



Chapter 14

Unicast Routing Protocols: RIP, OSPF, and BGP

Objectives

Upon completion you will be able to:

- *Distinguish between intra and interdomain routing*
- *Understand distance vector routing and RIP*
- *Understand link state routing and OSPF*
- *Understand path vector routing and BGP*

14.1 INTRA- AND INTERDOMAIN ROUTING

Routing inside an autonomous system is referred to as intradomain routing. Routing between autonomous systems is referred to as interdomain routing.

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Figure 14.1 *Autonomous systems*

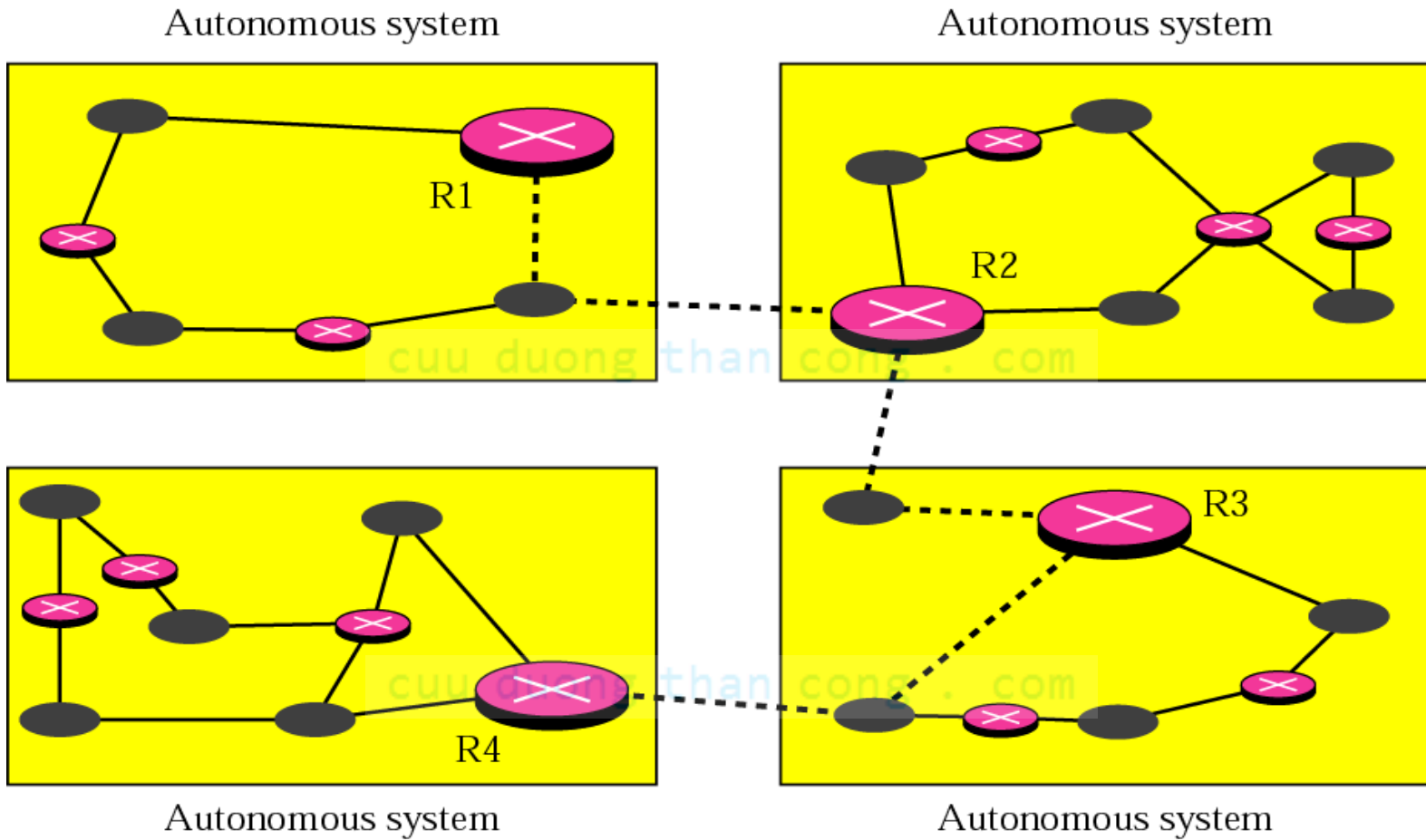
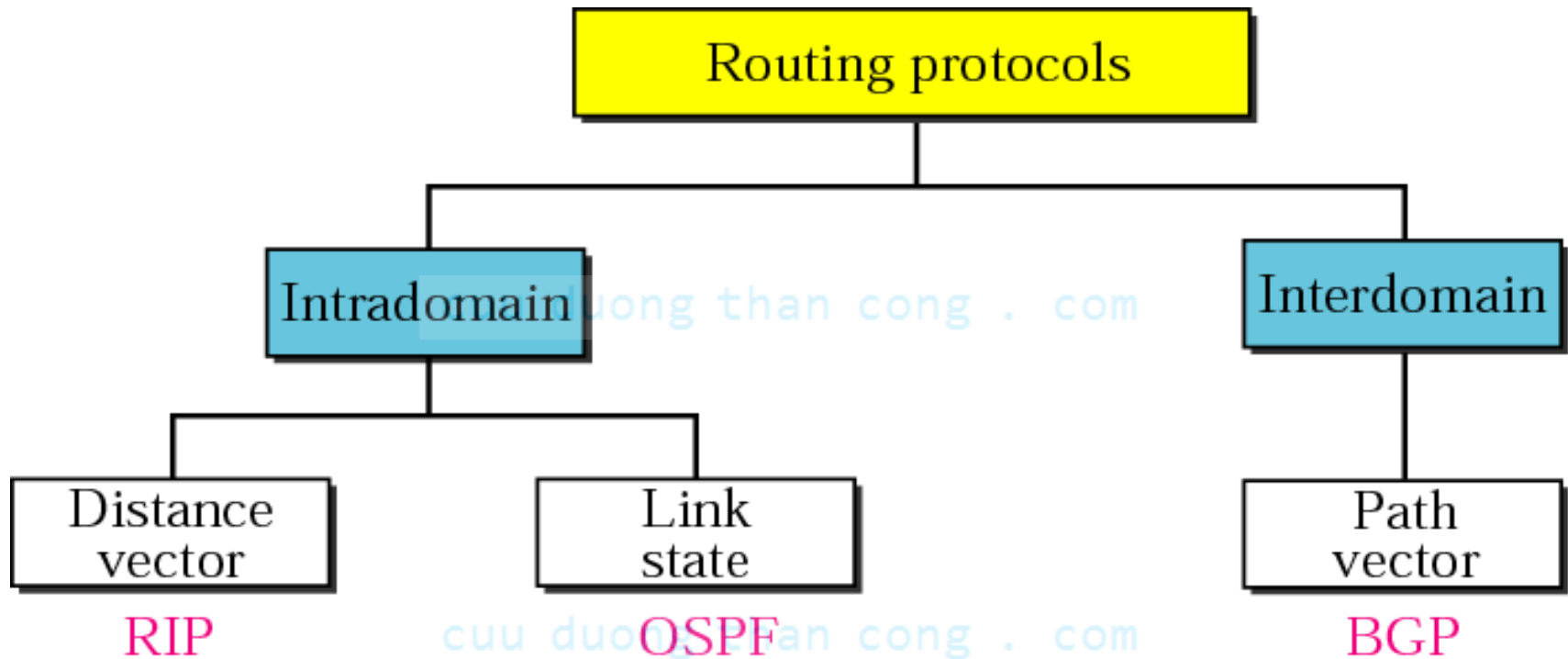


Figure 14.2 *Popular routing protocols*



14.2 DISTANCE VECTOR ROUTING

In distance vector routing, the least cost route between any two nodes is the route with minimum distance. In this protocol each node maintains a vector (table) of minimum distances to every node

The topics discussed in this section include:

Initialization

Sharing

Updating

When to Share

Two-Node Loop Instability

Three-Node Instability

Figure 14.3 *Distance vector routing tables*

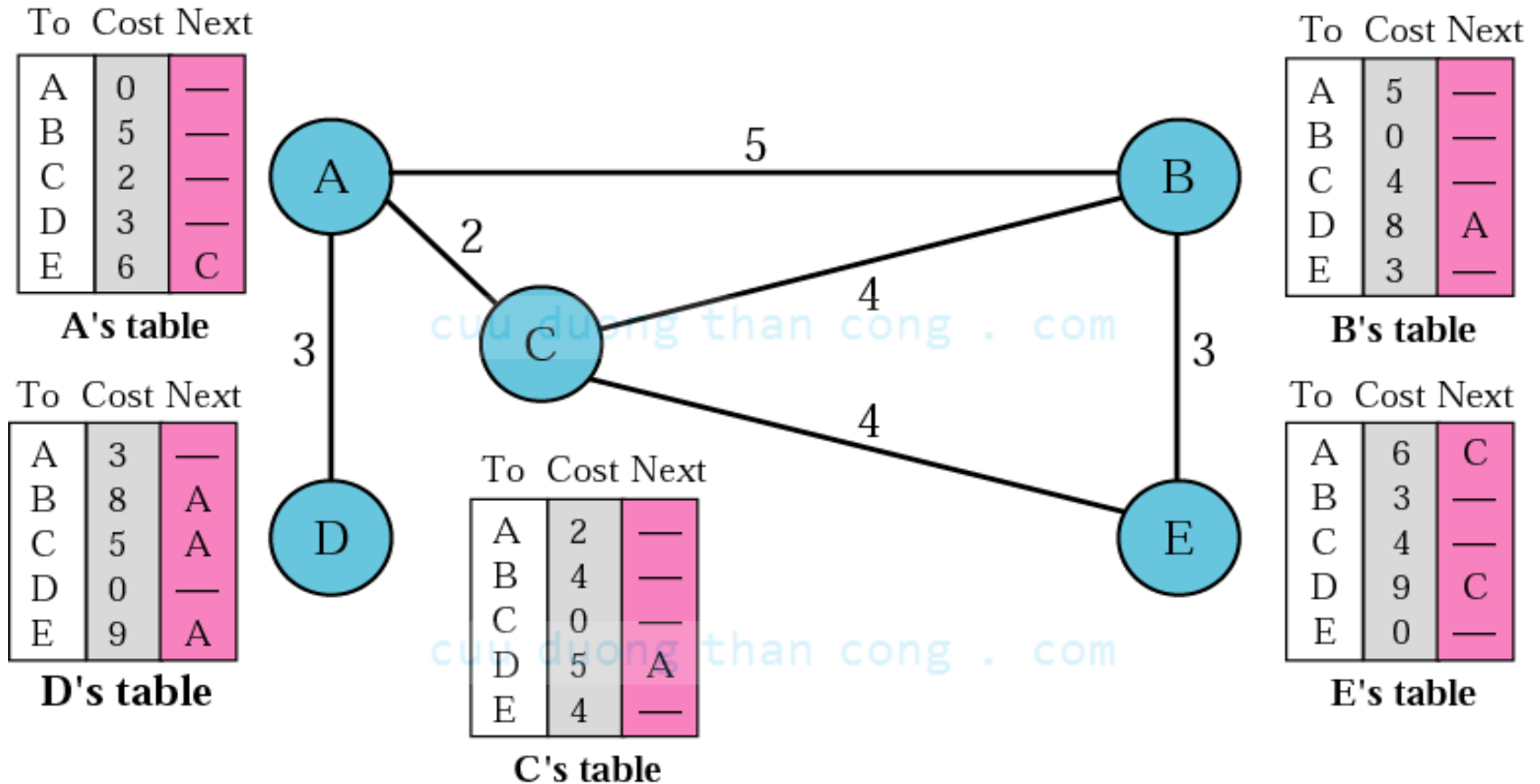
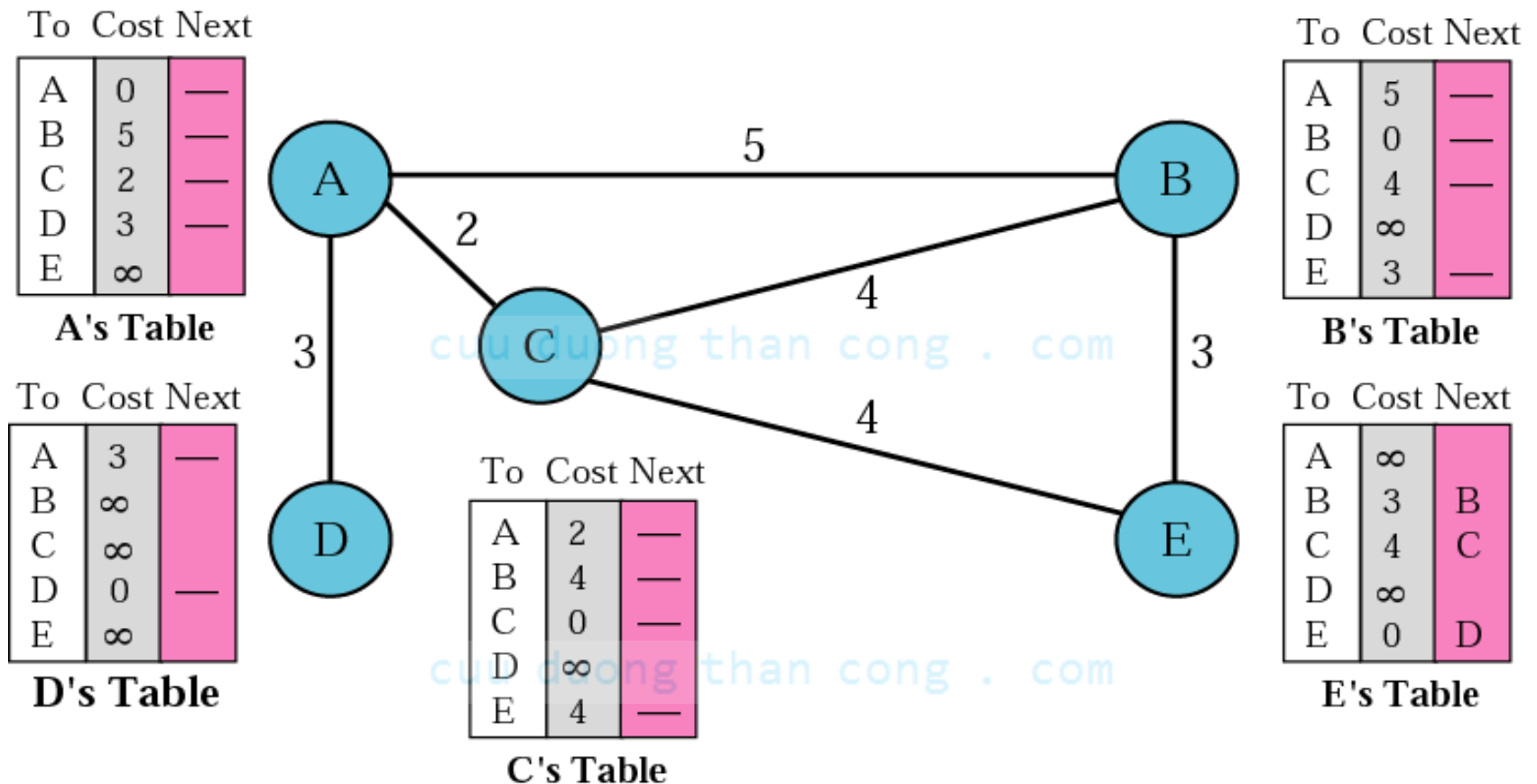


Figure 14.4 Initialization of tables in distance vector routing





Note:

In distance vector routing, each node shares its routing table with its immediate neighbors periodically and when there is a change.

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Figure 14.5 *Updating in distance vector routing*

