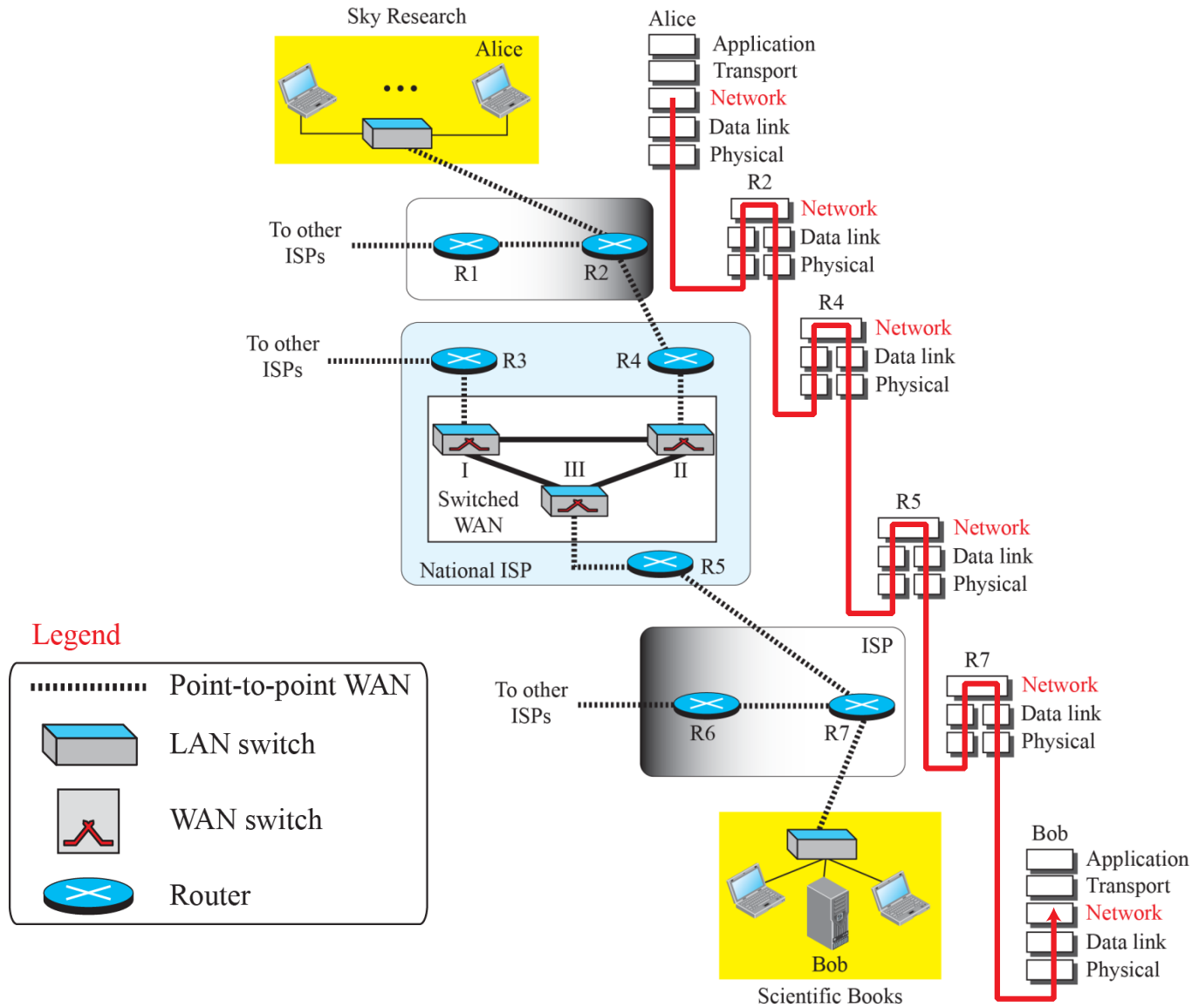


Chapter 18

Introduction to Network Layer

Communication at the network layer



Packetizing

- *encapsulating the payload in a network-layer packet at the source and decapsulating the payload from the network-layer packet at the destination.*
- *In other words, one duty of the network layer is to carry a payload from the source to the destination without changing it or using it.*
- *Similar to the service of a carrier such as the postal office*

