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

Areas

- OSPF divides an autonomous system into *areas*
  - To handle routing efficiently and in a timely manner
- A collection of networks, hosts, and routers all contained within an autonomous system
- Thus, an autonomous system can be divided into many different areas
- All networks inside an area must be connected

Areas (Cont.)

- Routers inside an area *flood the area* with *routing information*

- At the border of an area, special routers called *area border routers*
  - Summarize the information about the area and sent it to other areas

Areas (Cont.)

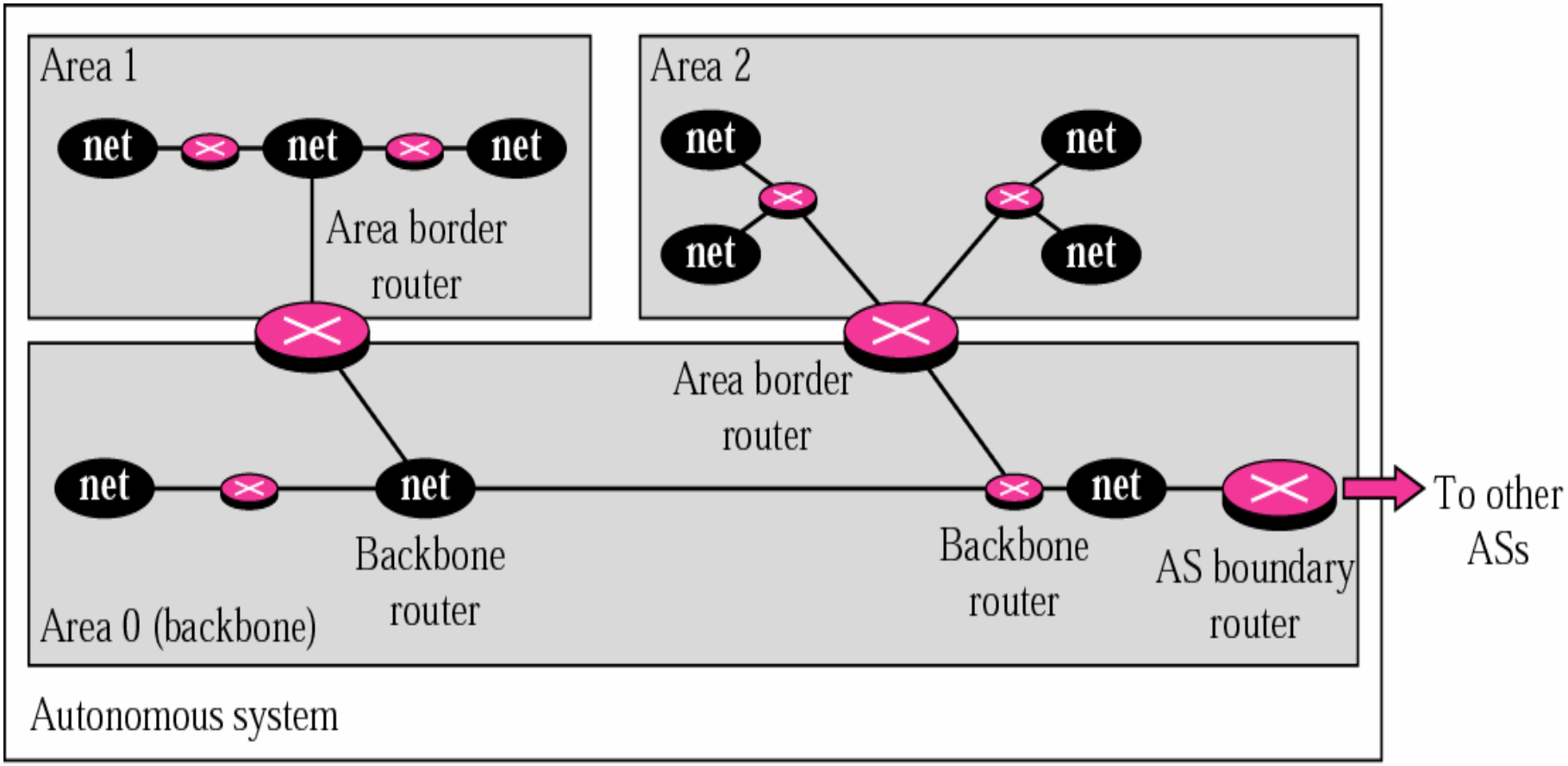
- Among the area inside an autonomous system is a *special area* called *backbone*
  - All of the areas inside an AS must be connected to the backbone
- The routers inside the backbone are called the *backbone routers*
  - A *backbone router* can also be an *area border router*

Areas (Cont.)

- If the connectivity between a backbone and an area is broken
  - A *virtual link* must be created by the administration
- Each area has an *area identification*
  - The area identification of the backbone is zero

Figure 12-18

Areas in an Autonomous System



The McGraw-Hill Companies, Inc., 2000

Metrics

- OSPF allows the administrator to assign a cost, called the *metric*, to each route
- Metric can be based on a type of service
  - Minimum delay
  - Maximum throughput
- A router can have multiple routing tables
  - Each based on a different type of service

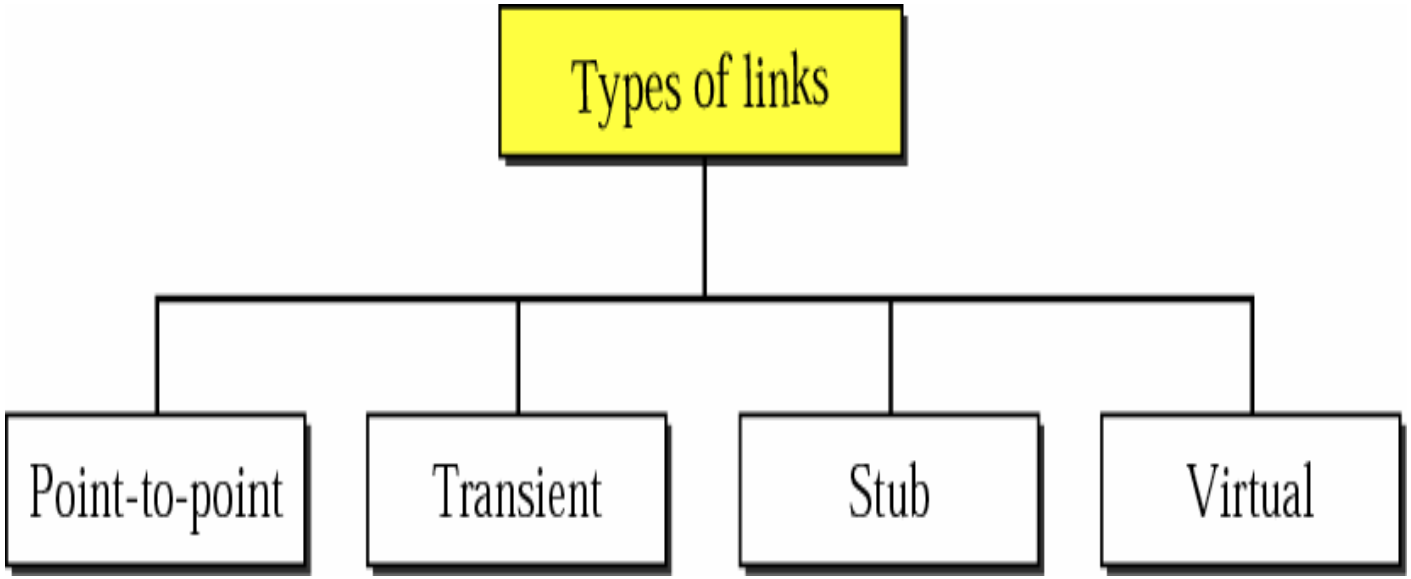
Types of Links

- In OSPF, a connection is called a *link*

- Four types of links
  - Point-to-point
  - Transient
  - Stub
  - Virtual

Figure 12-19

Types of Links



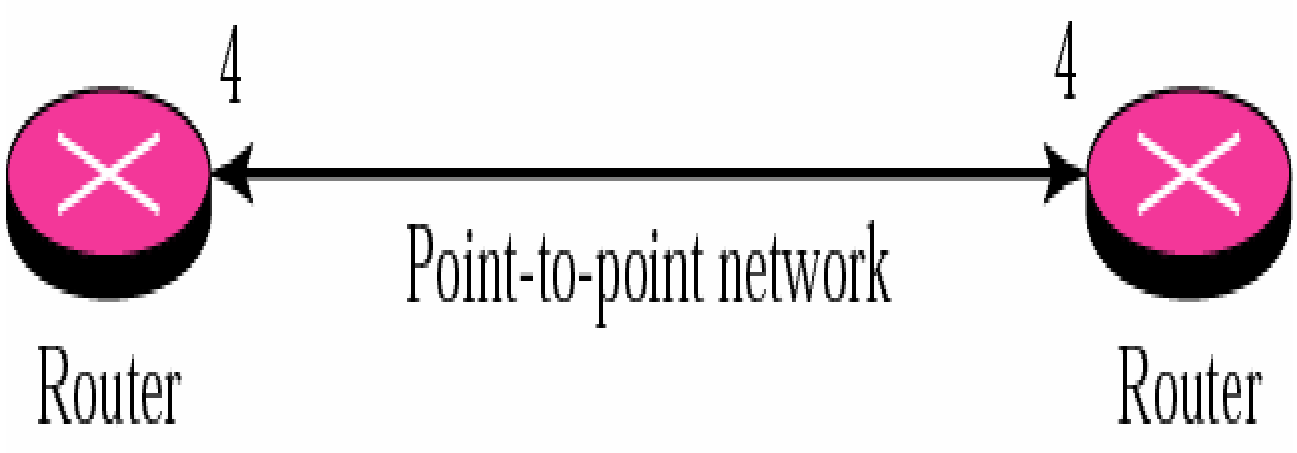
The McGraw-Hill Companies, Inc., 2000

Point-to-Point Link

- Connect two routers without any other host or router in these two routers
- Example
  - Telephone line
  - T-line
- Graphically representation
  - The routers are represented by *nodes*
  - The link is represented by a *bidirectional edge*
- The *metric*
  - Usually the same at the two ends

Figure 13-20

Point-to-Point Link



The McGraw-Hill Companies, Inc., 2000

Transient Link

- A network with several routers attached to it
  - Data can enter through any of the routers and leave through any router
- Example
  - All LANs and some WANs with two or more routers

Transient Link (Cont.)

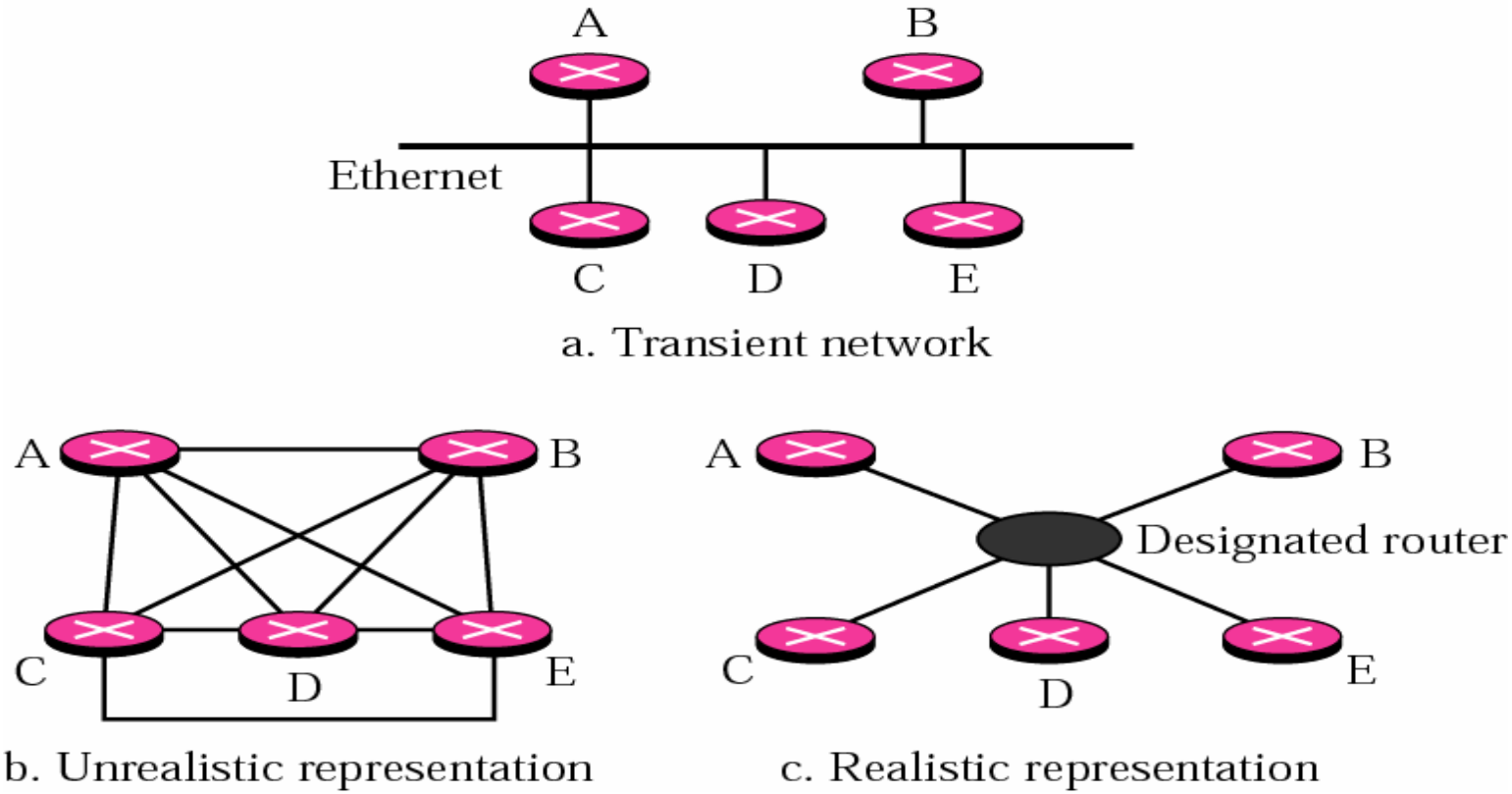
- Graphically representation
  - Figure b in the next slide. However, it is
    - **Not efficient**: each router need to advertise the neighborhood of four other routers
      - For a total of 20 advertisement
    - **Not realistic:** there is no single network (link) between each pair of routers
      - There should be only one network that serves as a crossroad between all five routers

Transient Link (Cont.)

