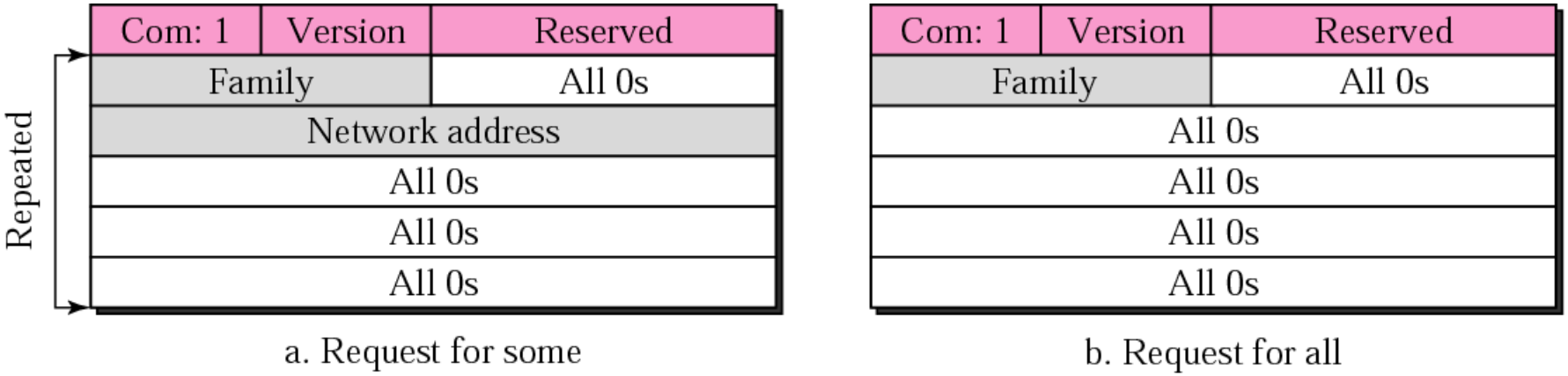
Final routing tables for the previous figure



RIP message format



Request messages



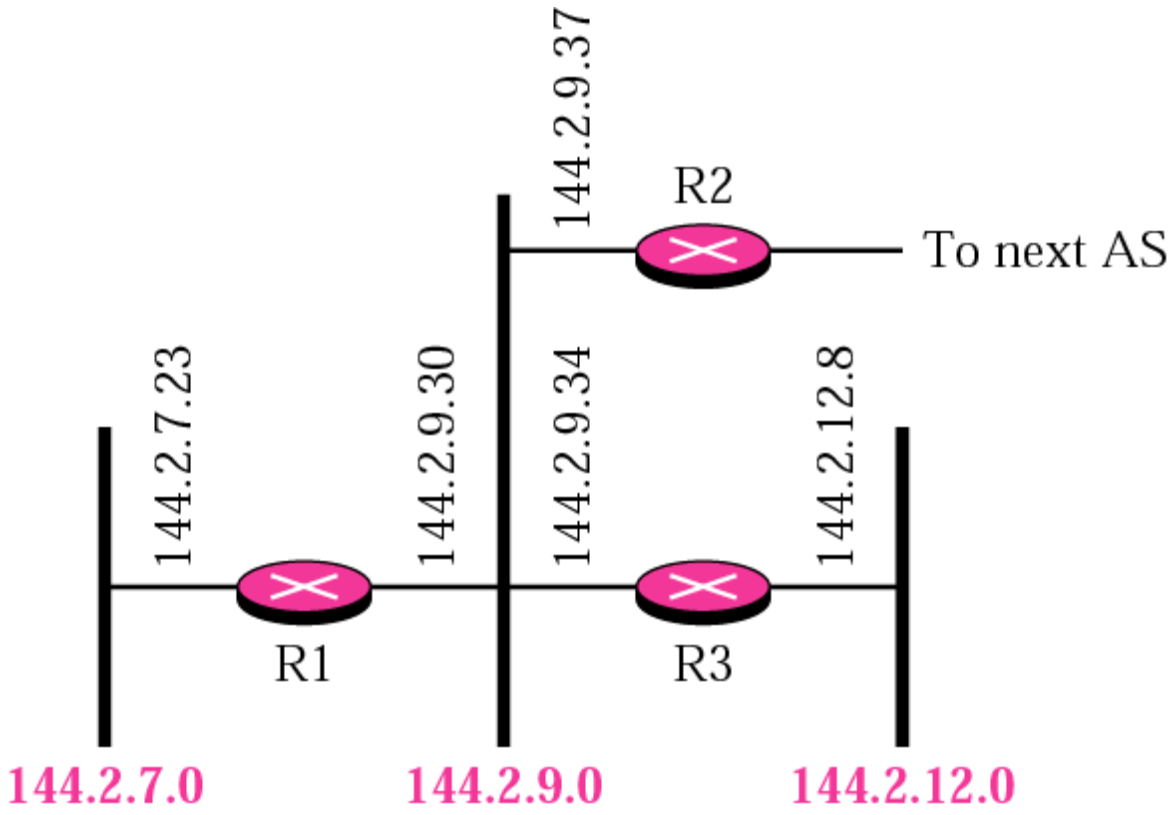
a. Request for some

b. Request for all

Example 1

What is the periodic response sent by router R1 in Figure 13.8 (next slide)? Assume R1 knows about the whole autonomous system.

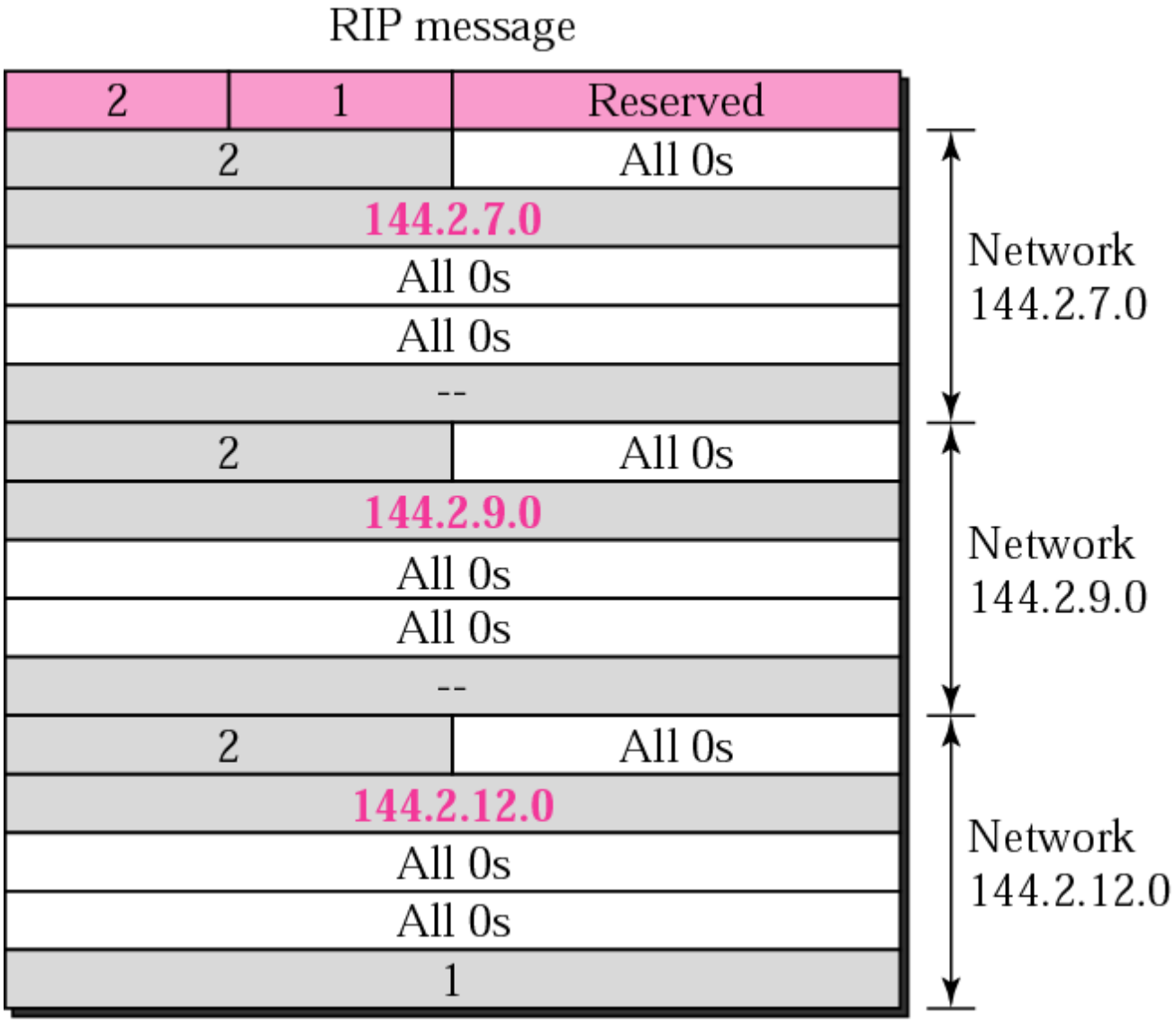
Example 1


144.2.9.37
R2
To next AS
144.2.7.23
144.2.9.30
144.2.9.34
144.2.12.8
R1
R3
144.2.7.0
144.2.9.0
144.2.12.0

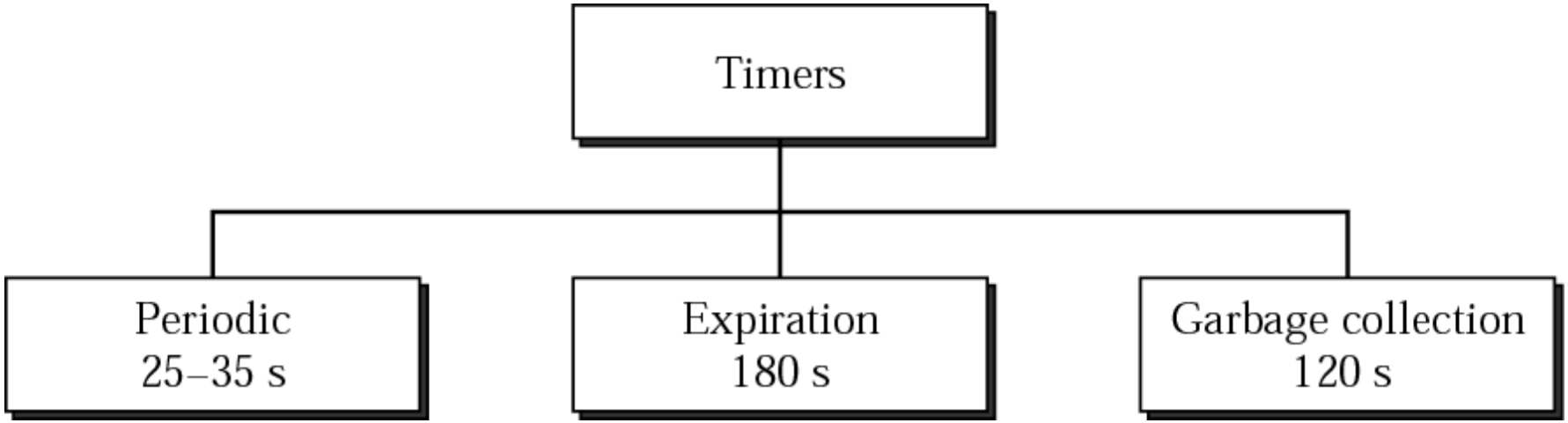
Solution

R1 can advertise three networks 144.2.7.0, 144.2.9.0, and 144.2.12.0. The periodic response (update packet) is shown in Figure 13.9 (next slide).

Solution to Example 1



RIP timers


Timers
Periodic
25–35 s
Expiration
180 s
Garbage collection
120 s

Example 2

A routing table has 20 entries. It does not receive information about five routes for 200 seconds. How many timers are running at this time?

Solution

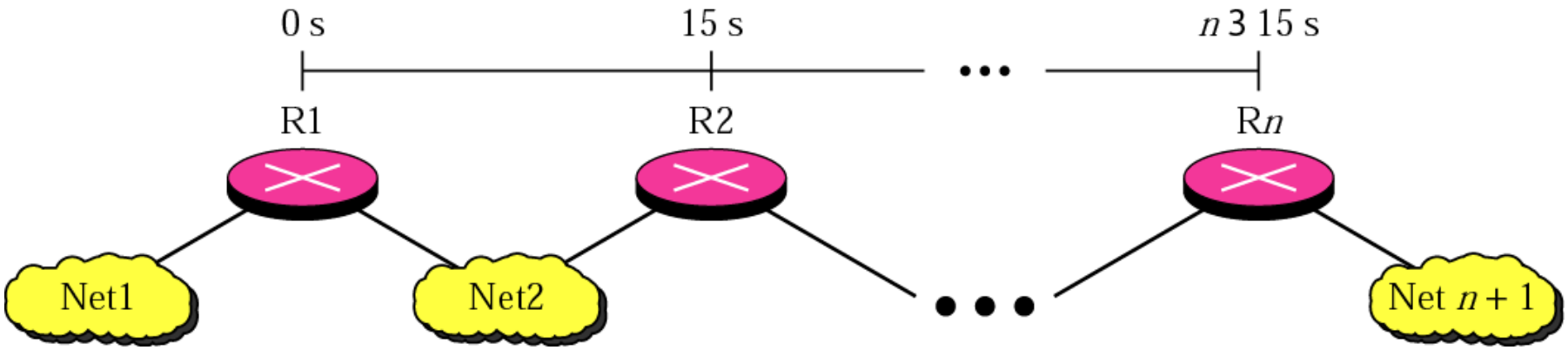
The timers are listed below:

Periodic timer: 1

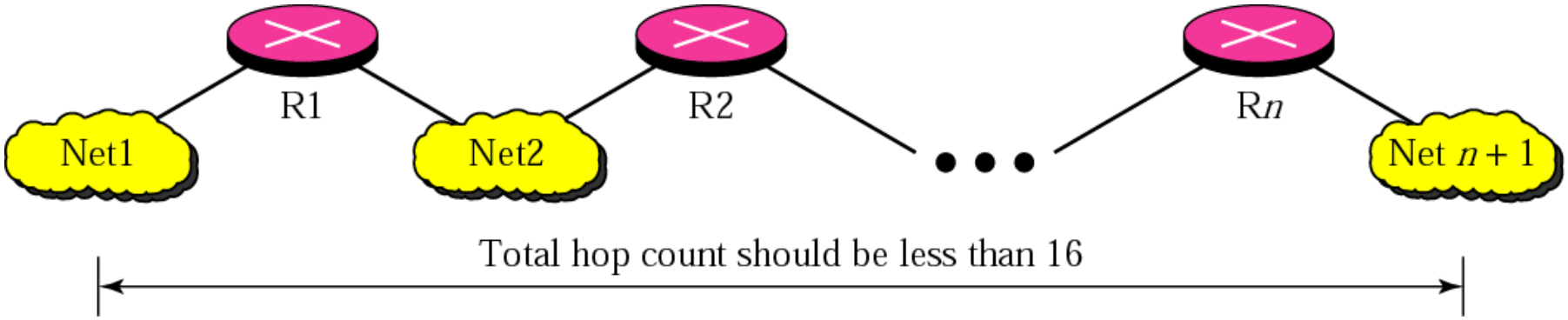
Expiration timer: 20 – 5 = 15

Garbage collection timer: 5

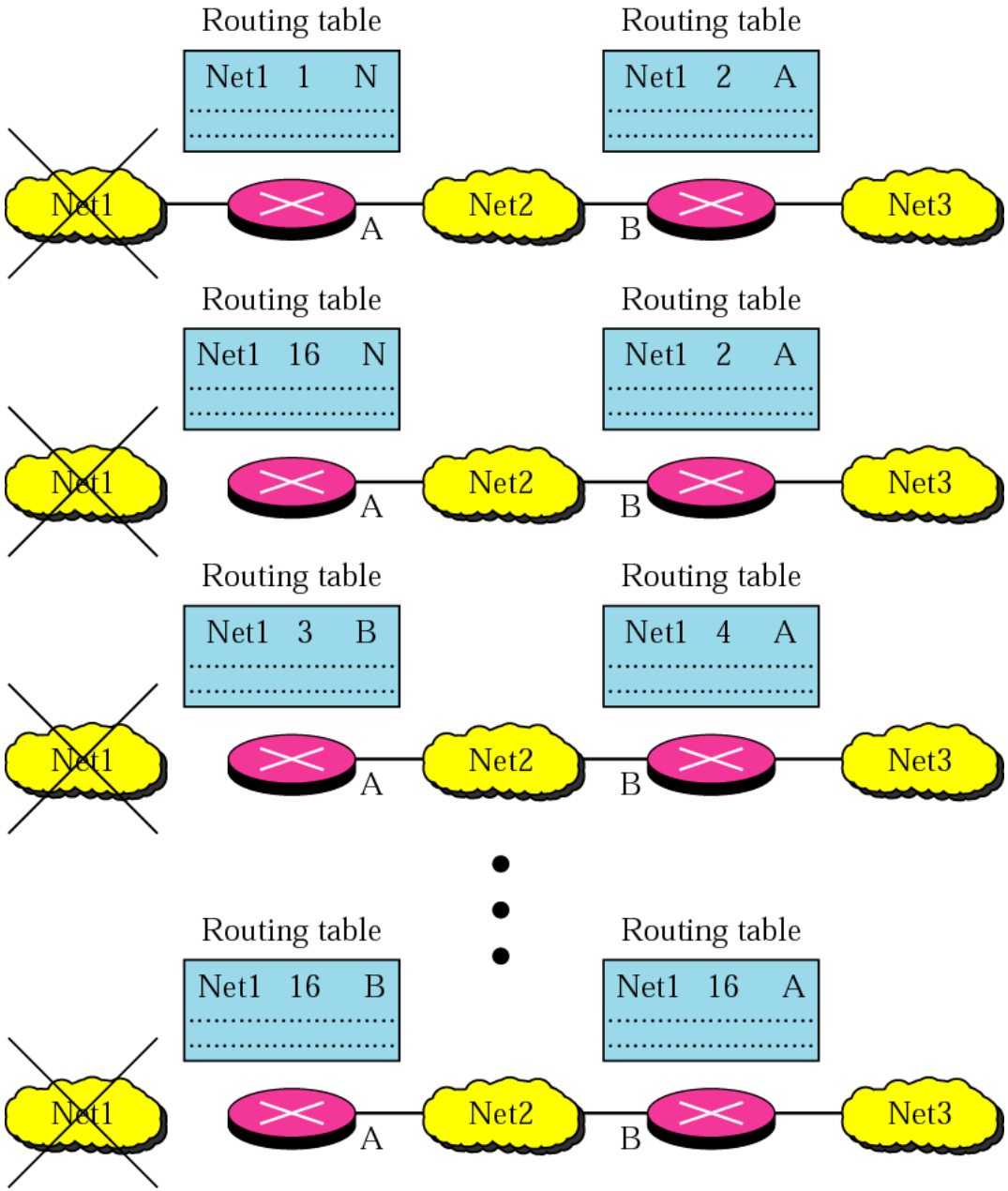
Slow convergence



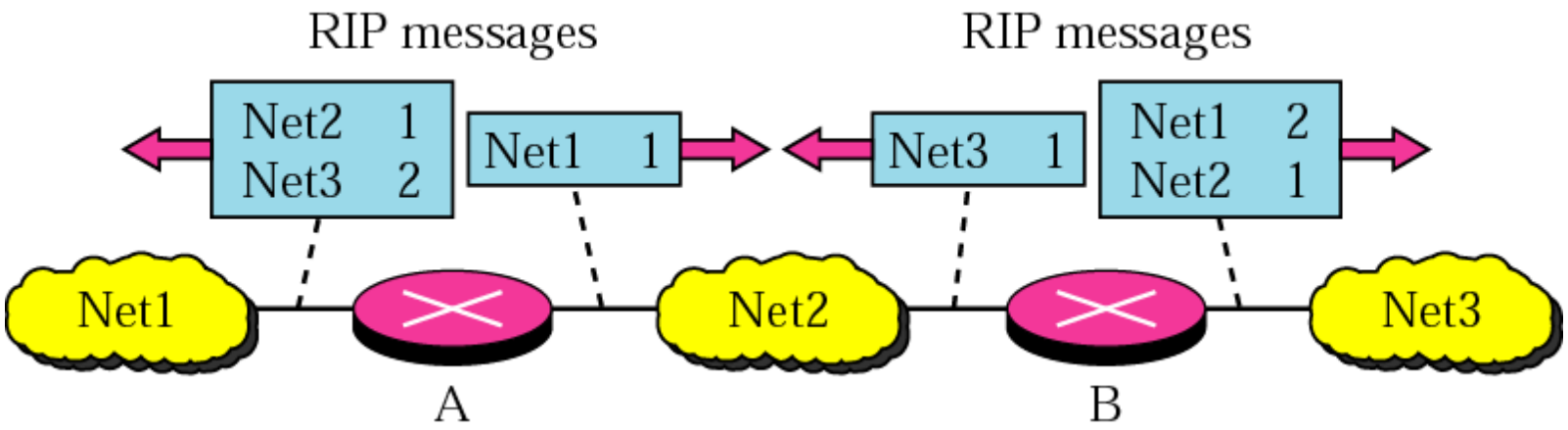
Hop count


R1
R2
Rn
Net1
Net2
Net n + 1
Total hop count should be less than 16

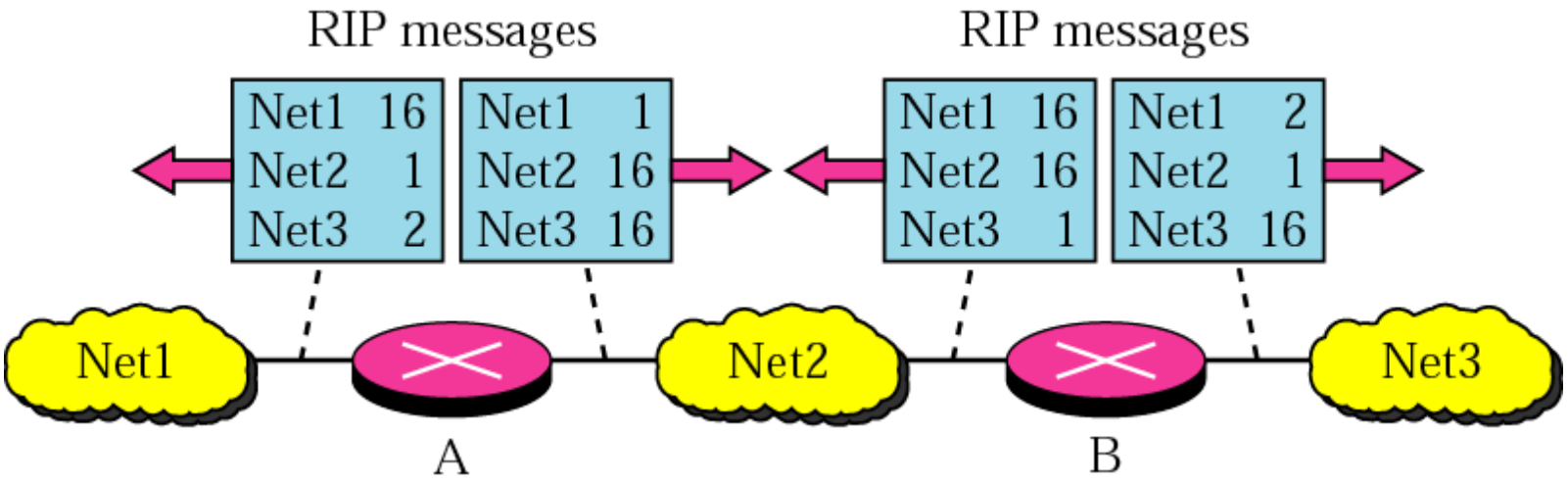
Instability



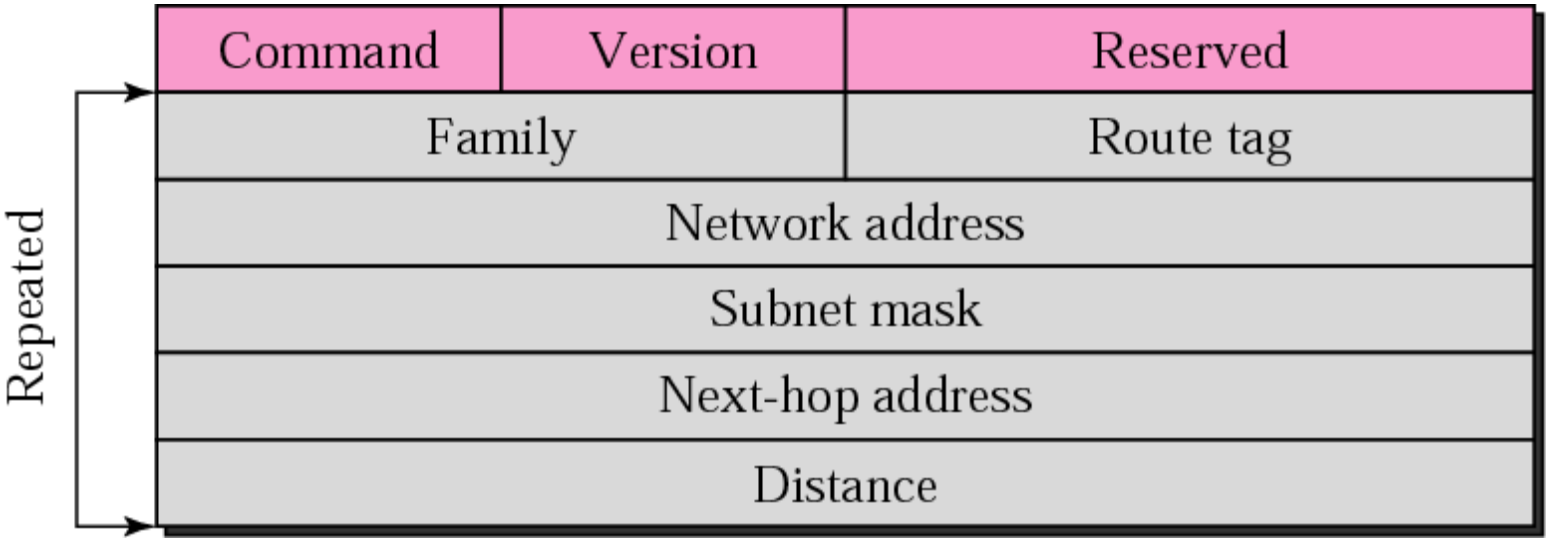
Split horizon



Poison reverse



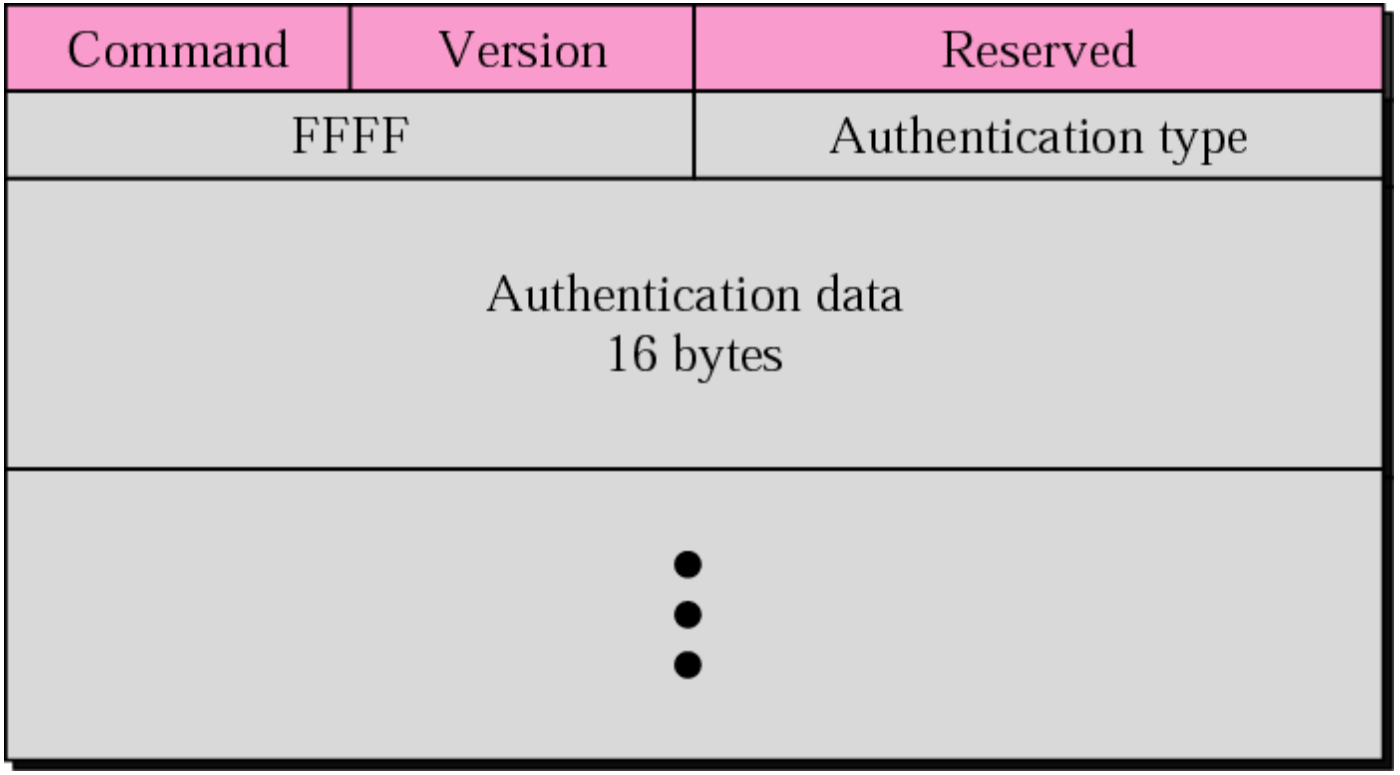
RIP-v2 Format



Note

RIP version 2 supports CIDR.

Authentication

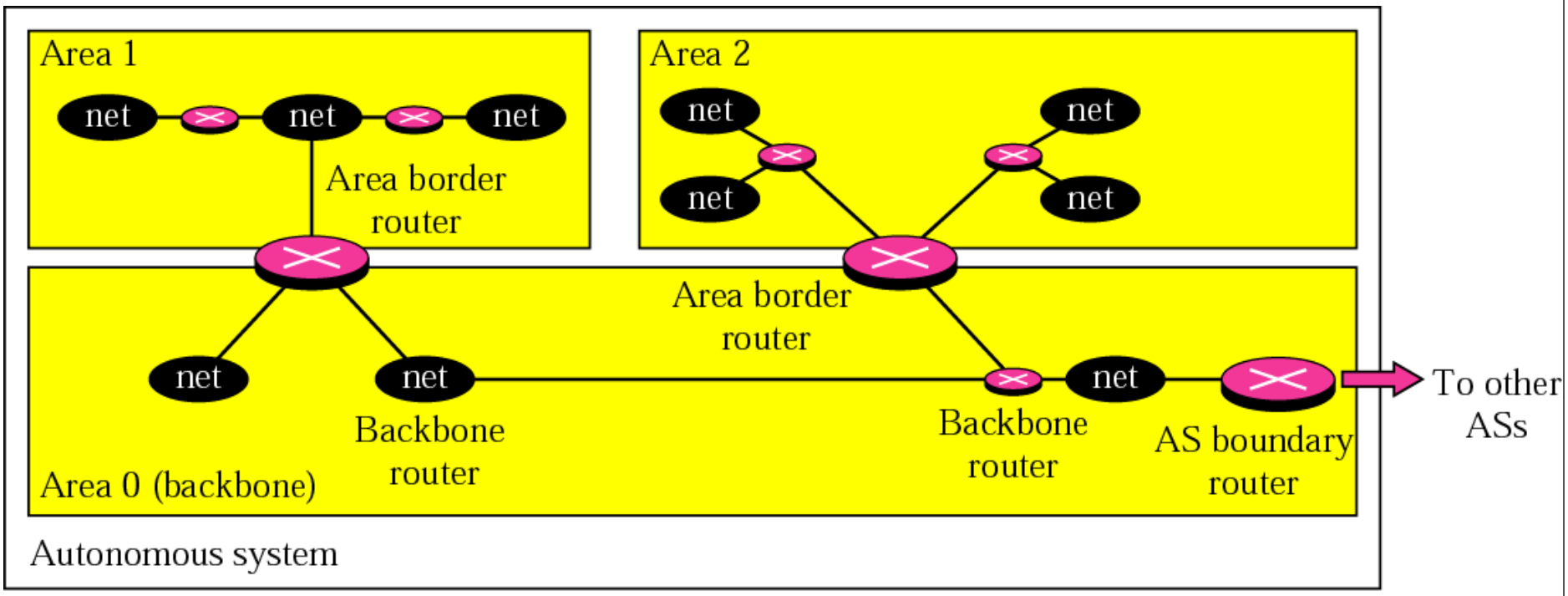


Note

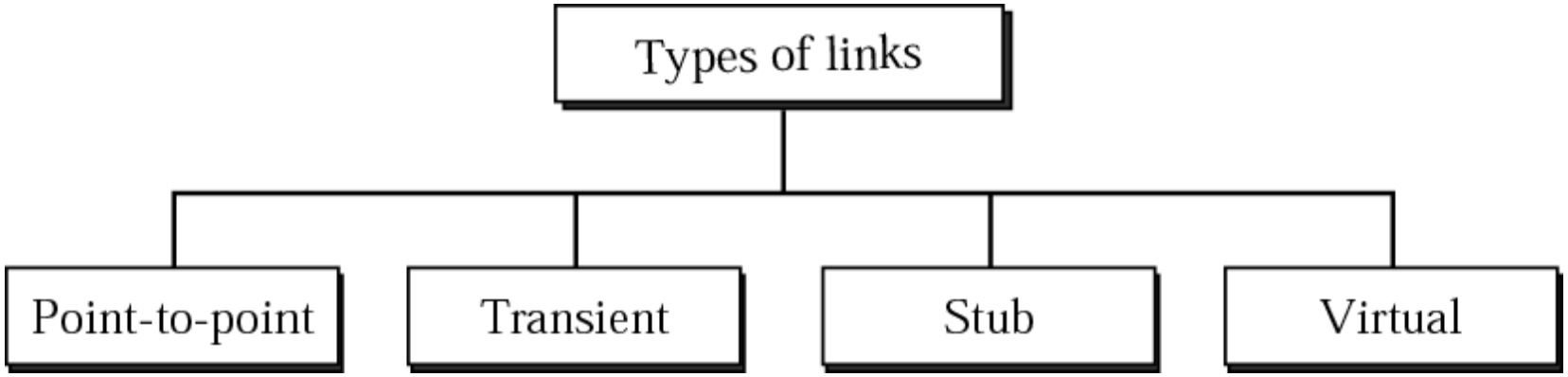
RIP uses the services of UDP on well-known port 520.