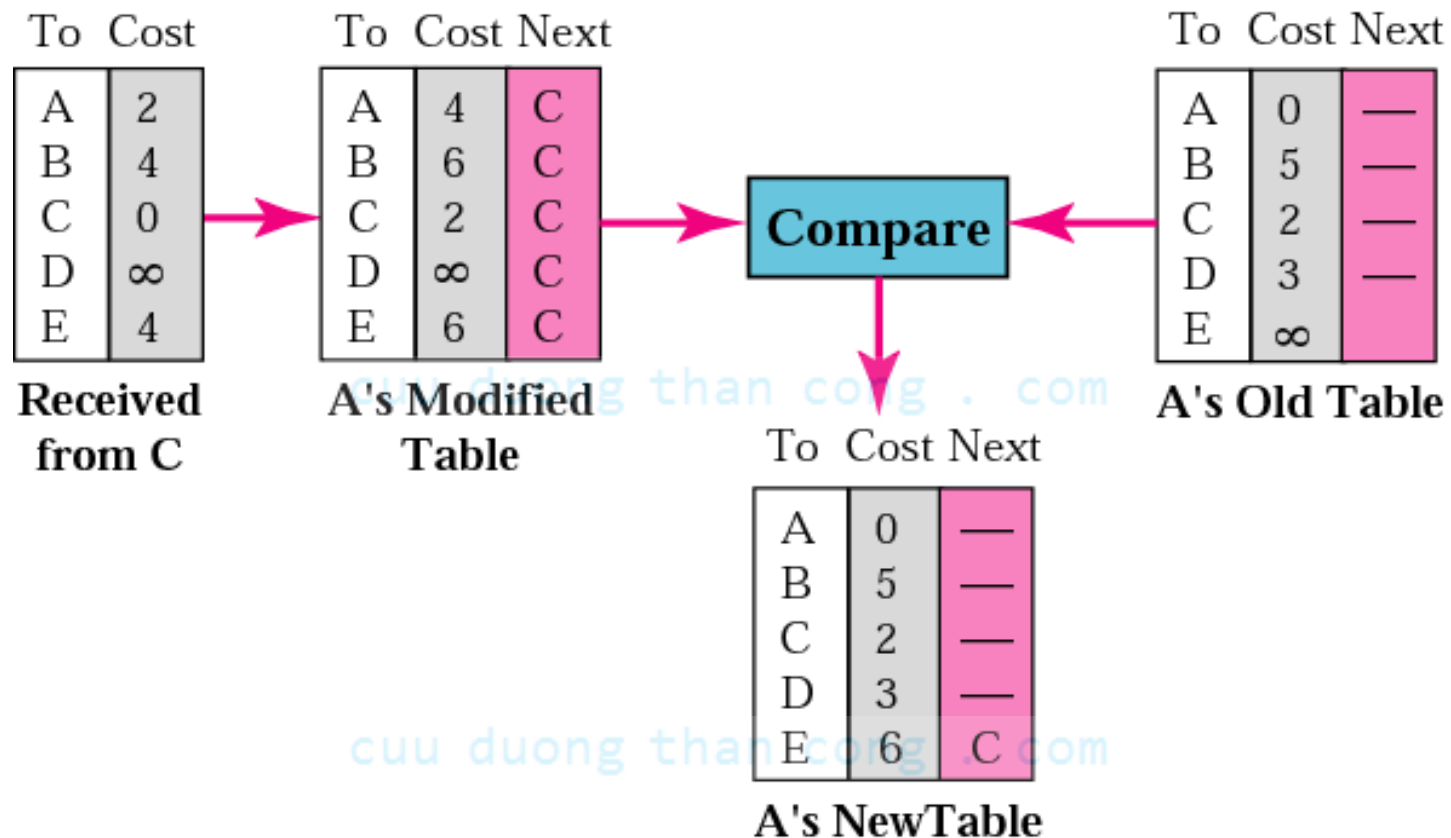


Figure 14.6 *Two-node instability*

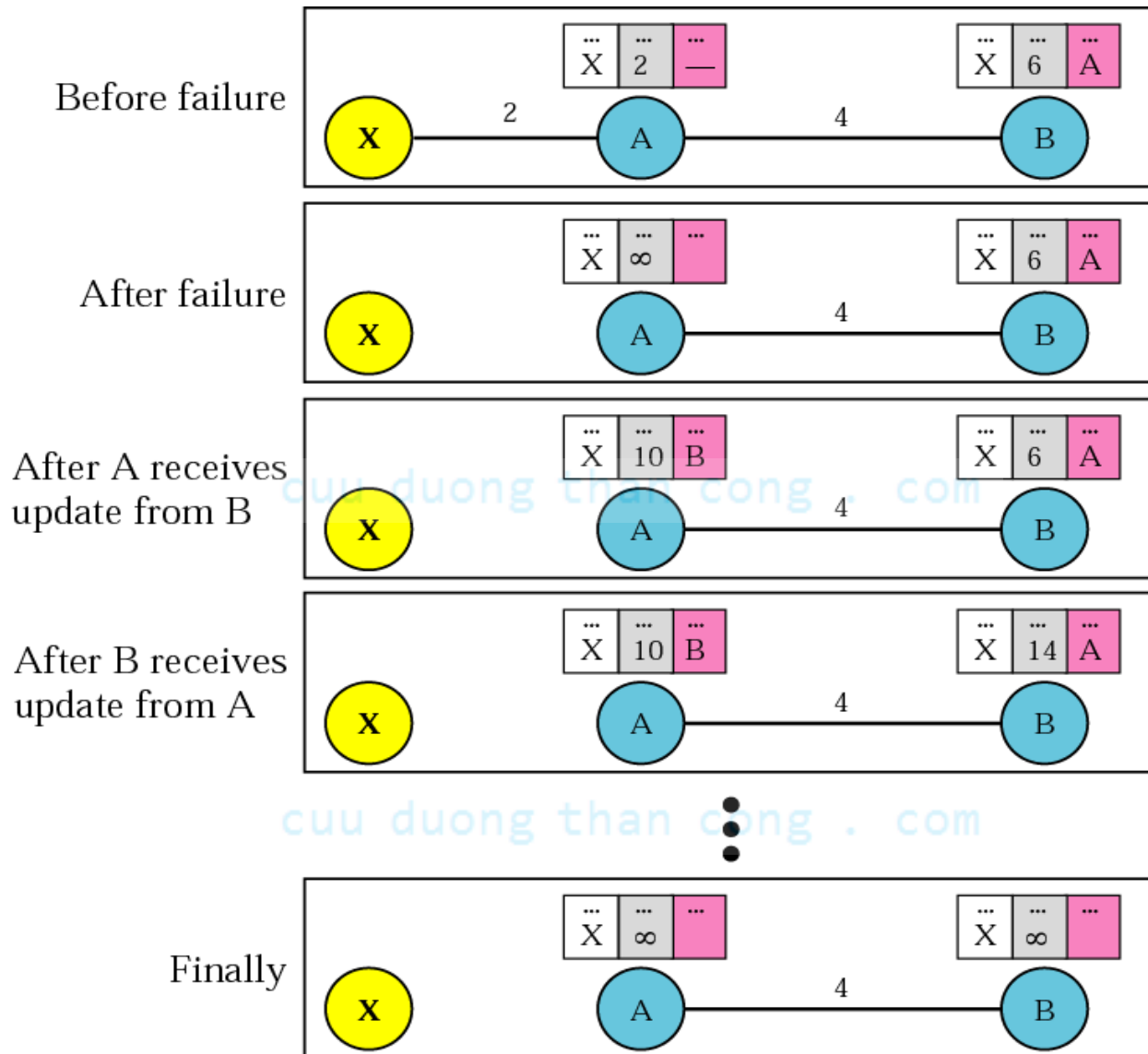
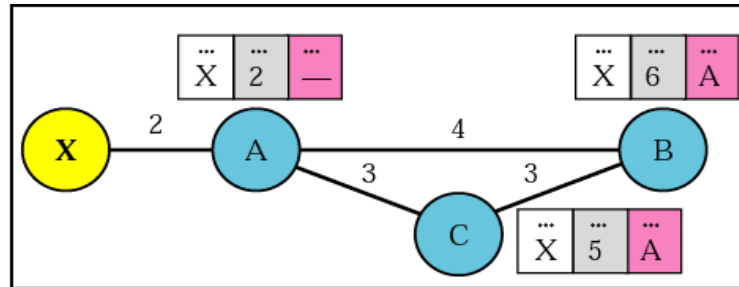
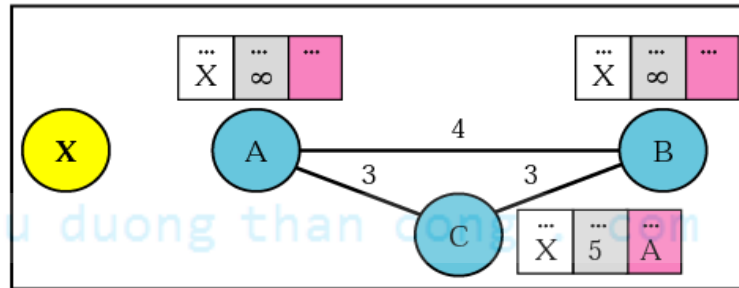


Figure 14.7 *Three-node instability*

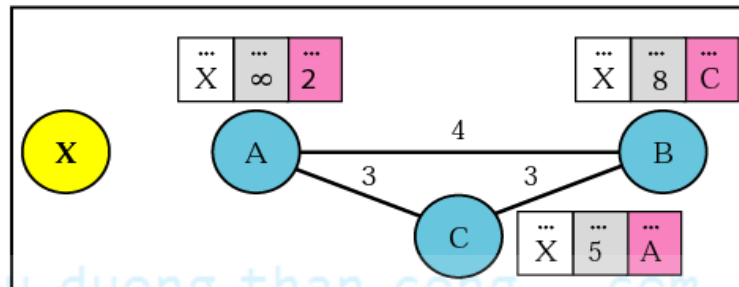
Before failure



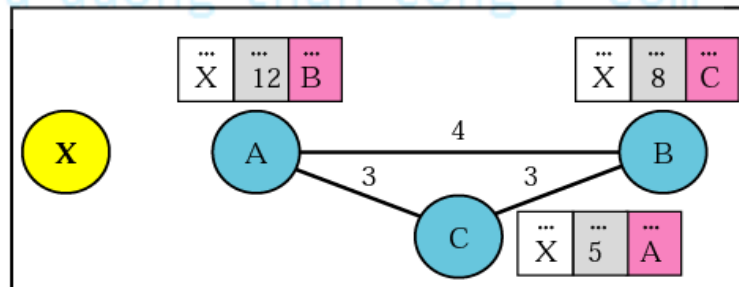
After A sends the route to B and C, but the packet to C is lost



After C sends the route to B



After B sends the route to A



14.3 RIP

The Routing Information Protocol (RIP) is an intradomain routing protocol used inside an autonomous system. It is a very simple protocol based on distance vector routing.

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The topics discussed in this section include:

RIP Message Format

Requests and Responses

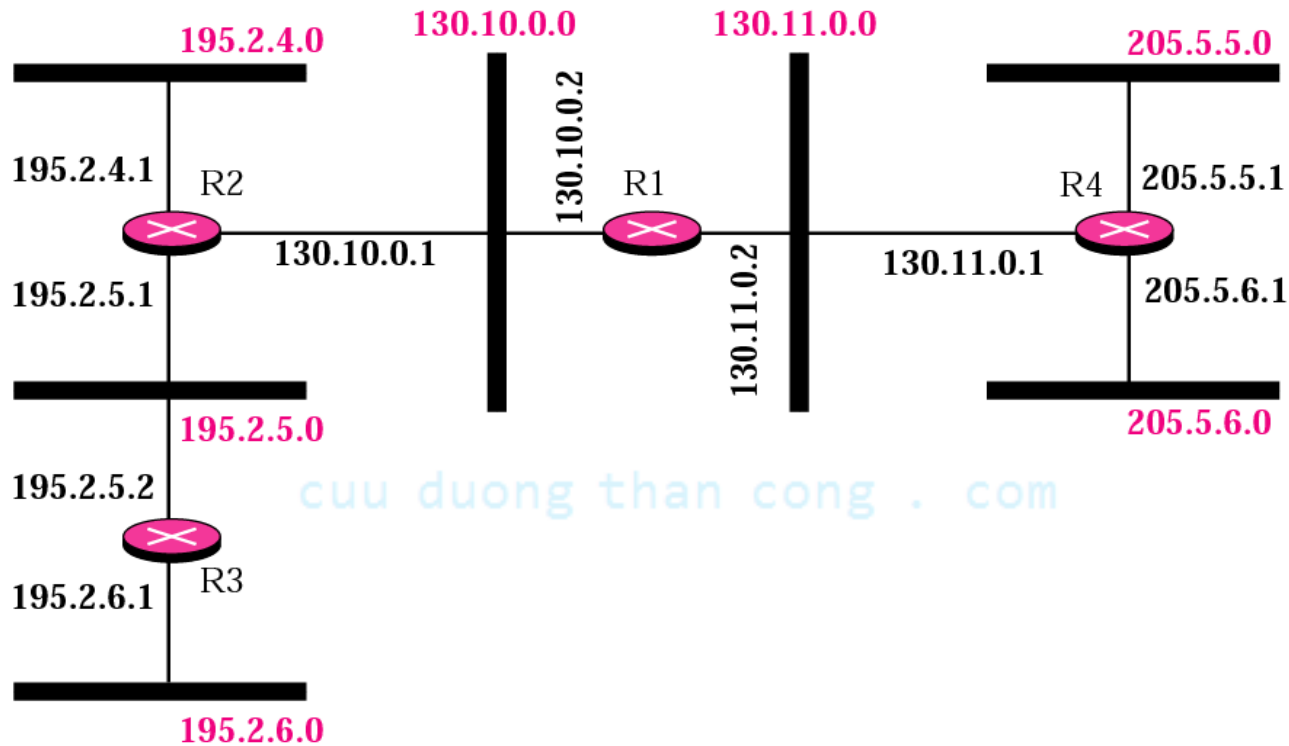
Timers in RIP

RIP Version 2

Encapsulation

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Figure 14.8 *Example of a domain using RIP*



Dest.	Hop	Next
130.10.0.0	1	_____
130.11.0.0	1	_____
195.2.4.0	2	130.10.0.1
195.2.5.0	2	130.10.0.1
195.2.6.0	3	130.10.0.1
205.5.5.0	2	130.11.0.1
205.5.6.0	2	130.11.0.1

R1 Table

Dest.	Hop	Next
130.10.0.0	1	_____
130.11.0.0	2	130.10.0.2
195.2.4.0	1	_____
195.2.5.0	1	_____
195.2.6.0	2	195.2.5.2
205.5.5.0	3	130.10.0.2
205.5.6.0	3	130.10.0.2

R2 Table

Dest.	Hop	Next
130.10.0.0	2	195.2.5.1
130.11.0.0	3	195.2.5.1
195.2.4.0	2	195.2.5.1
195.2.5.0	1	_____
195.2.6.0	1	_____
205.5.5.0	4	195.2.5.1
205.5.6.0	4	195.2.5.1

R3 Table

Dest.	Hop	Next
130.10.0.0	2	130.11.0.2
130.11.0.0	1	_____
195.2.4.0	3	130.11.0.2
195.2.5.0	3	130.11.0.2
195.2.6.0	4	130.11.0.2
205.5.5.0	1	_____
205.5.6.0	1	_____

R4 Table

Figure 14.9 *RIP message format*

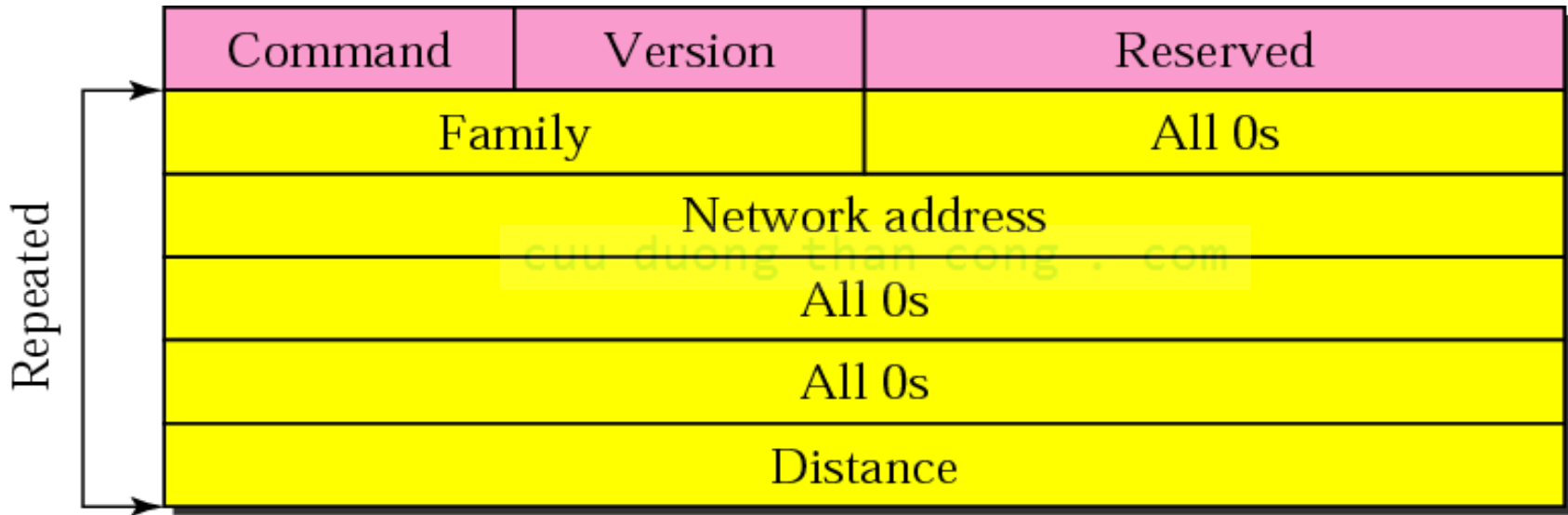
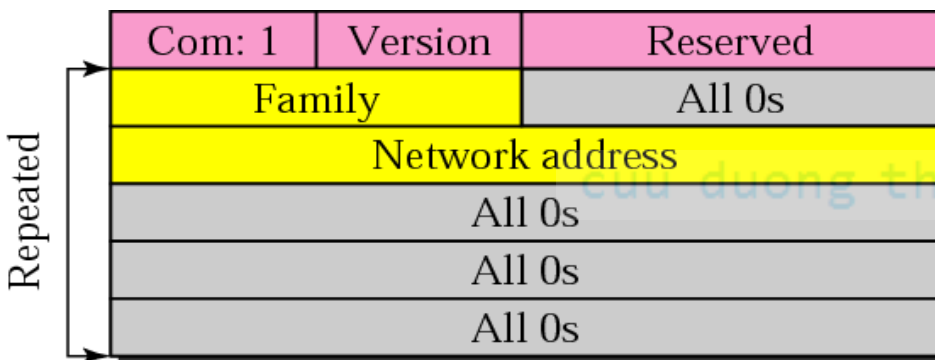
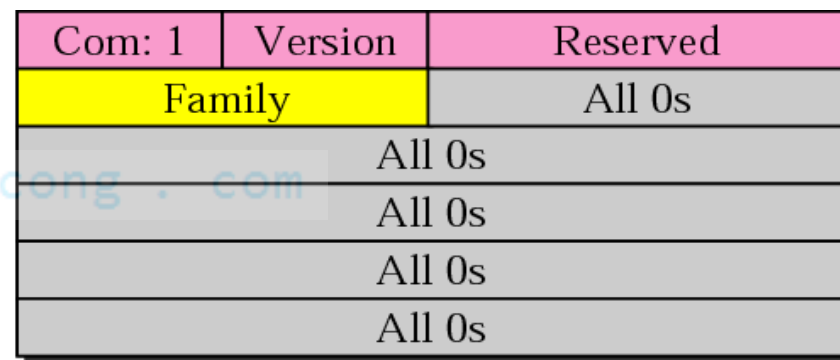


Figure 14.10 *Request messages*



a. Request for some



b. Request for all



EXAMPLE 1

Figure 14.11 shows the update message sent from router R1 to router R2 in Figure 14.8. The message is sent out of interface 130.10.0.2.

The message is prepared with the combination of split horizon and poison reverse strategy in mind. Router R1 has obtained information about networks 195.2.4.0, 195.2.5.0, and 195.2.6.0 from router R2. When R1 sends an update message to R2, it replaces the actual value of the hop counts for these three networks with 16 (infinity) to prevent any confusion for R2. The figure also shows the table extracted from the message. Router R2 uses the source address of the IP datagram carrying the RIP message from R1 (130.10.0.2) as the next hop address.

See Next Slide

Figure 14.11 *Solution to Example 1*

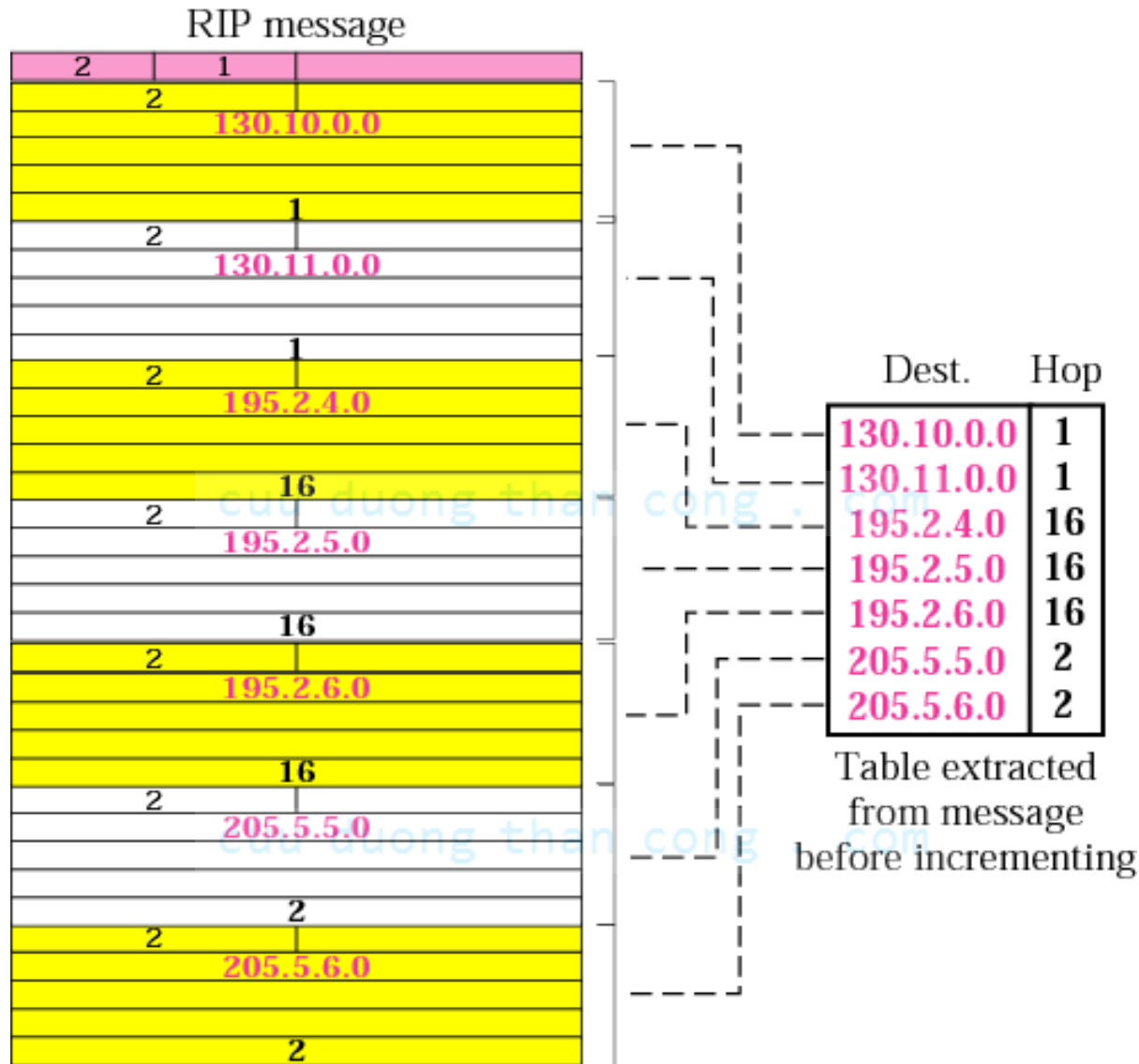
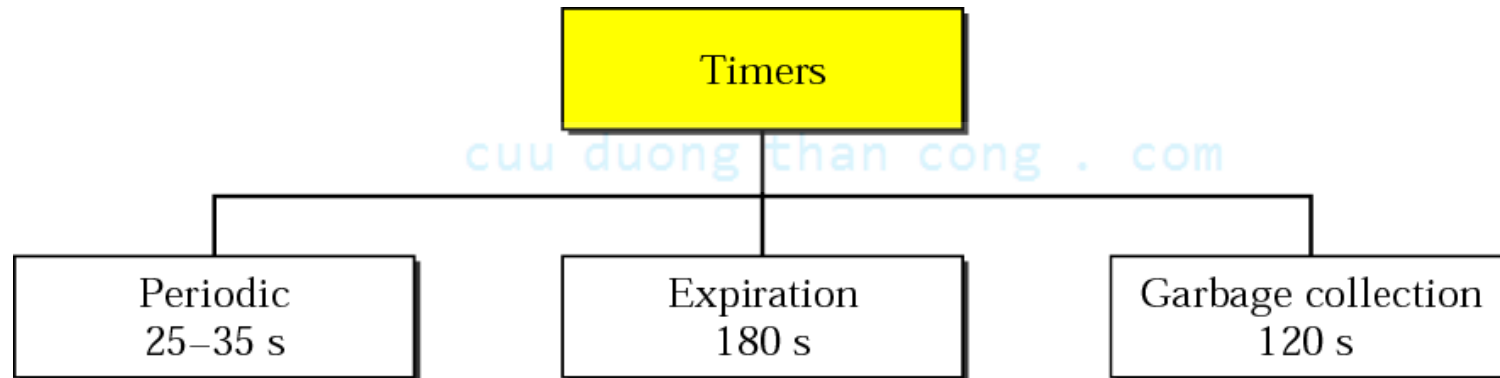


Figure 14.12 *RIP timers*





EXAMPLE 2

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

Solution

The 21 timers are listed below:

Periodic timer: 1

Expiration timer: $20 - 5 = 15$

Garbage collection timer: 5

Figure 14.13 *RIP version 2 format*

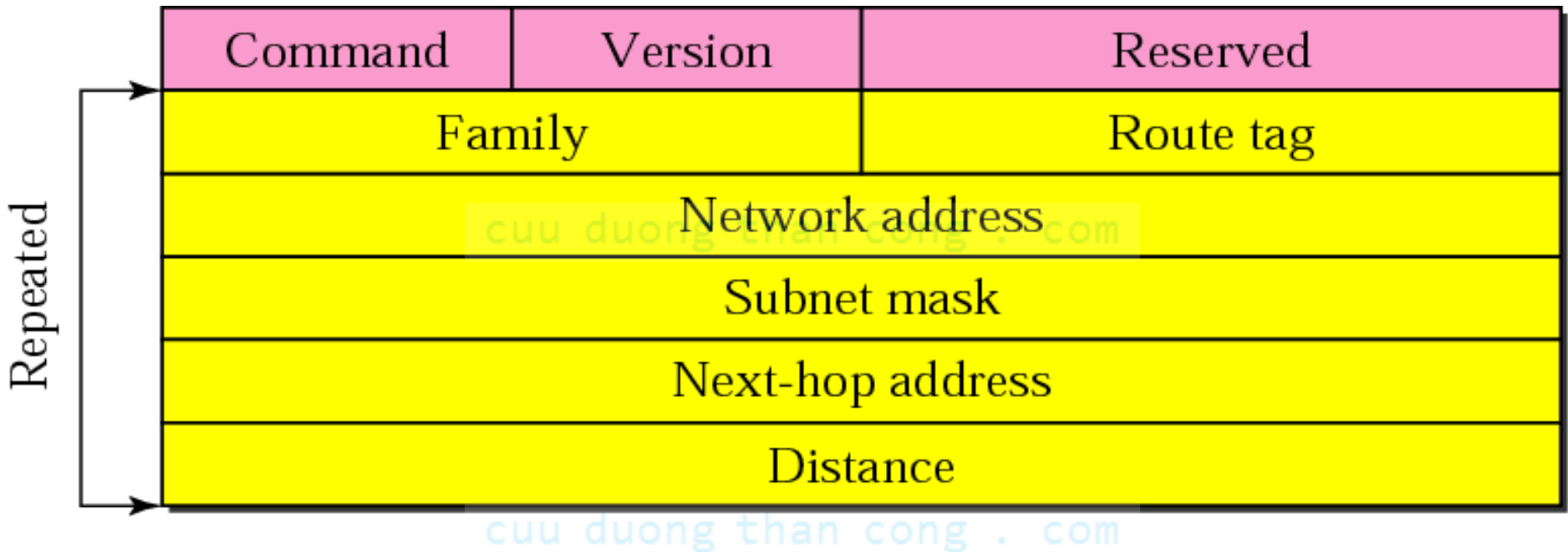
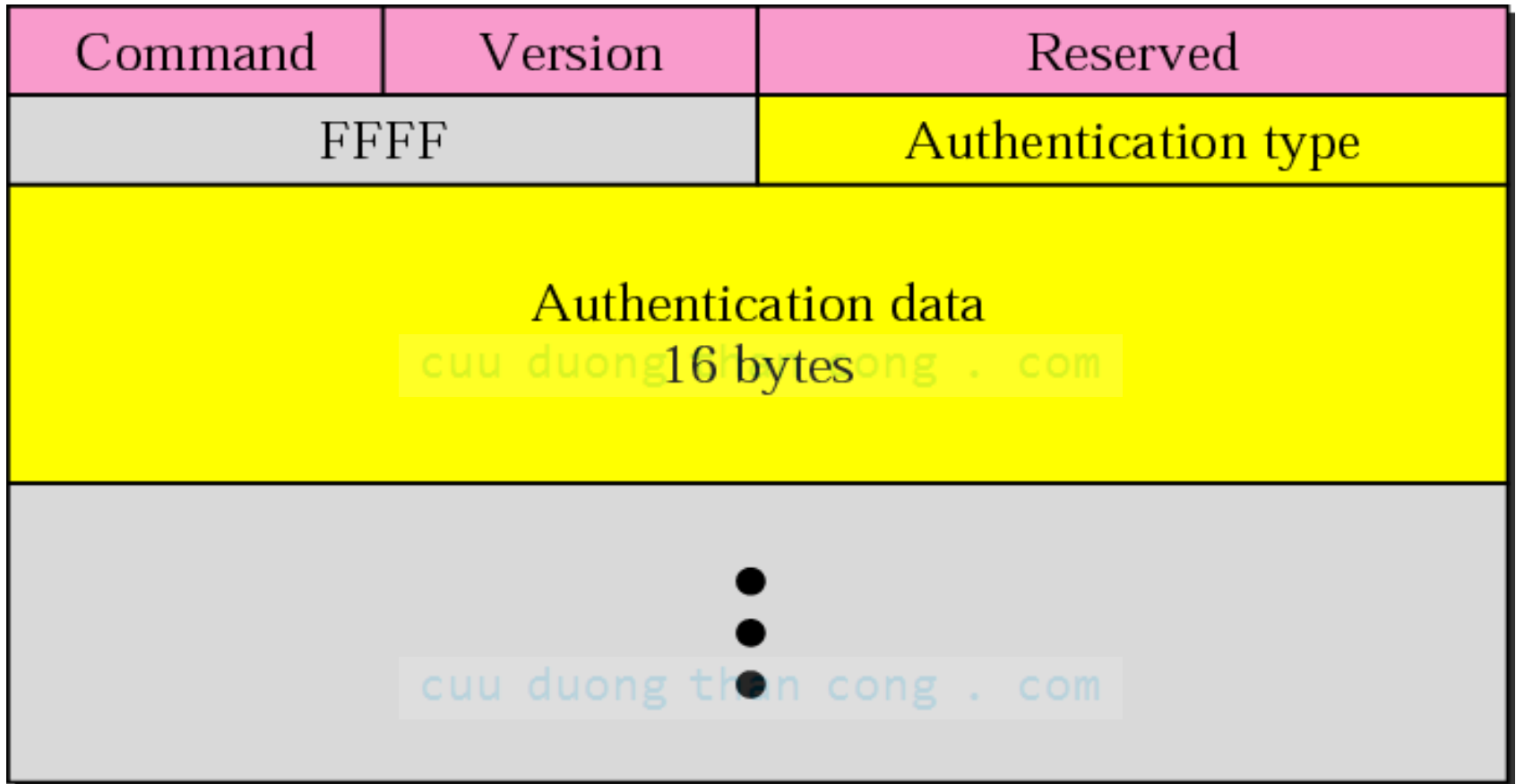


Figure 14.14 *Authentication*





Note:

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

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14.4 LINK STATE ROUTING

In link state routing, if each node in the domain has the entire topology of the domain, the node can use Dijkstra's algorithm to build a routing table.

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The topics discussed in this section include:

Building Routing Tables

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Figure 14.15 *Concept of link state routing*

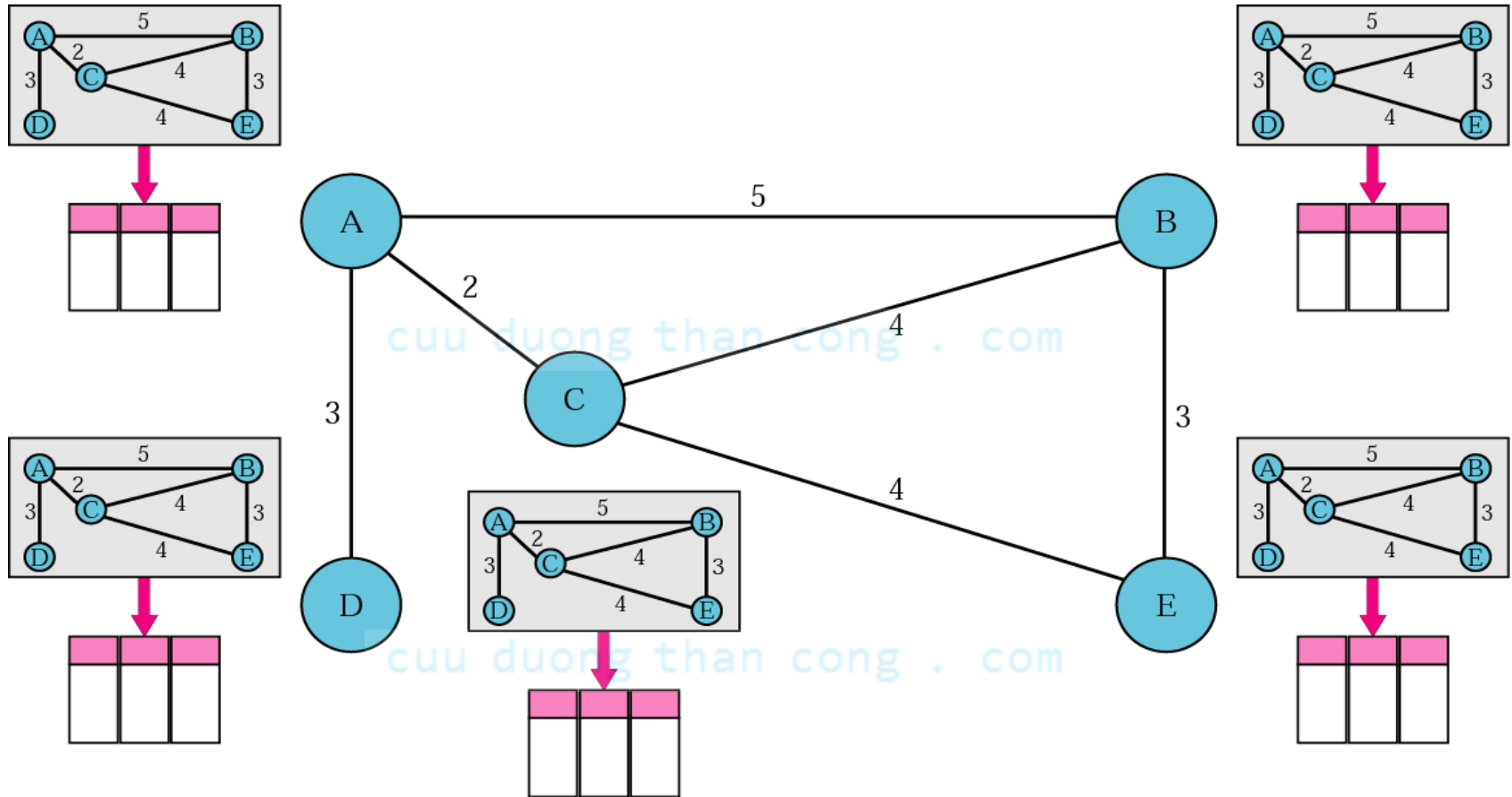


Figure 14.16 *Link state knowledge*

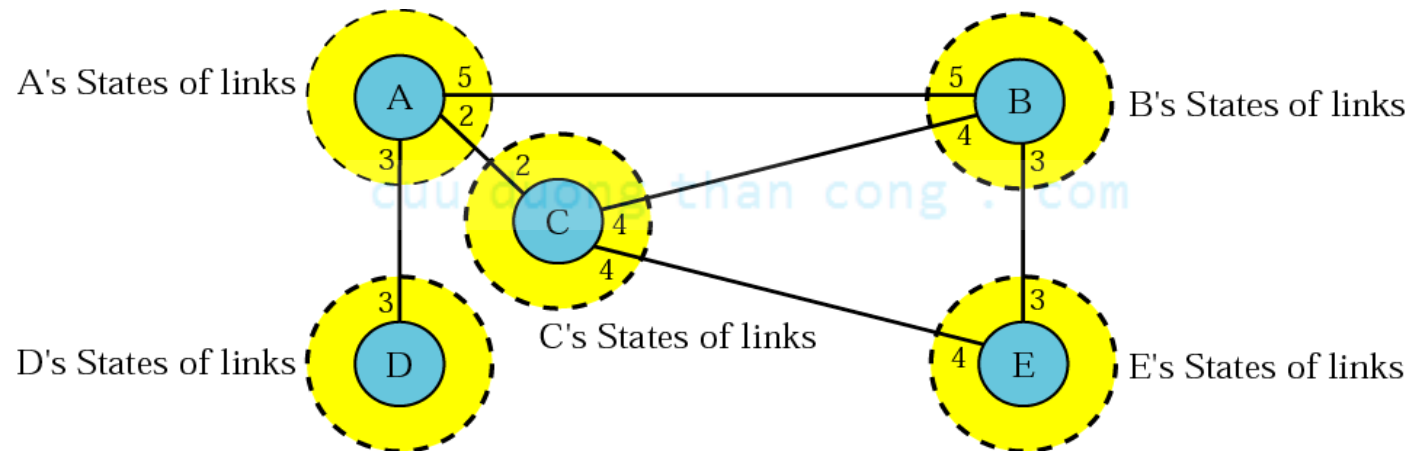


Figure 14.17 *Dijkstra algorithm*

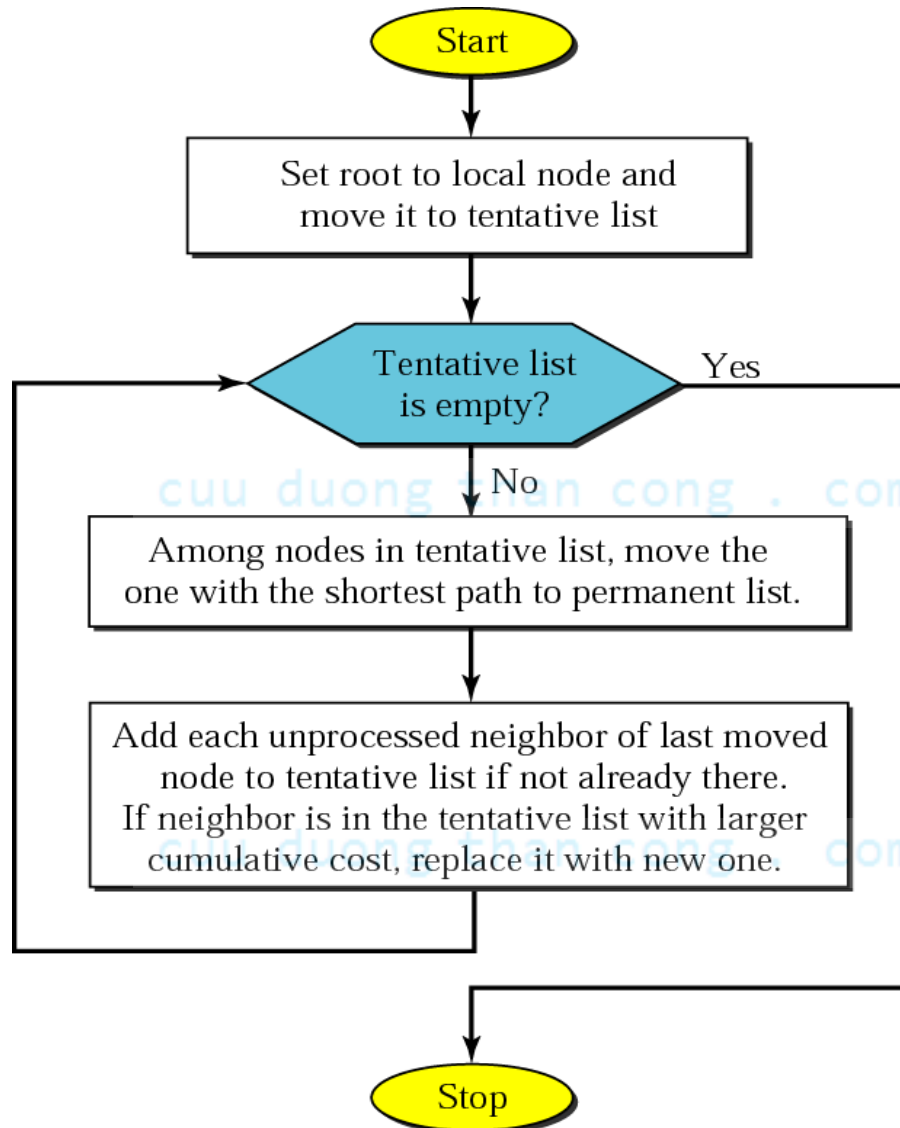
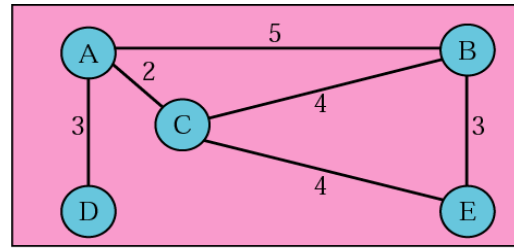
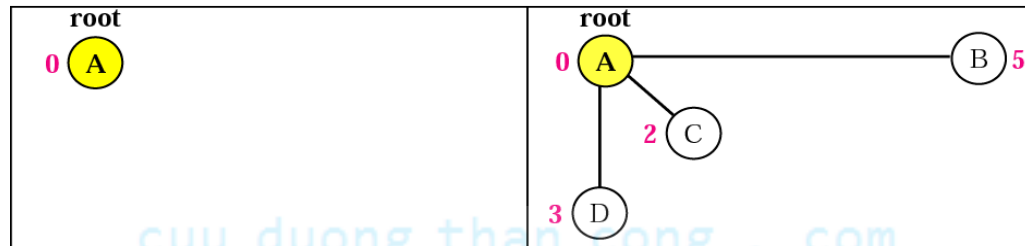


Figure 14.18 *Example of formation of shortest path tree*

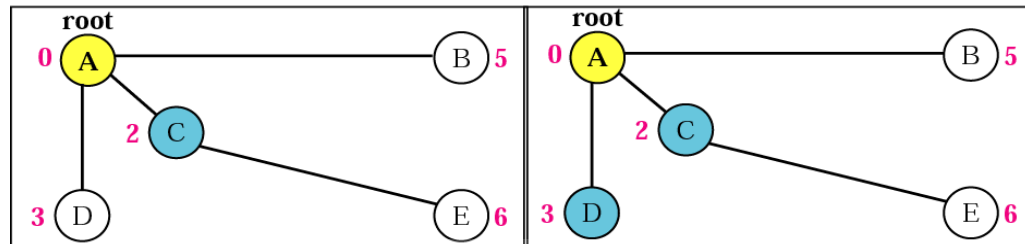


Topology



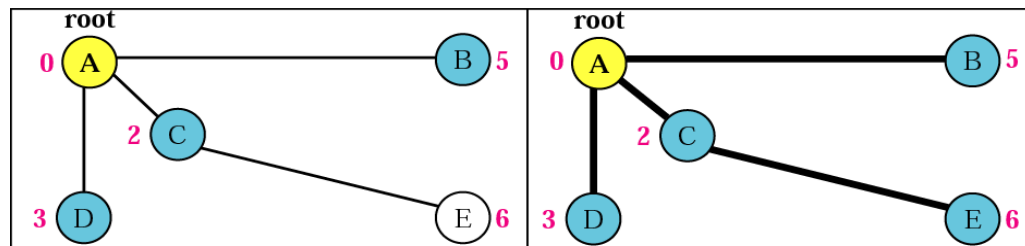
1. Set root to A and move A to tentative list

2. Move A to permanent list and add B, C, and D to tentative list



3. Move C to permanent and add E to tentative list

4. Move D to permanent list.



5. Move B to permanent list

6. Move E to permanent list (tentative list is empty)

Table 14.1 Routing table for node A

<i>Node</i>	<i>Cost</i>	<i>Next Router</i>
A	0	—
B	5	—
C	2	—
D	3	—
E	6	C

14.5 OSPF

The Open Shortest Path First (OSPF) protocol is an intradomain routing protocol based on link state routing. Its domain is also an autonomous system.