- Reality: each router should be connected to every router *through one single network*
  - The network is represented by a node
  - However, network is not a machine
    - Cannot function as a router
- Solution: one of the routers acts as a single network
  - This router has a dual purpose: a *true router* and a *designated router*
    - The link is represented as a *bidirectional edge*
    - Figure c in the next slide

Figure 12.21

Transient Link



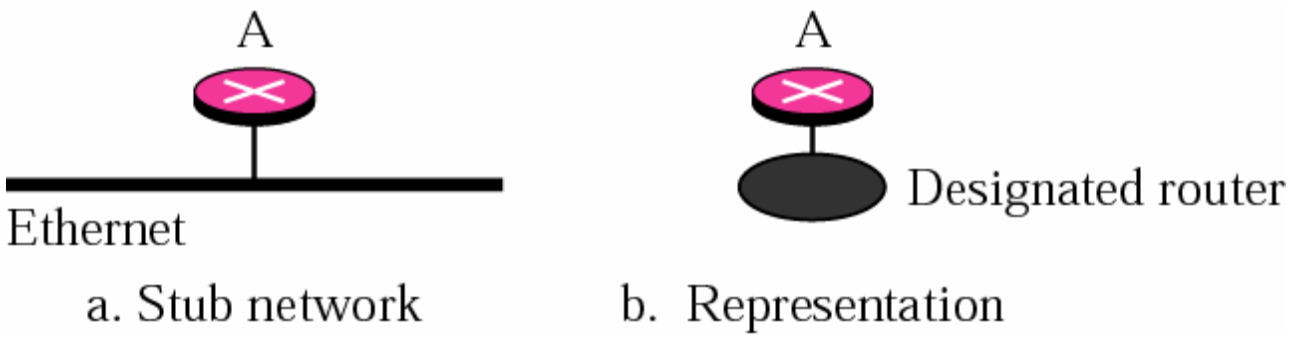
The McGraw-Hill Companies, Inc., 2000

Stub Link

- A network that is connected to only one router
  - Data packet enter and leave through this only one router
- A special case of transient network
- Graphically representation
  - The router as a node
  - The designated router as the network
  - Note, the link is only one-directional
    - From the router to the network
    - Because the network is the end point in the graph representation
      - See the following third slides

Figure 12.22

Stub Link



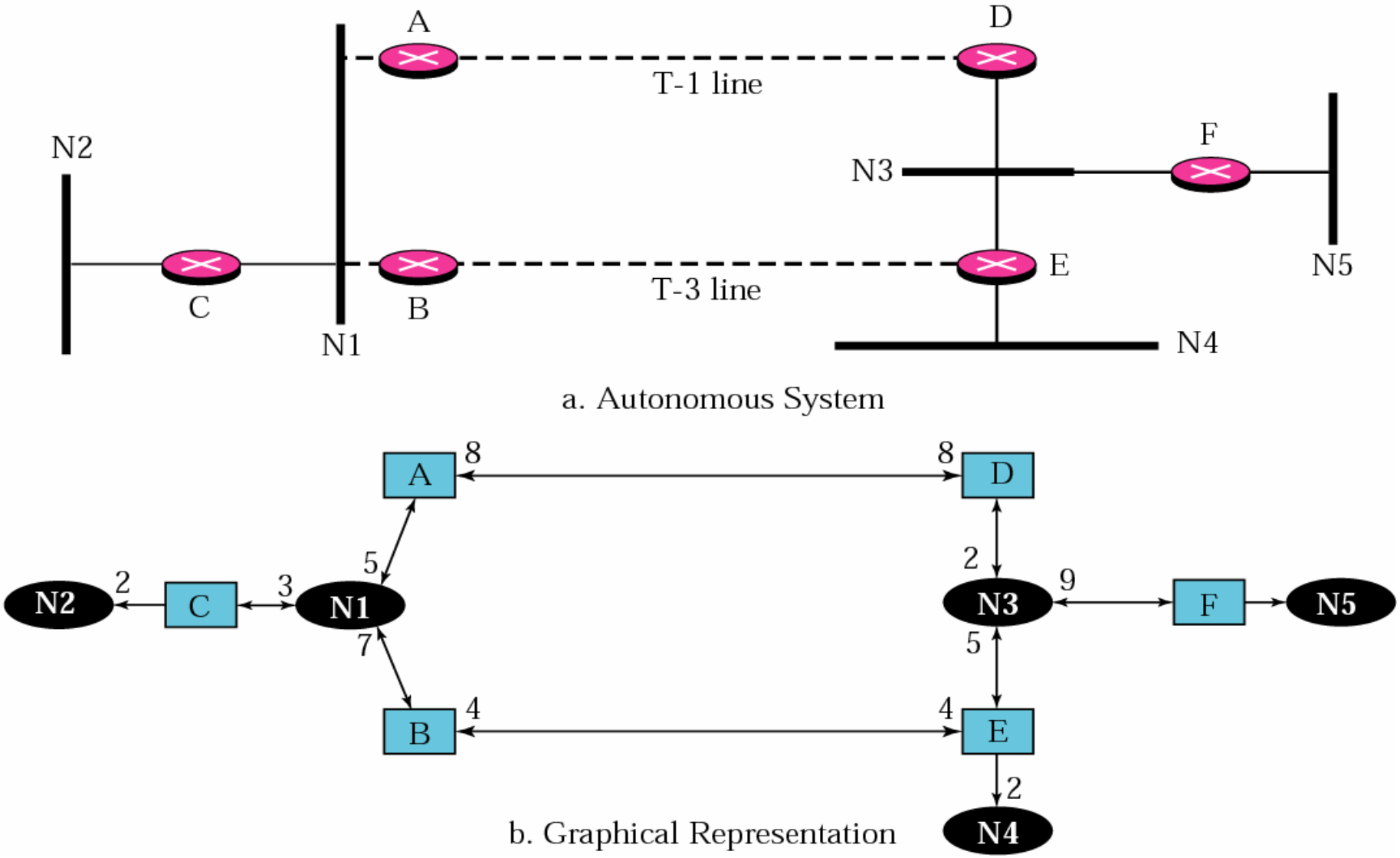
a. Stub network b. Representation

The McGraw-Hill Companies, Inc., 2000

Virtual Link

- When the link between two routers is broken
  - The administrator may create a virtual path between them using a longer path and may go through several routers

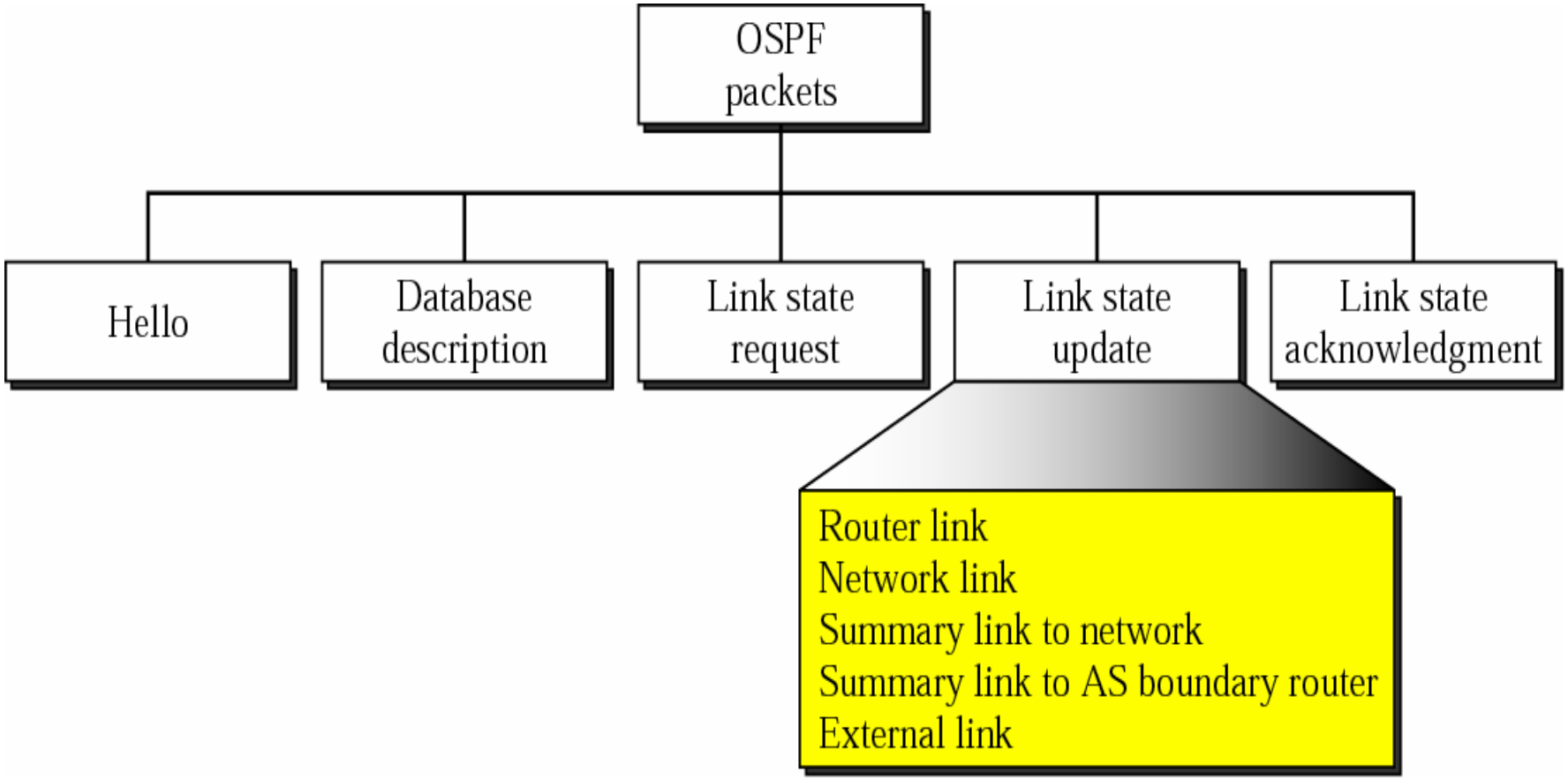
Figure 14.24 *Example of an AS and its graphical representation in OSPF*



Types of Packets

- OSPF uses five different packets
  - Hello packet
  - Database description packet
  - Link state request packet
  - Link state update packet
    - Router link
    - Network link
    - Summary link to network
    - Summary link to AS boundary router
    - External link
  - Link state acknowledgment packet