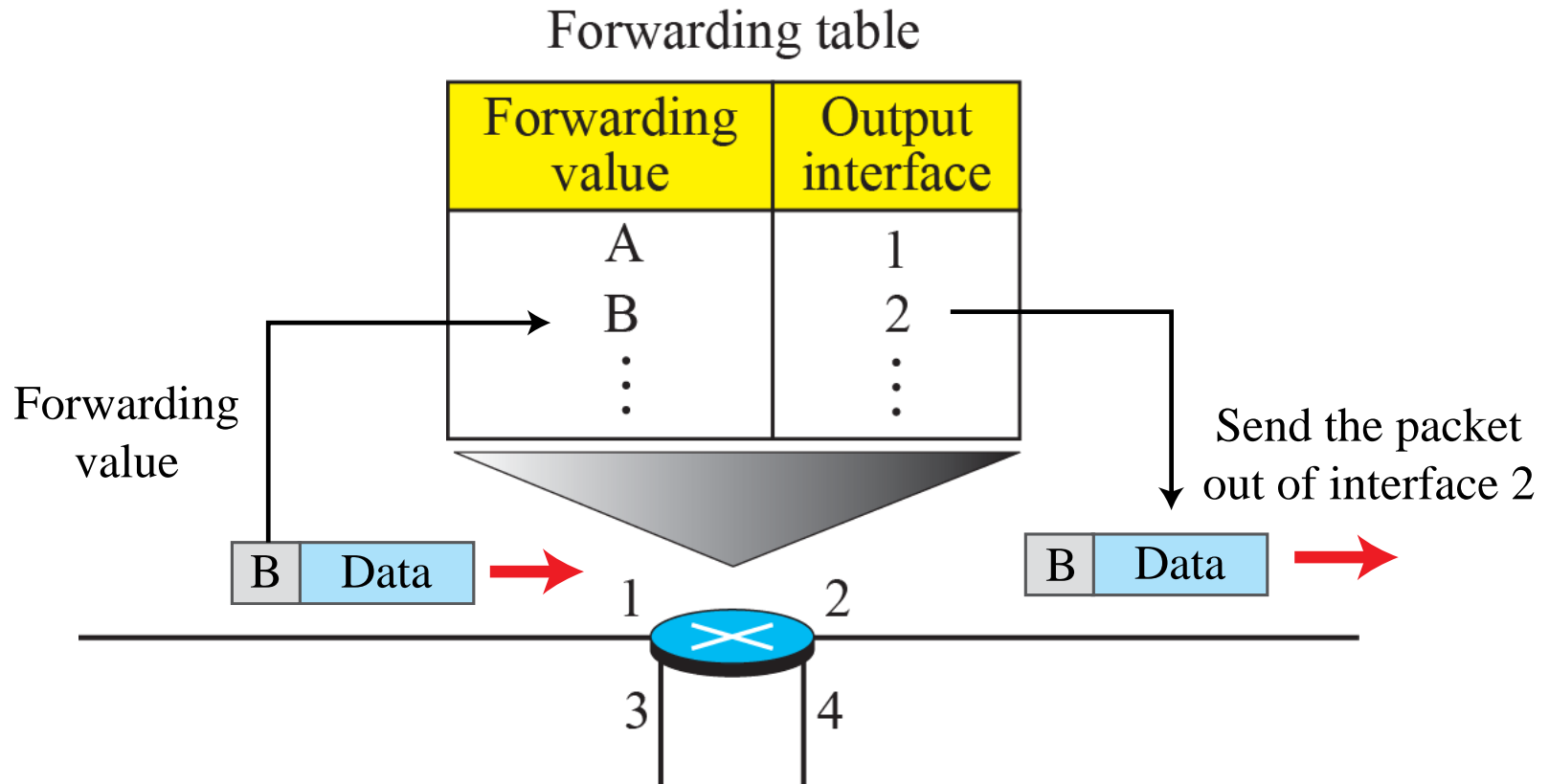
Routing and Forwarding

Other duties of the network layer are

- routing

- forwarding

Forwarding process



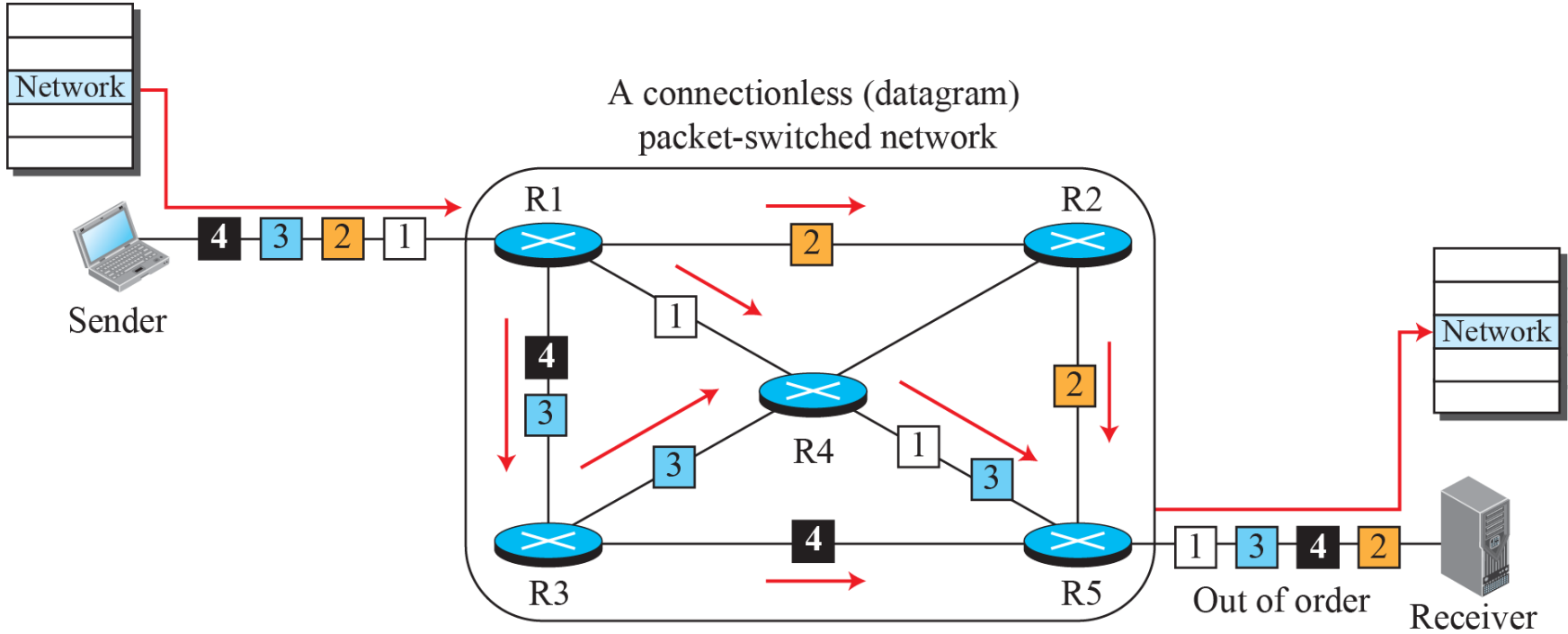
PACKET SWITCHING

A router is a switch that creates a connection between an input port and an output port (or a set of output ports)

Datagram Approach

- *The network layer was designed to provide a connectionless service in which the network-layer protocol treats each packet independently, with each packet having no relationship to any other packet.*
- *The idea was that the network layer is only responsible for delivery of packets from the source to the destination.*
- *In this approach, the packets in a message may or may not travel the same path to their destination.*

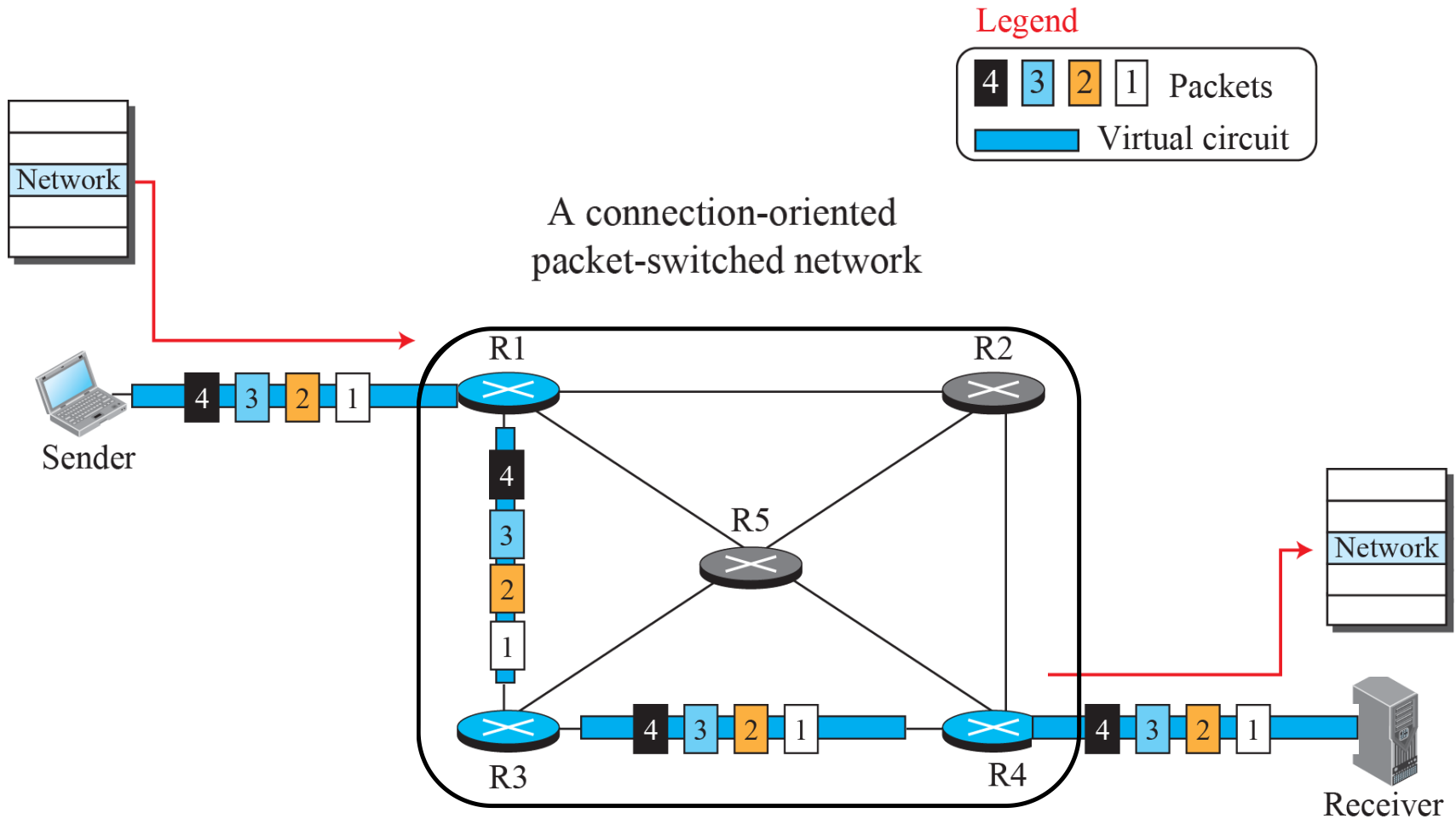
A connectionless packet-switched network