The topics discussed in this section include:

Areas

Metric

Types of Links

Graphical Representation

OSPF Packets

Link State Update Packet

Other Packets

Encapsulation

Figure 14.19 *Areas in an autonomous system*

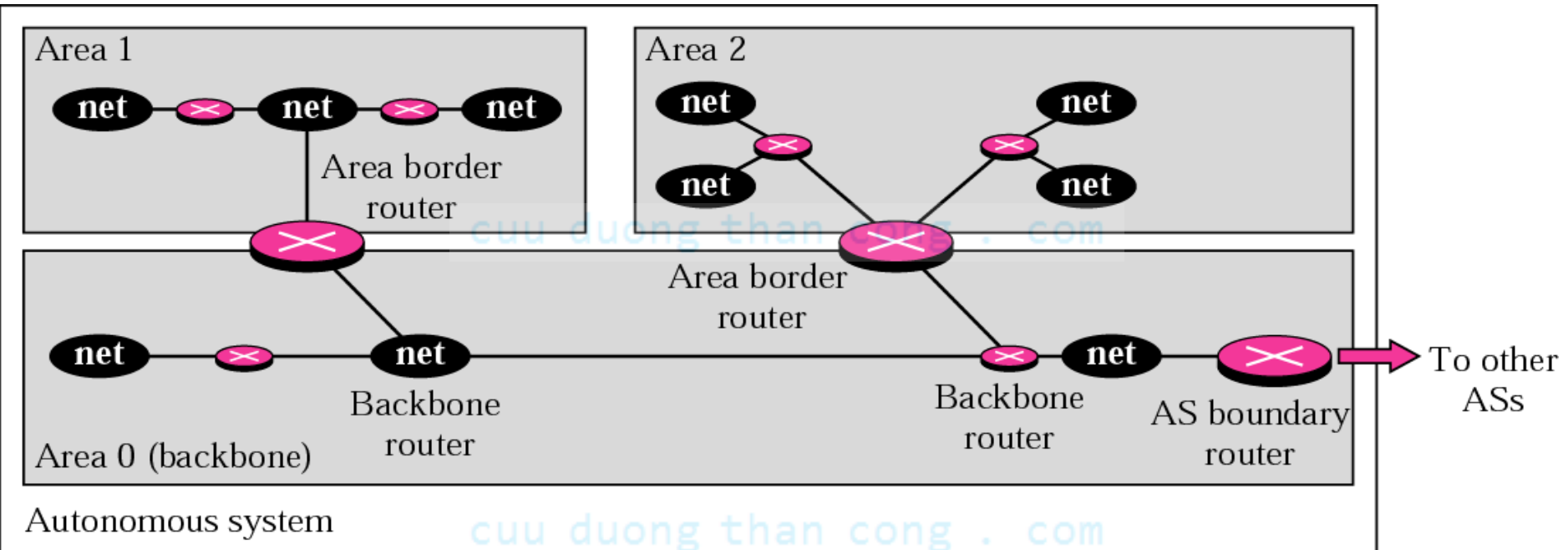


Figure 14.20 *Types of links*

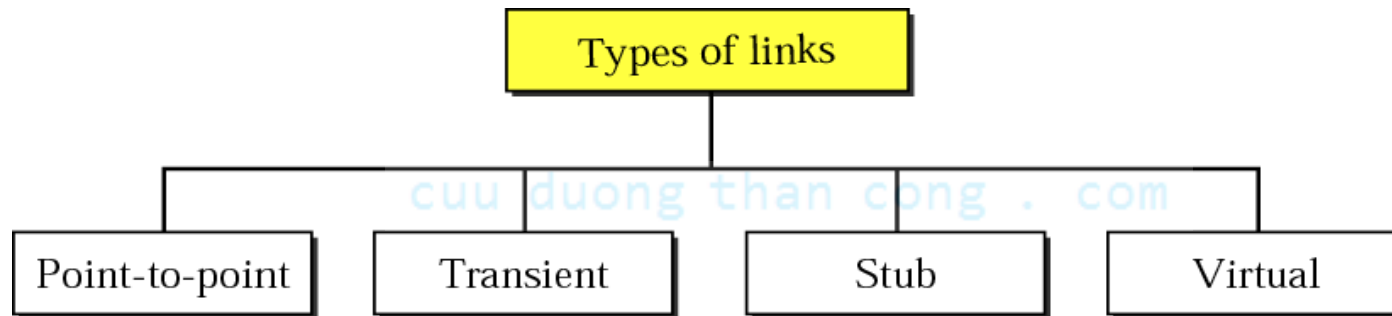


Figure 14.21 *Point-to-point link*

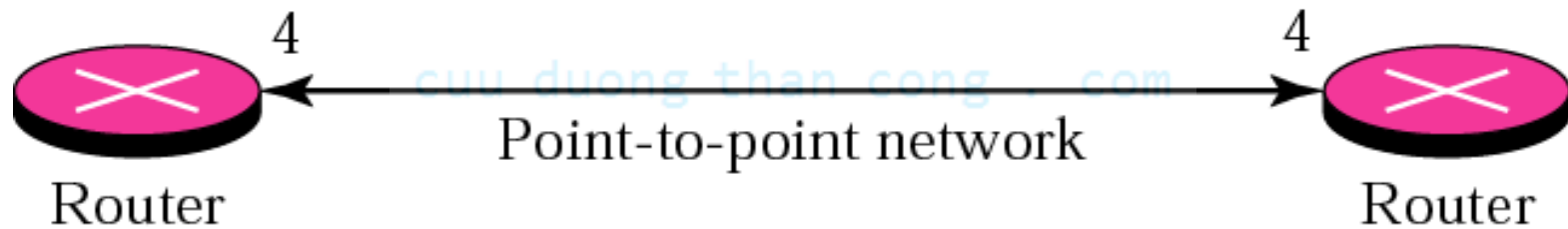
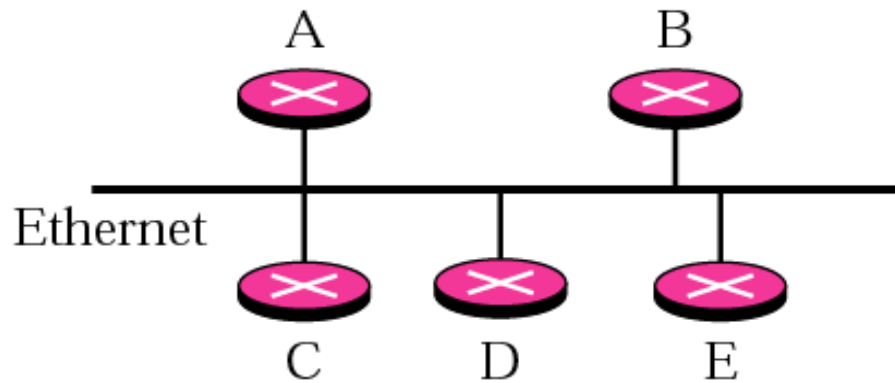
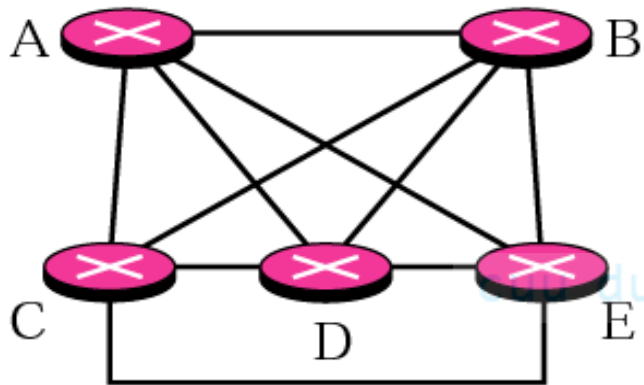


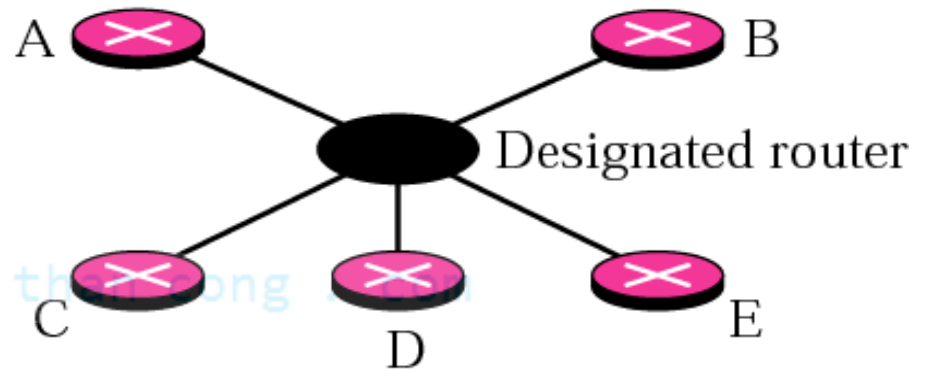
Figure 14.22 *Transient link*



a. Transient network



b. Unrealistic representation



c. Realistic representation

Figure 14.23 *Stub link*

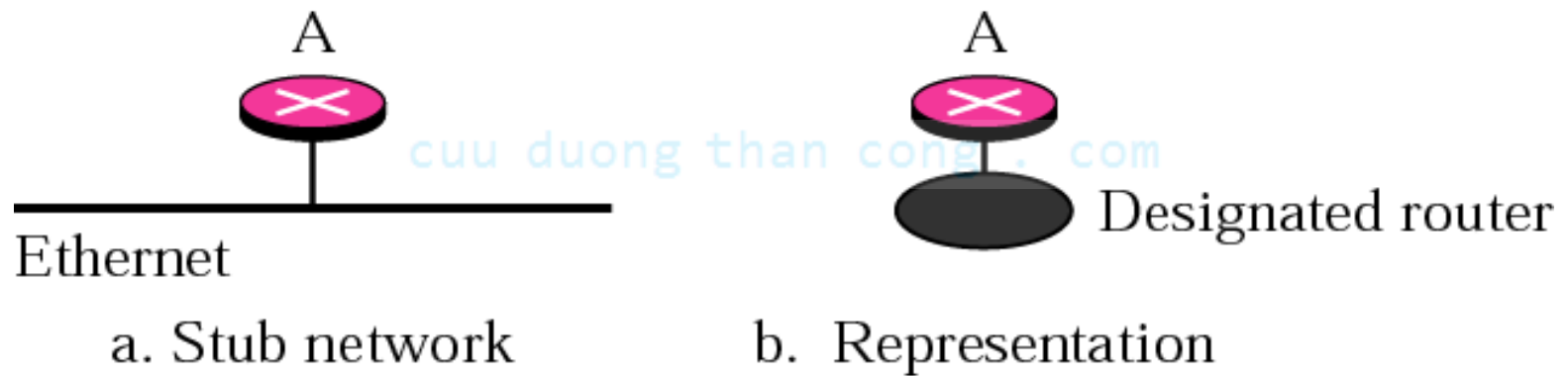
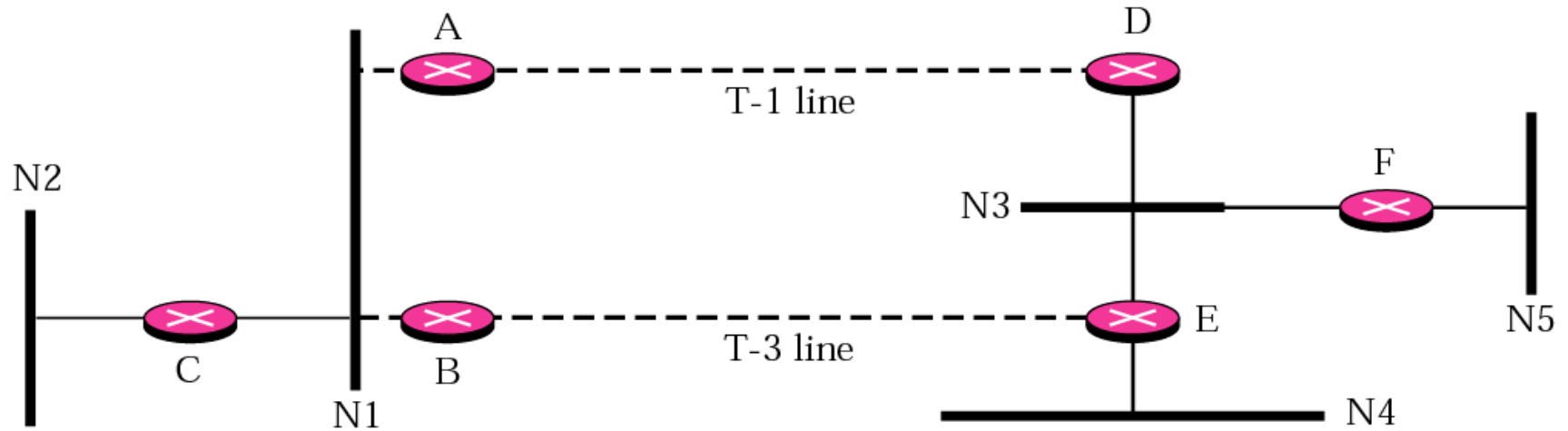
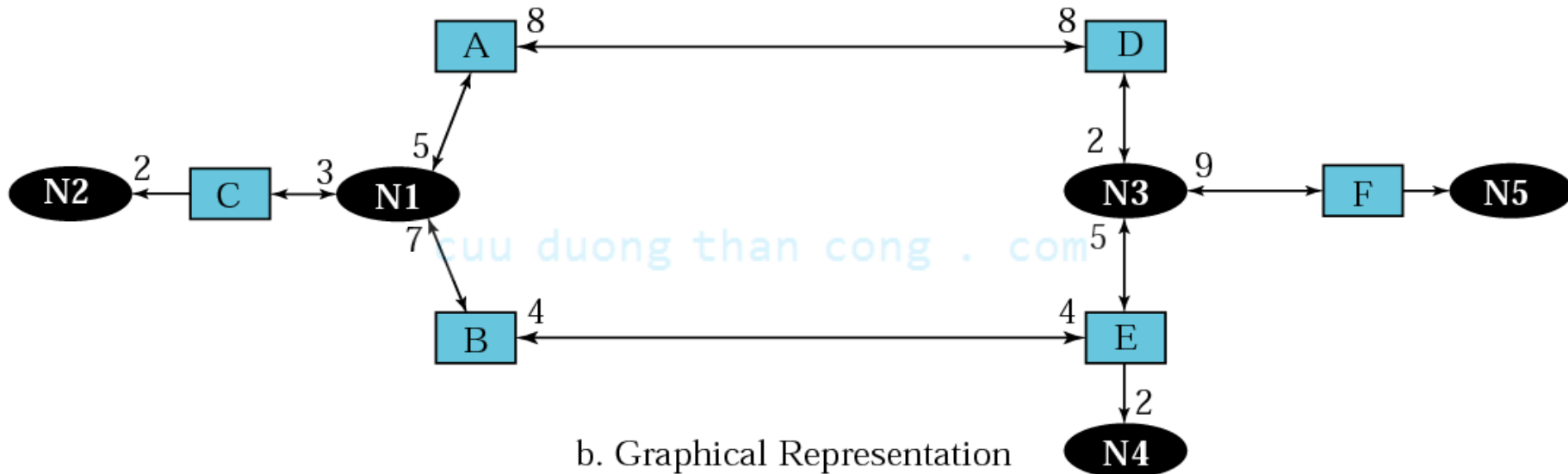