Types of OSPF Packets



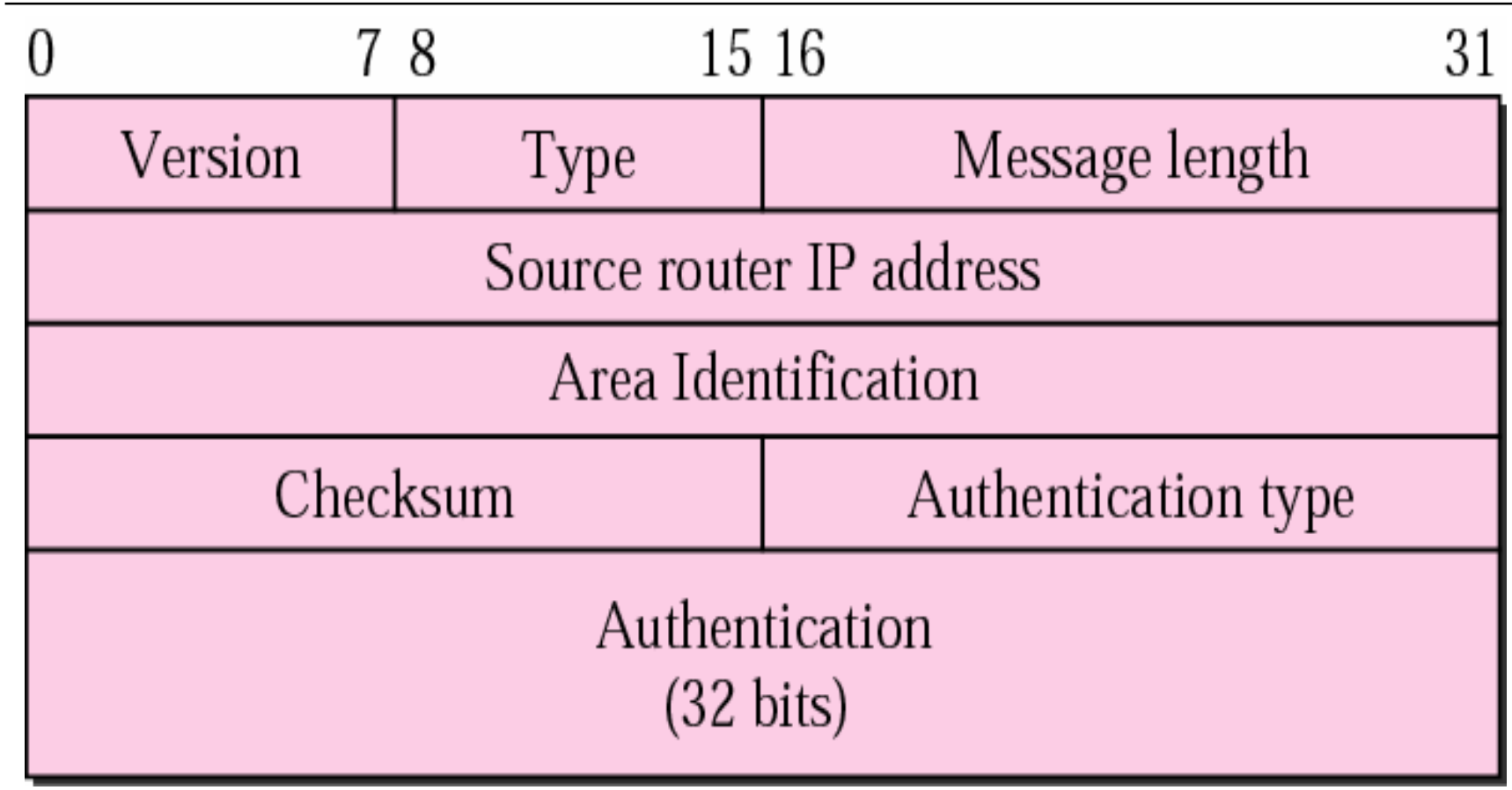
The McGraw-Hill Companies, Inc., 2000

Common Header

- All OSPF packets share the same header
  - Version: 8-bit
    - The version of the OSPF protocol. Currently, it is 2
  - Type: 8-bit
    - The type of the packet
  - Message length: 16-bit
    - The length of the total message including the header
  - Source router IP address: 32-bit
    - The IP address of the router that sends the packet

Figure 12.24

OSPF Common Header



The McGraw-Hill Companies, Inc., 2000

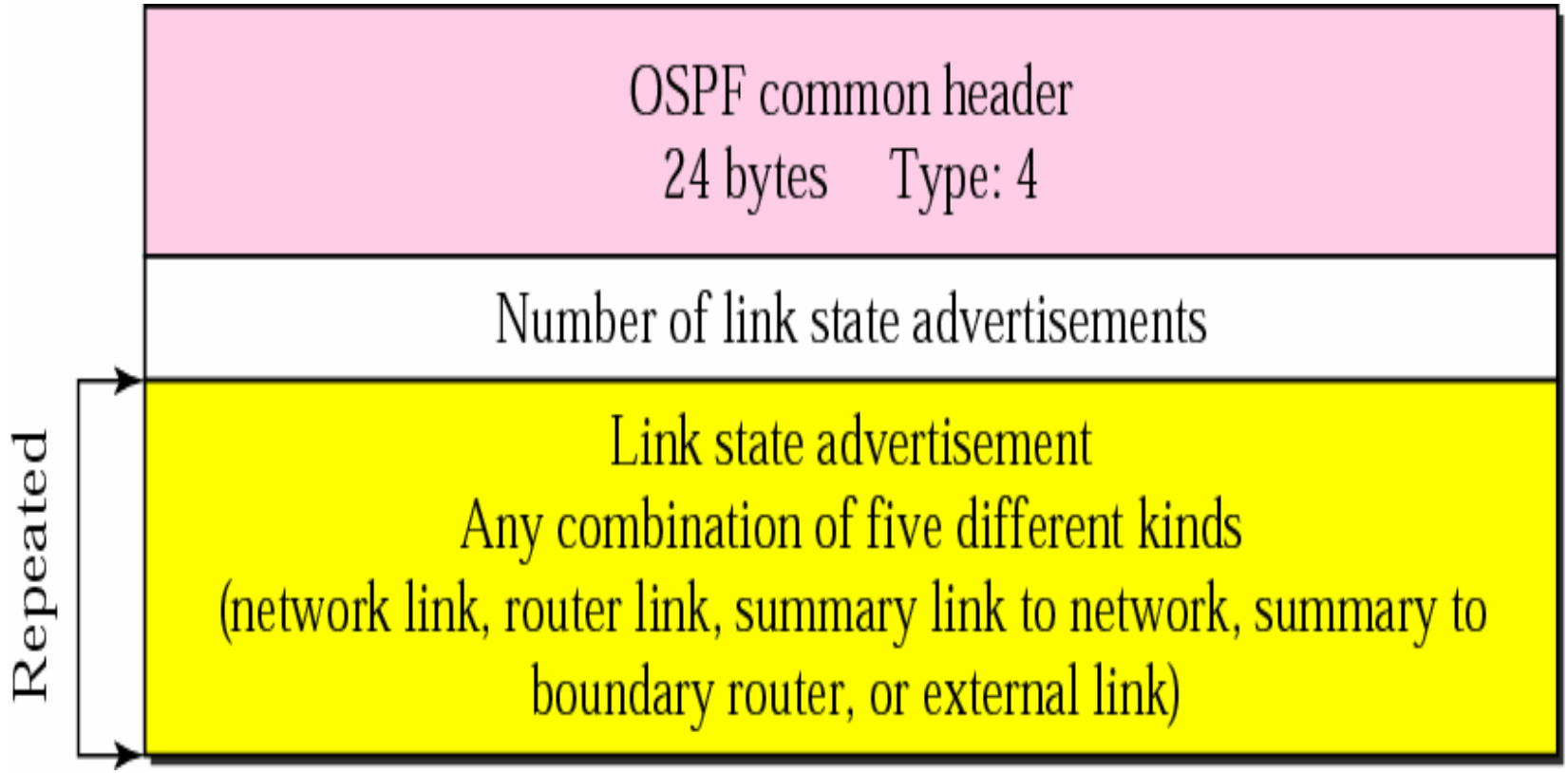
Common Header (Cont.)

- Area identification: 32-bit
  - The area within which the routing take place
- Checksum: 16-bit
  - Error detection on the entire packet excluding the authentication type and authentication data field
- Authentication type: 16-bit
  - Define the authentication method used in this area
  - 0: none, 1: password
- Authentication: 64-bit
  - The actual value of the authentication data
  - Filled with 0 if type = 0; eight-character password if type = 1

Link State Update Packet

- Used by a router to advertise the state of its links
- Each update packet may contain several different LSAs (List State Advertisement)
- Packet format
  - Number of link state advertisements: 32-bit
  - Link state advertisement
    - There are five different LSAs, as discussed before
    - All have the same general header, but different bodies

Figure 14.27 *Link state update packet*



LSA General Header

- Link state age: the number of seconds elapsed since this message was first generated
  - LSA goes from router to router, i.e., flooding
  - When a router create a message, age = 0
  - When each successive router forwards this message
    - Estimate the transmit time and add it to the age field
- E flag: if 1, the area is a stub area
  - i.e., an area that is connected to the backbone area by only one path

LSA General Header (Cont.)

- T flag: if 1, the router can handle multiple types of service
- Link state type
  - 1: router link
  - 2: network link
  - 3: summary link to network
  - 4: summary link to AS boundary router
  - 5: external link

LSA General Header (Cont.)

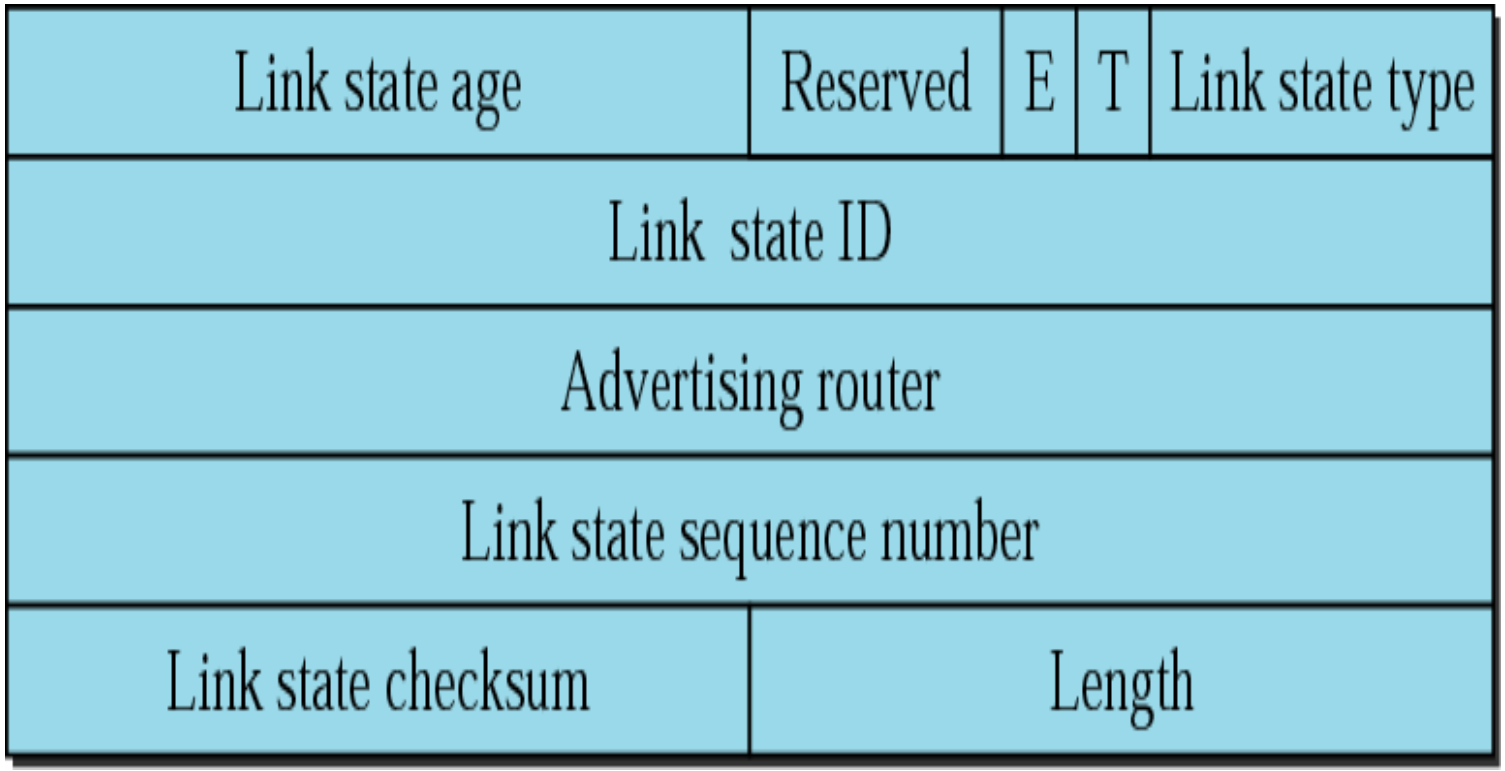
- Link state ID: depend on the type of link
  - Router link: IP address of the router
  - Network link: IP address of the designated router
  - Summary link to network: address of the network
  - Summary link to AS boundary router: IP address of the AS boundary router
  - External link: address of the external network

LSA General Header (Cont.)