OSPF: Open Shortest Path First

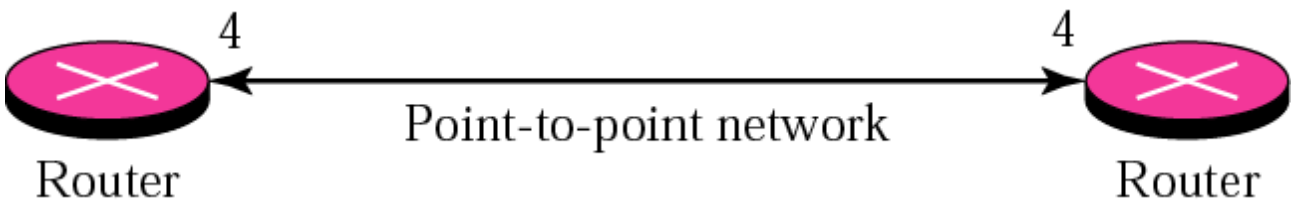
Areas in an autonomous system



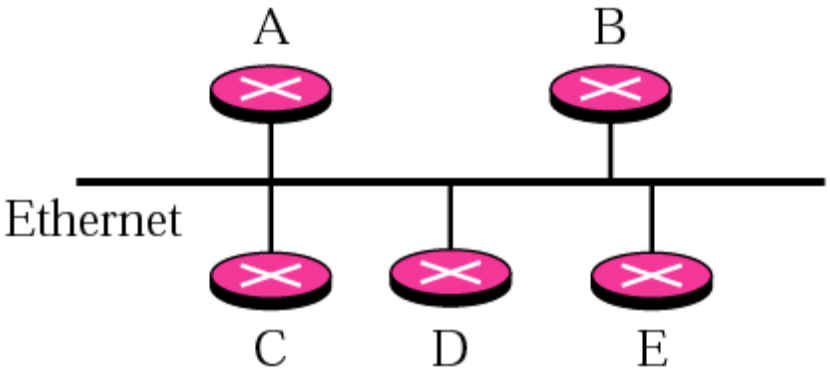
Types of links



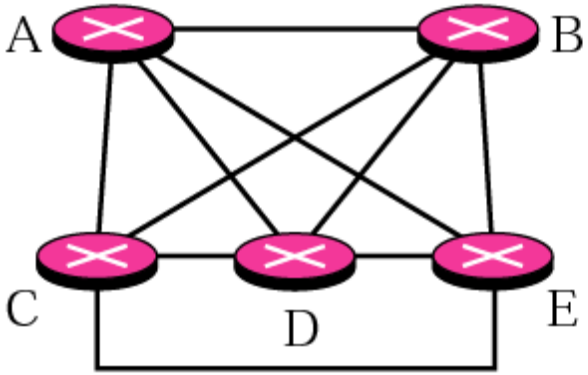
Point-to-point link



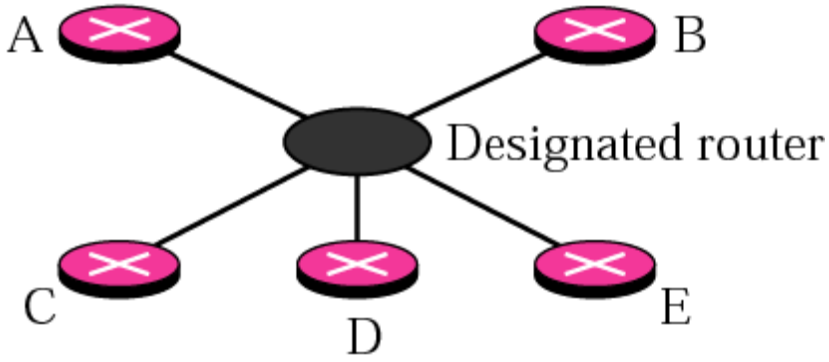
Transient link



a. Transient network



b. Unrealistic representation

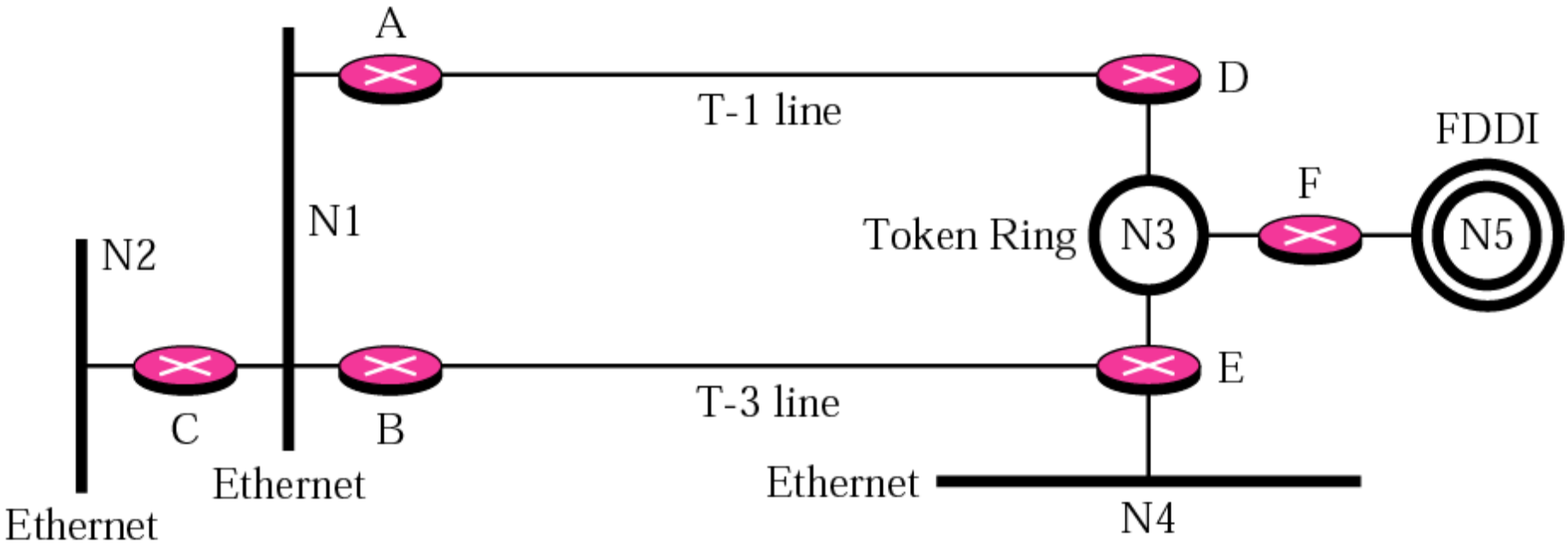


c. Realistic representation

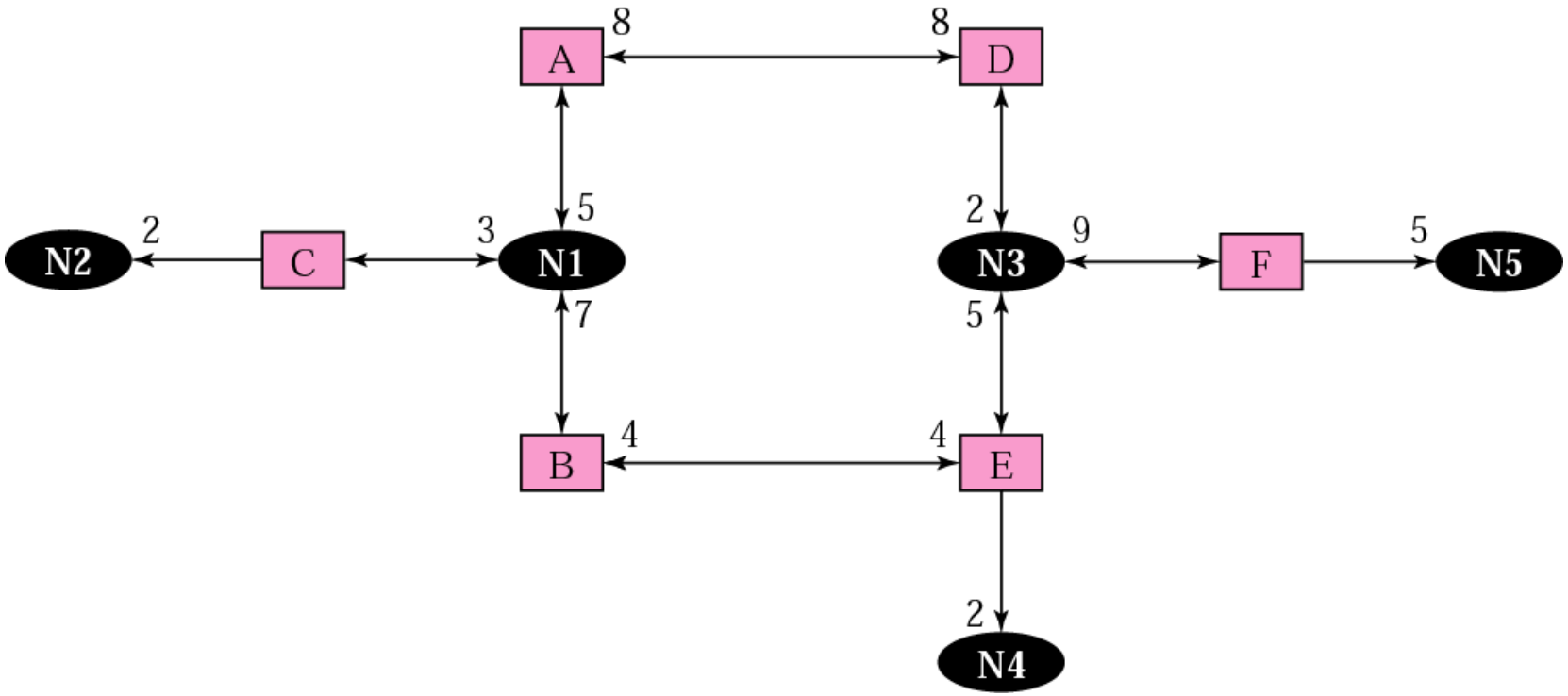
Stub link

a. Stub network b. Representation

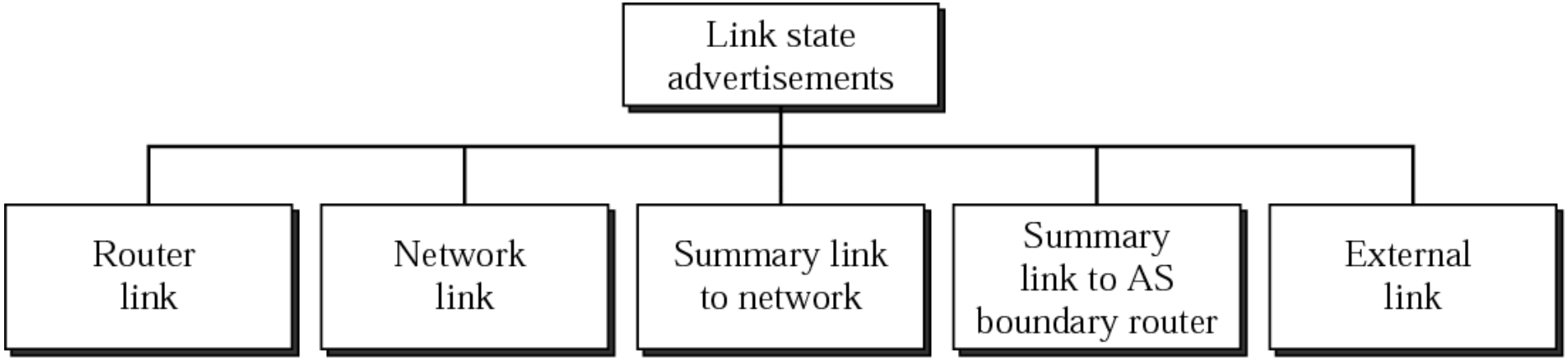
Example of an internet



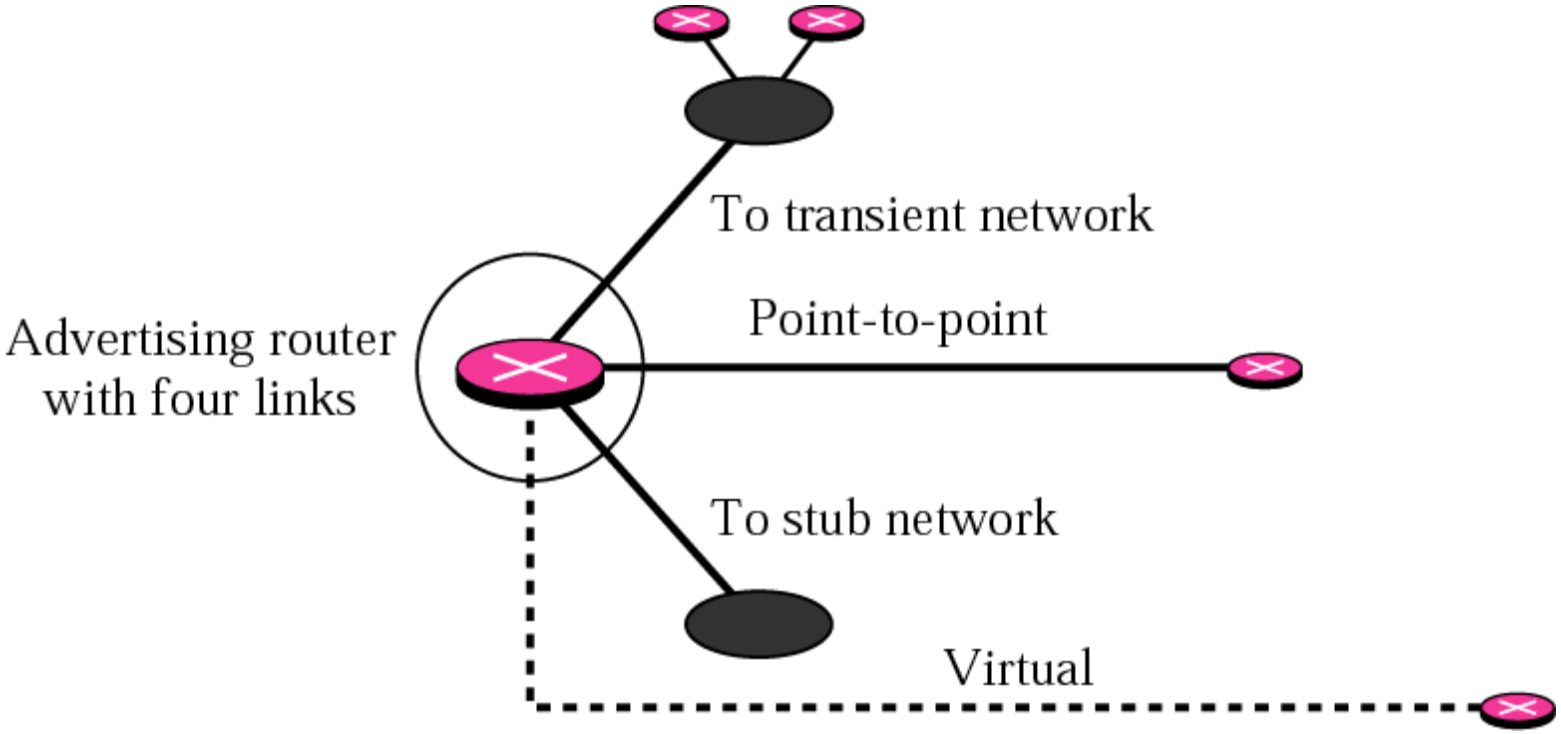
Graphical representation of an internet



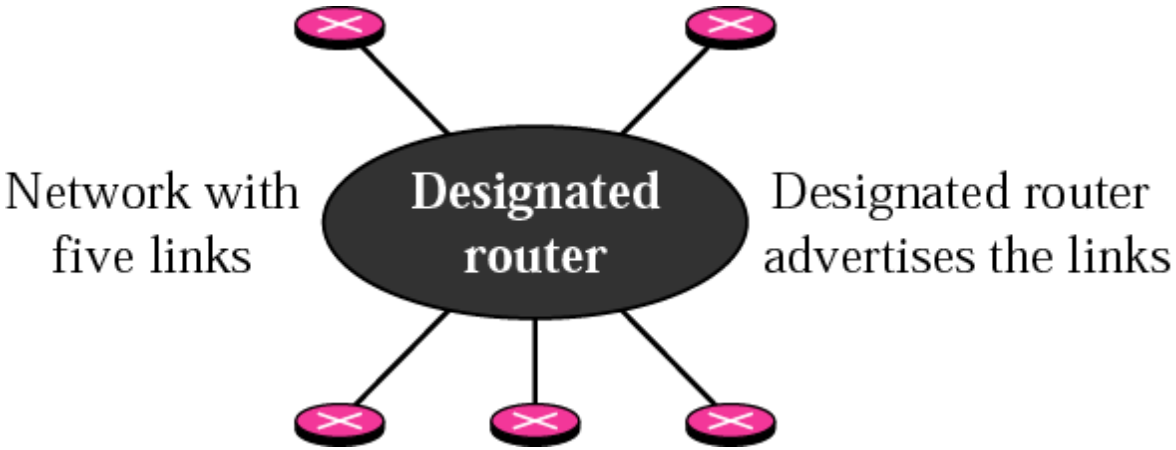
Types of LSAs



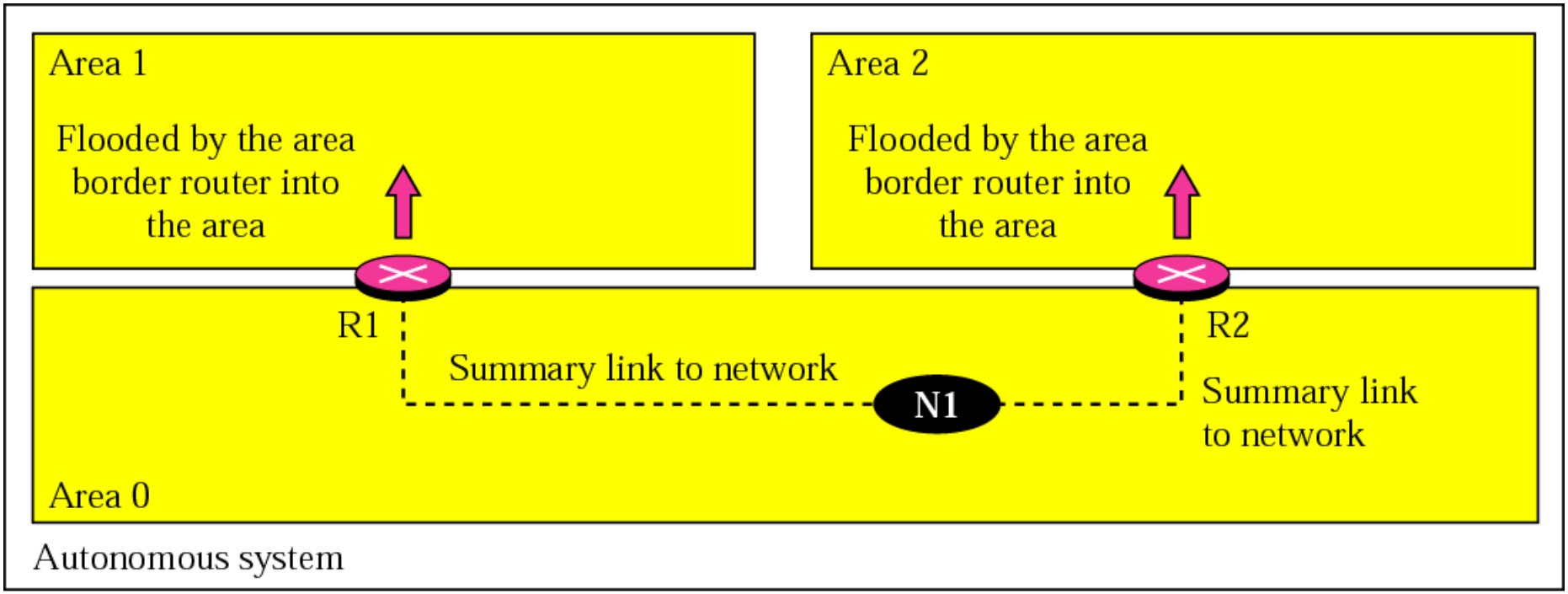
Router link


To transient network
Advertising router
with four links
Point-to-point
To stub network
Virtual