Figure 14.24 *Example of an AS and its graphical representation in OSPF*



a. Autonomous System



b. Graphical Representation

Figure 14.25 *Types of OSPF packets*

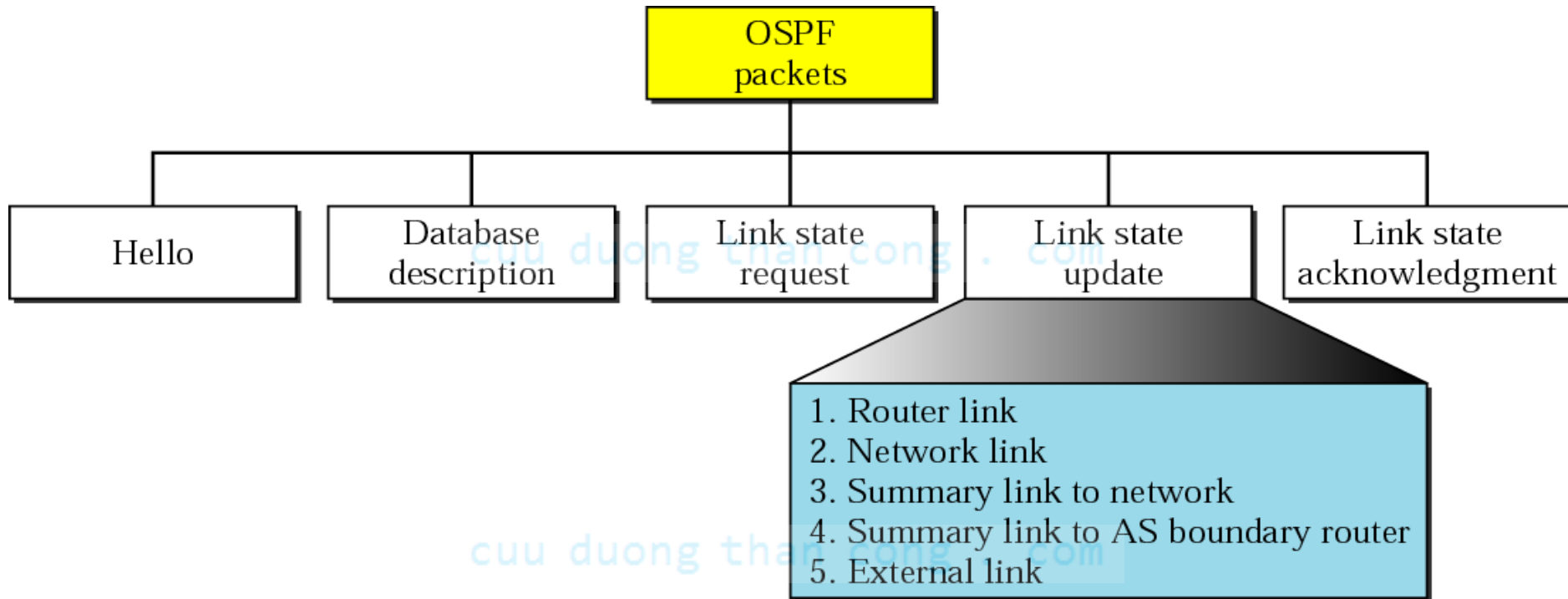


Figure 14.26 *OSPF common header*

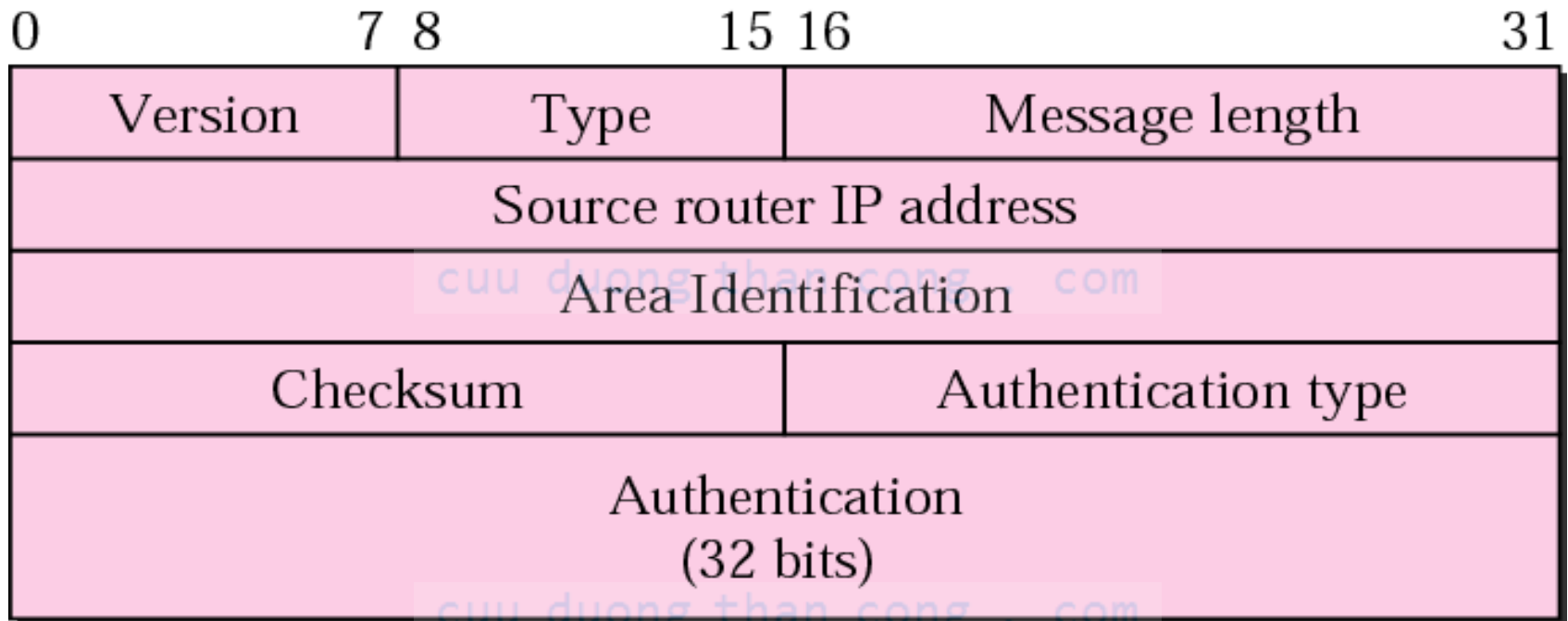


Figure 14.27 *Link state update packet*

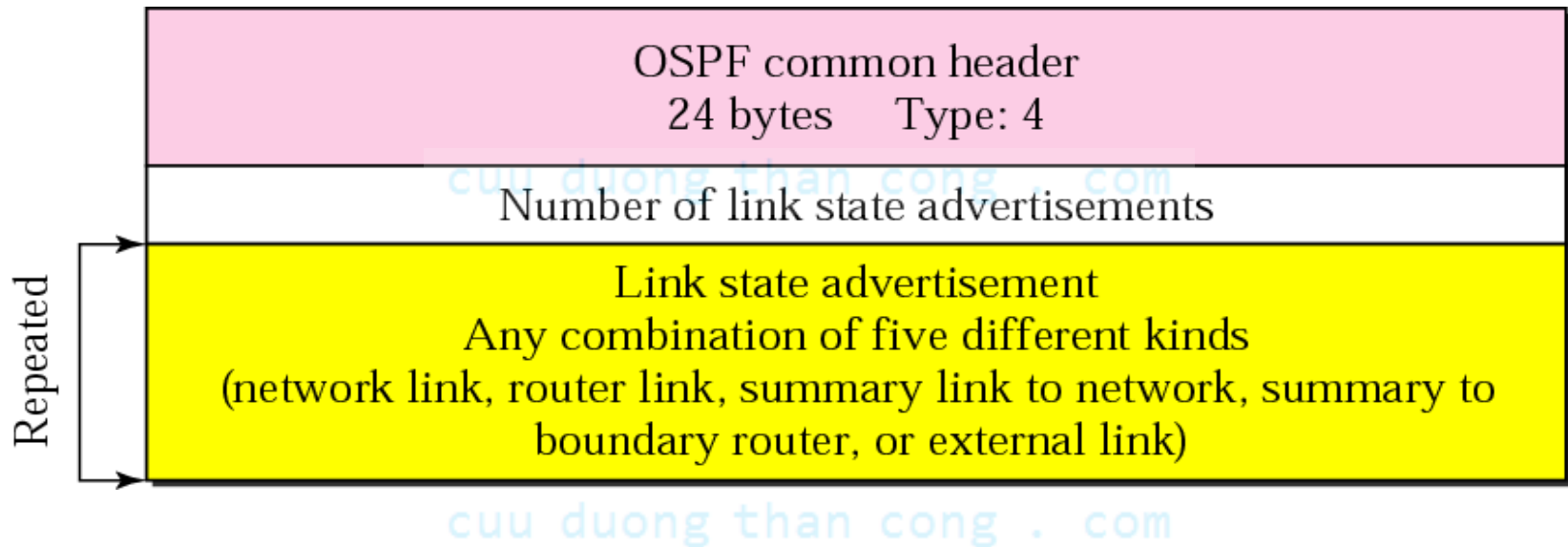


Figure 14.28 *LSA general header*

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

Figure 14.29 *Router link*

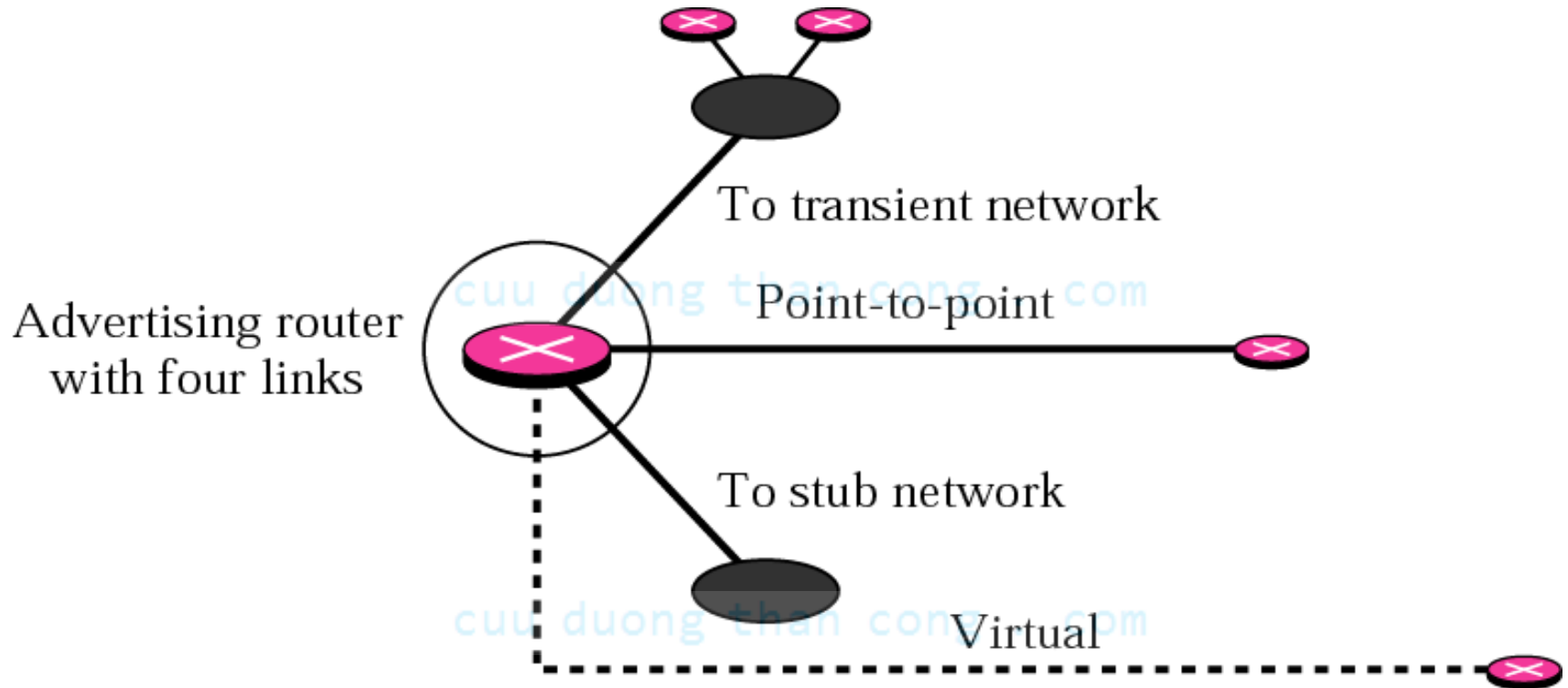


Figure 14.30 Router link LSA

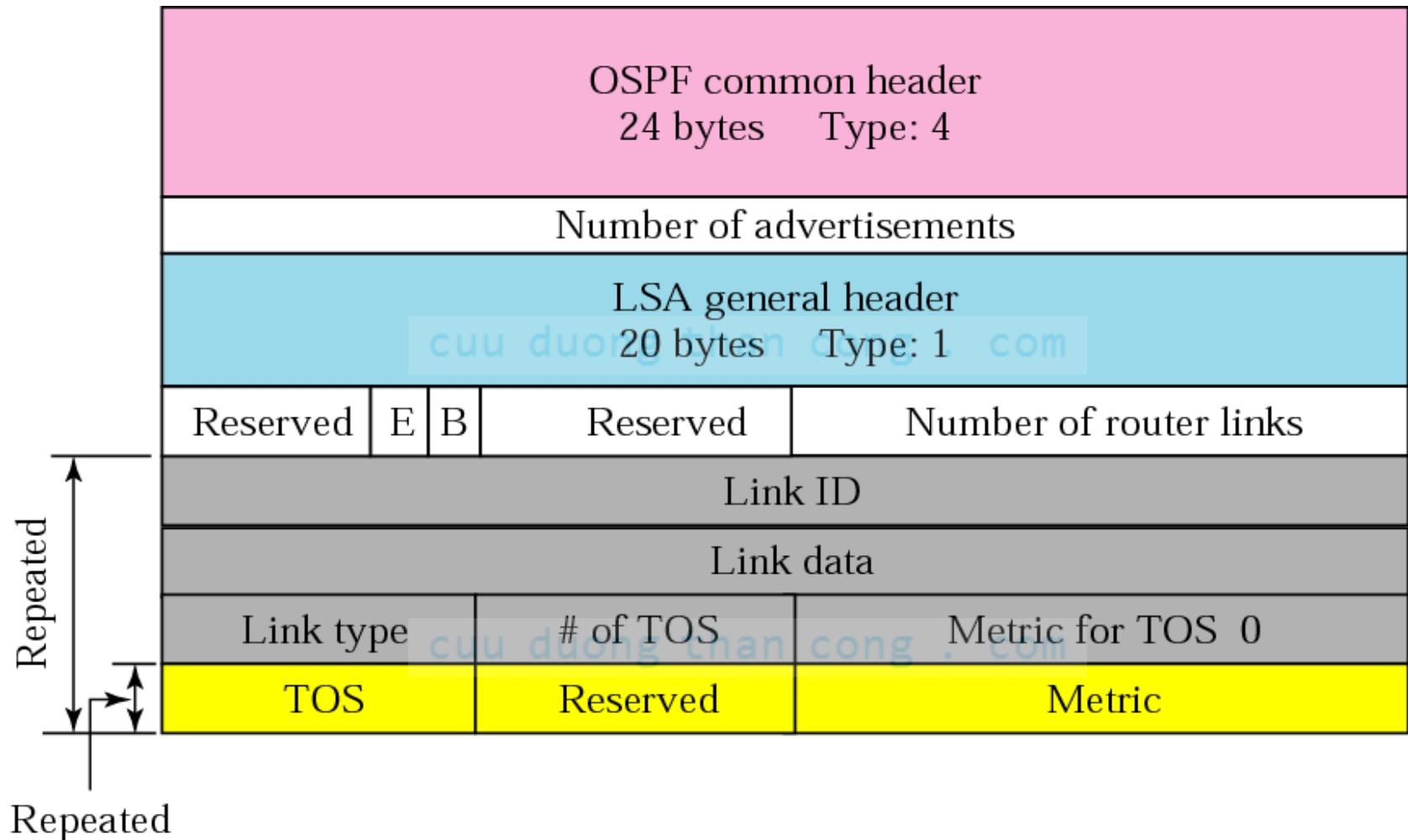


Table 14.2 Link types, link identification, and link data

<i>Link Type</i>	<i>Link Identification</i>	<i>Link Data</i>
Type 1: Point-to-point	Address of neighbor router	Interface number
Type 2: Transient	Address of designated router	Router address
Type 3: Stub	Network address	Network mask
Type 4: Virtual	Address of neighbor router	Router address



EXAMPLE 3

Give the router link LSA sent by router 10.24.7.9 in Figure 14.31.

See Next Slide

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Solution

This router has three links: two of type 1 (point-to-point) and one of type 3 (stub network). Figure 14.32 shows the router link LSA.

See Figure 14.32

Figure 14.31 *Example 3*

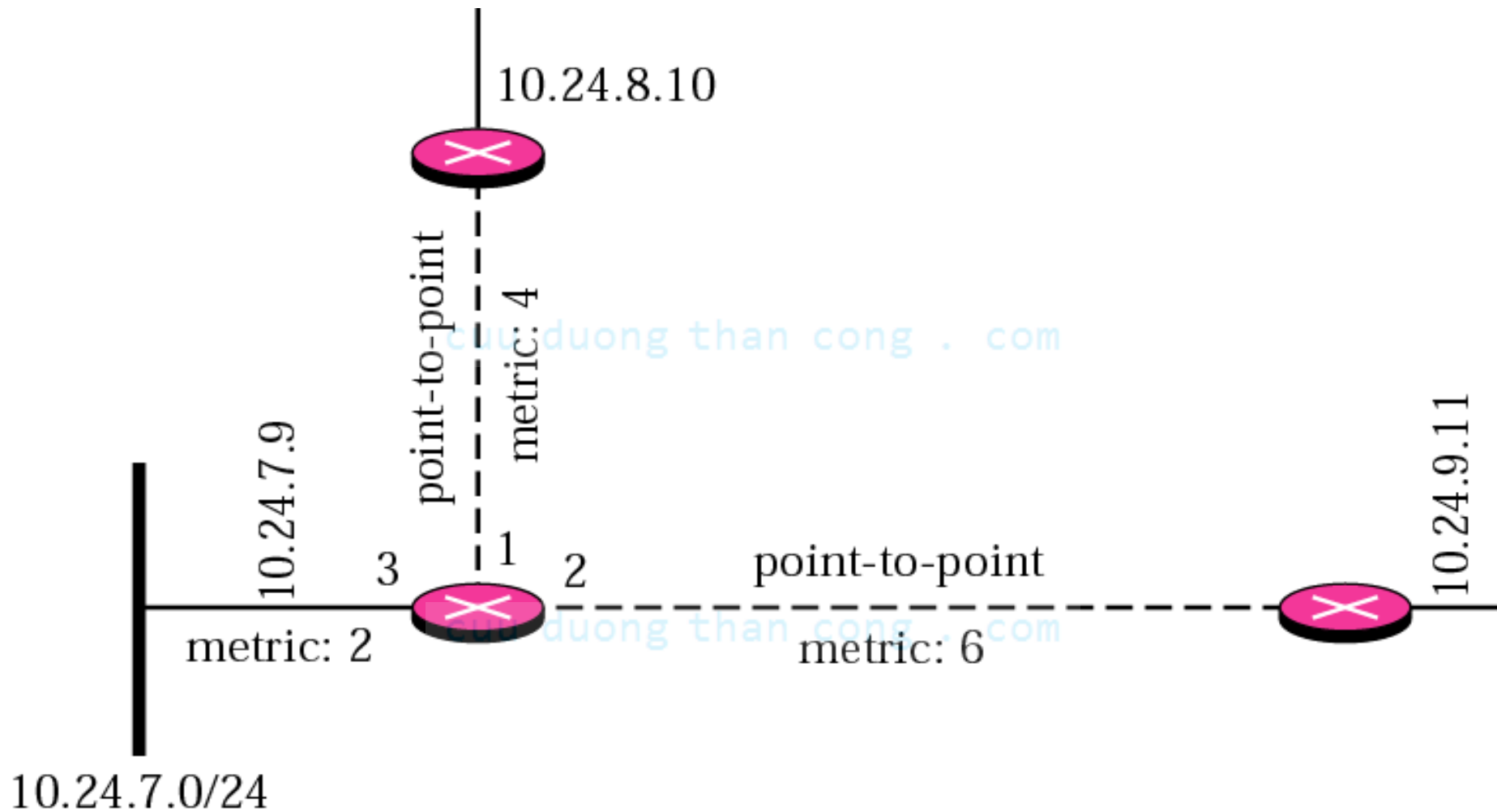


Figure 14.32 *Solution to Example 3*

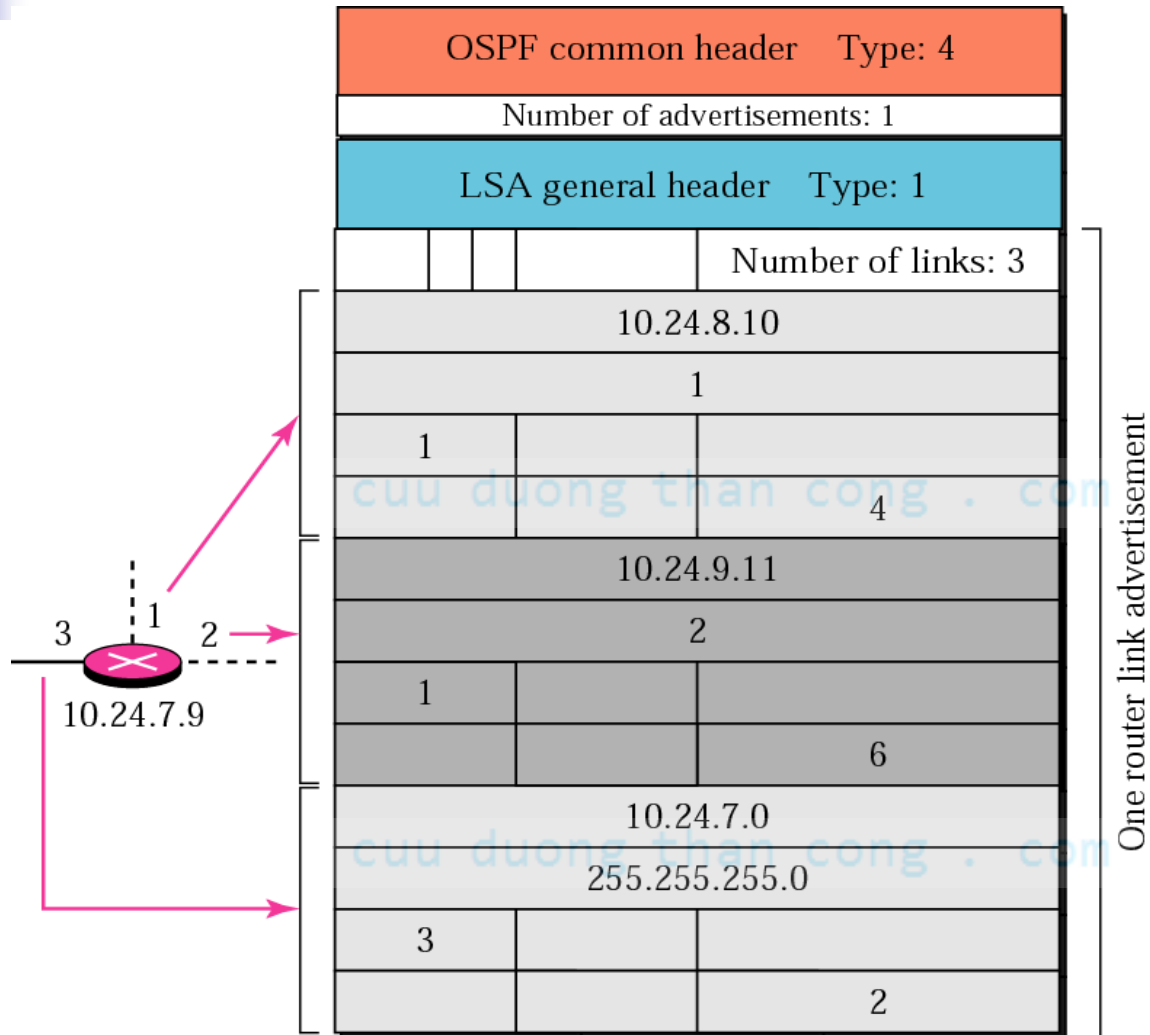


Figure 14.33 *Network link*

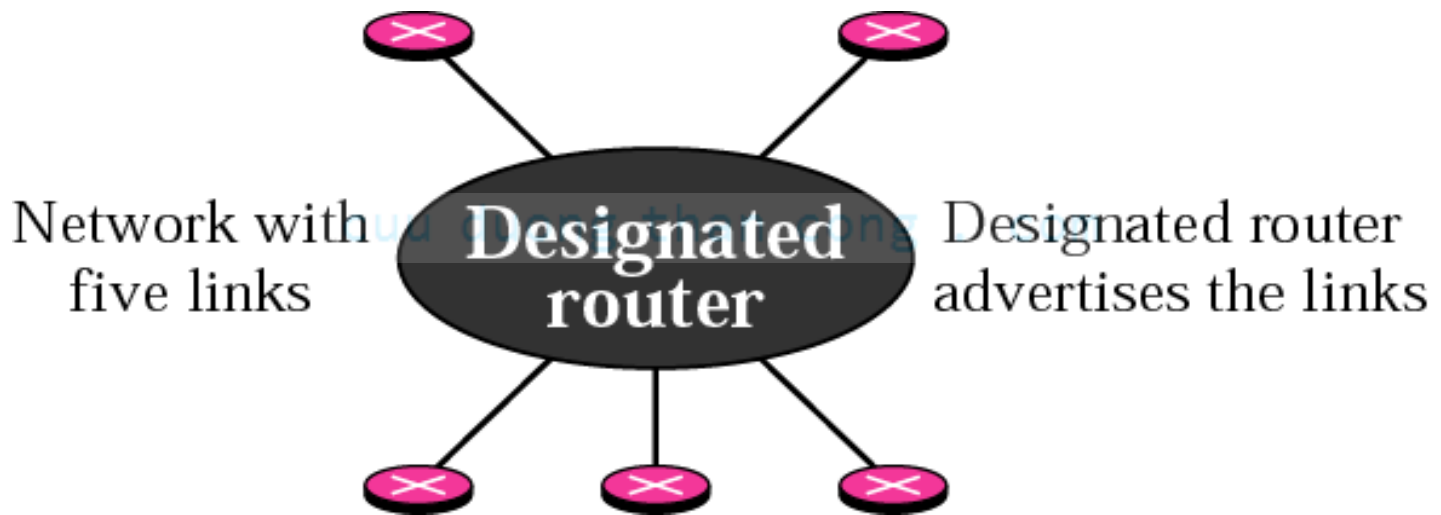
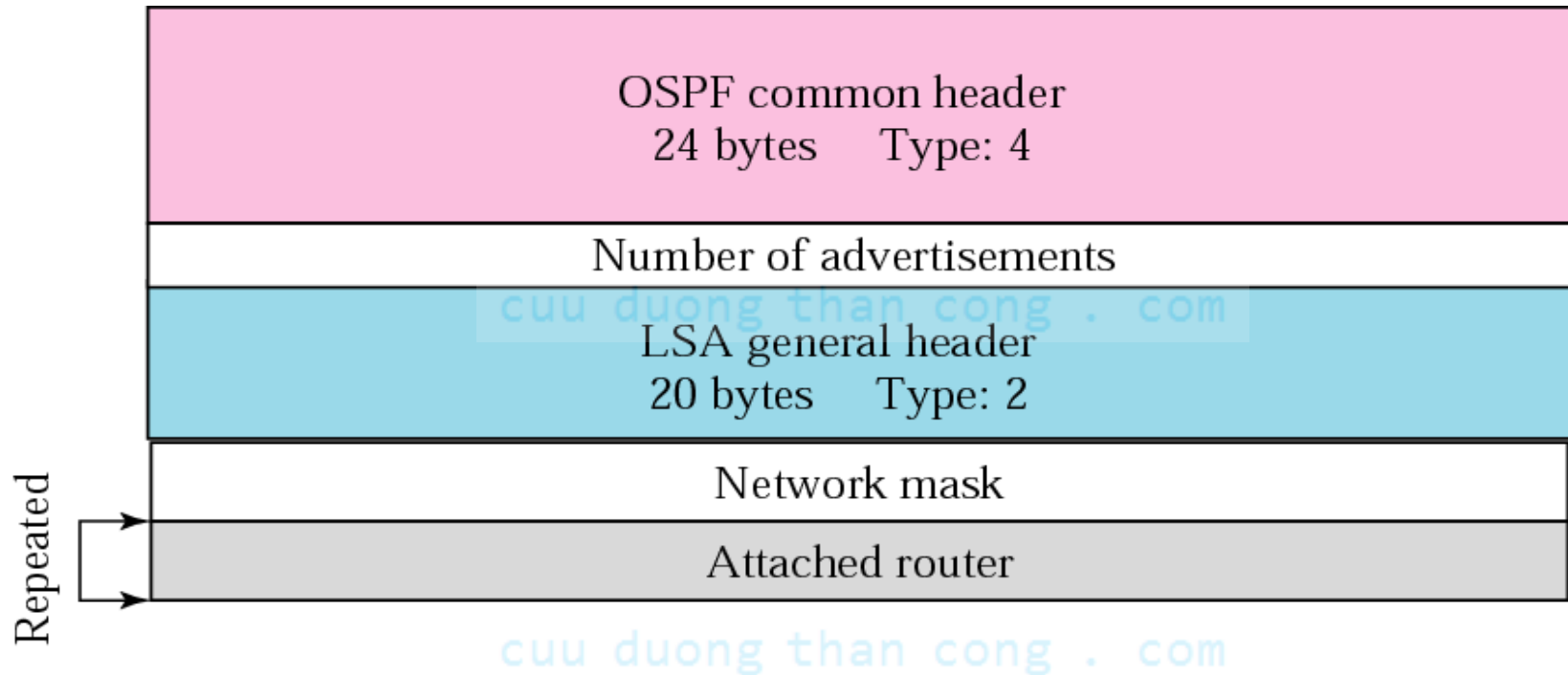


Figure 14.34 *Network link advertisement format*





EXAMPLE 4

Give the network link LSA in Figure 14.35.