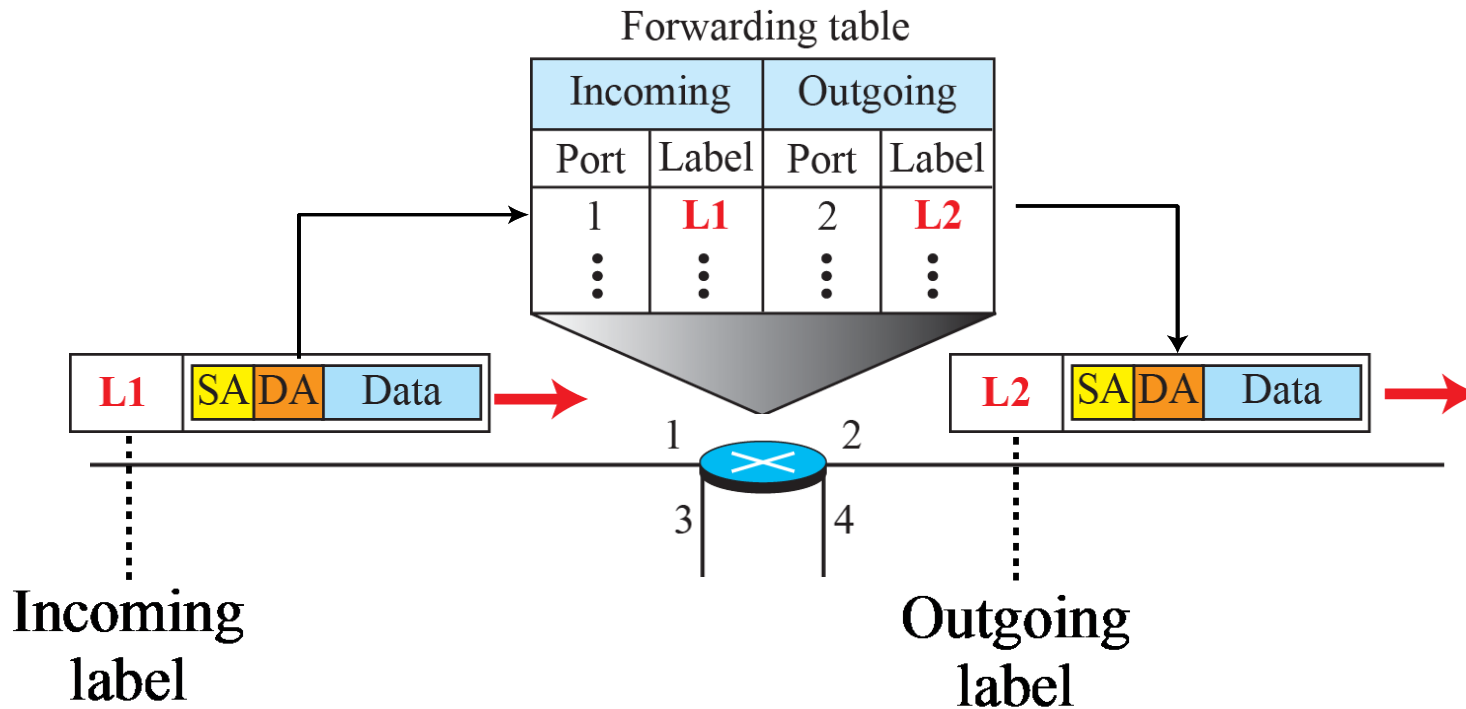
Virtual-Circuit Approach

- *There is a relationship between all packets belonging to a message.*
- *Before all datagrams in a message can be sent, a virtual connection should be set up to define the path for the datagrams.*
- *After connection setup, the datagrams can all follow the same path.*
- *In this type of service, not only must the packet contain the **source and destination addresses**, it must also contain **a flow label**, a virtual circuit identifier that defines the virtual path the packet should follow.*

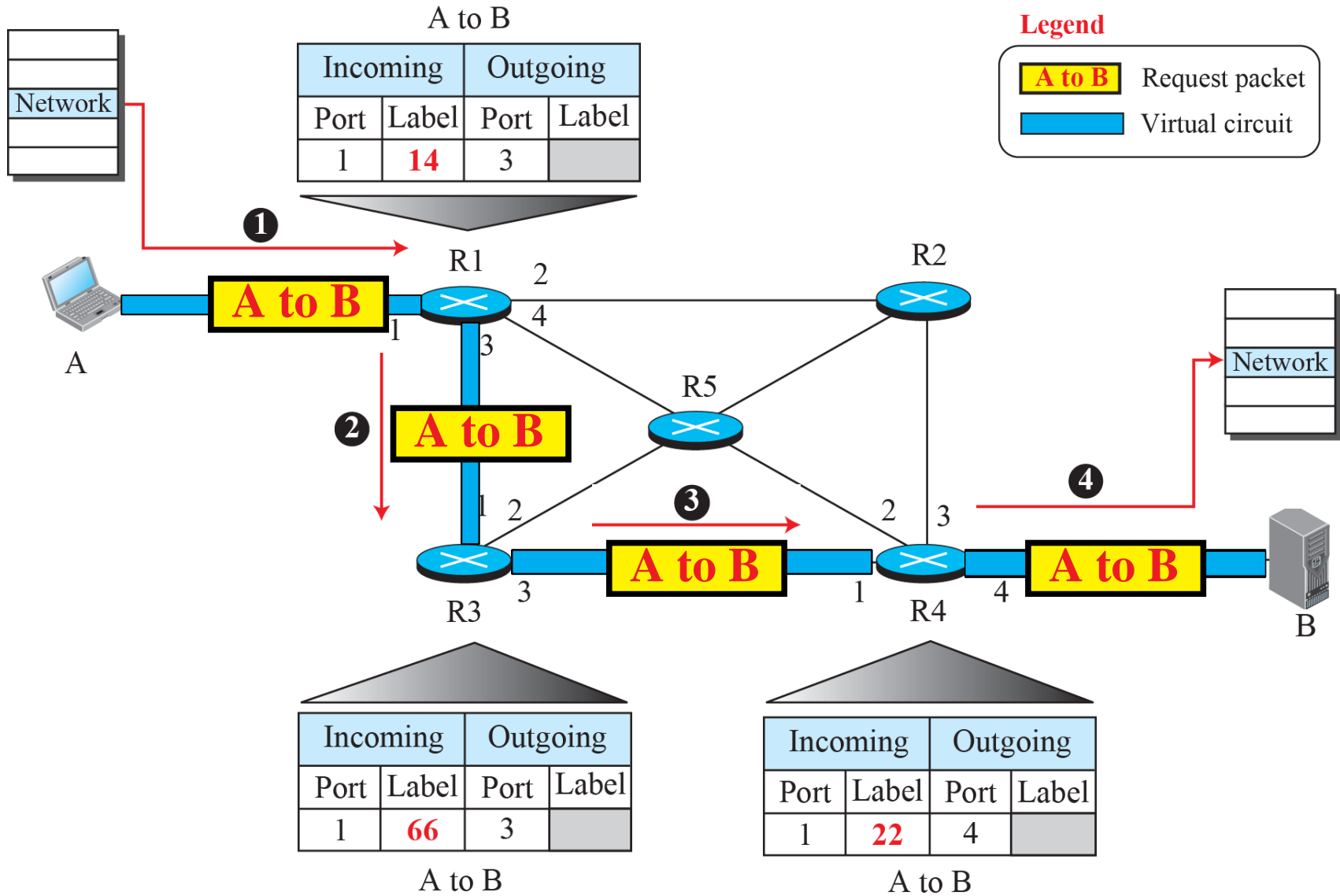
A virtual-circuit packet-switched network