- Advertisement router:
  - IP address of the router advertising this message
- Link state sequence number:
  - Sequence number assigned to each link state update message
- Link state checksum:
  - A special checksum algorithm: Fletcher's checksum
- Length:
  - Total packet length

Figure 13-29

LSA General Header



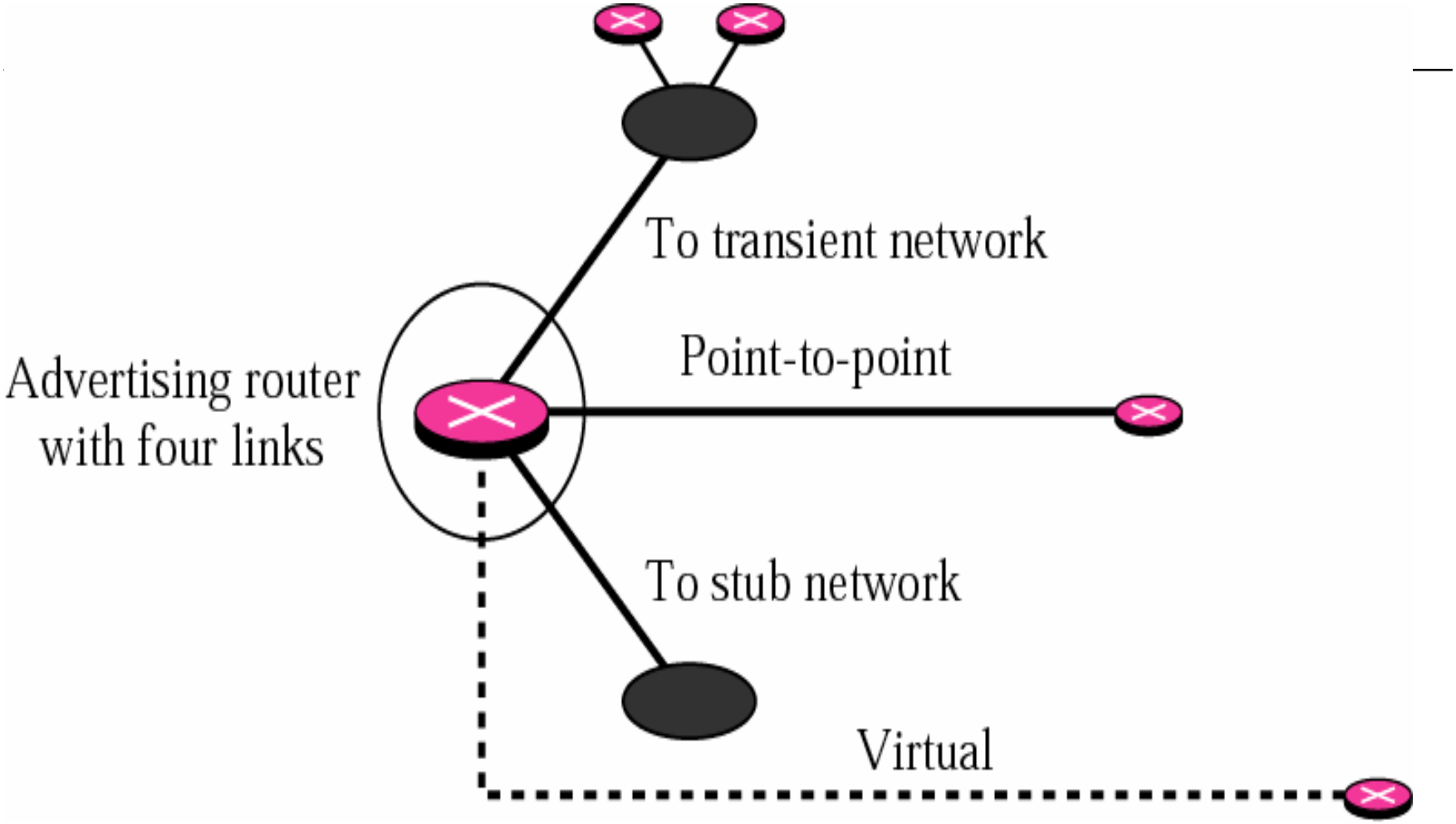
The McGraw-Hill Companies, Inc., 2000

Router Link LSA

- Define the link of a true router

- A true router uses this advertisement to announce information about
  - All of its links
  - What is at the other side of the links (neighbors)

Figure 14.29 *Router link*



Router Link LSA (Cont.)

- **Format**
  - Link ID:
    - Depend on the type of link, see Table 14.2
  - Link data:
    - Give additional information about the link, also depend on the type of link, see Table 14.2
  - Link type:
    - Four different types of links are defined based on the type of network, see Table 14.2
  - Number of types of services (TOS)
    - The number of type of services announced for each link
  - Metric for TOS 0:
    - Define the metrics for the default type of service (TOS 0)
  - TOS:
    - Define the type of service
  - Metric:
    - Define the metric for the corresponding TOS

Figure 14.30 *Router link LSA*

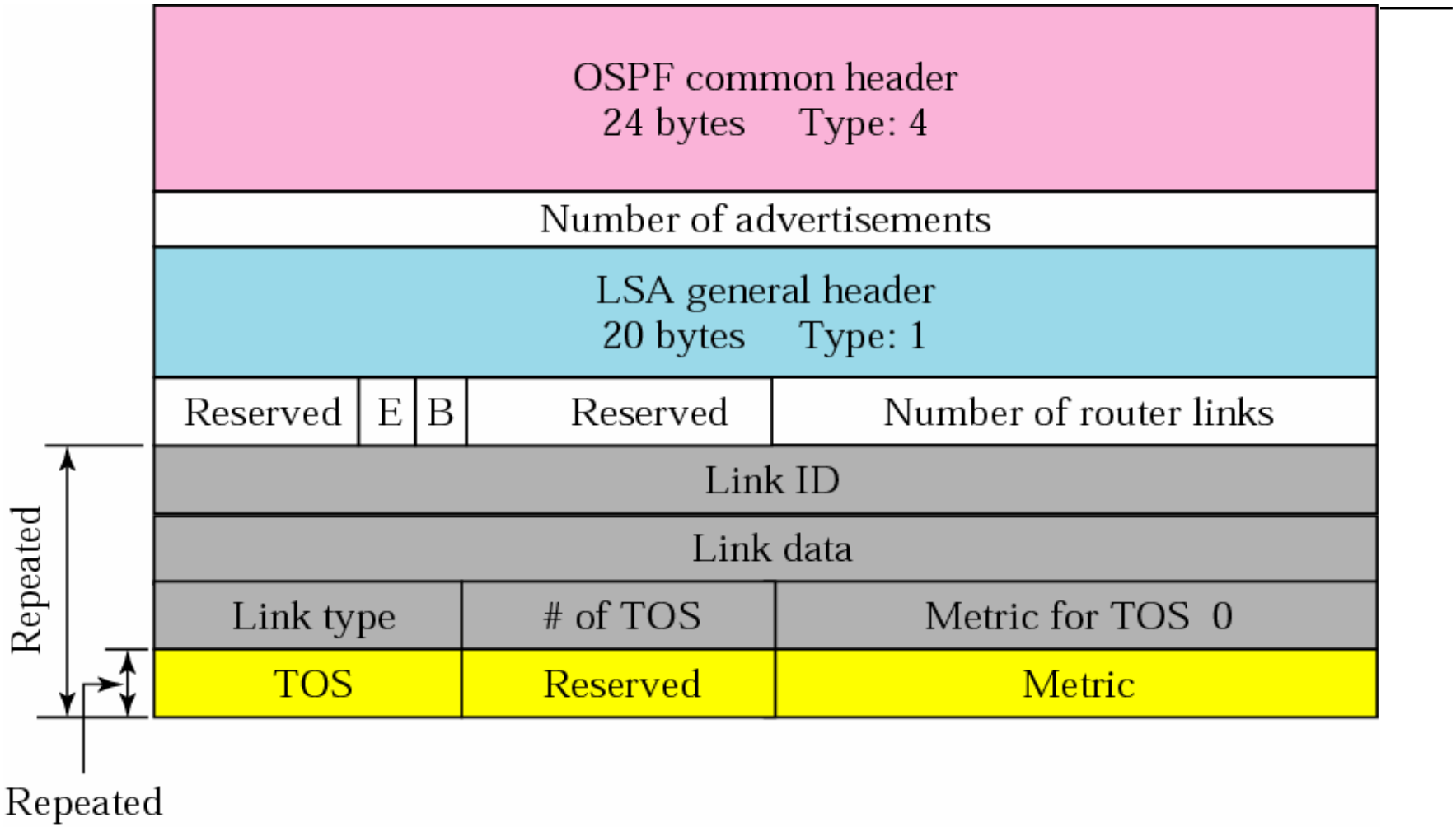


Table 14.2 *Link types, link identification, and link data*

Link Type	*Link Identification*	*Link Data*
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.

- This router has three links
  - Two of type 1 (point-to-point)
  - One of type 3 (stub network)
- Figure 14.32 shows the router link LSA

The McGraw-Hill Companies, Inc., 2000

Figure 14.31 *Example 3*

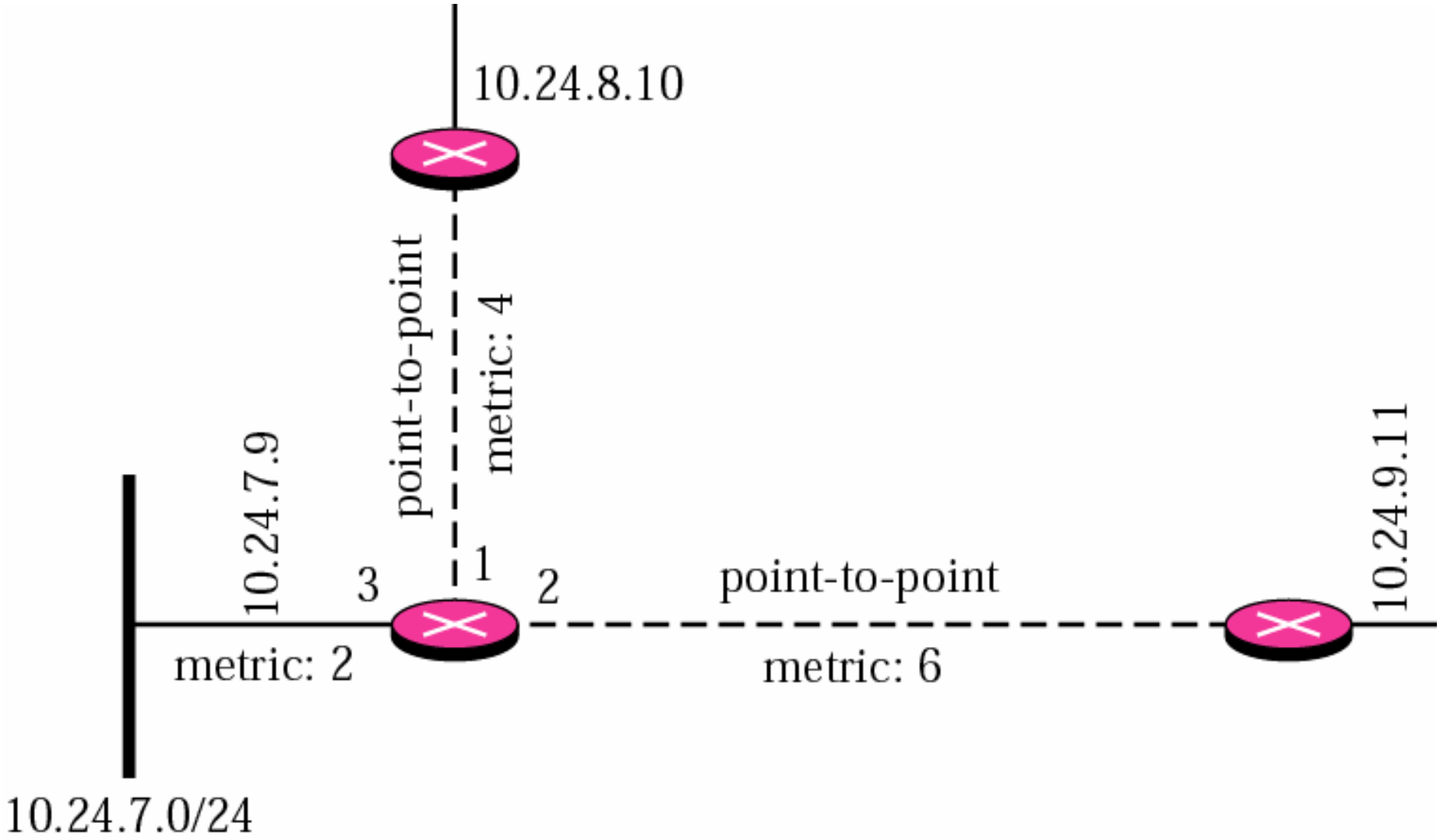
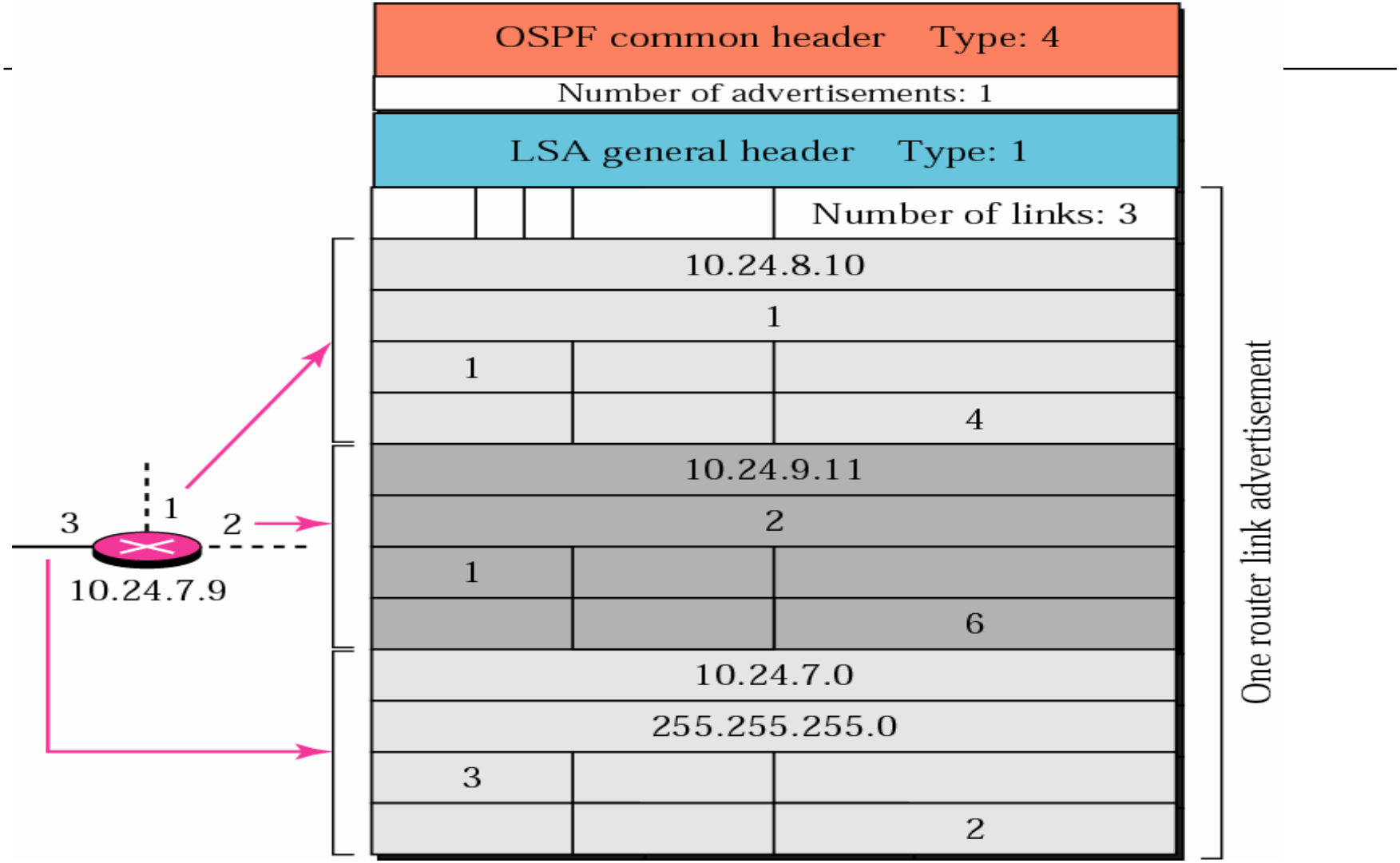


Figure 14.32 *Solution to Example 3*



Network Link LSA

- Define the links of a network
- A ***designed router***, on behalf of the ***transient network***, distributes this type of LSA packet
- Announce the *existence of all of the routers connected to* the network
  - See Fig. 14.33

Network Link LSA (Cont.)