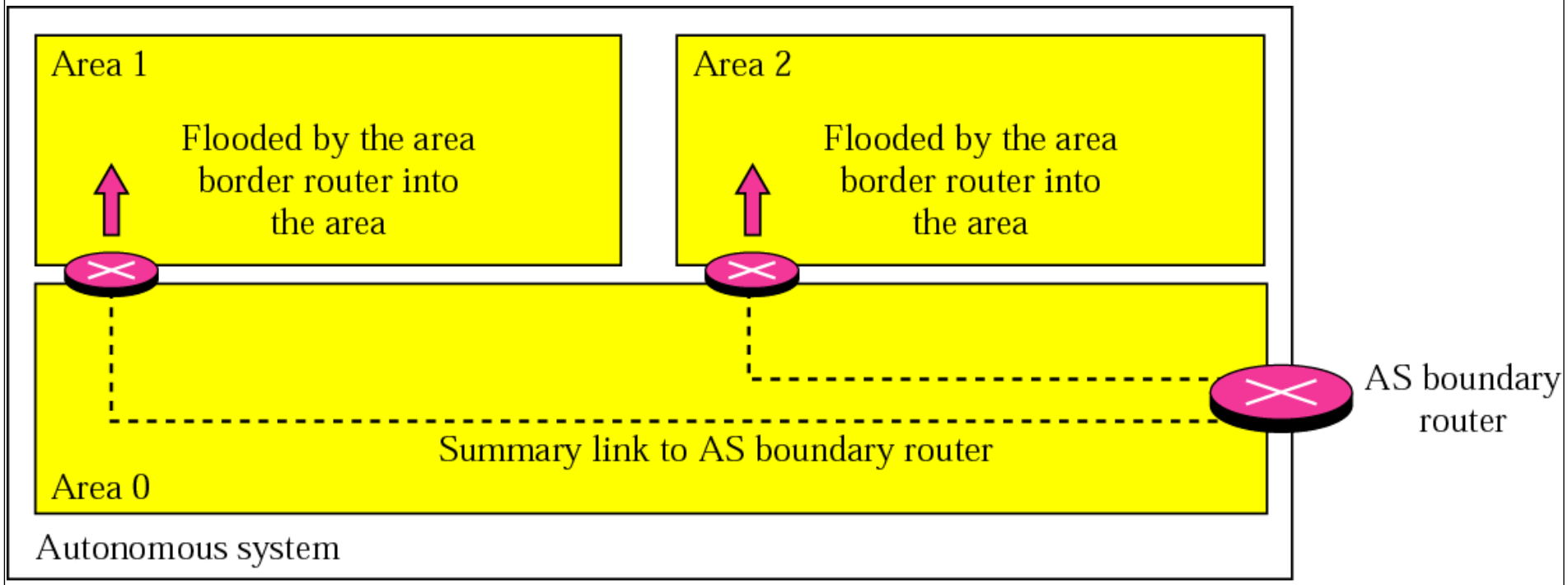
Network link



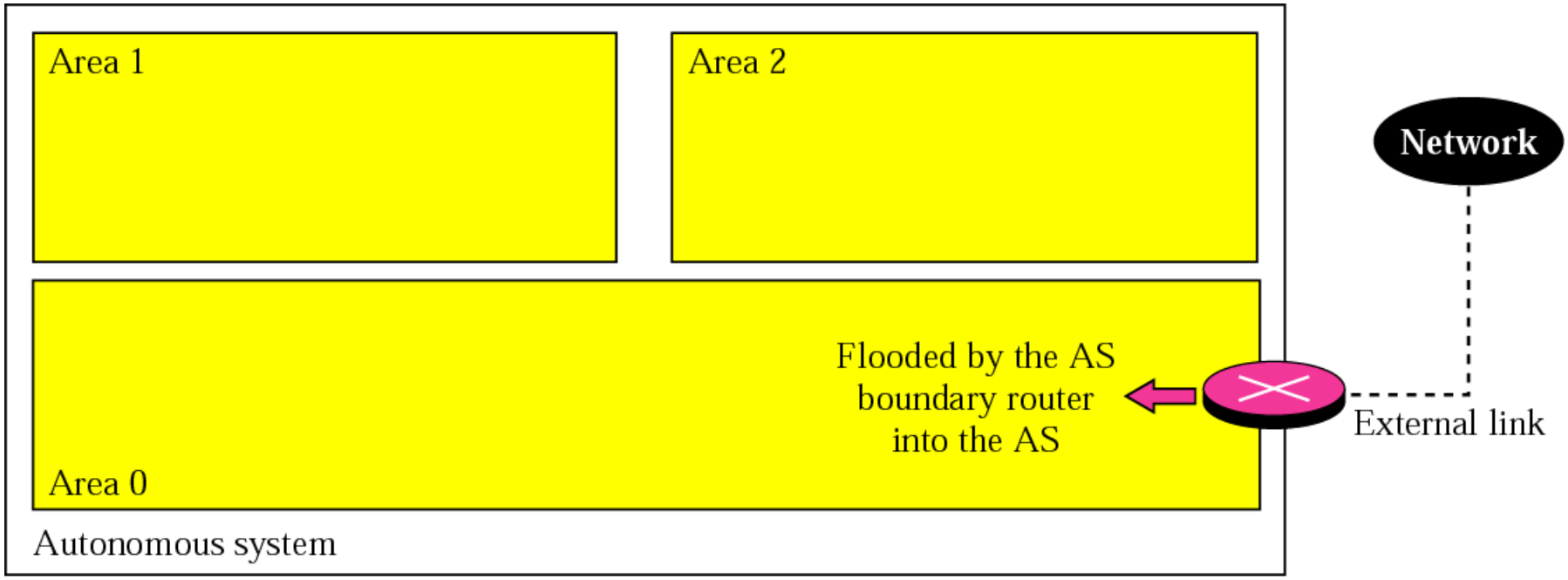
Summary link to network



Summary link to AS boundary router



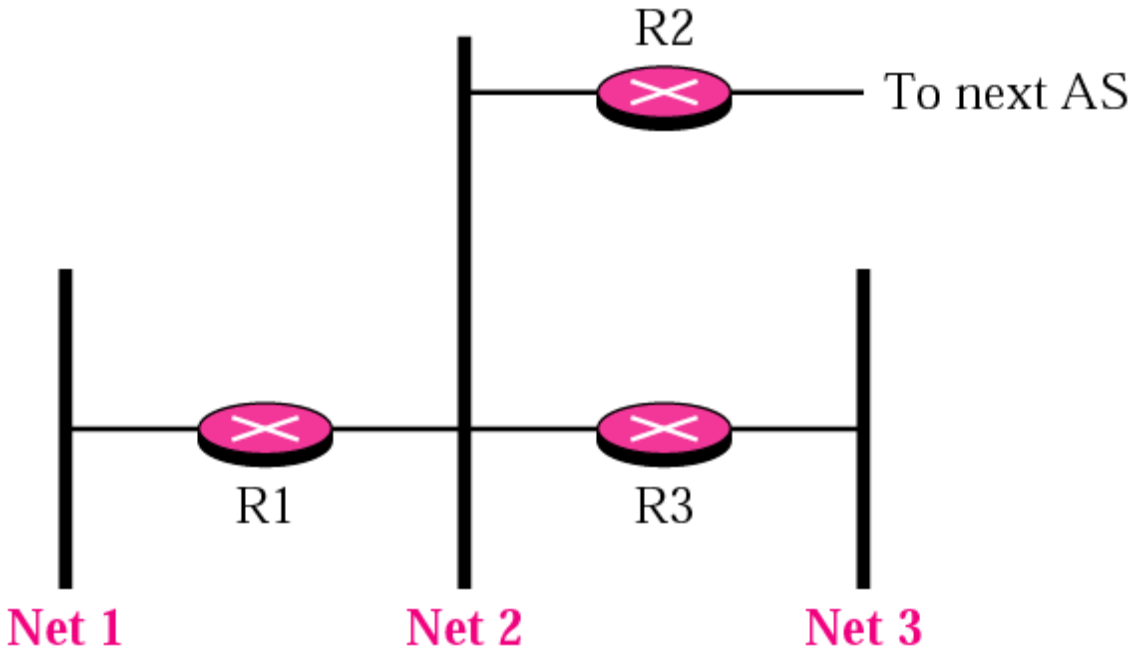
External link



Example 3

In Figure 13.31 (next slide), which router(s) sends out router link LSAs?

Example 3 and Example 4



Solution

All routers advertise router link LSAs.

R1 has two links, Net1 and Net2.

R2 has one link, Net1 in this AS.

R3 has two links, Net2 and Net3.

Example 4

In Figure 13.31, which router(s) sends out the network link LSAs?

Solution

All three network must advertise network links:

Advertisement for Net1 is done by R1 because it is the only router and therefore the designated router.

Advertisement for Net2 can be done by either R1, R2, or R3, depending on which one is chosen as the designated router.

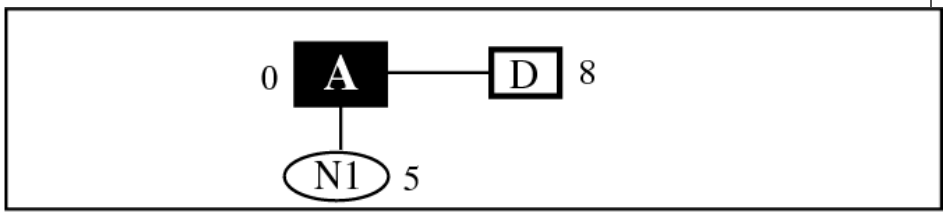
Advertisement for Net3 is done by R3 because it is the only router and therefore the designated router.

Note

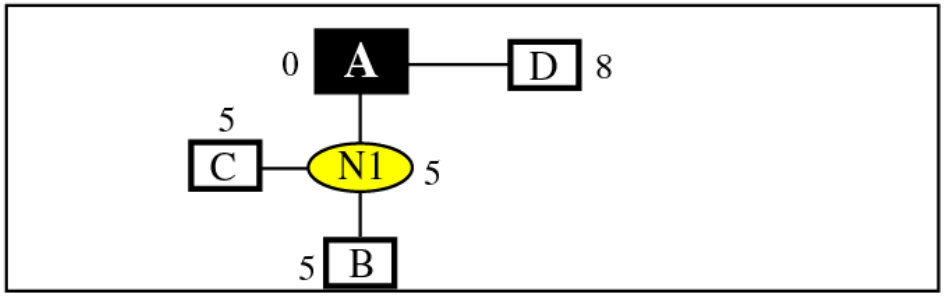
In OSPF, all routers have the same link state database.