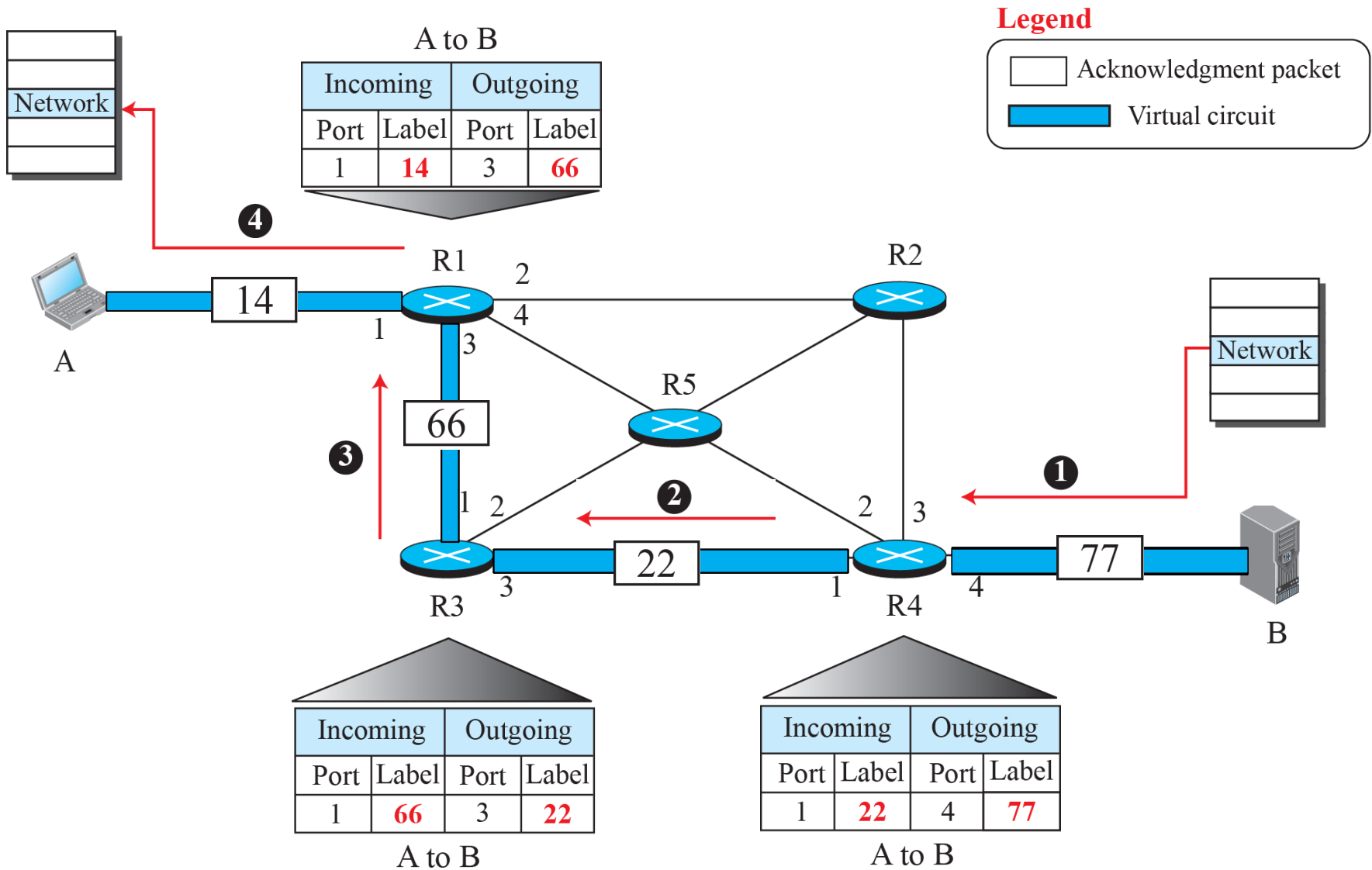
Forwarding process in a router when used in a virtual circuit network



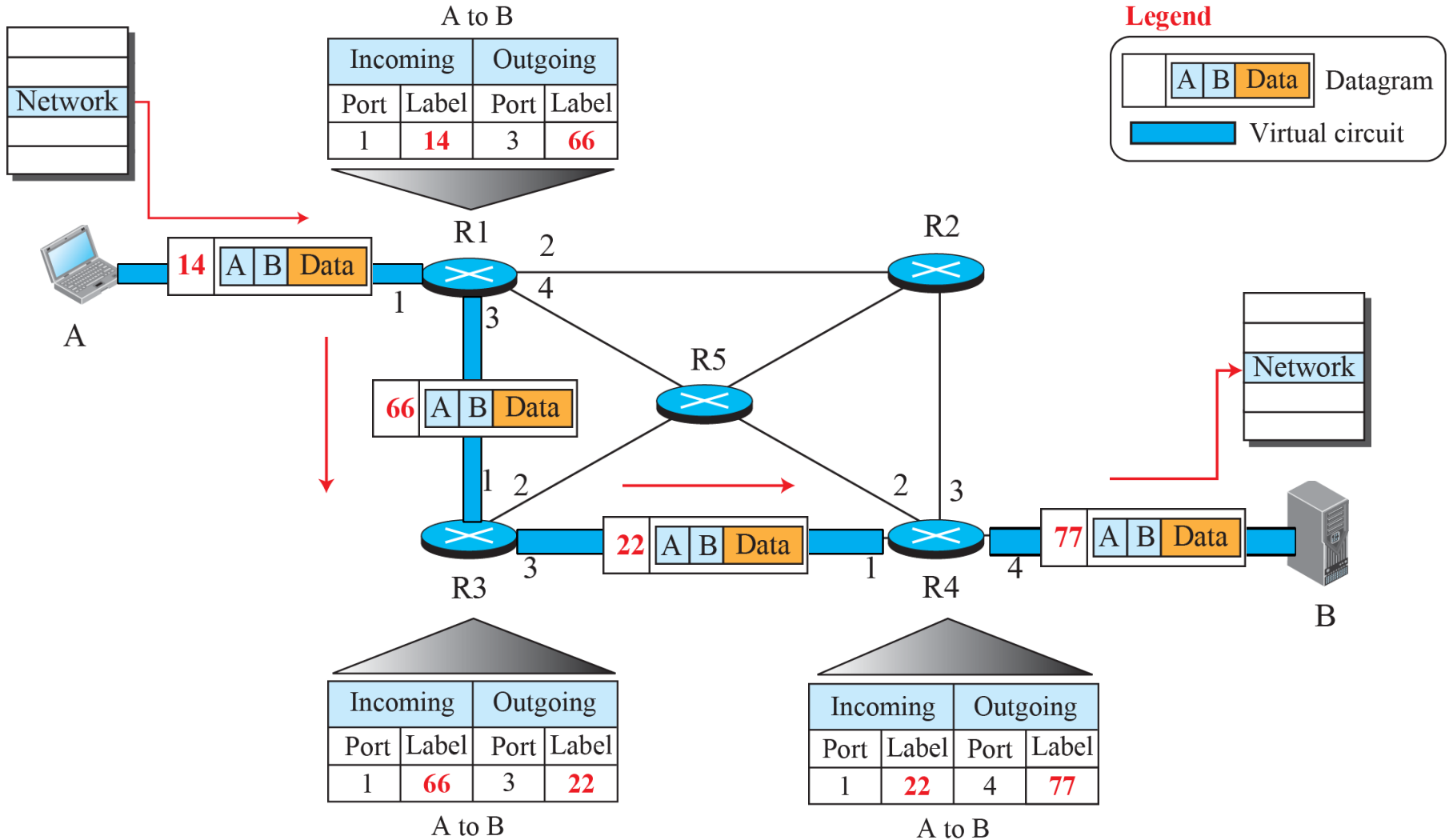
Sending request packet in a virtual-circuit network