- **Format**
  - Network mask
    - Define the network mask
  - Attached router
    - Define the IP addresses of all attached routers

Figure 14.33 *Network link*

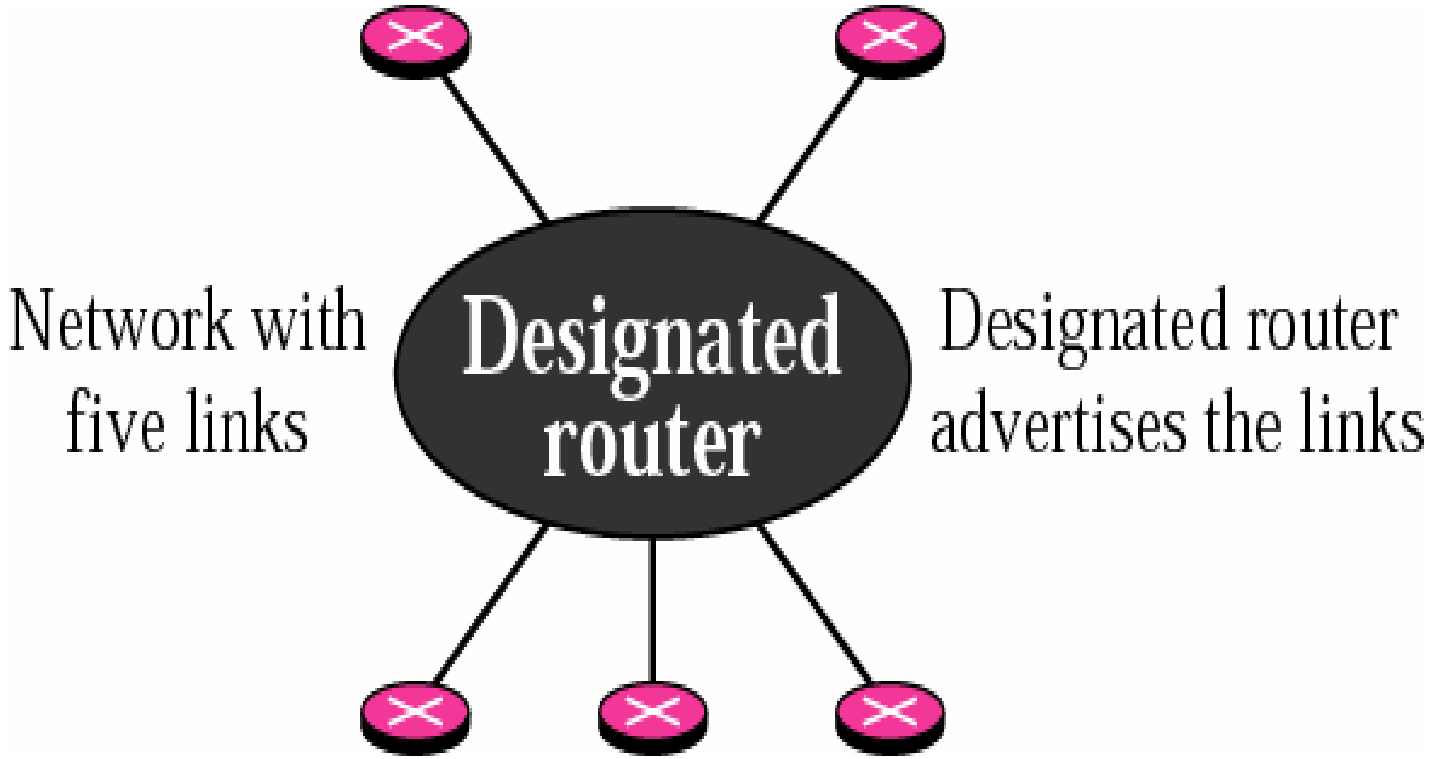
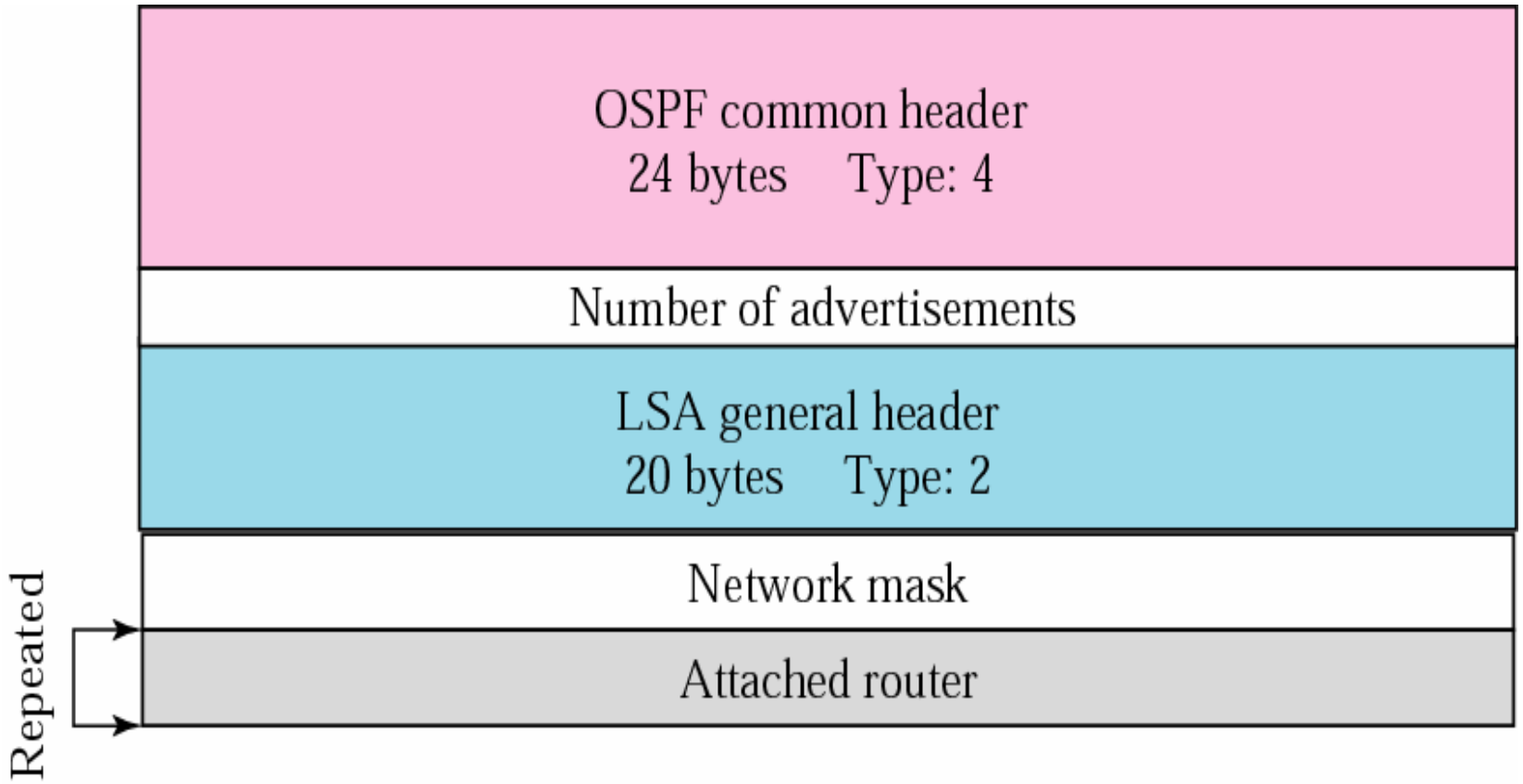
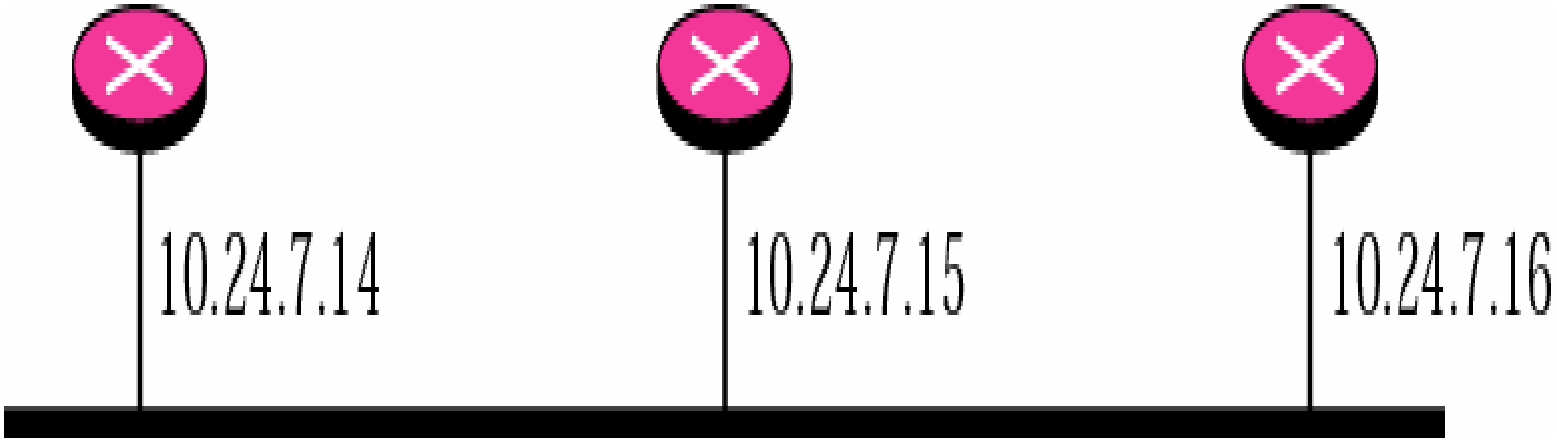


Figure 14.34 *Network link advertisement format*



Example 4

Give the network link LSA in the following Figure.