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Solution.

See Figure 14.36

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Figure 14.35 *Example 4*



Figure 14.36 *Solution to Example 4*

OSPF common header	Type: 4
Number of advertisements: 1	
LSA general header	Type: 2
255.255.255.0	
10.24.7.14	
10.24.7.15	
10.24.7.16	



EXAMPLE 5

In Figure 14.37, which router(s) sends out router link LSAs?

See Next Slide

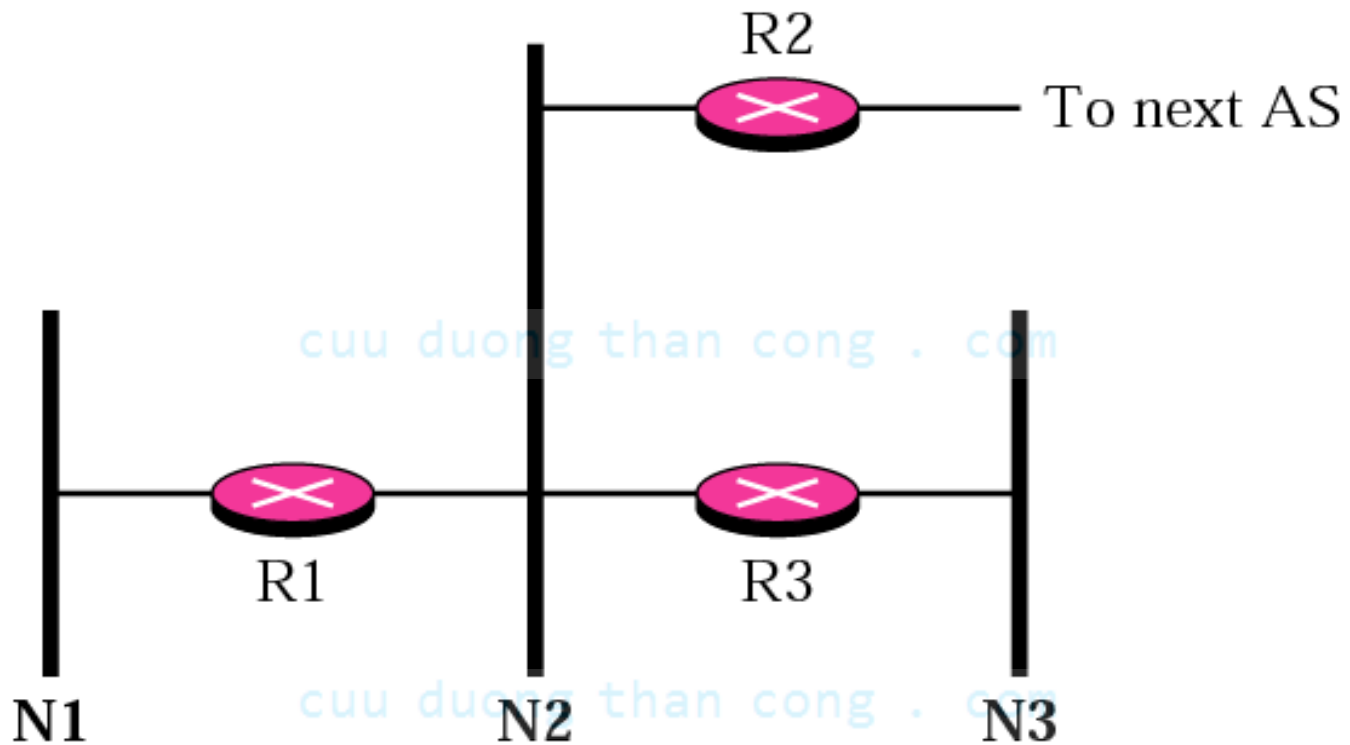
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Solution

All routers advertise router link LSAs.

- a. R1 has two links, N1 and N2.*
- b. R2 has one link, N1.*
- c. R3 has two links, N2 and N3.*

Figure 14.37 *Example 5 and Example 6*





EXAMPLE 6

In Figure 14.37, which router(s) sends out the network link LSAs?

Solution

All three network must advertise network links:

- a. Advertisement for N1 is done by R1 because it is the only attached router and therefore the designated router.*
- b. Advertisement for N2 can be done by either R1, R2, or R3, depending on which one is chosen as the designated router.*
- c. Advertisement for N3 is done by R3 because it is the only attached router and therefore the designated router.*