Sending acknowledgments in a virtual-circuit network



Flow of one packet in an established virtual circuit



NETWORK-LAYER PERFORMANCE

*The performance of a network can be measured in terms of **delay**, **throughput**, and **packet loss**. Congestion control is an issue that can improve the performance.*

Delay

The delays in a network can be divided into four types:

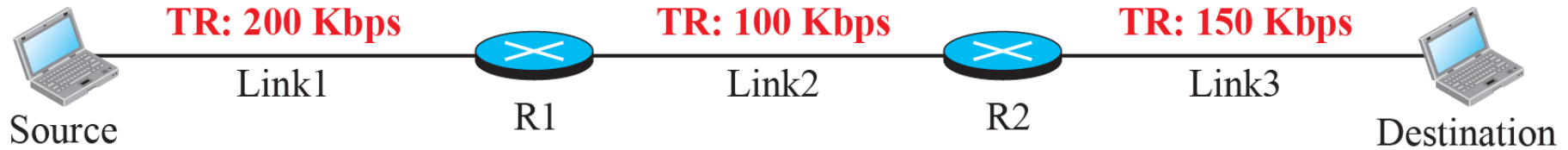
- transmission delay*
- propagation delay*
- processing delay*
- queuing delay*

Throughput

- *is defined as the number of bits passing through the point in a second, which is actually the transmission rate of data at that point.*
- *In a path from source to destination, a packet may pass through several links (networks), each with a different transmission rate.*
- *How can we determine the throughput of the whole path?*