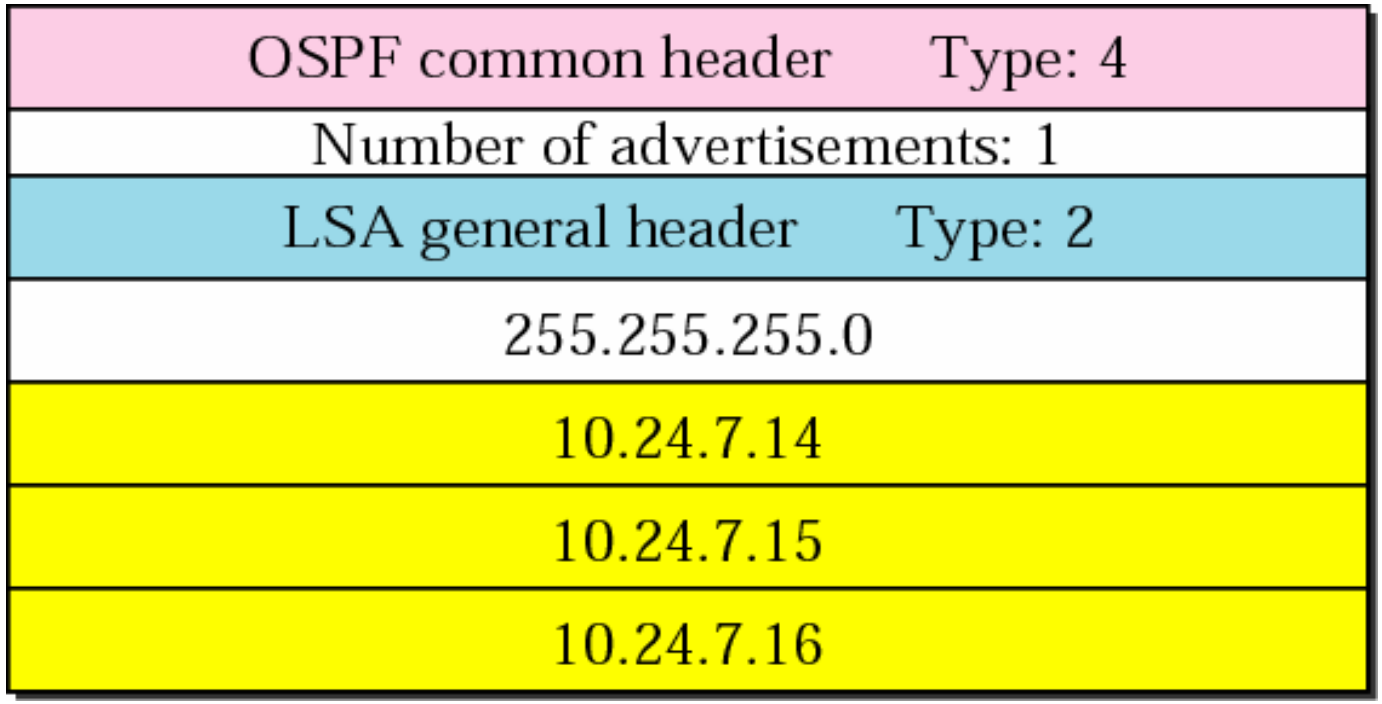
The McGraw-Hill Companies, Inc., 2000

Solution

The network, for which the network link advertises, has three routers attached. The LSA shows the mask and the router addresses. See Figure 14.36.

The McGraw-Hill Companies, Inc., 2000

Figure 14.36 *Solution to Example 4*



Example 5

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

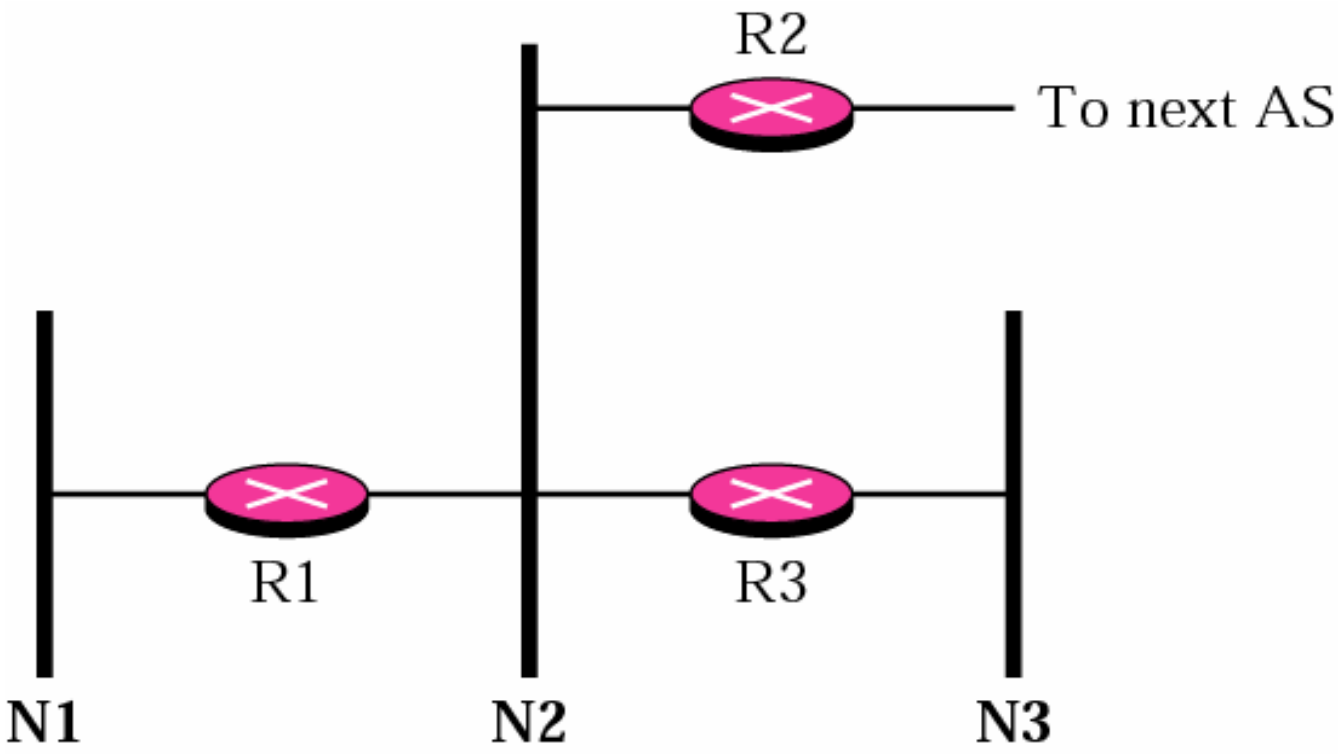
See Next Slide

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.

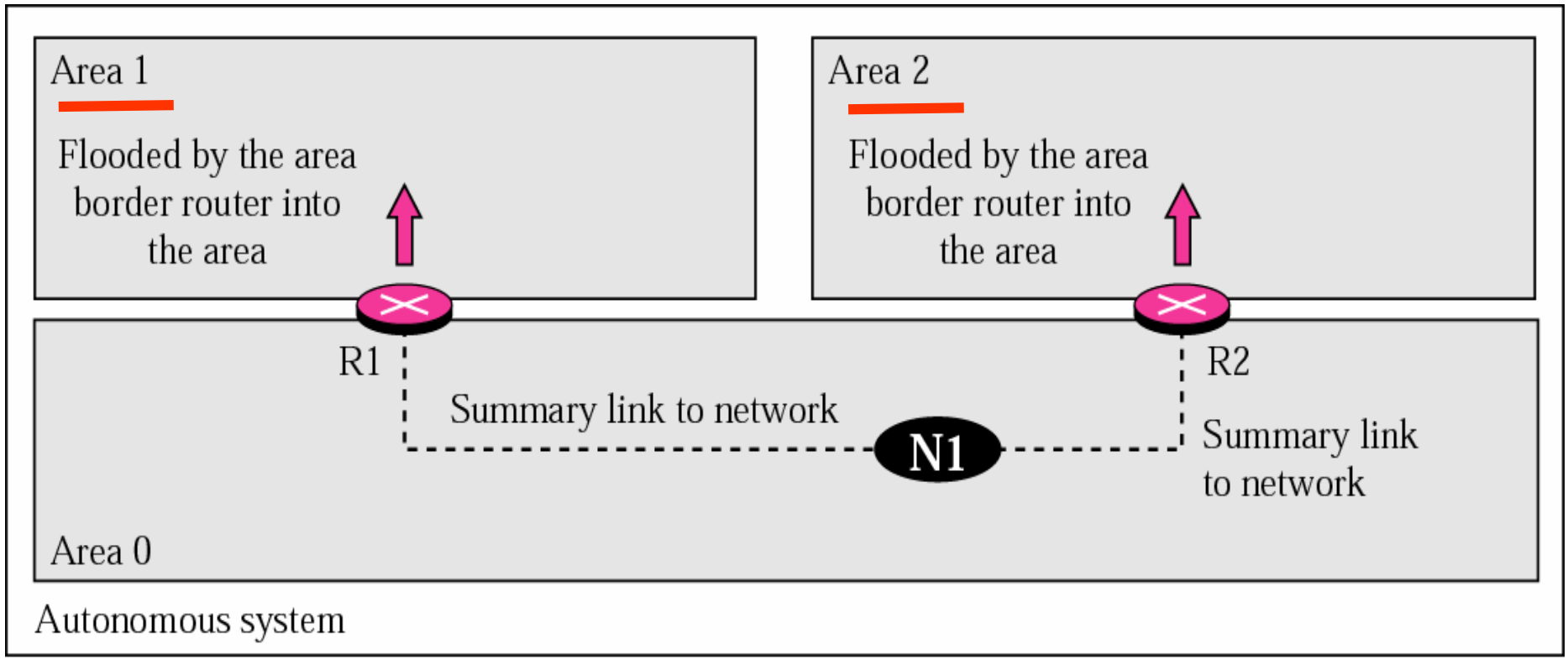
Summary Link to Network LSA

- Router link and network link advertisements
  - Flood the area with information inside an area
- But a router must also know about the networks outside its area
  - The *area border routers* provide this information
- An area border router is active in more than one area
  - Receive *router link* and *network link advertisements*
  - Create a router table for each area
  - Provide one area's information to other areas by the *summary link to network advertisement*

Example

- R1 is an area border router and has two routing tables
  - One for area 1 and one for area 0
- R1 will flood *area 1* with information about how to reach a network located in *area 0*
- R2 plays the same role

Figure 14.38 *Summary link to network*

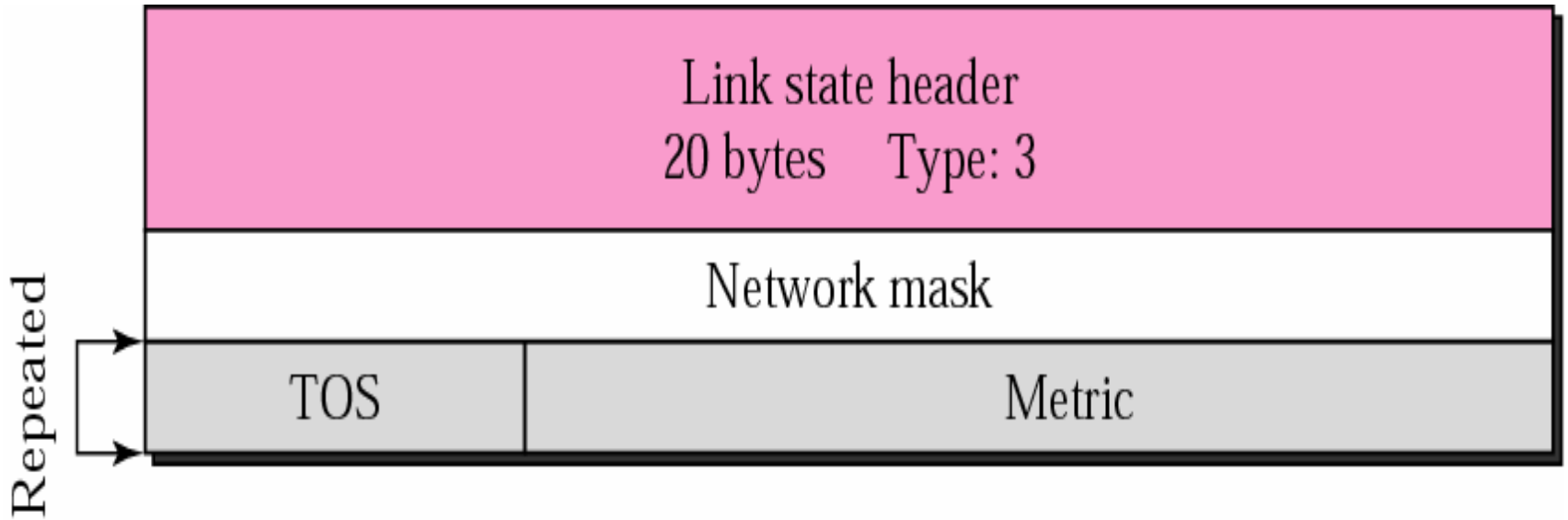


Summary Link to Network LSA (Cont.)