Shortest path calculation

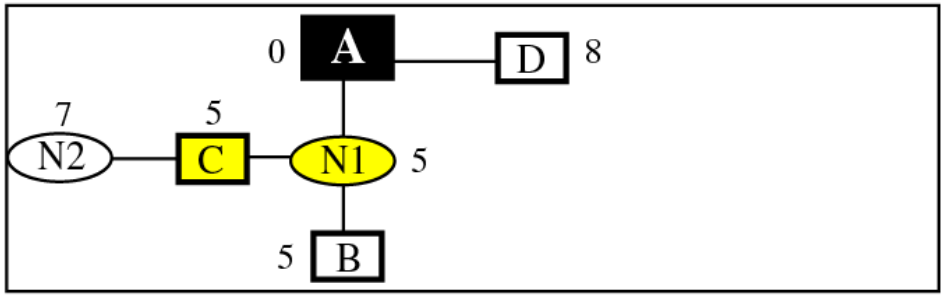
a. Start with A



b. Make A permanent, add its neighbors

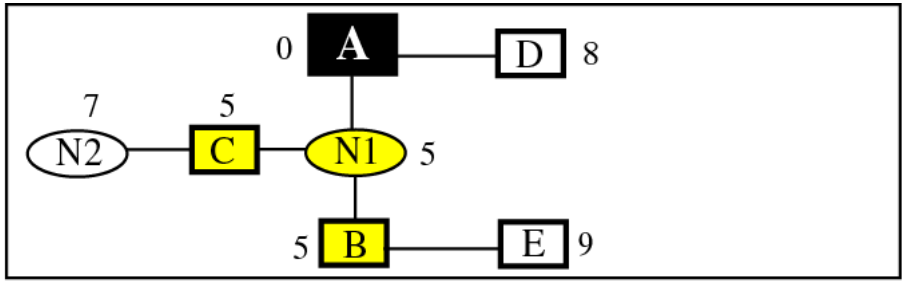


c. Make N1 permanent, add its neighbors

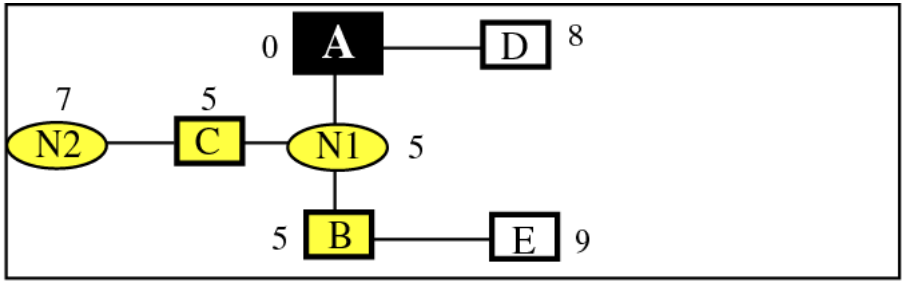


d. Make C permanent, add its neighbors

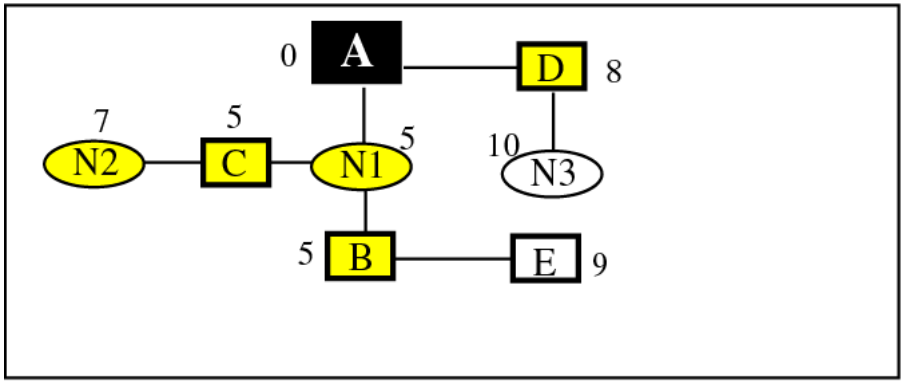
Shortest path calculation



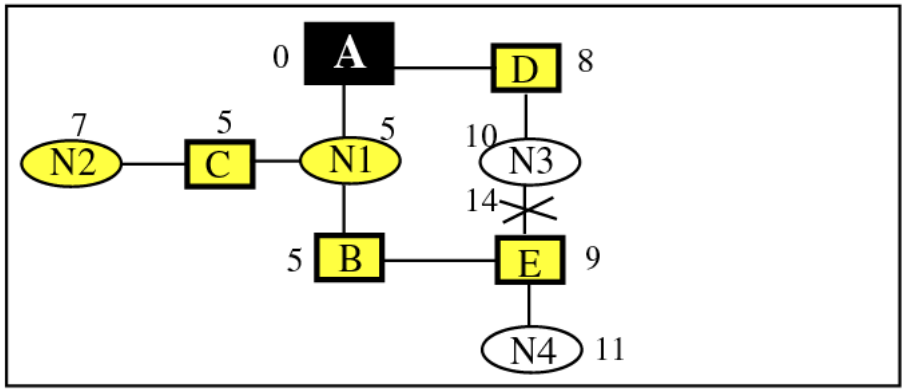
e. Make B permanent, add its neighbors



f. Make N2 permanent

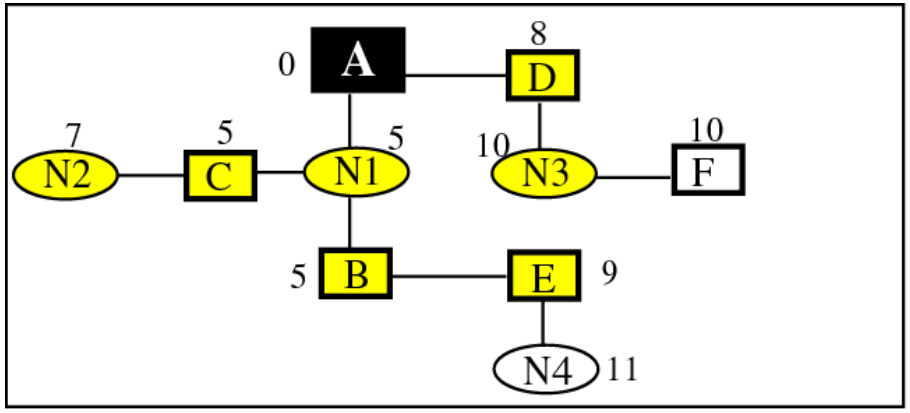


g. Make D permanent, add its neighbors

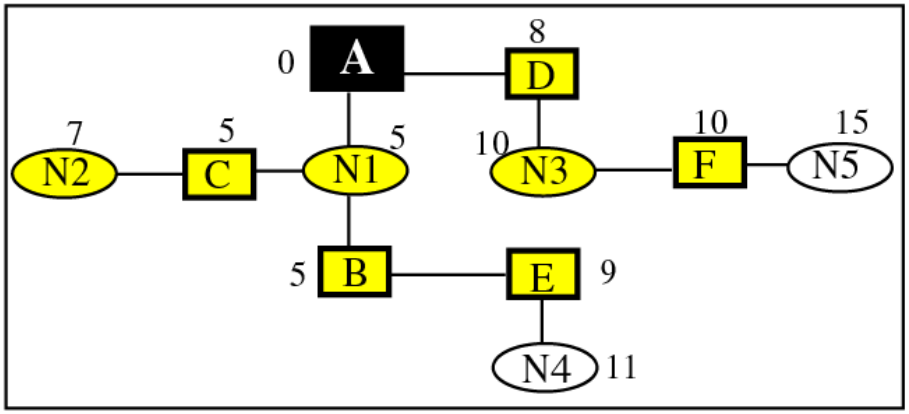


h. Make E permanent, add its neighbors

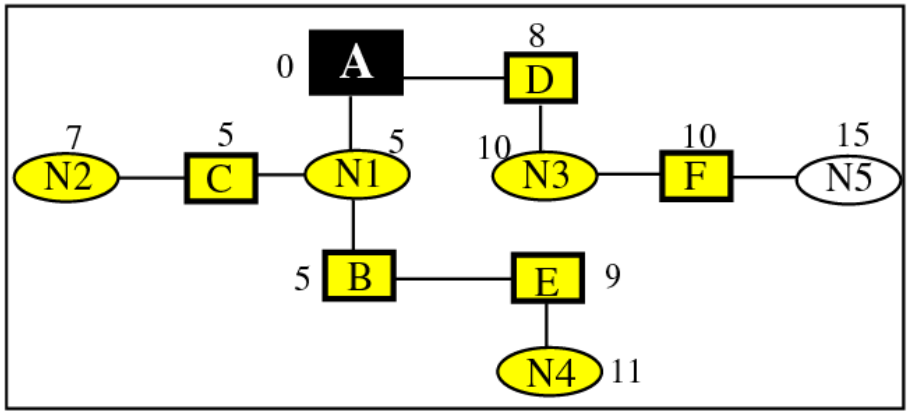
Shortest path calculation



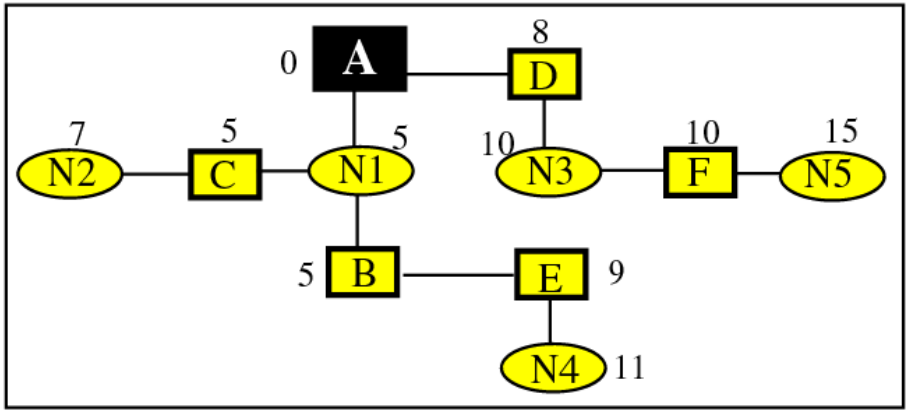
i. Make N3 permanent, add its neighbors



j. Make F permanent, add its neighbors

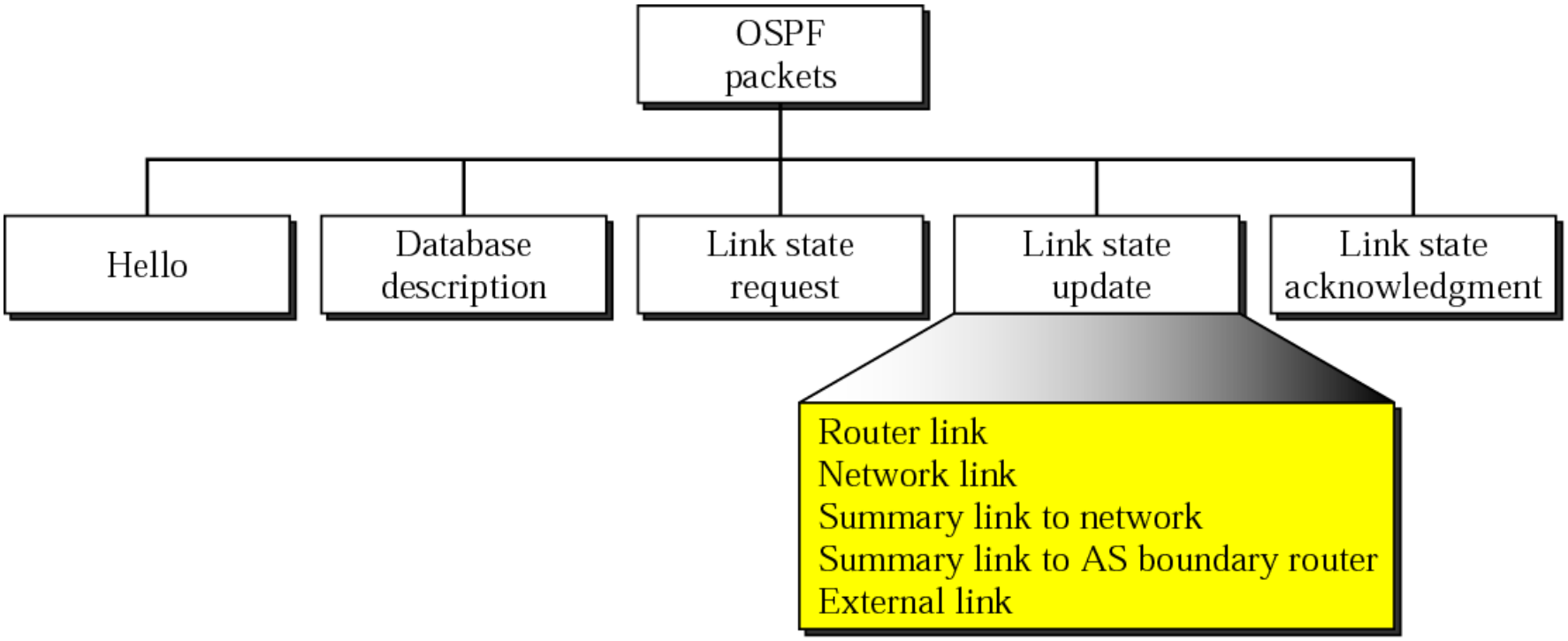


k. Make N4 permanent

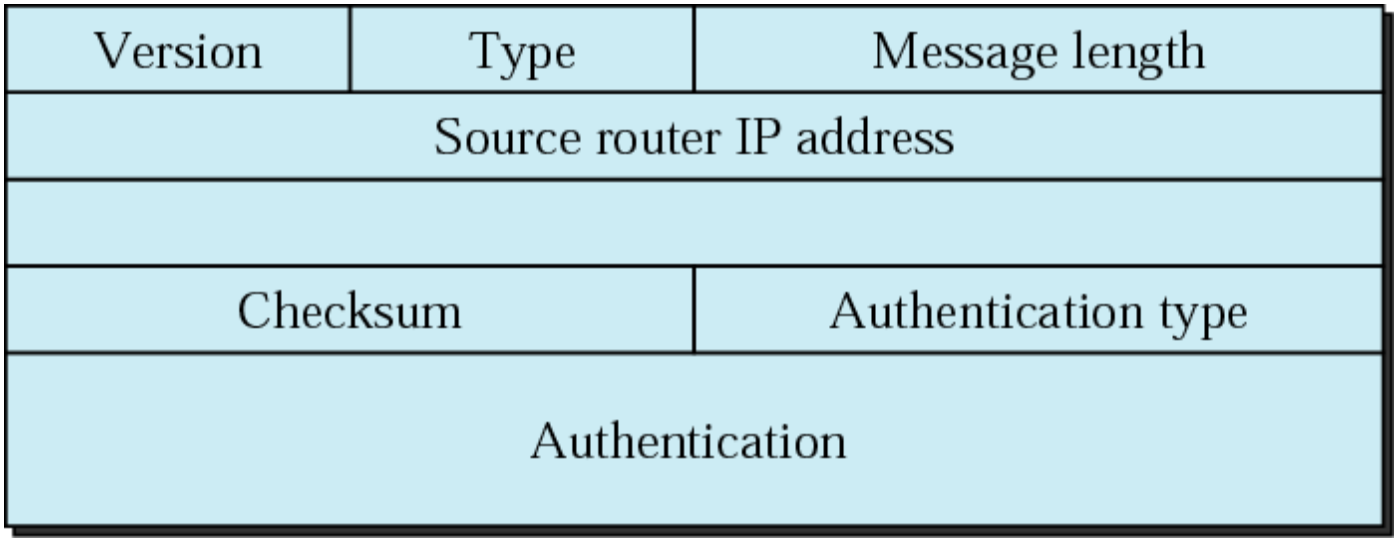


l. Make N5 permanent

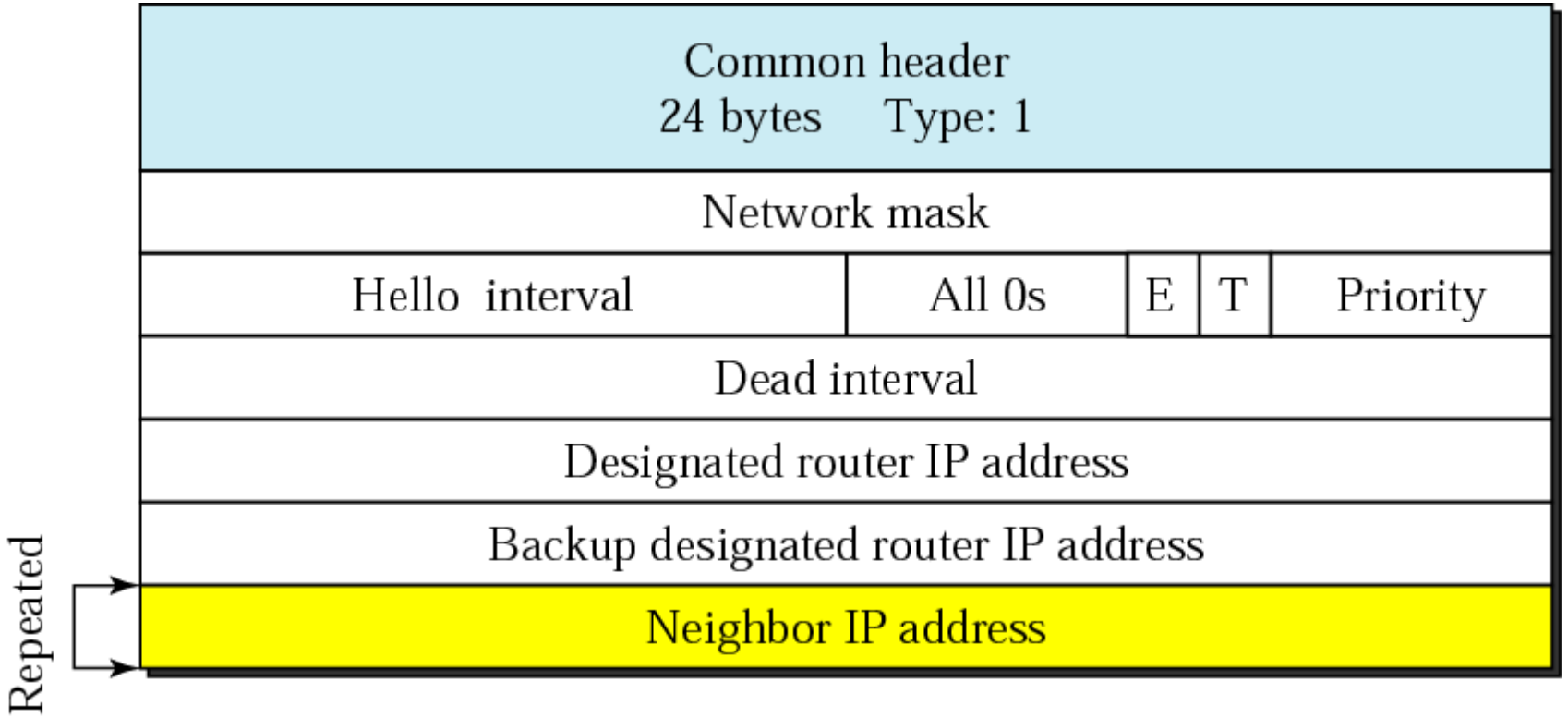