Figure 14.38 *Summary link to network*

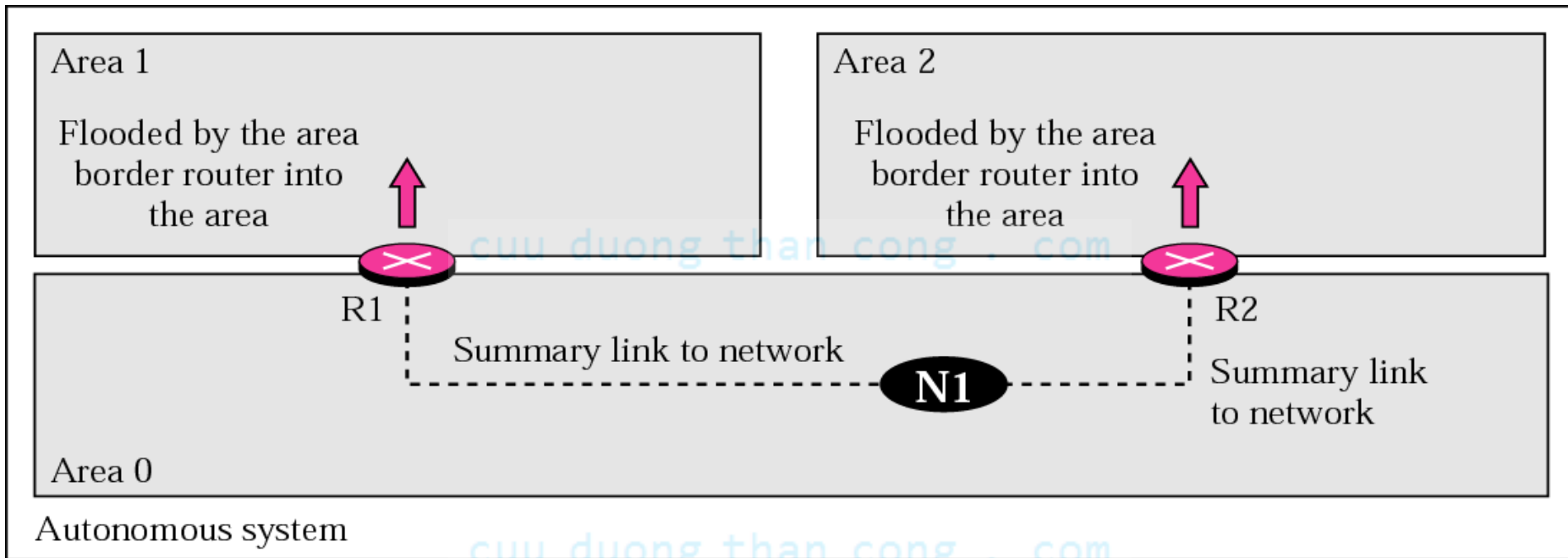


Figure 14.39 *Summary link to network LSA*

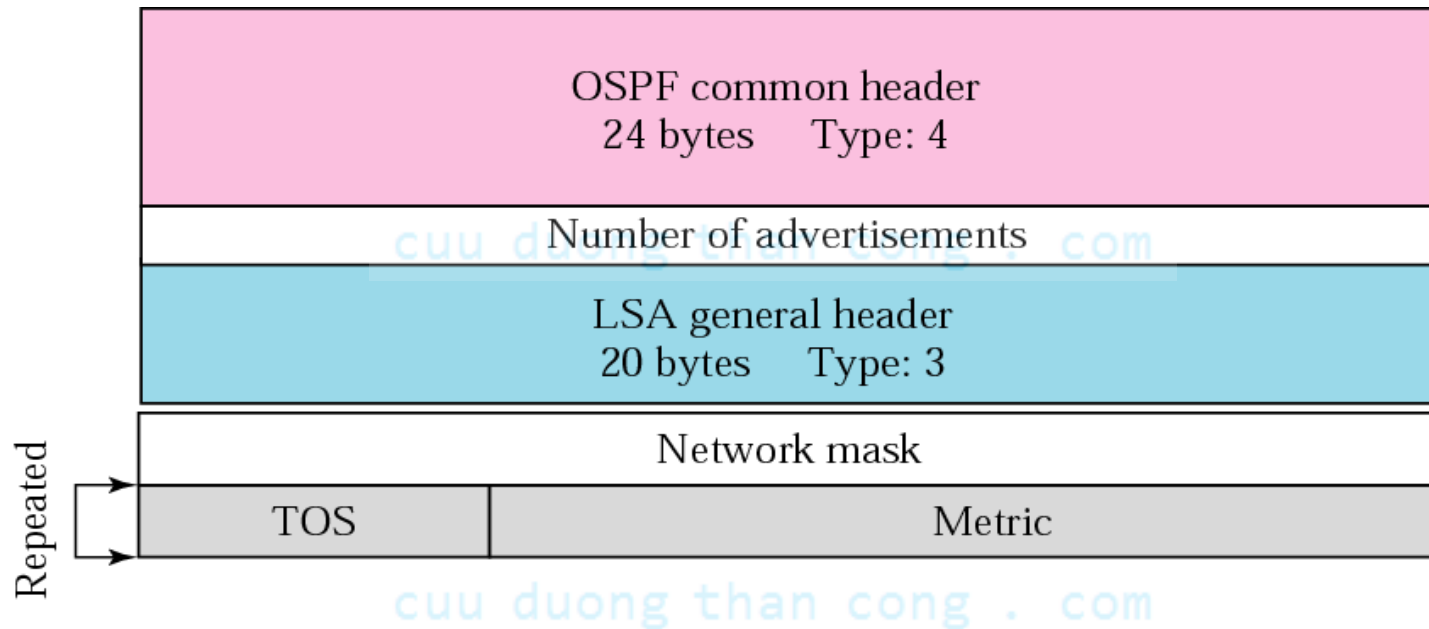


Figure 14.40 *Summary link to AS boundary router*

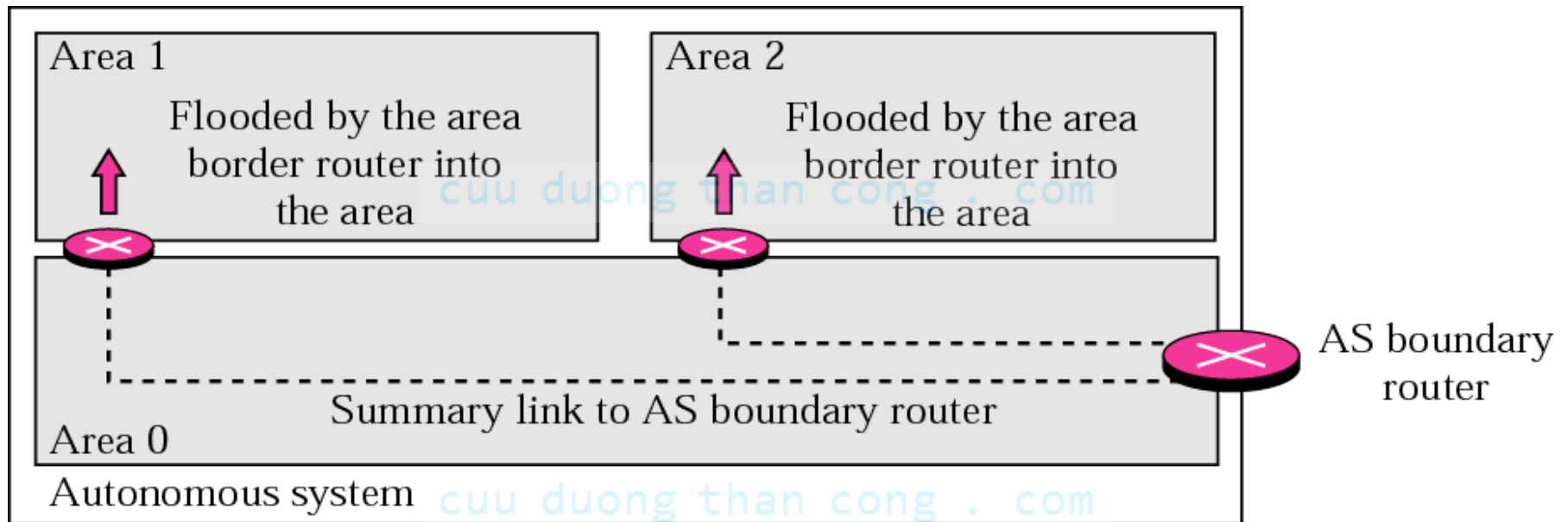


Figure 14.41 *Summary link to AS boundary router LSA*

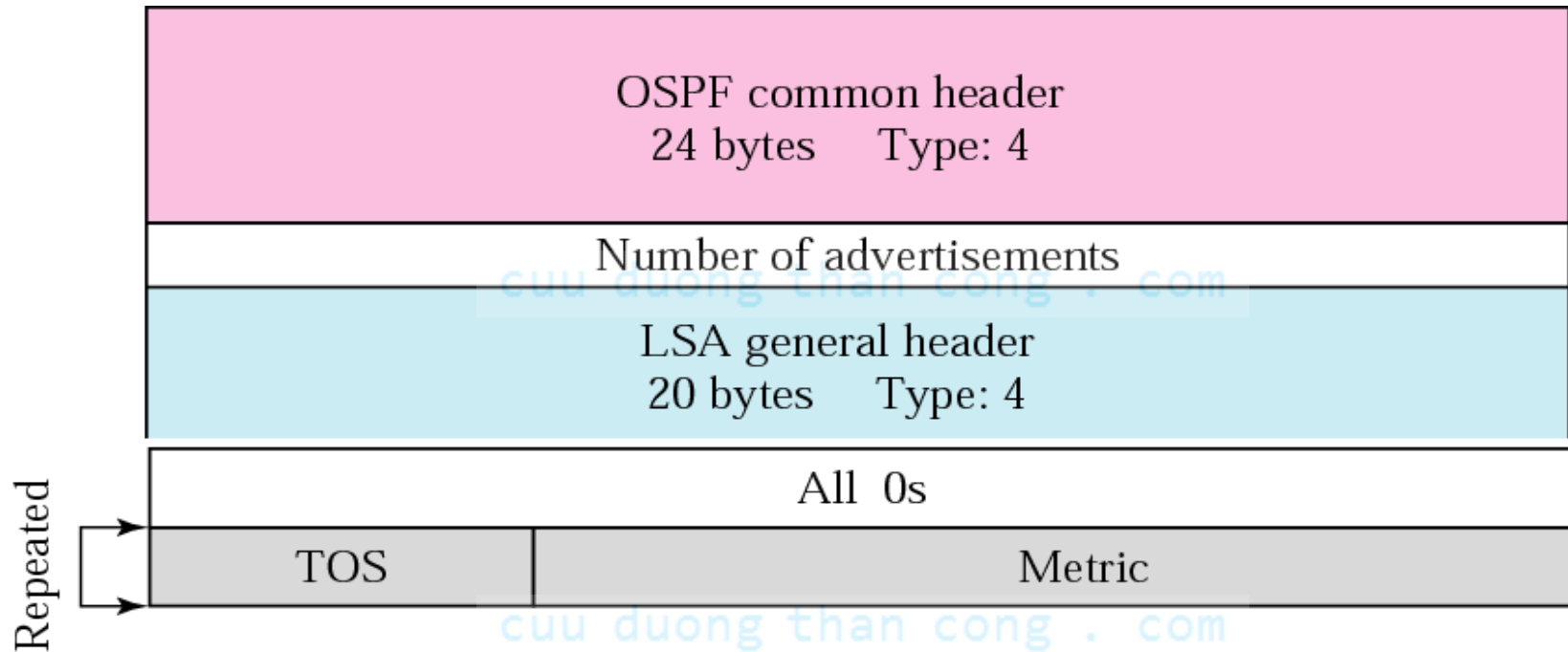


Figure 14.42 *External link*

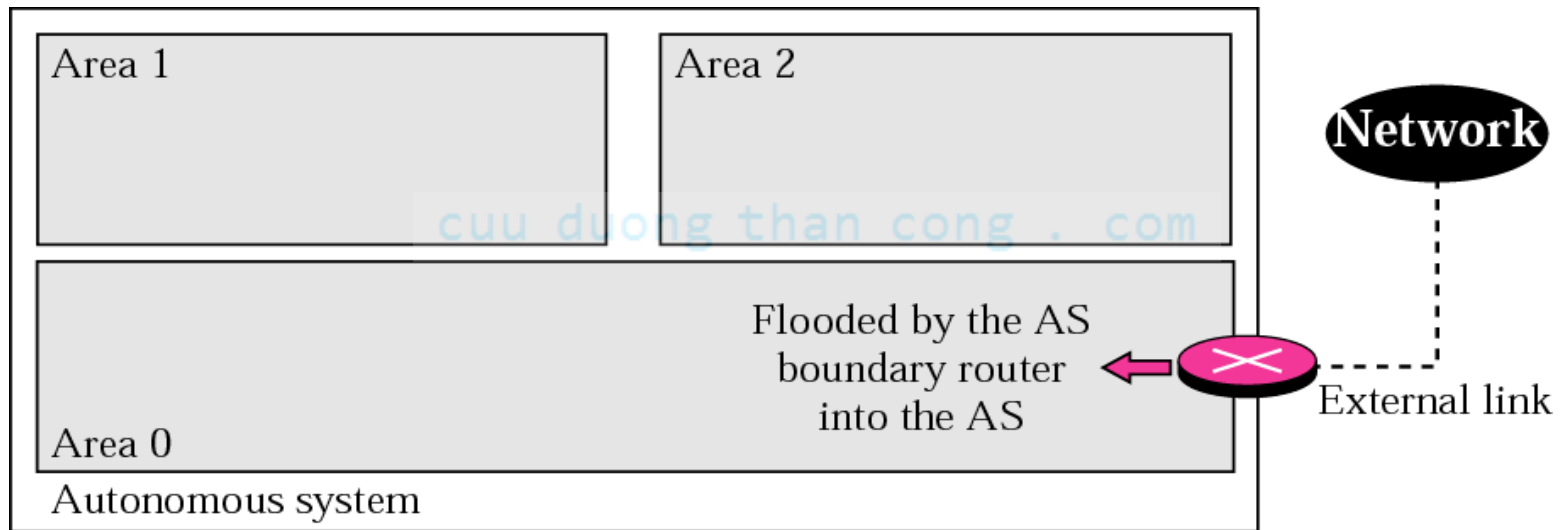


Figure 14.43 *External link LSA*

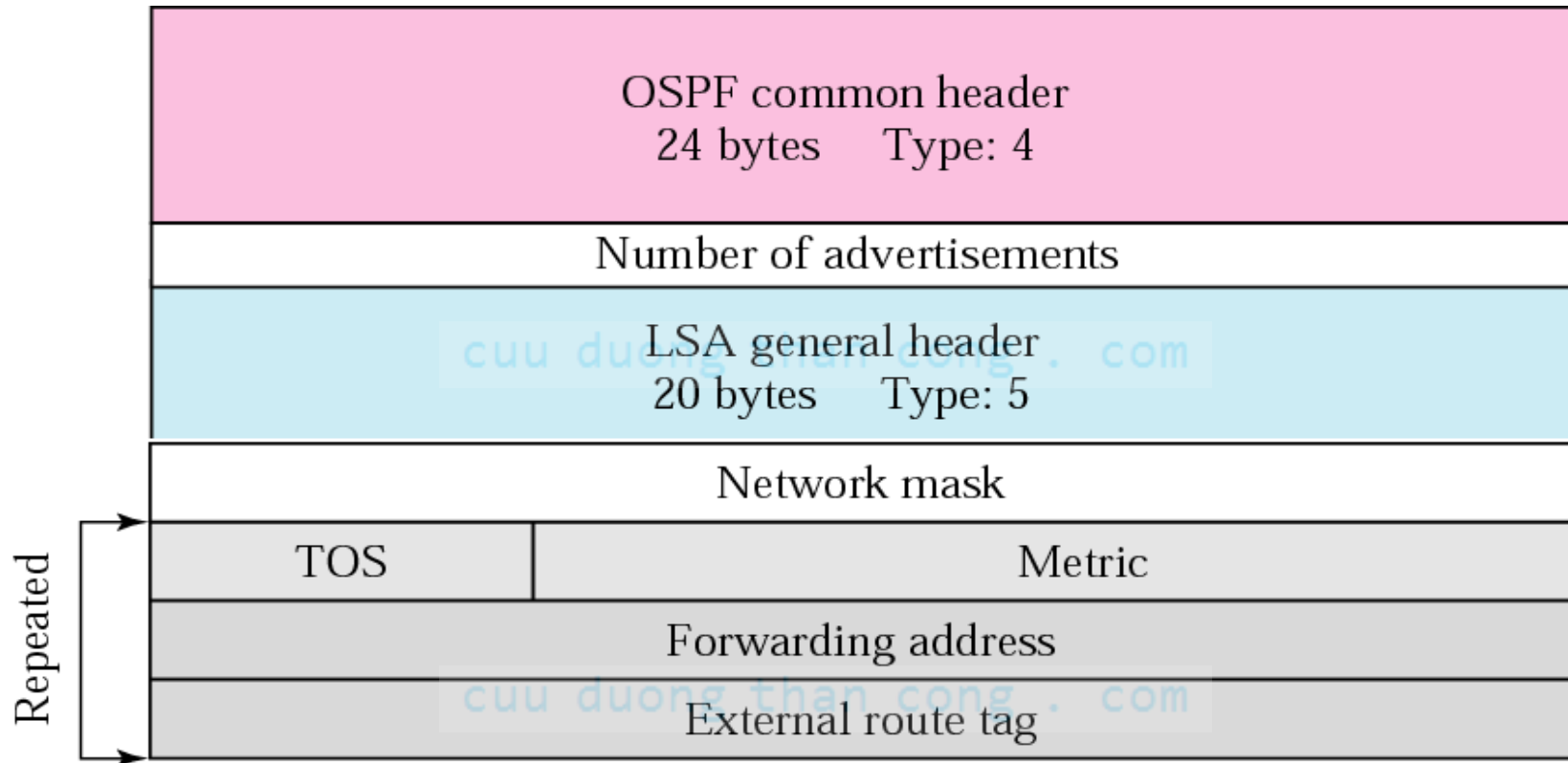


Figure 14.44 *Hello packet*

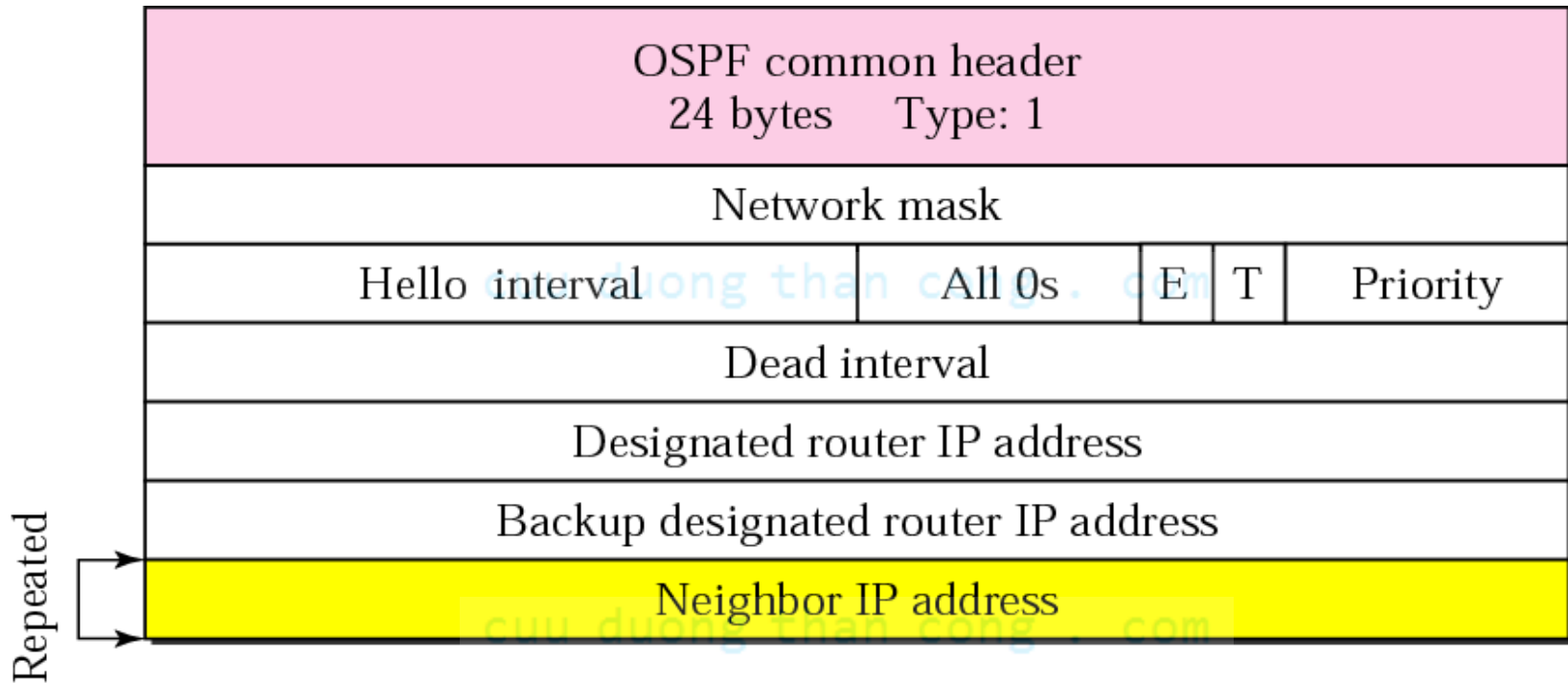


Figure 14.45 *Database description packet*

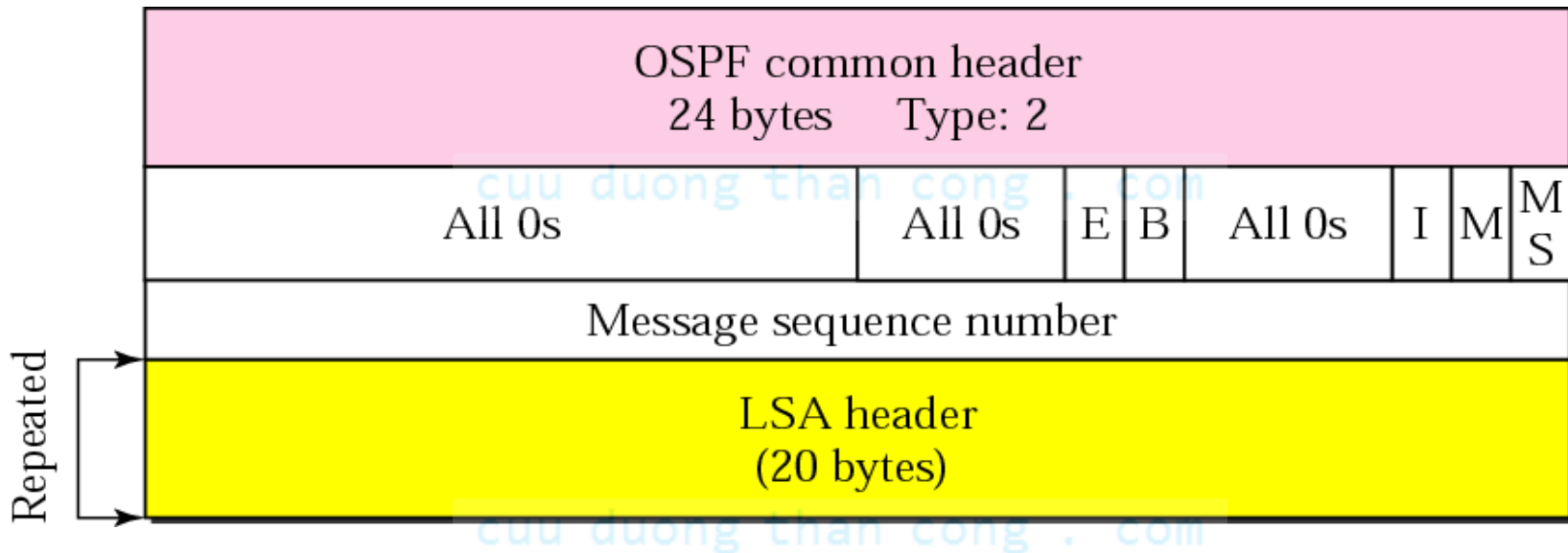


Figure 14.46 *Link state request packet*

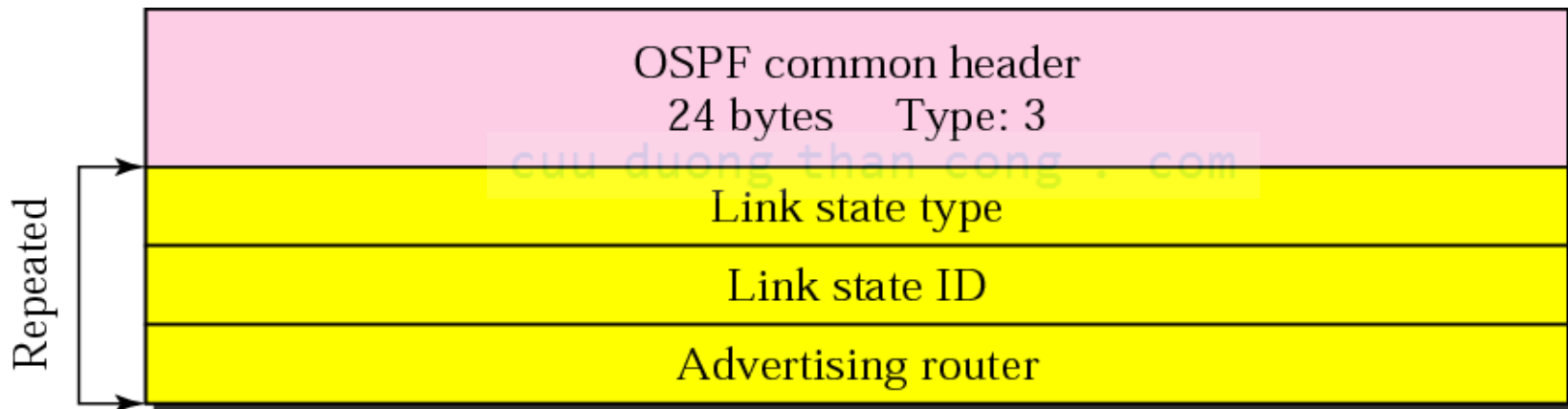
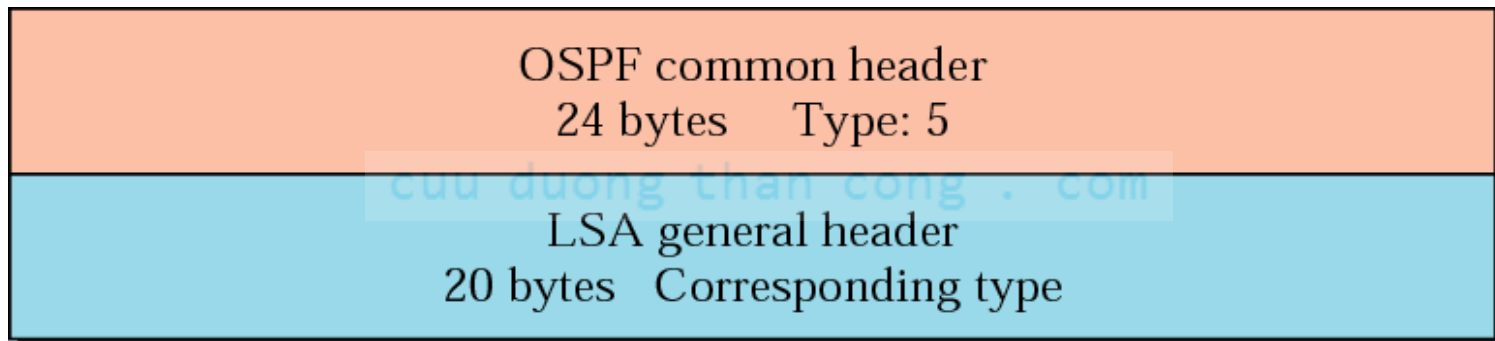


Figure 14.47 *Link state acknowledgment packet*





Note:

OSPF packets are encapsulated in IP datagrams.

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14.6 PATH VECTOR ROUTING

Path vector routing is similar to distance vector routing. There is at least one node, called the speaker node, in each AS that creates a routing table and advertises it to speaker nodes in the neighboring ASs..

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The topics discussed in this section include:

Initialization

Sharing

Updating

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Figure 14.48 *Initial routing tables in path vector routing*

Dest. Path

A1	AS1
A2	AS1
A3	AS1
A4	AS1
A5	AS1

A1 Table AS 1

Dest. Path

C1	AS3
C2	AS3
C3	AS3

C1 Table

AS 3

Dest. Path

D1	AS4
D2	AS4
D3	AS4
D4	AS4

D1 Table

Dest. Path

B1	AS2
B2	AS2
B3	AS2
B4	AS2

B1 Table

AS 2

AS 4

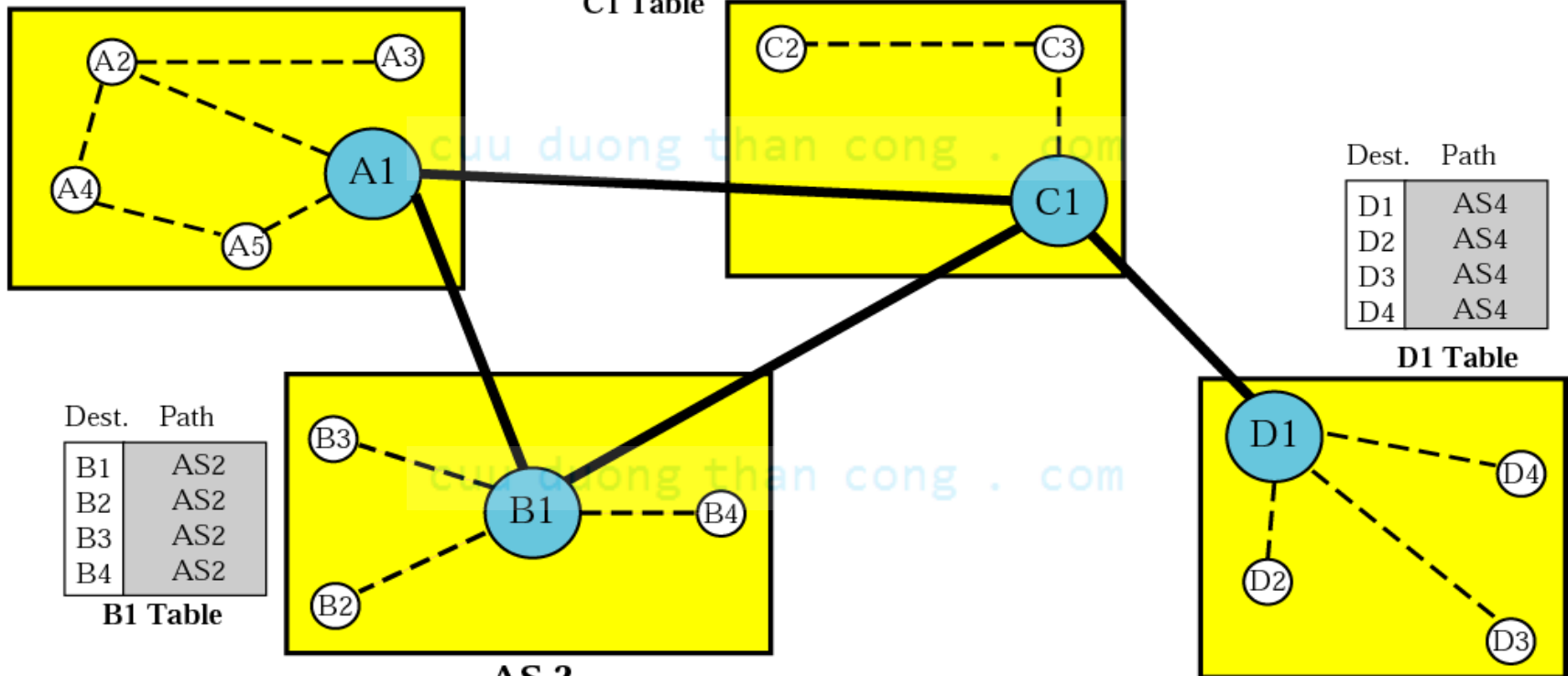


Figure 14.49 *Stabilized tables for four autonomous systems*

Dest.	Path
A1	AS1
...	
A5	AS1
B1	AS1-AS2
...	...
B4	AS1-AS2
C1	AS1-AS3
...	...
C3	AS1-AS3
D1	AS1-AS2-AS4
...	...
D4	AS1-AS2-AS4

A1 Table

Dest.	Path
A1	AS2-AS1
...	
A5	AS2-AS1
B1	AS2
...	...
B4	AS2
C1	AS2-AS3
...	...
C3	AS2-AS3
D1	AS2-AS3-AS4
...	...
D4	AS2-AS3-AS4

B1 Table

Dest.	Path
A1	AS3-AS1
...	
A5	AS3-AS1
B1	AS3-AS2
...	...
B4	AS3-AS2
C1	AS3
...	...
C3	AS3
D1	AS3-AS4
...	...
D4	AS3-AS4

C1 Table

Dest.	Path
A1	AS4-AS3-AS1
...	
A5	AS4-AS3-AS1
B1	AS4-AS3-AS2
...	...
B4	AS4-AS3-AS2
C1	AS4-AS3
...	...
C3	AS4-AS3
D1	AS4
...	...
D4	AS4

D1 Table

14.7 BGP

Border Gateway Protocol (BGP) is an interdomain routing protocol using path vector routing. It first appeared in 1989 and has gone through four versions.