- The LSA consists of only network mask and metric for each type of service
  - Not include the *network address*
  - Since the IP address of the advertising router is in the header
- Each advertisement announces *only one network*
  - If more than one network, a separate advertisement must be issued for each
- Format
  - Network mask
  - TOS:
    - Type of service
  - Metric:
    - Metric for the type of service defined in the TOS field

Figure 13-46

Summary Link to Network LSA



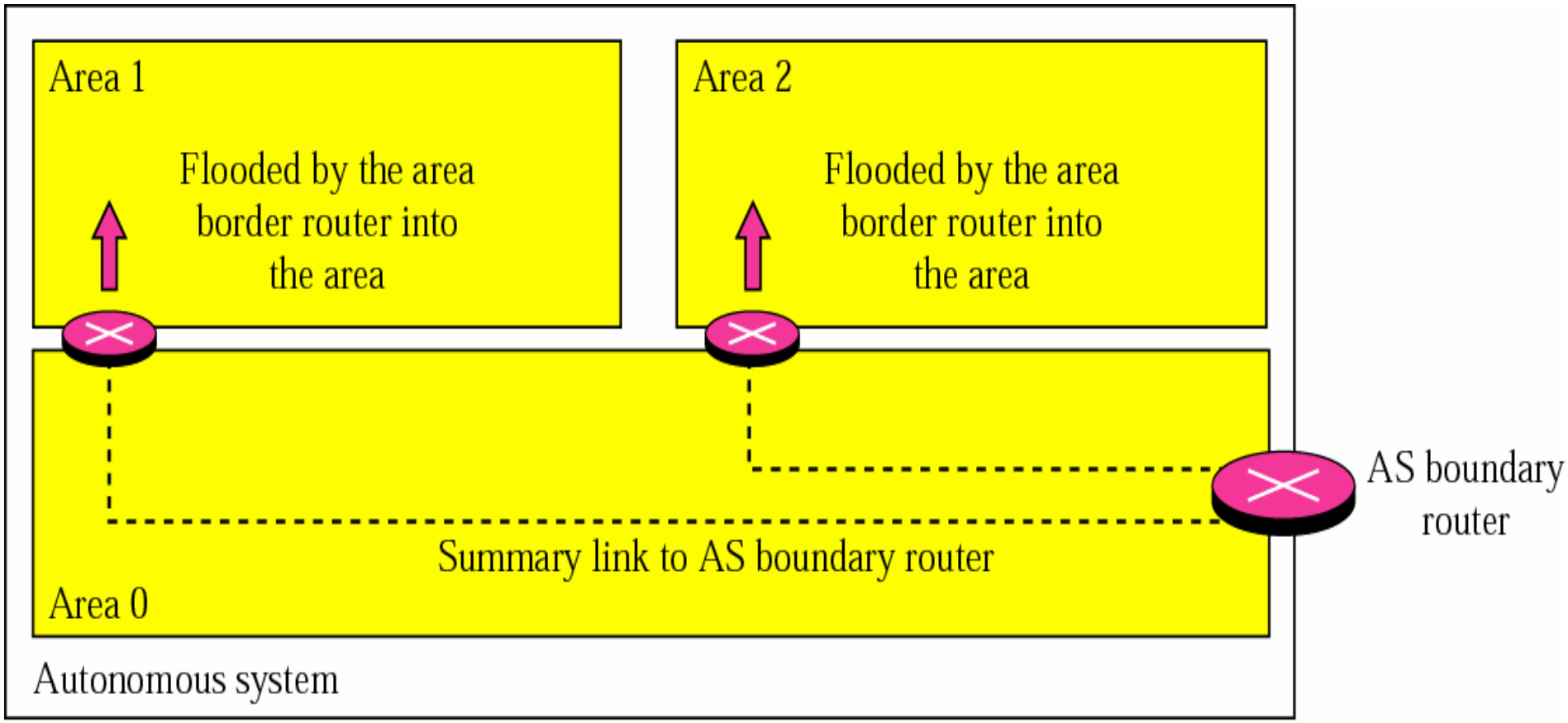
The McGraw-Hill Companies, Inc., 2000

Summary Link to AS Boundary Router LSA

- Previous advertisement lets every router know the cost to reach all of the networks inside the AS
- But, how to reach a network outside an AS?
- A router must know *how to reach the autonomous boundary router first*
- The *summary link to AS boundary router* provides this information
  - The *area border routers* flood their area with this information

Figure 13-29

Summary Link to AS Boundary Router LSA

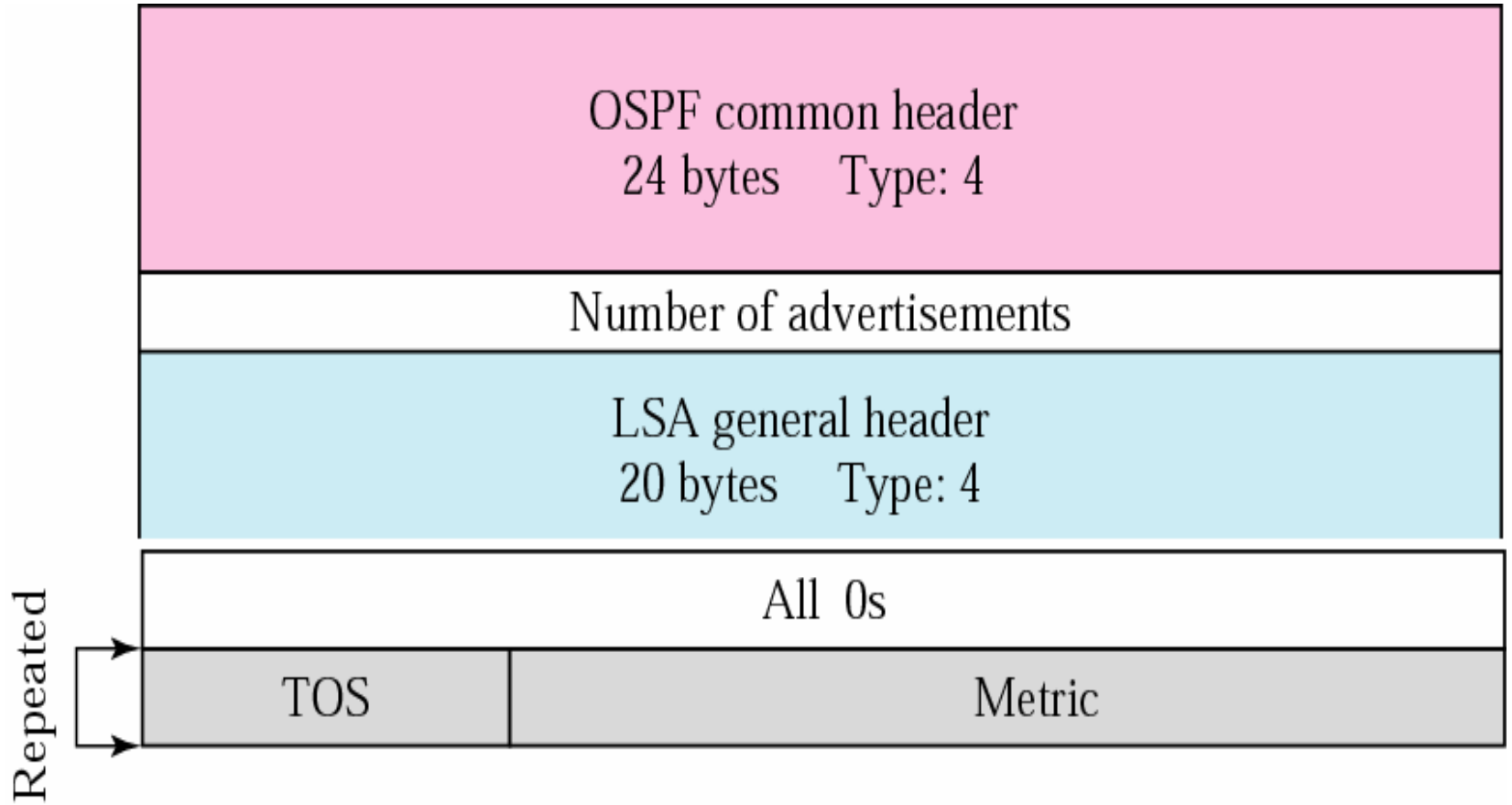


The McGraw-Hill Companies, Inc., 2000

Summary Link to AS Boundary Router LSA (Cont.)

- Announce the *route to an AS boundary router*
  - Define the network to which the AS boundary router is attached
  - The *area border routers* flood their area with this LAS
- Format
  - The same as the summary link to network LSA

Figure 14.41 *Summary link to AS boundary router LSA*



External Link LSA

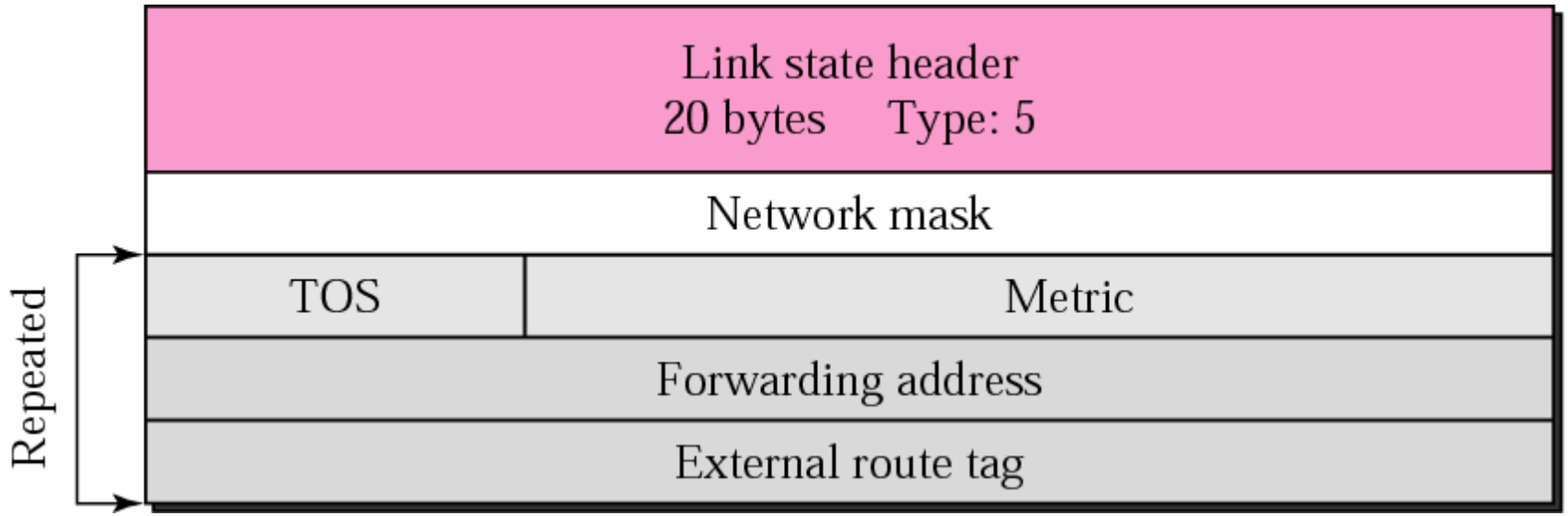
- How a router inside an AS know which networks are available outside the AS ?
  - The ***external link advertisement*** provides this information
- The *AS boundary routers* floods the autonomous system with the cost of each network outside the AS
  - Using a routing table created by an *exterior routing protocol*
- Notably, each advertisement announces one single network
  - Separate announcements are made if more than one network exists Announce all the networks outside the AS

External Link LSA

- Use to announce all of the networks outside the AS
- Format: similar to the summary link to AS boundary router LSA but add two fields
  - *Forwarding address*
    - May define a *forward router* than can provide a better route to the destination
  - *External route tag*
    - Used by other protocol, but not by OSPF

Figure 12.48

External Link LSA



The McGraw-Hill Companies, Inc., 2000

Other Packets

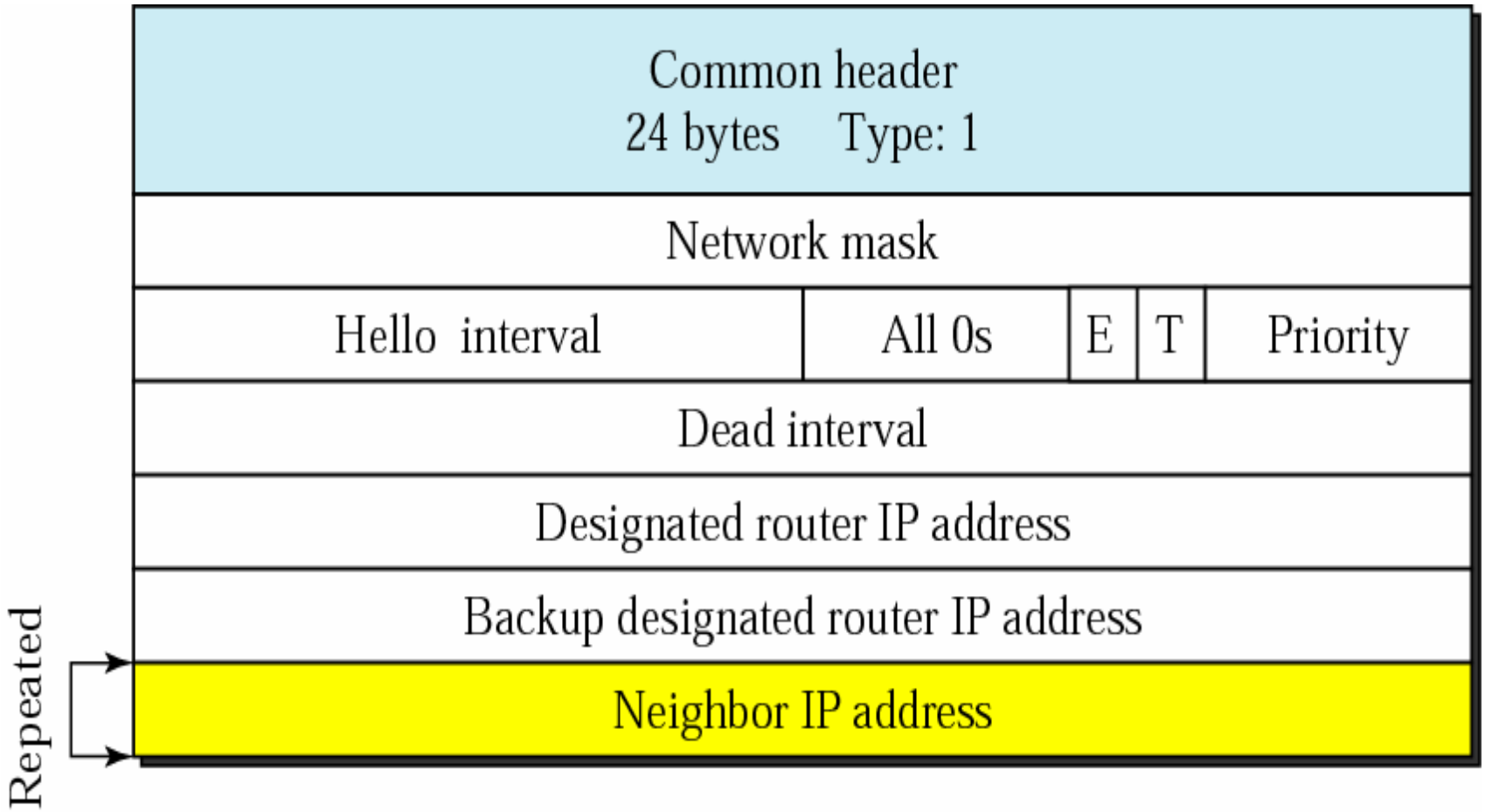
- Not used as LSA but are essential to the OSPF
  - Hello message
  - Database description message
  - Link state request packet
  - Link state acknowledgment packet

Hello Message

- OSPF uses the hello message to
  - Create neighborhood relationships
  - Test the reachability of neighbors
- First step in link state routing
  - It must first greet its neighbors

Figure 12-25

Hello Packet



The McGraw-Hill Companies, Inc., 2000

Hello Packet Format

- Network mask: 32-bit
  - Define the network mask of the network over which the hello message is sent
- Hello interval: 16-bit
  - Define the number of seconds between hello message
- E flag: 1-bit
  - If it is set, the area is a stub area
- T flag: 1-bit
  - If it is set, the router supports multiple metrics

Hello Packet Format (Cont.)