Types of OSPF packets



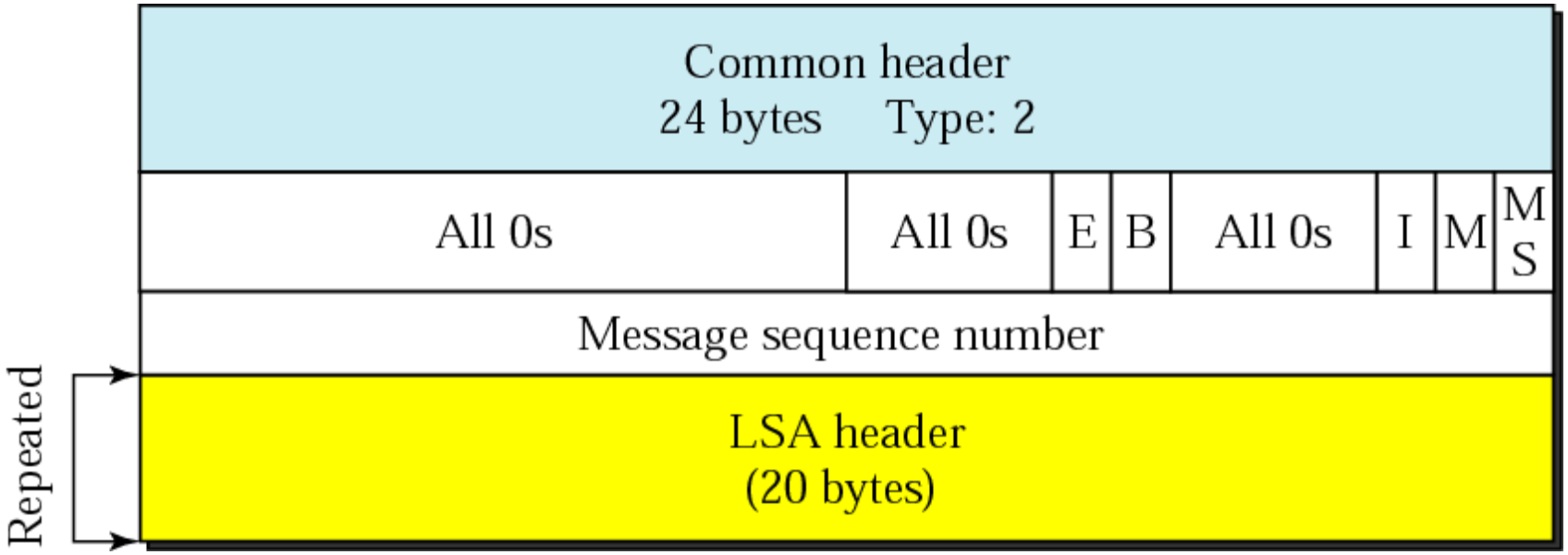
OSPF packet header



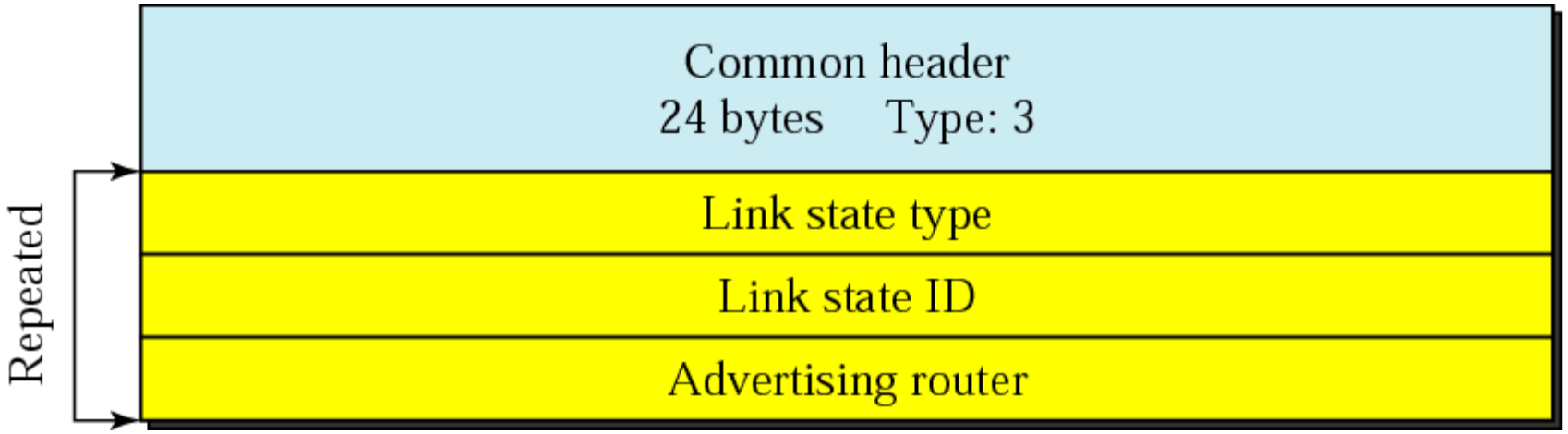
Hello packet



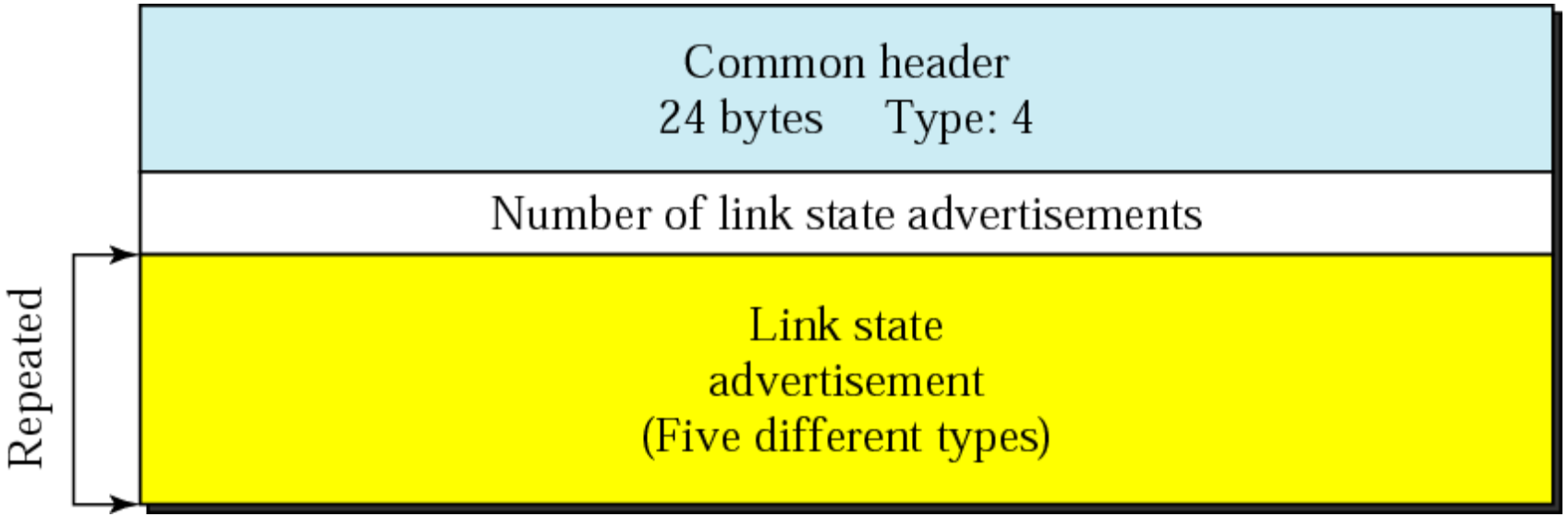
Database description packet



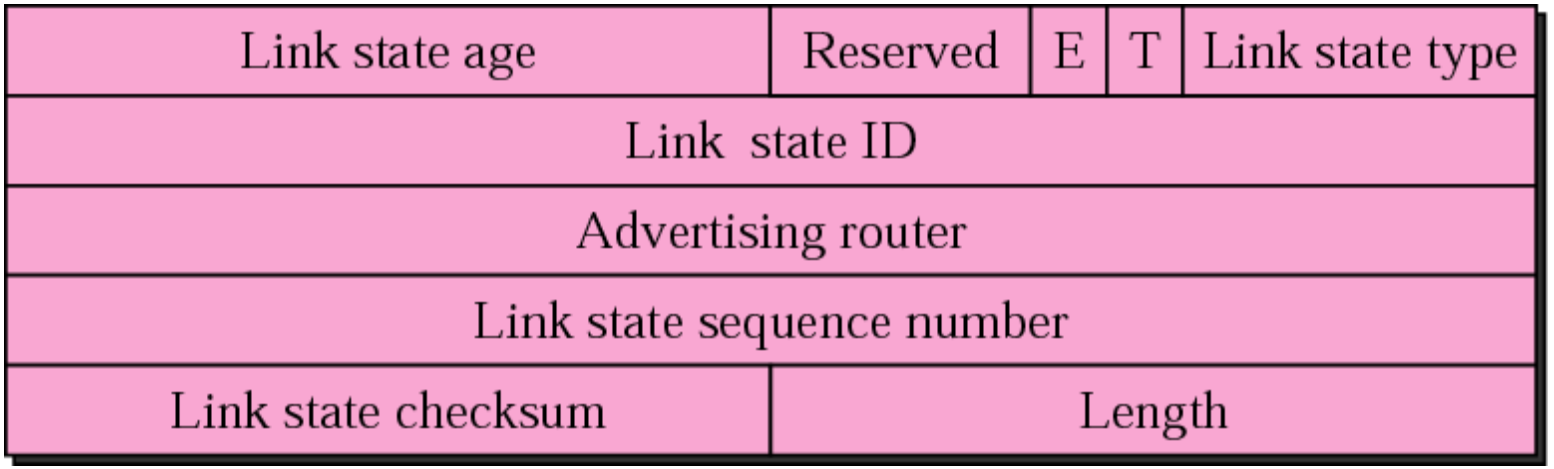
Link state request packet



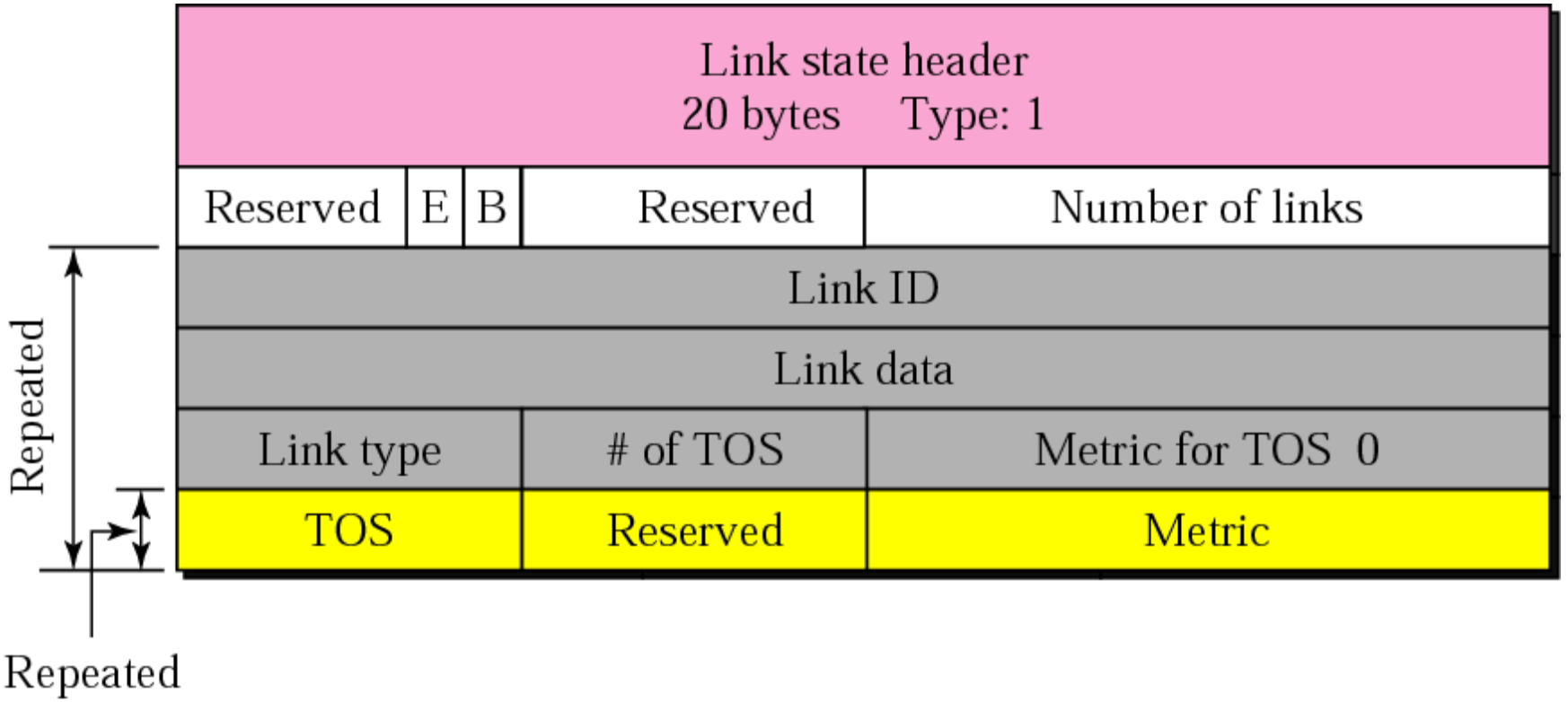
Link state update packet



LSA header


Link state age
Reserved
E
T
Link state type
Link state ID
Advertising router
Link state sequence number
Link state checksum
Length

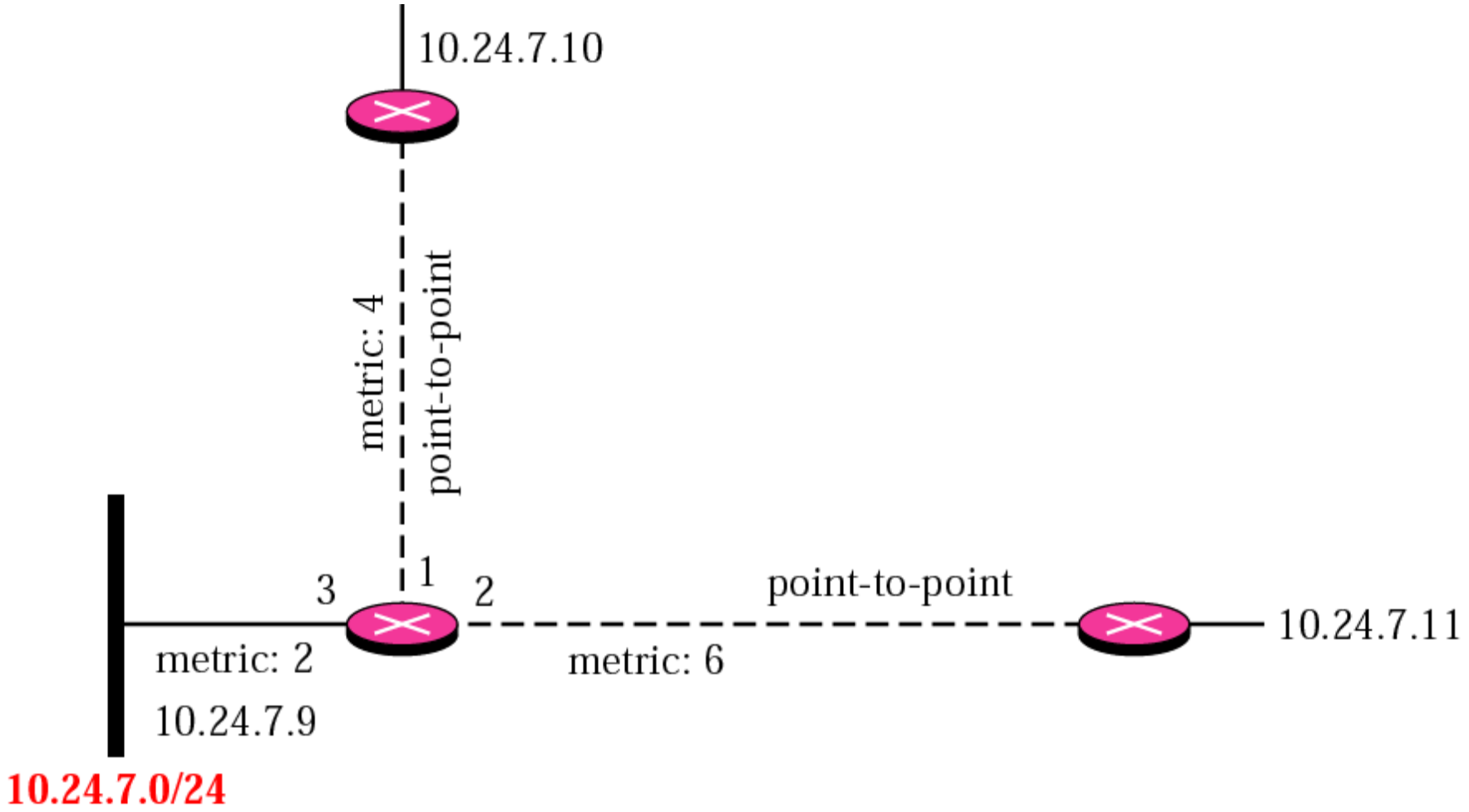
Router link LSA



Example 5

Give the router link LSA sent by router 10.24.7.9 in Figure 13.41.

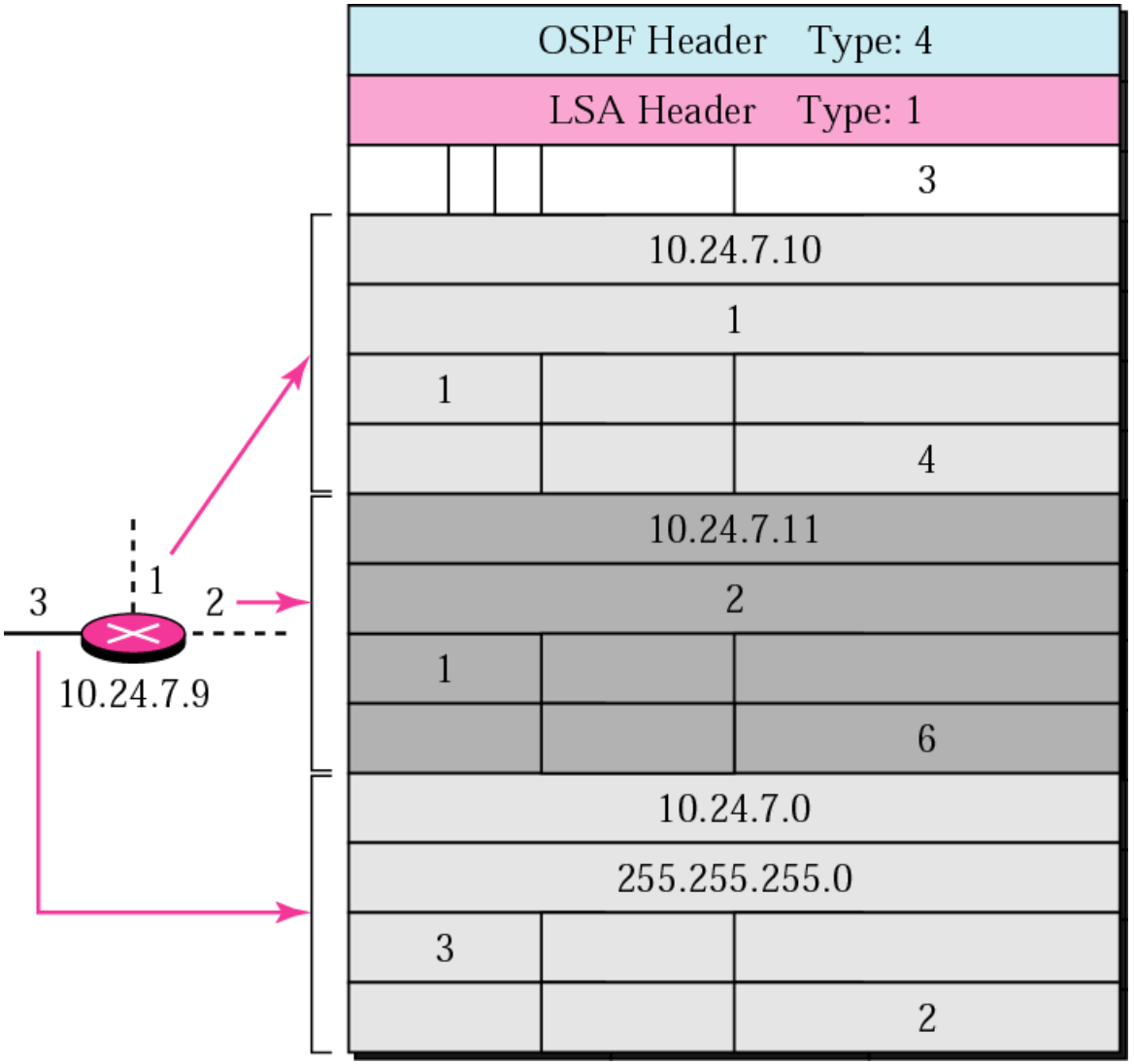
Example 5


10.24.7.10
metric: 4
point-to-point
3
1
2
point-to-point
10.24.7.11
metric: 2
metric: 6
10.24.7.9
10.24.7.0/24

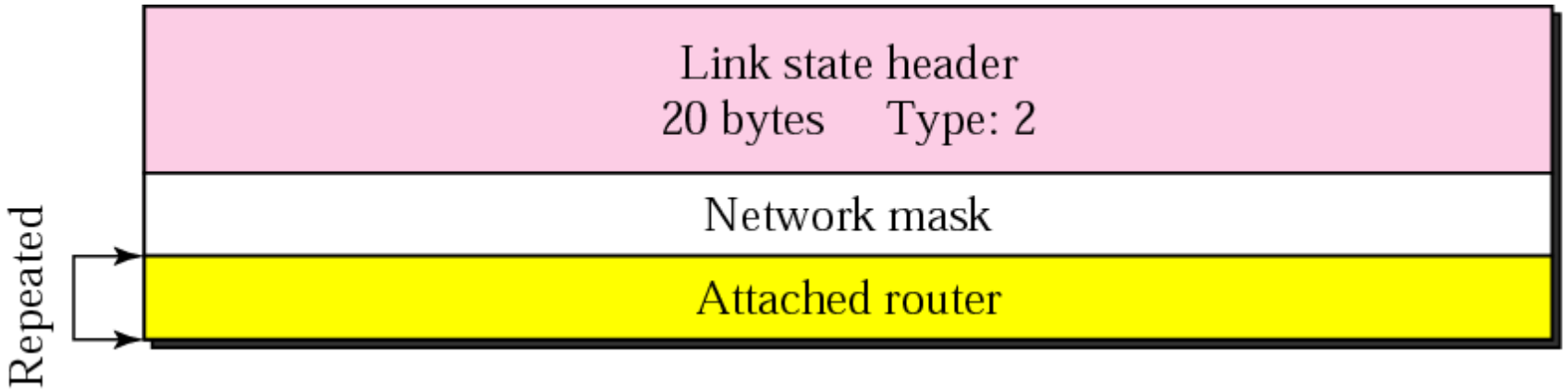
Solution

This router has three links: two of type 1 (point-to-point) and one of type 3 (stub network). Figure 13.42 shows the router link LSA.