Throughput in a path with three links in a series

TR: Transmission rate

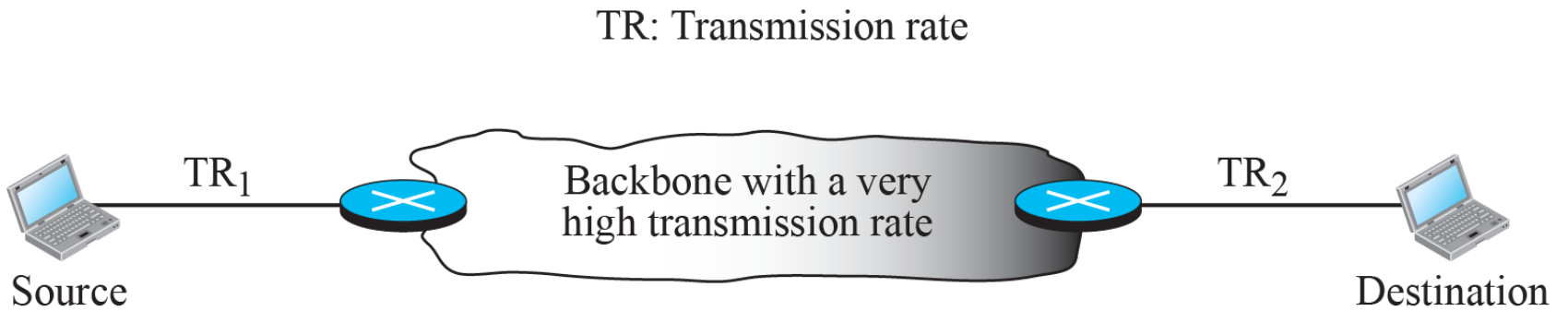


a. A path through three links

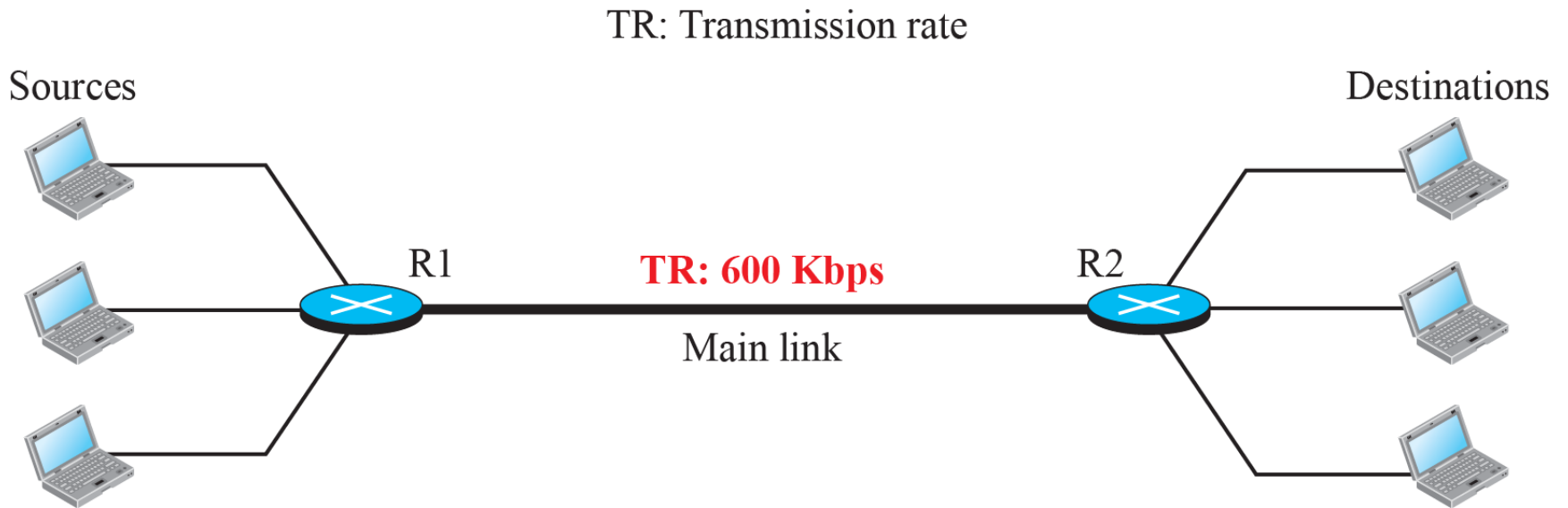


b. Simulation using pipes

A path through the Internet backbone



Effect of throughput in shared links



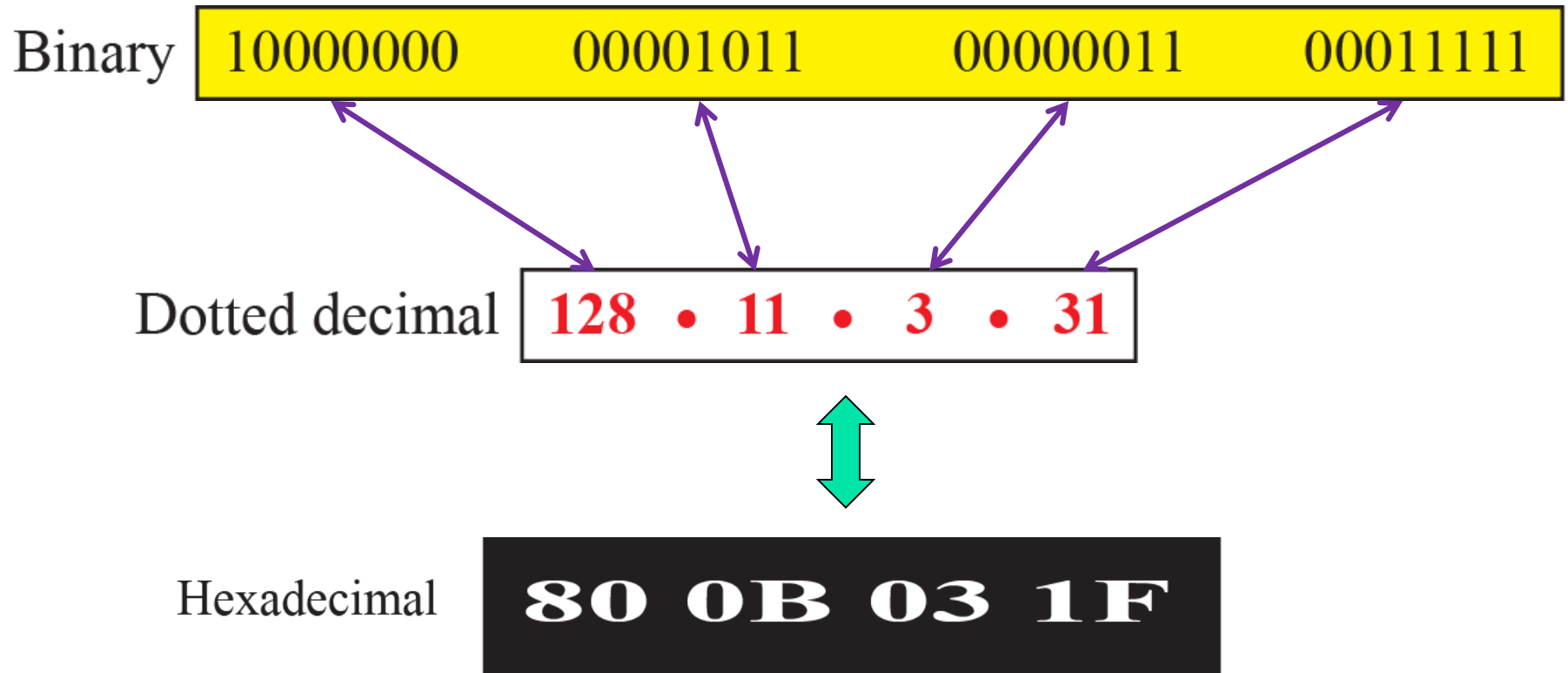
Packet Loss

- *Another issue that severely affects the performance of communication is the number of packets lost during transmission.*
- *The effect of packet loss on the Internet network layer is that the packet needs to be resent, which in turn may create overflow and cause more packet loss.*

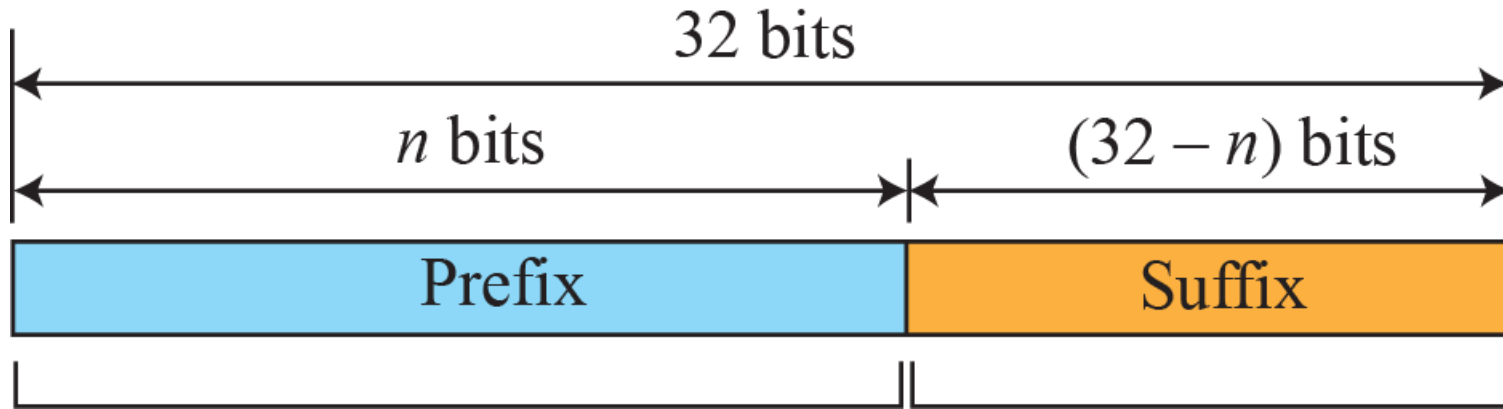
IPv4 ADDRESSES

- *The identifier used in the IP layer of the TCP/IP protocol suite to identify the connection of each device to the Internet.*
- *An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a host or a router to the Internet.*
- *The IP address is the address of the connection, not the host or the router.*

Three different notations in IPv4 addressing

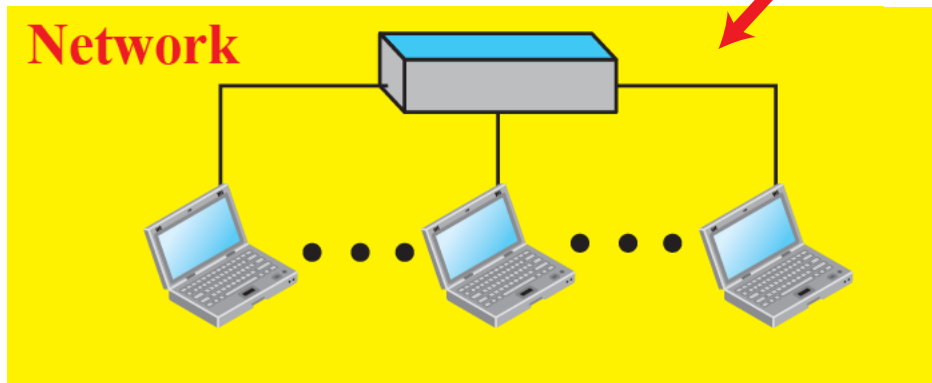


Hierarchy in addressing



Defines network

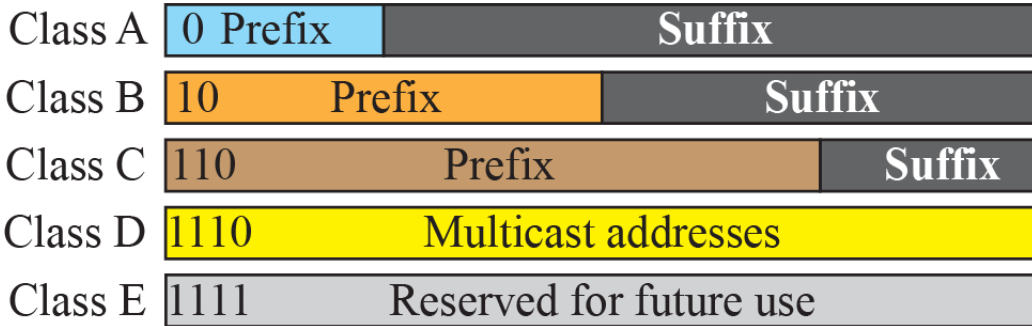
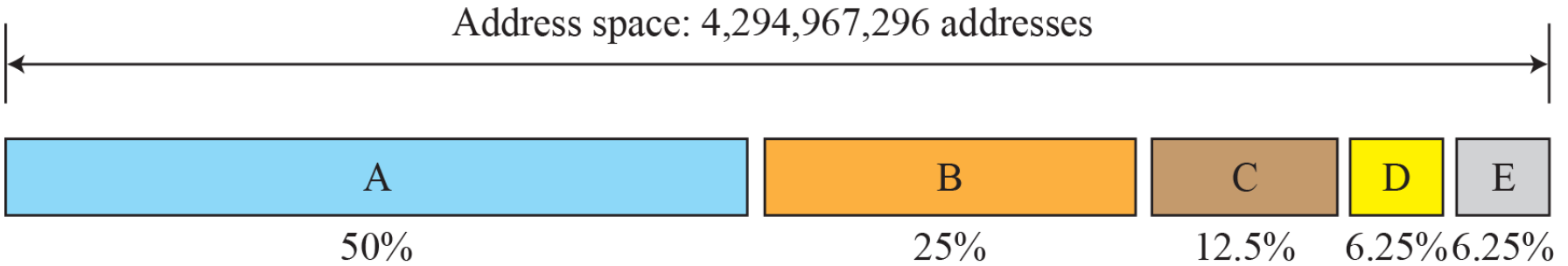
Defines connection to the node