- Priority
  - The priority of the router. Used for the selection of the designated router
  - The router with the highest priority is chosen as the *designated router*
  - The router with the second highest priority is chosen as the *backup designated router*
  - If it is 0, the router never wants to be a designated or backup designated router

Hello Packet Format (Cont.)

- Dead interval: 32-bit
  - The number of seconds before a router assumes that a neighbor is dead
- Designated router IP address: 32-bit
- Backup designated router IP address: 32-bit
- Neighbor IP address: a repeated 32-bit field
  - A current list of all the neighbors from which the sending router has received the hello message

Database Description Message

- When a router is connected to the system *for the first time* or *after a failure*
  - It needs the complete link state database immediately
- Thus, it sends hello packets to greet its neighbors
- If this is the first time that the neighbors hear from the router
  - They send a *database description packet*

Database Description Message (Cont.)

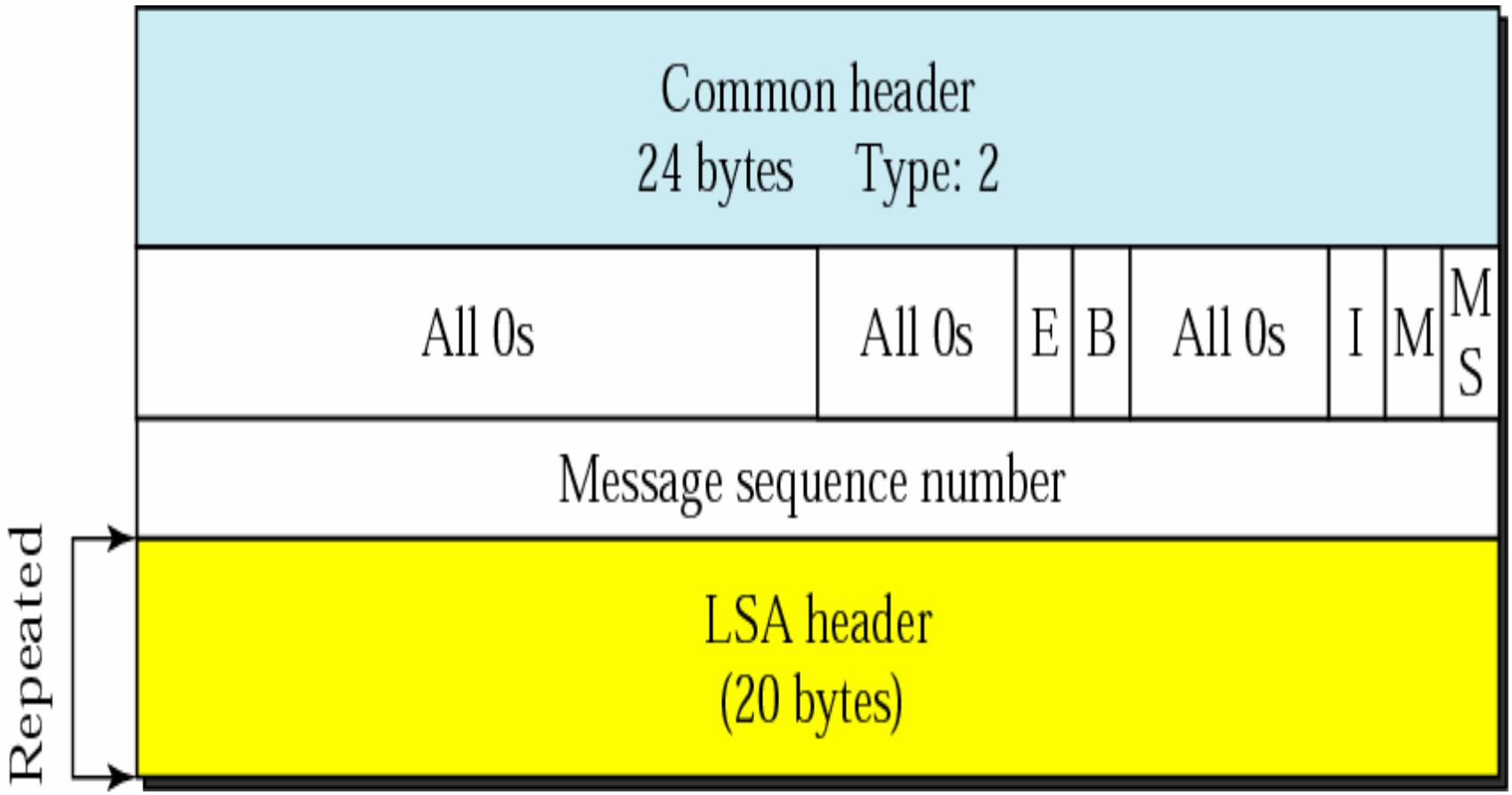
- The database description message does not contain complete database information
  - It only gives an *outline*, the title of each line in the database
- The newly router examines the outline and find out which lines it does not have
  - Send one or more *link state request packets* to get full information about that particular link
  - The content of the database may be divided into several message

Database Description Message (Cont.)

- When two routers want to exchange database description packets
  - One of them acts as mater
  - The other is the slave

Figure 12-26

Database Description Packet



The McGraw-Hill Companies, Inc., 2000

Database Description Message Format

- E flag: 1-bit
  - Set to 1 if the advertising router is an autonomous boundary router
- B flag: 1-bit
  - Set to 1 if the advertising router is an area border router
- I flag: 1-bit, the initialization flag
  - Set to 1 if the message is the first message
- M flag: 1-bit, more flag
  - Set to 1 if this is not the last message

Database Description Message Format (Cont.)

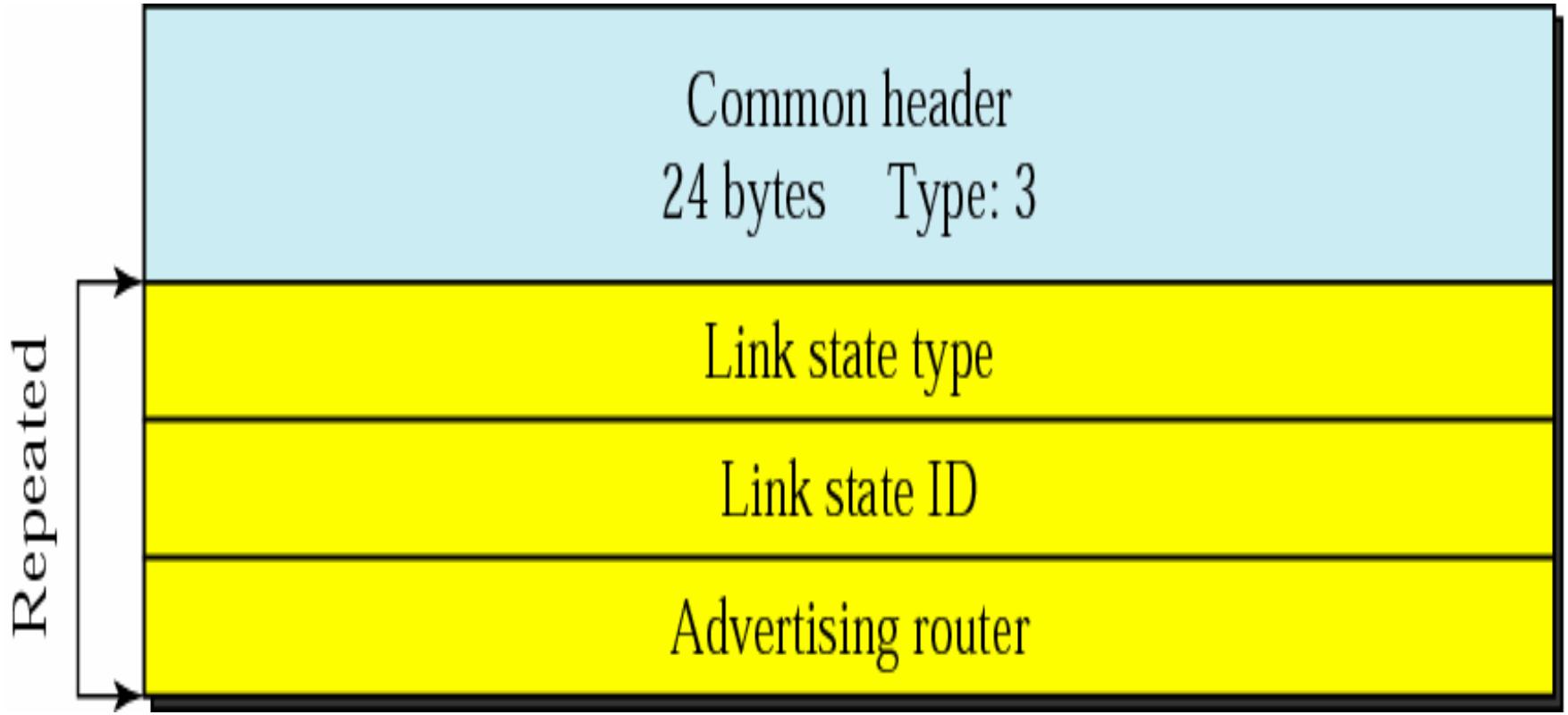
- M/S flag: 1-bit, master/slave flag
  - Indicate the origin of the packet. Master = 1, Slave = 0
- Message sequence number: 32-bit
  - Contain the sequence number of the message
- LSA header: 20-bit
  - Used in each LSA
  - The format of this header is discussed in the *link state update* message
    - Only give the outline of each link
  - It is repeated for each link in the link state database

Link State Request Packet

- Sent by a router that needs information about a specific route or routes
  - Answered with a *link state update packet*
- Used by a newly connected router to request more information after receiving the *database description packet*

Figure 13.27

Link State Request Packet



The McGraw-Hill Companies, Inc., 2000

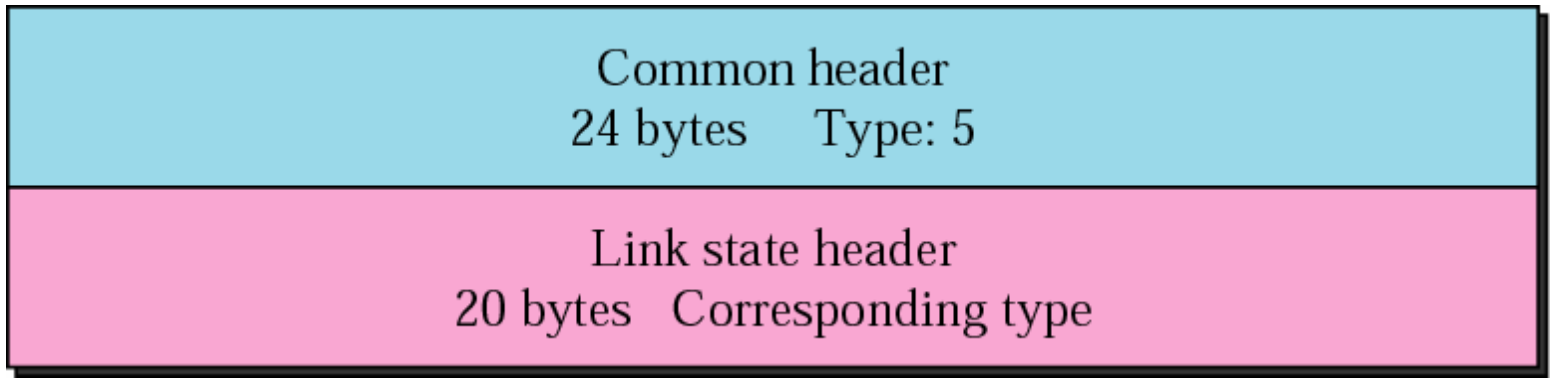
Link State Acknowledgment Packet

- OSPF forces every router to **acknowledge** the receipt of every link state update packet
  - Make routing more reliable

- Format
  - Common header
  - Link state header

Figure 13-49

Link State Acknowledgment Packet



The McGraw-Hill Companies, Inc., 2000

Encapsulation

- OSPF packets are encapsulated in IP datagram
  - OSPF contains the acknowledgment mechanism for flow and error control
  - Doe not need a transport layer protocol to provide these services