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The topics discussed in this section include:

Types of Autonomous Systems

Path Attributes

BGP Sessions

External and Internal BGP

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Types of Packets

Packet Format

Encapsulation

Figure 14.50 *Internal and external BGP sessions*

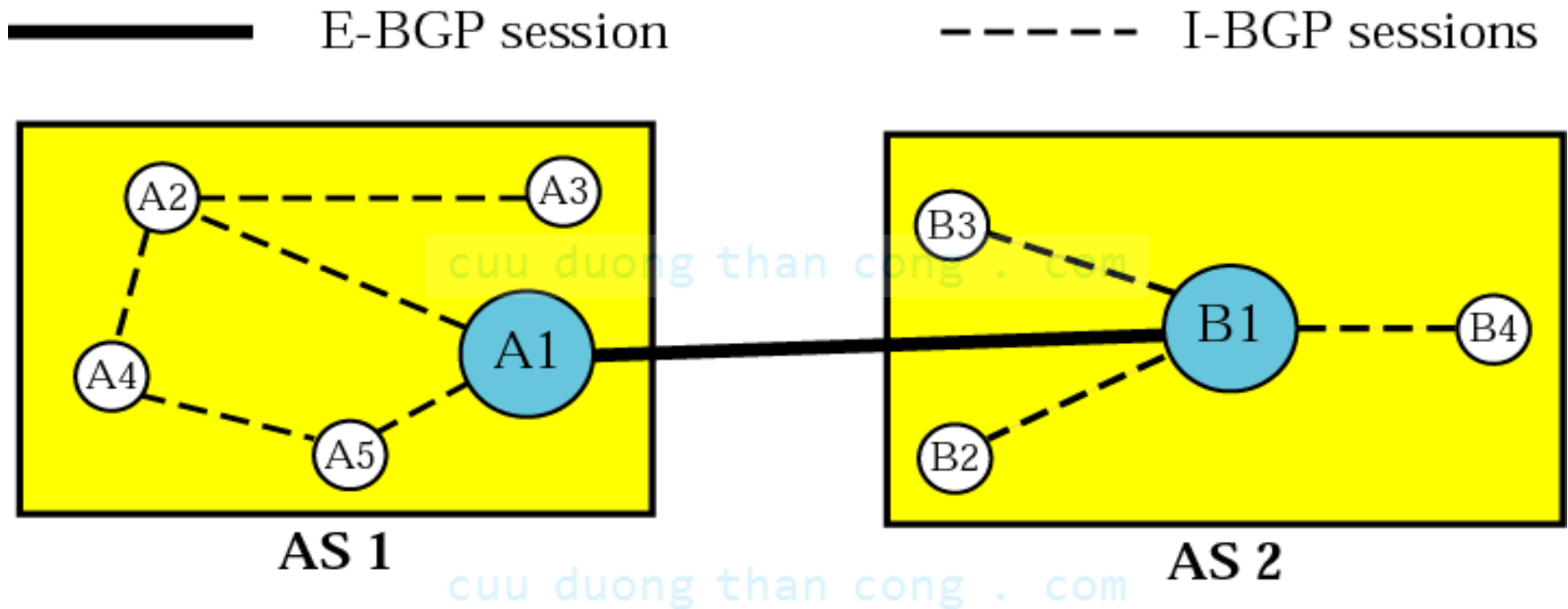


Figure 14.51 *Types of BGP messages*

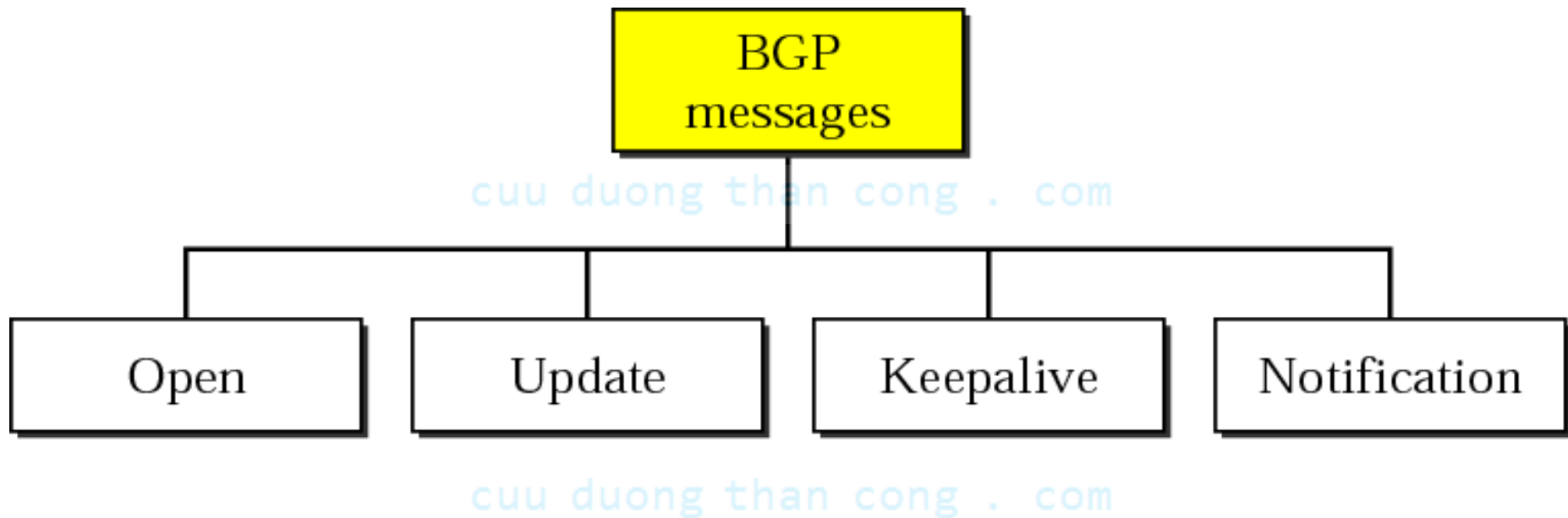


Figure 14.52 *BGP packet header*

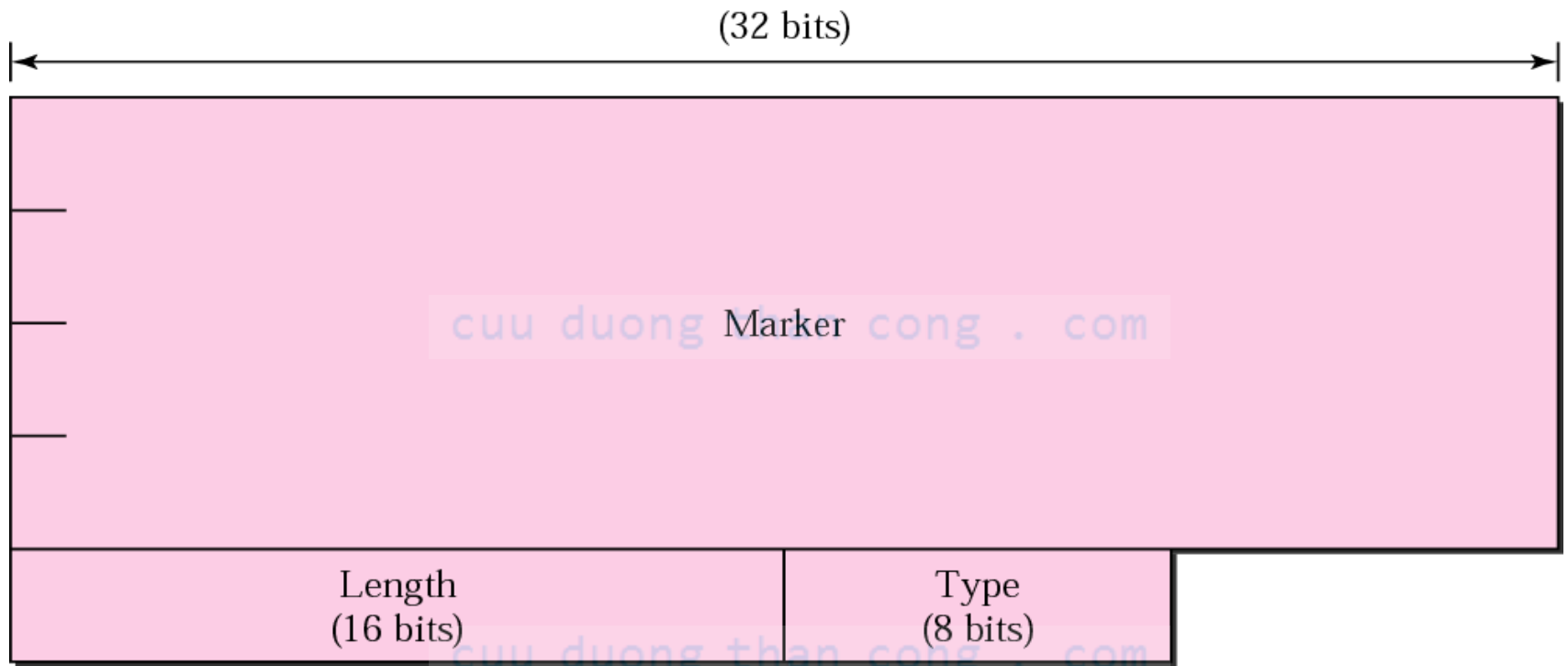


Figure 14.53 *Open message*

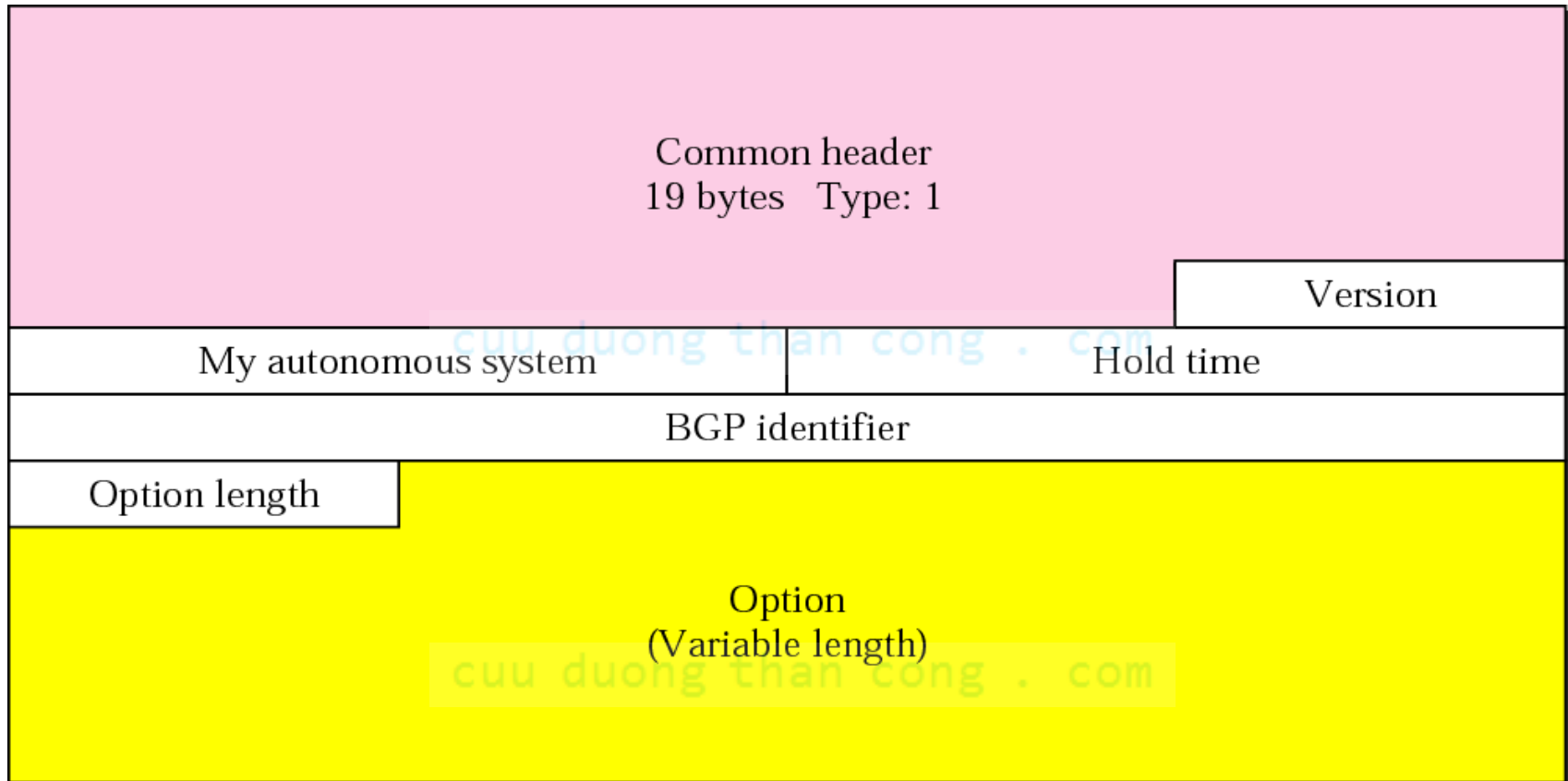
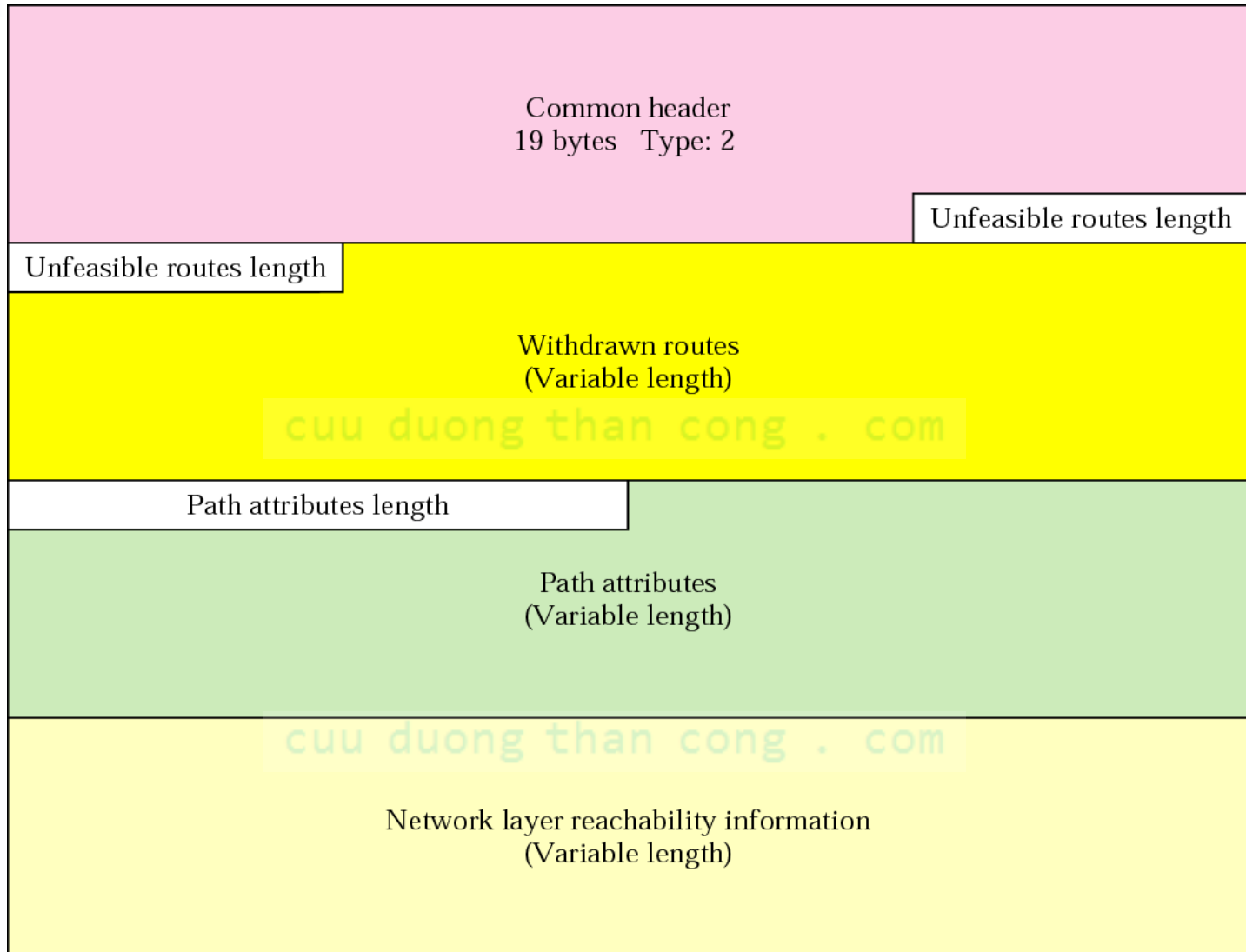


Figure 14.54 *Update message*



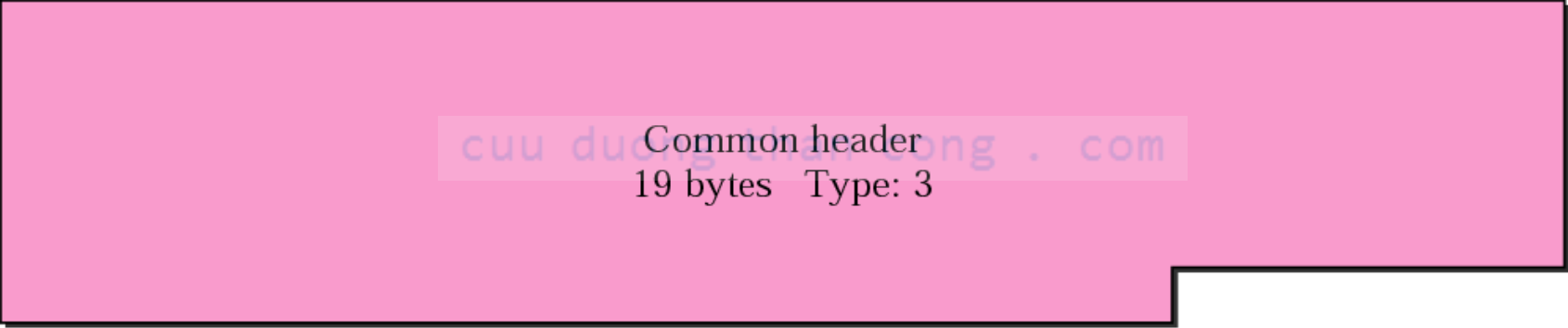


Note:

BGP supports classless addressing and CIDR.

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Figure 14.55 *Keepalive message*



Common header
19 bytes Type: 3

Figure 14.56 *Notification message*

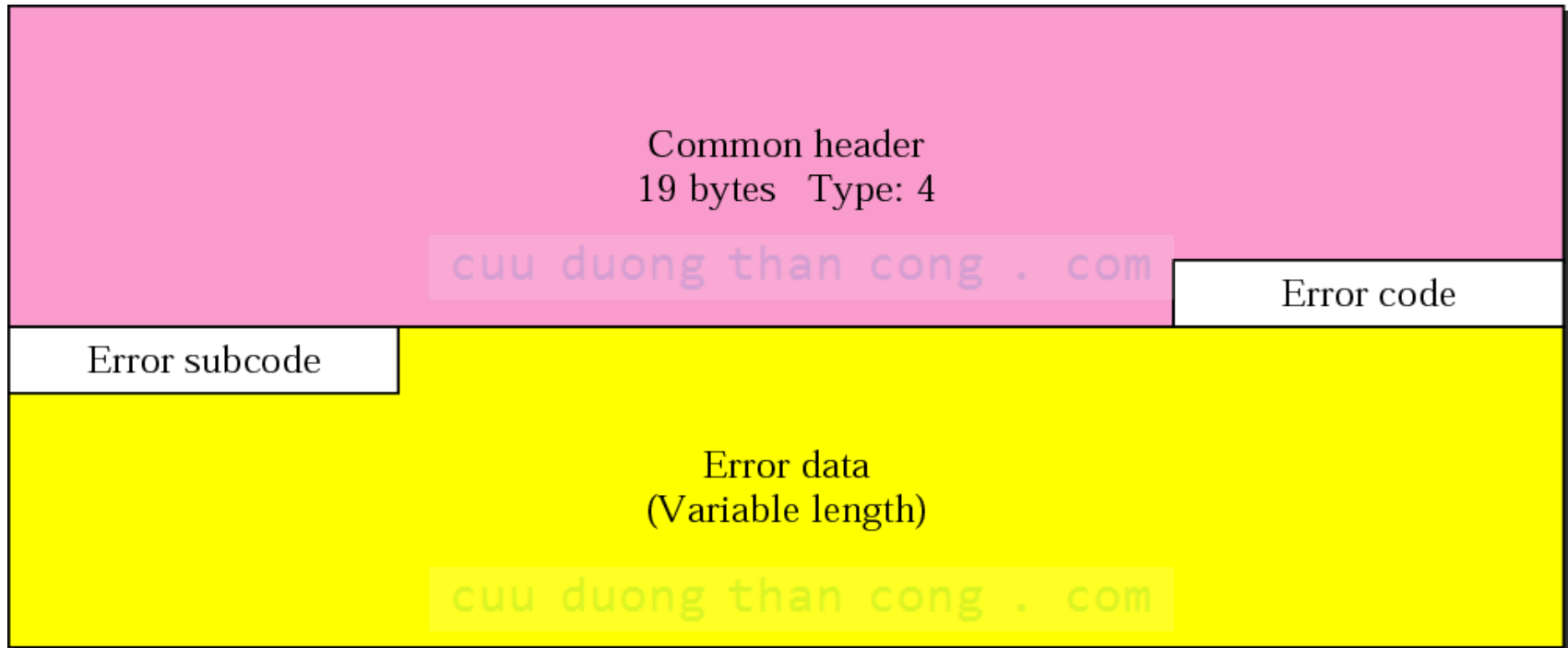


Table 14.3 Error codes

<i>Error Code</i>	<i>Error Code Description</i>	<i>Error Subcode Description</i>
1	Message header error	Three different subcodes are defined for this type of error: synchronization problem (1), bad message length (2), and bad message type (3).
2	Open message error	Six different subcodes are defined for this type of error: unsupported version number (1), bad peer AS (2), bad BGP identifier (3), unsupported optional parameter (4), authentication failure (5), and unacceptable hold time (6).
3	Update message error	Eleven different subcodes are defined for this type of error: malformed attribute list (1), unrecognized well-known attribute (2), missing well-known attribute (3), attribute flag error (4), attribute length error (5), invalid origin attribute (6), AS routing loop (7), invalid next hop attribute (8), optional attribute error (9), invalid network field (10), malformed AS_PATH (11).
4	Hold timer expired	No subcode defined.
5	Finite state machine error	This defines the procedural error. No subcode defined.
6	Cease	No subcode defined.



Note:

***BGP uses the services of TCP
on port 179.***