Solution to Example 5



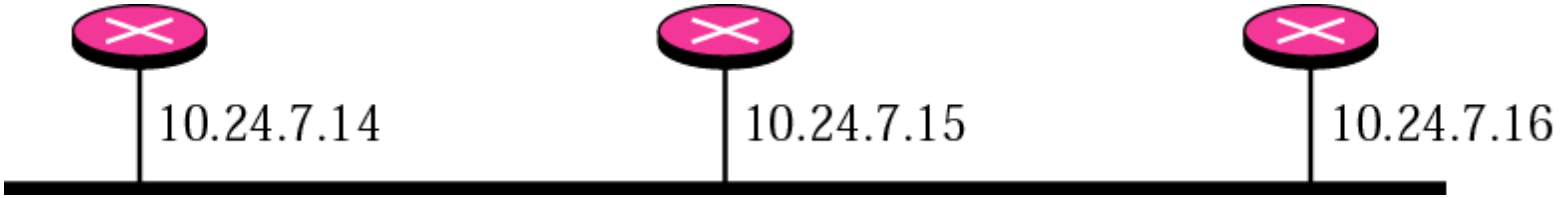
Network link advertisement format



Example 6

Give the network link LSA in Figure 13.44.

Example 6

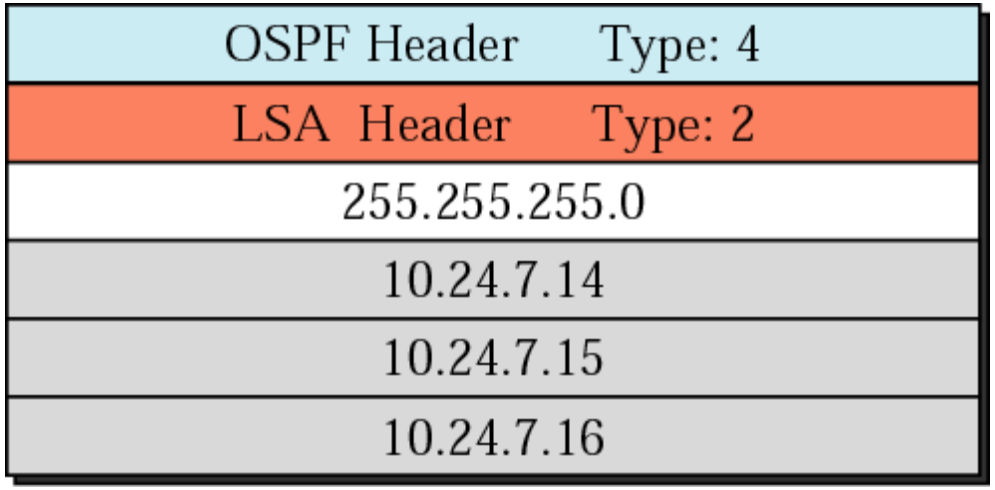


Solution

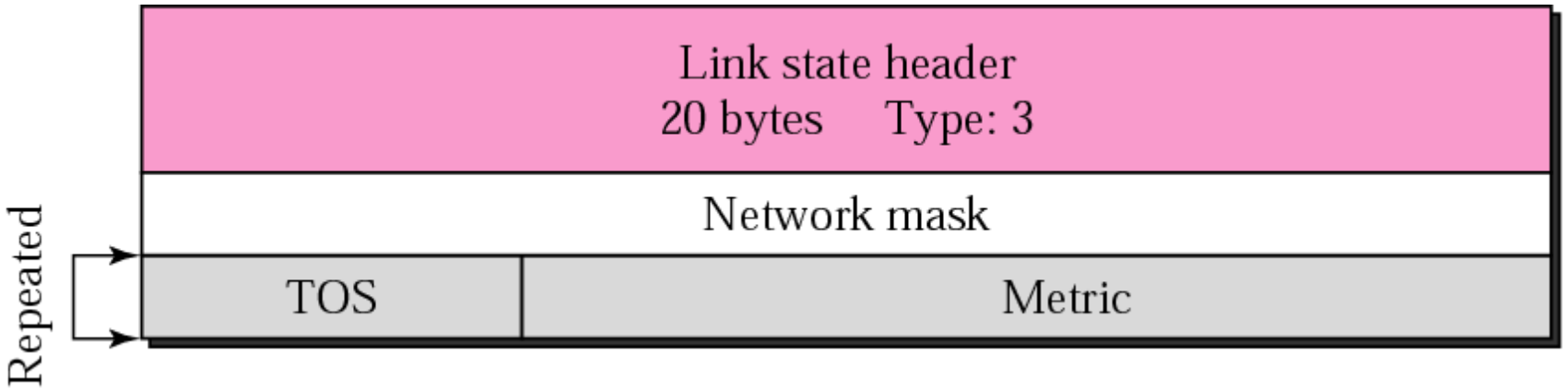
The network, for which the network link advertises, has three routers attached. The LSA shows the mask and the router addresses. See Figure 13.45.

Note that only one of the routers, *the designated router*, advertises the network link.

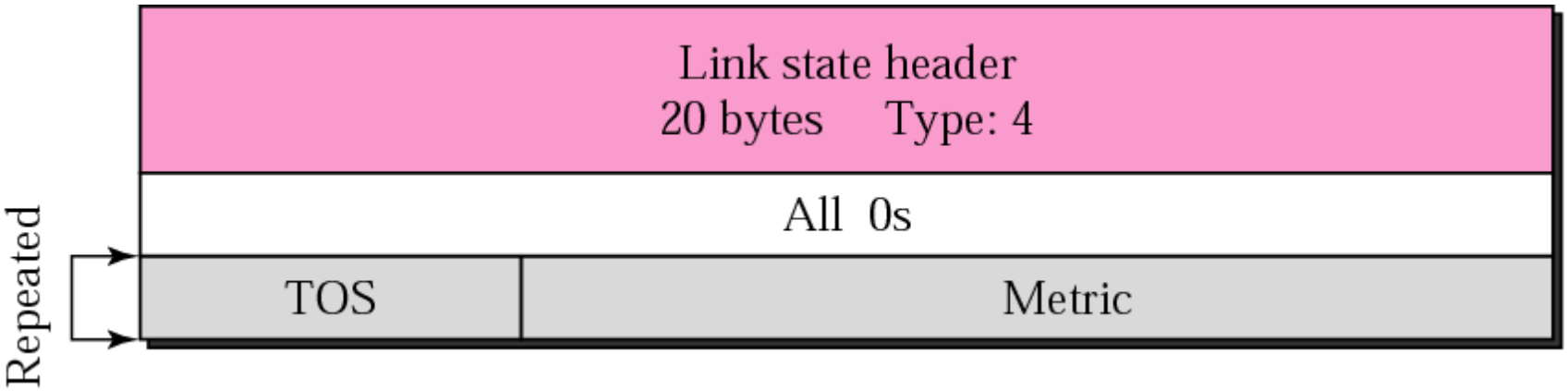
Solution to Example 6



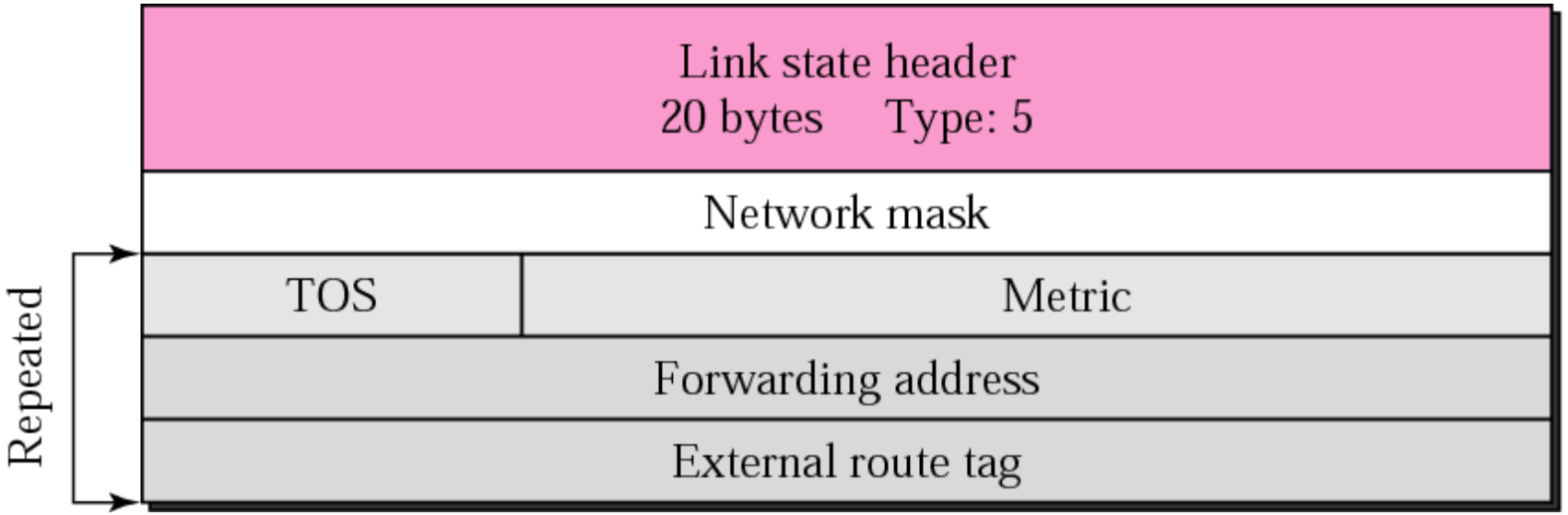
Summary link to network LSA



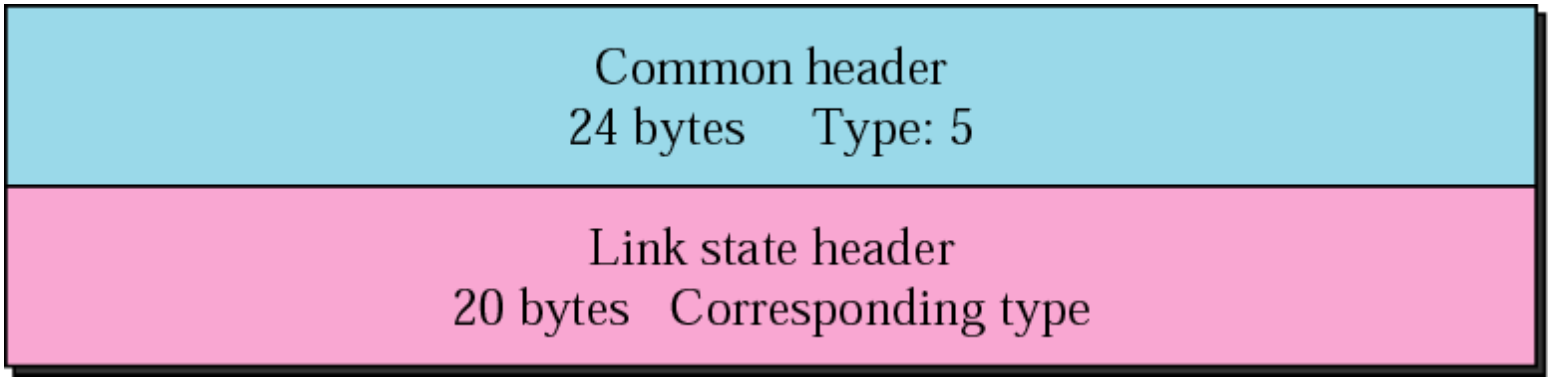
Summary link to AS boundary LSA



External link LSA



Link state acknowledgment packet

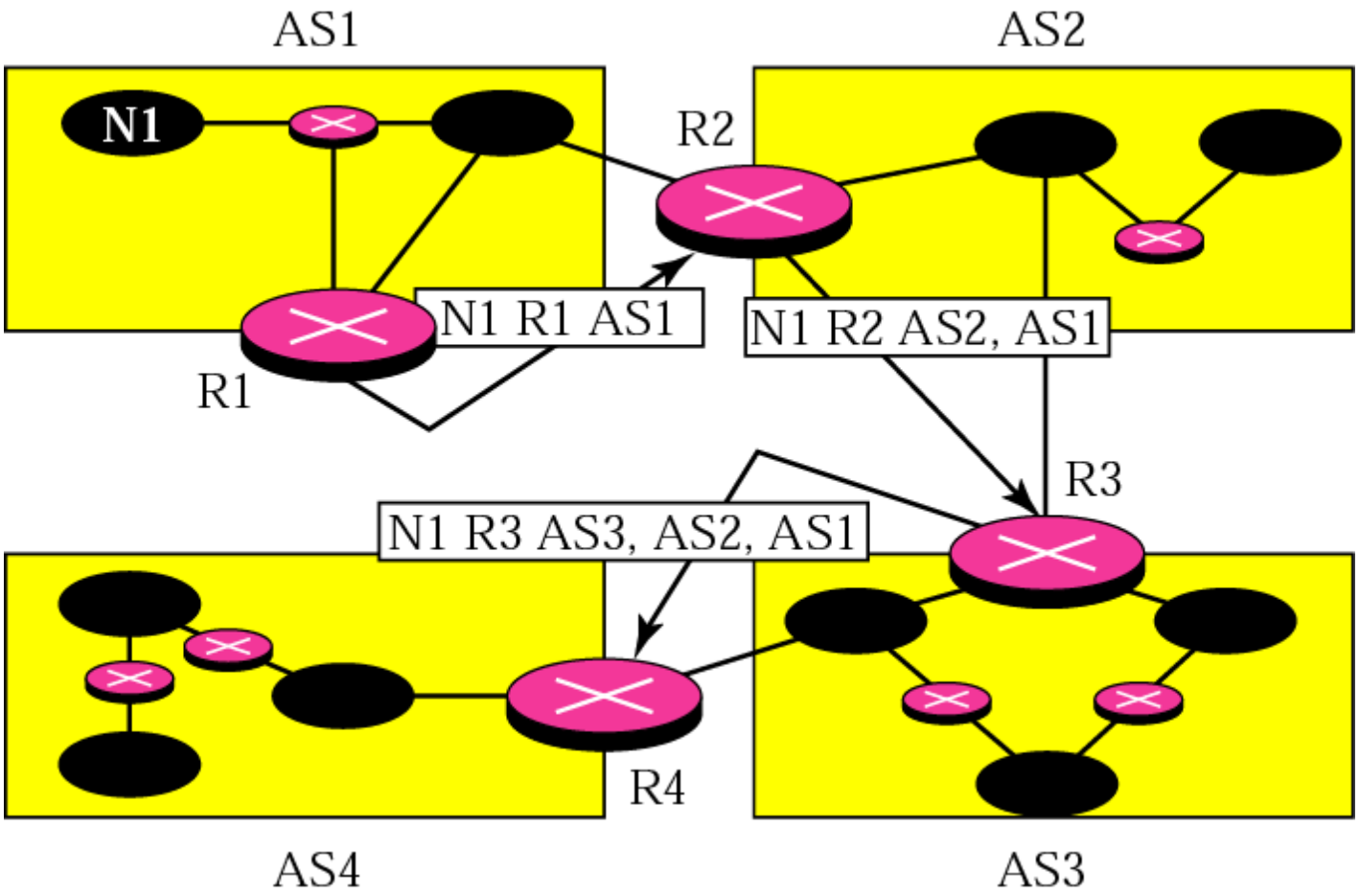


Note

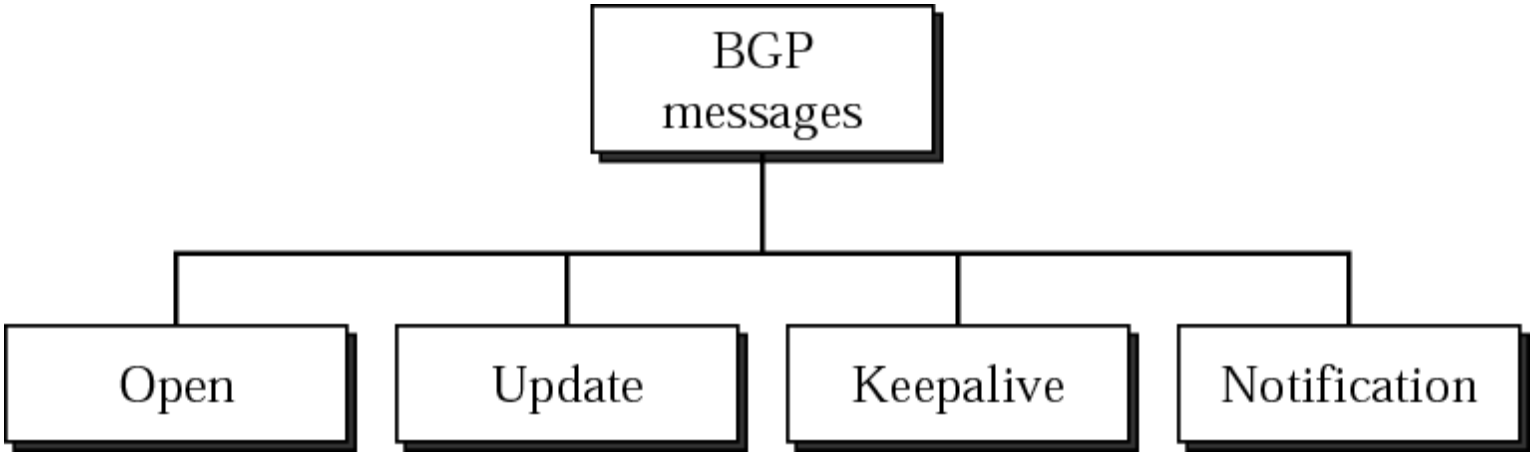
OSPF packets are encapsulated in IP datagrams.