Classful Addressing

- *The whole address space was divided into five classes (class A, B, C, D, and E)*
- *This scheme is referred to as classful addressing.*

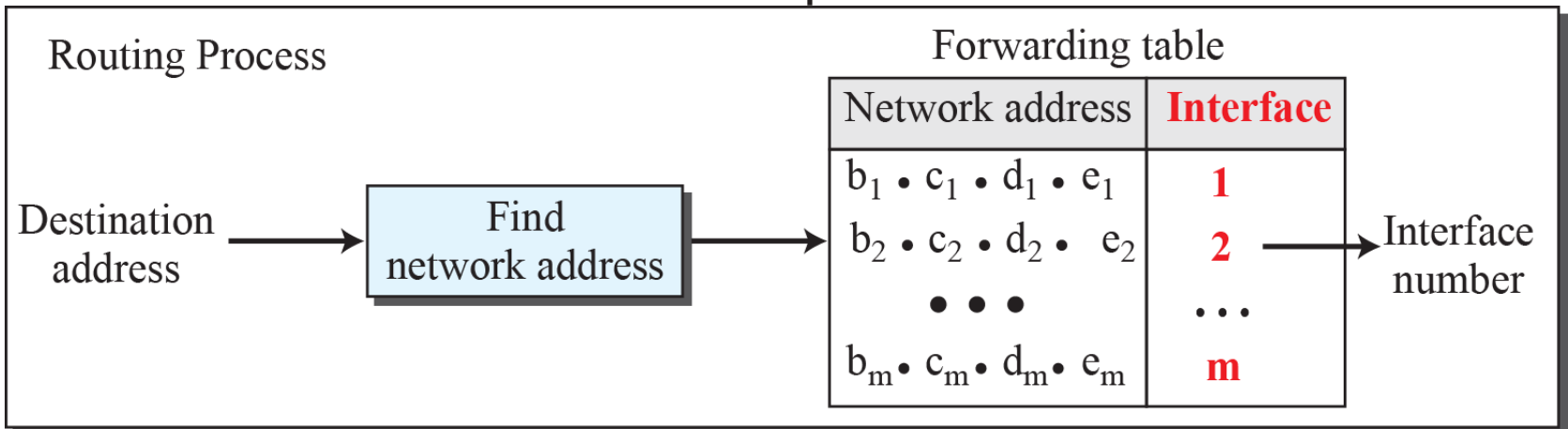
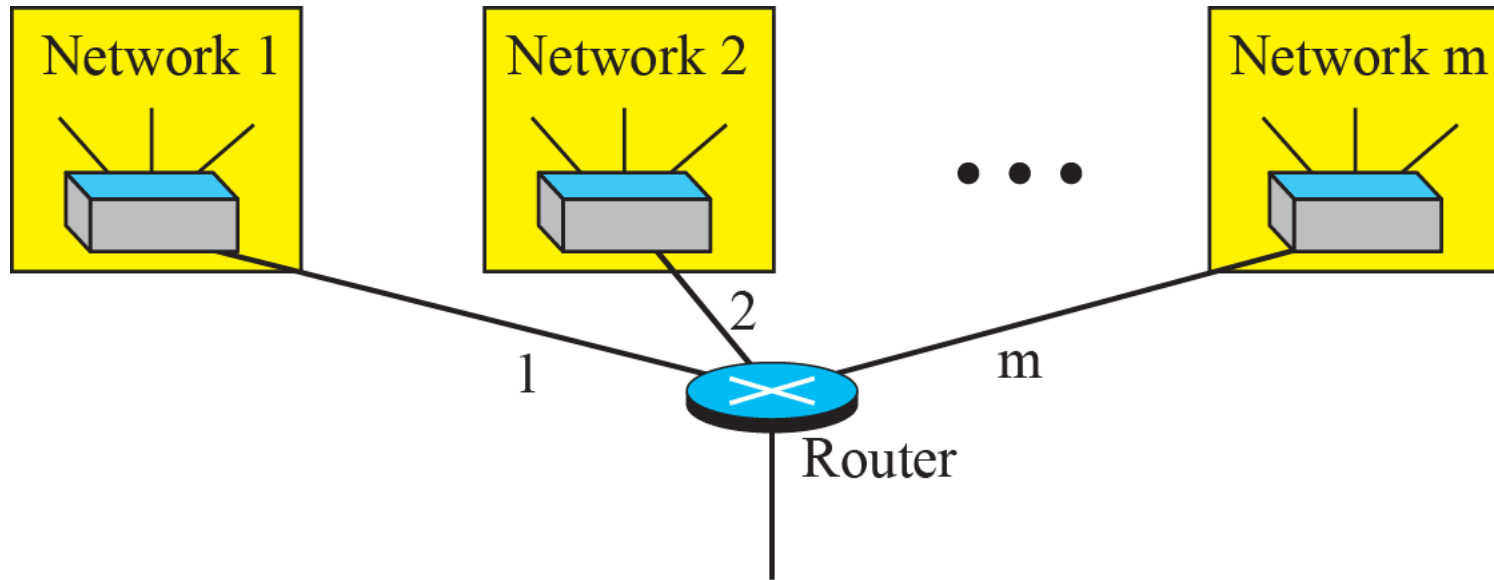
Occupation of the address space in classful addressing



Class Prefixes First byte

A	$n = 8$ bits	0 to 127
B	$n = 16$ bits	128 to 191
C	$n = 24$ bits	192 to 223
D	Not applicable	224 to 239
E	Not applicable	240 to 255

Network address



Example 18.5

An organization is granted a block of addresses with the beginning address 14.24.74.0/24. The organization needs to have 3 subblocks of addresses to use in its three subnets: one subblock of 10 addresses, one subblock of 60 addresses, and one subblock of 120 addresses. Design the subblocks.

Solution

There are $2^{32-24} = 256$ addresses in this block. The first address is 14.24.74.0/24; the last address is 14.24.74.255/24. To satisfy the third requirement, we assign addresses to subblocks, starting with the largest and ending with the smallest one.

Example 18.5 (continued)

a. The number of addresses in the largest subblock, which requires 120 addresses, is not a power of 2. We allocate 128 addresses. The subnet mask for this subnet can be found as $n_1 = 32 - \log_2 128 = 25$. The first address in this block is 14.24.74.0/**25**; the last address is 14.24.74.127/**25**.