BGP: Border Gateway Protocol

Path vector packets



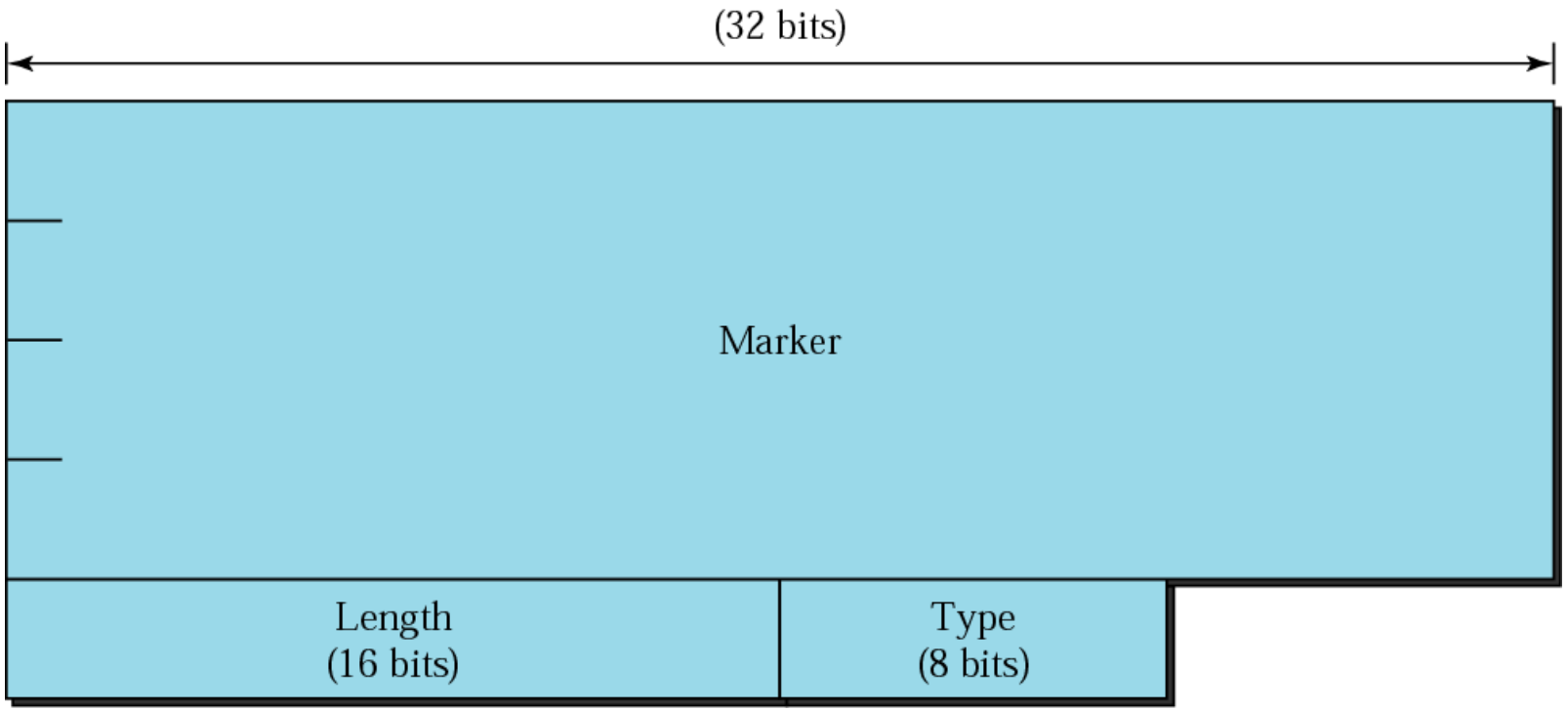
Types of BGP messages



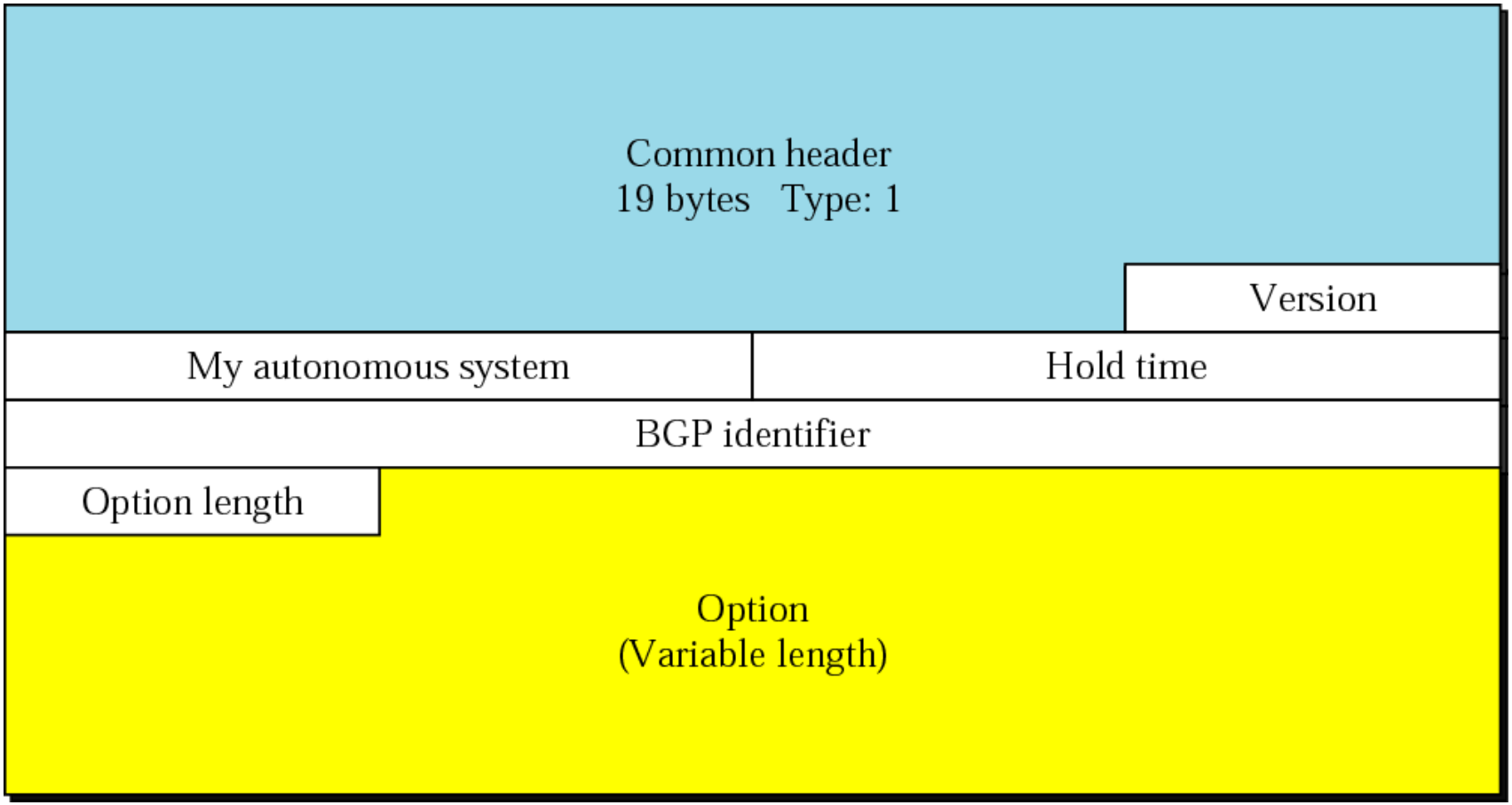
Note

BGP supports classless addressing and CIDR.

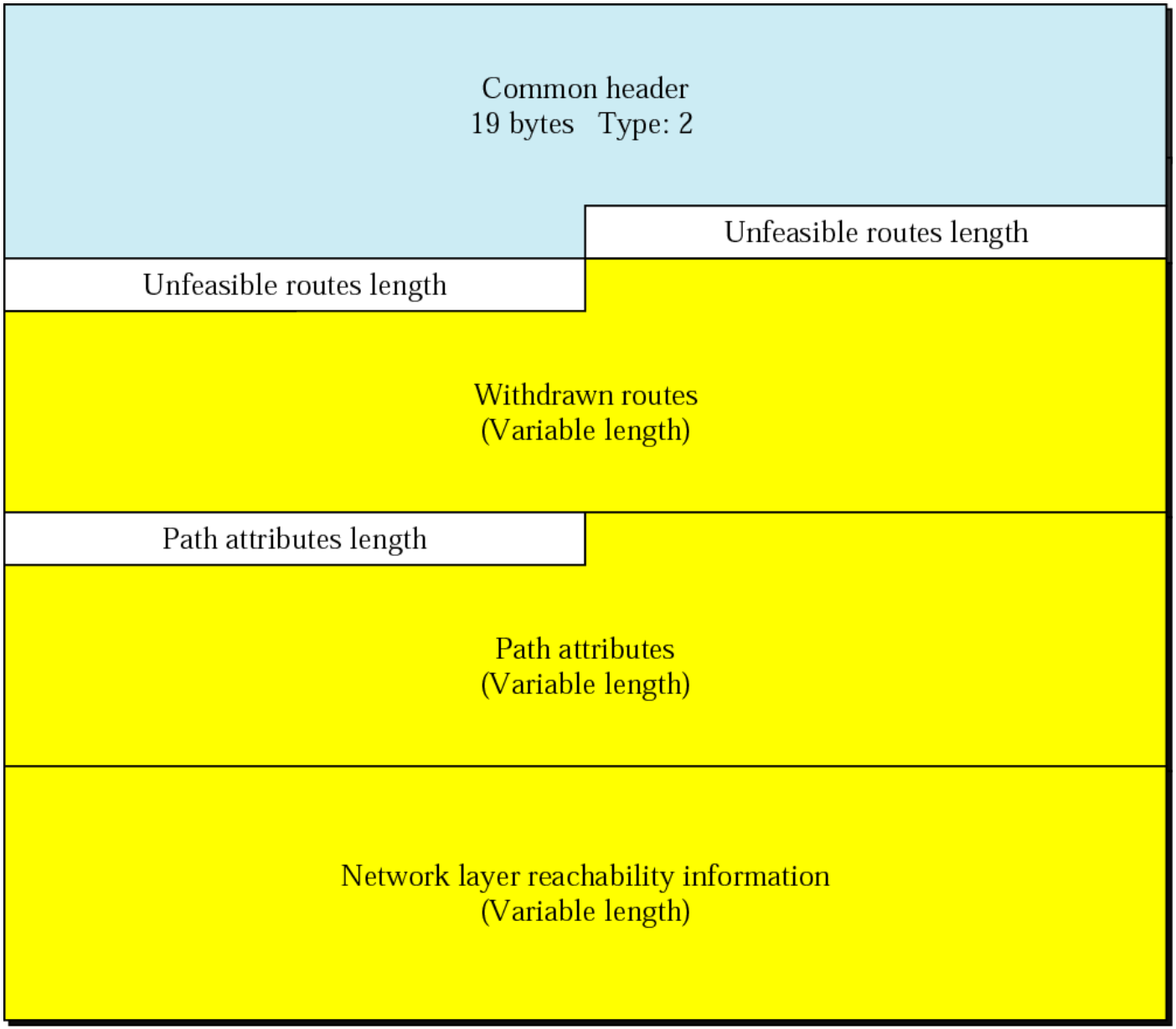
BGP packet header



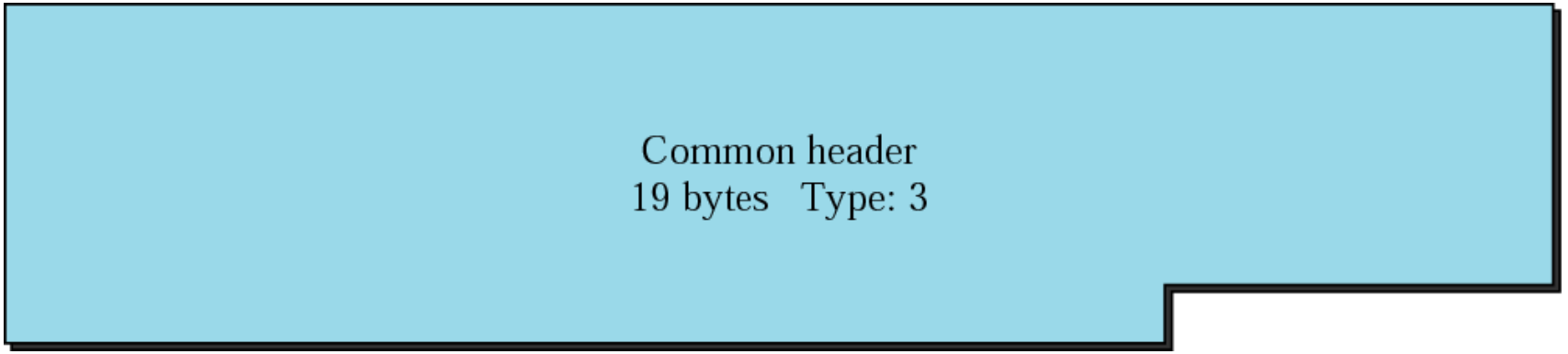
Open message



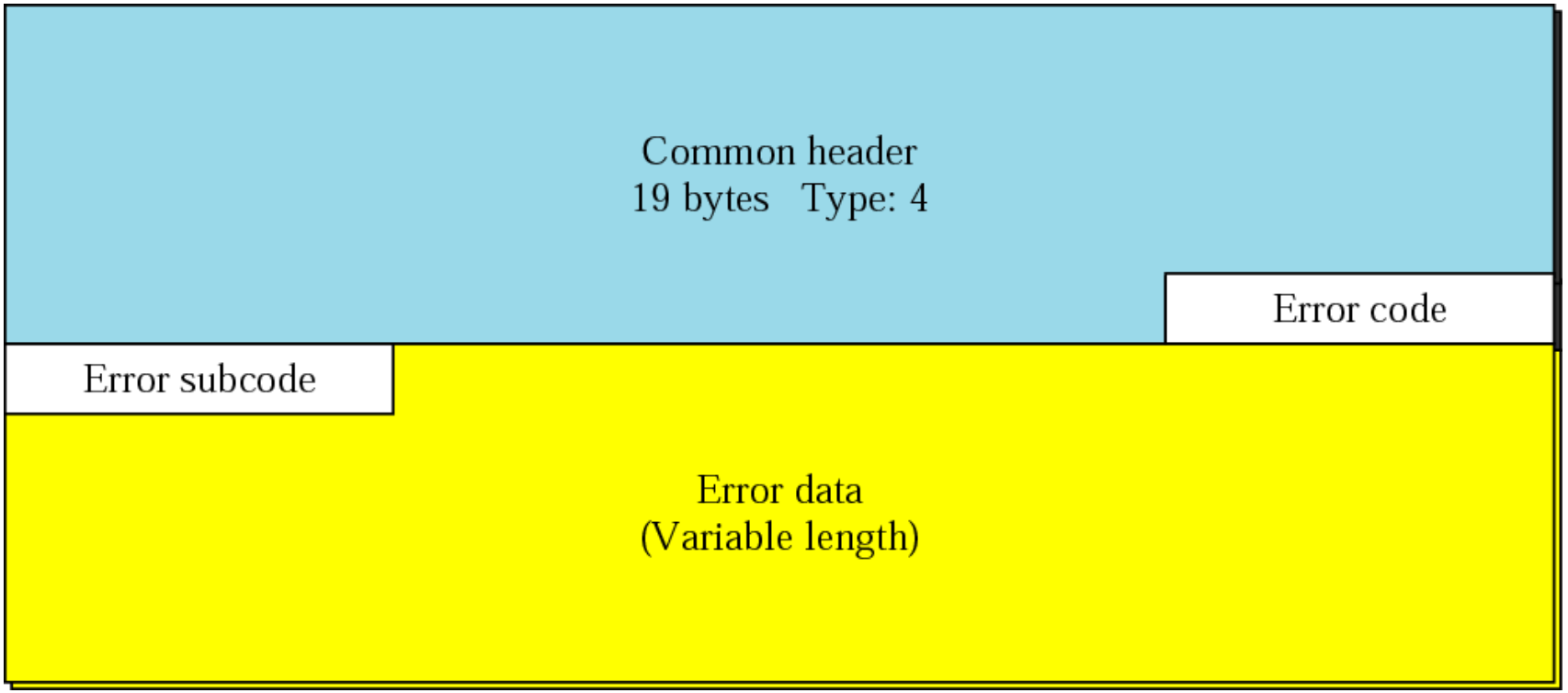
Update message



Keepalive message



Notification message



Note

BGP uses the services of TCP on port 179.