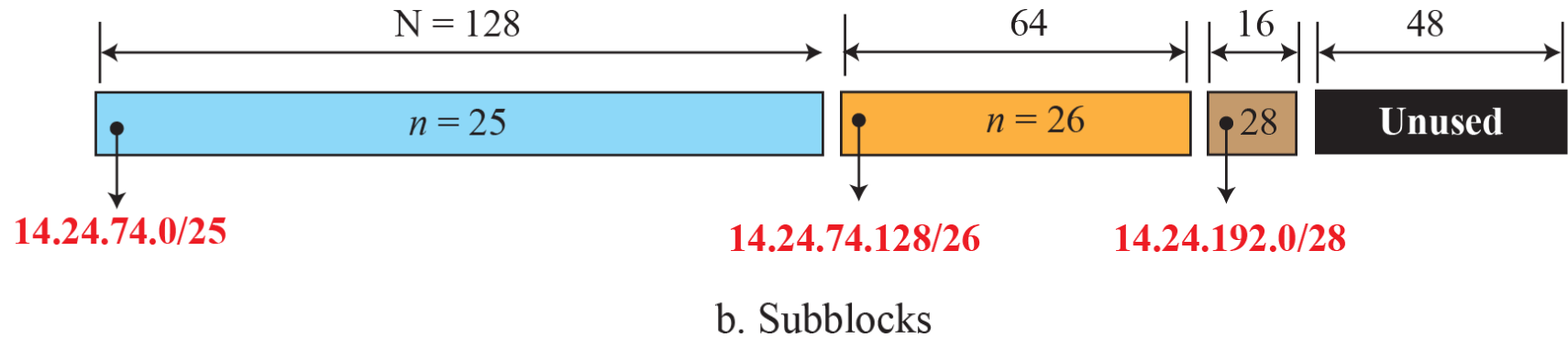
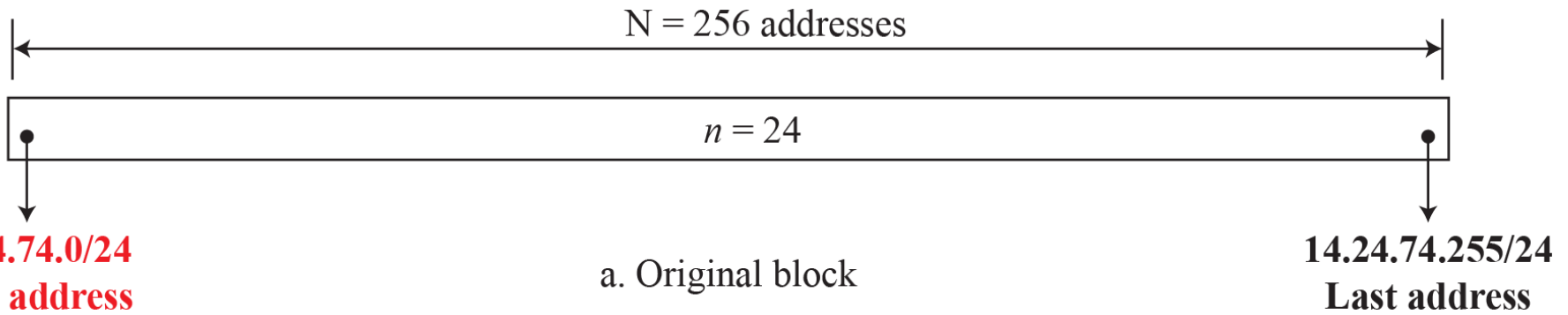
b. The number of addresses in the second largest subblock, which requires 60 addresses, is not a power of 2 either. We allocate 64 addresses. The subnet mask for this subnet can be found as $n_2 = 32 - \log_2 64 = 26$. The first address in this block is 14.24.74.128/**26**; the last address is 14.24.74.191/**26**.

Example 18.5 (continued)

c. The number of addresses in the largest subblock, which requires 120 addresses, is not a power of 2. We allocate 128 addresses. The subnet mask for this subnet can be found as $n_1 = 32 - \log_2 128 = 25$. The first address in this block is 14.24.74.0/**25**; the last address is 14.24.74.127/**25**.

If we add all addresses in the previous subblocks, the result is 208 addresses, which means 48 addresses are left in reserve. The first address in this range is 14.24.74.208. The last address is 14.24.74.255. We don't know about the prefix length yet.

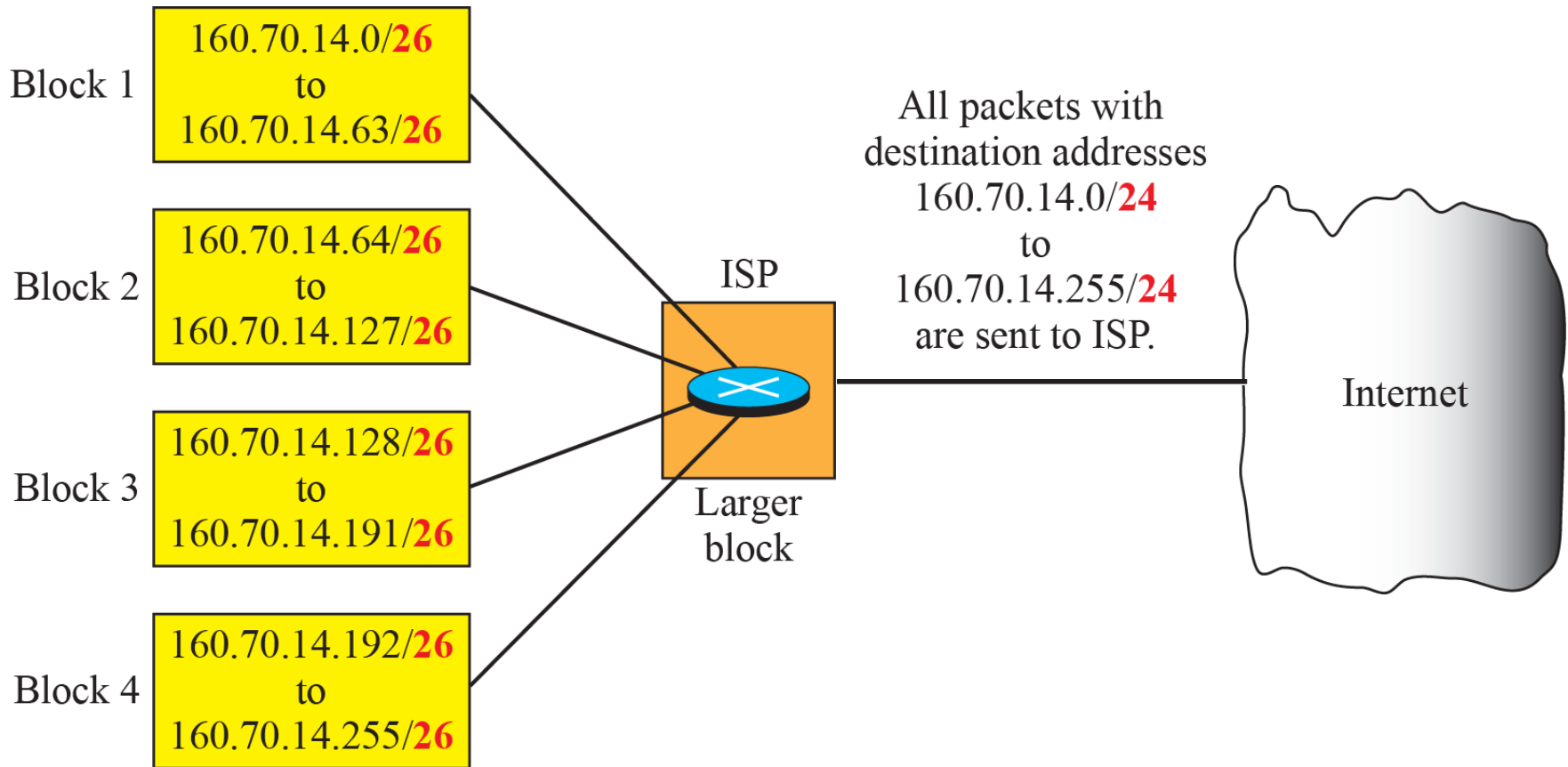
Solution to Example 4.5



Example 18.6

Figure 18.24 shows how four small blocks of addresses are assigned to four organizations by an ISP. The ISP combines these four blocks into one single block and advertises the larger block to the rest of the world. Any packet destined for this larger block should be sent to this ISP. It is the responsibility of the ISP to forward the packet to the appropriate organization. This is similar to routing we can find in a postal network. All packages coming from outside a country are sent first to the capital and then distributed to the corresponding destination.

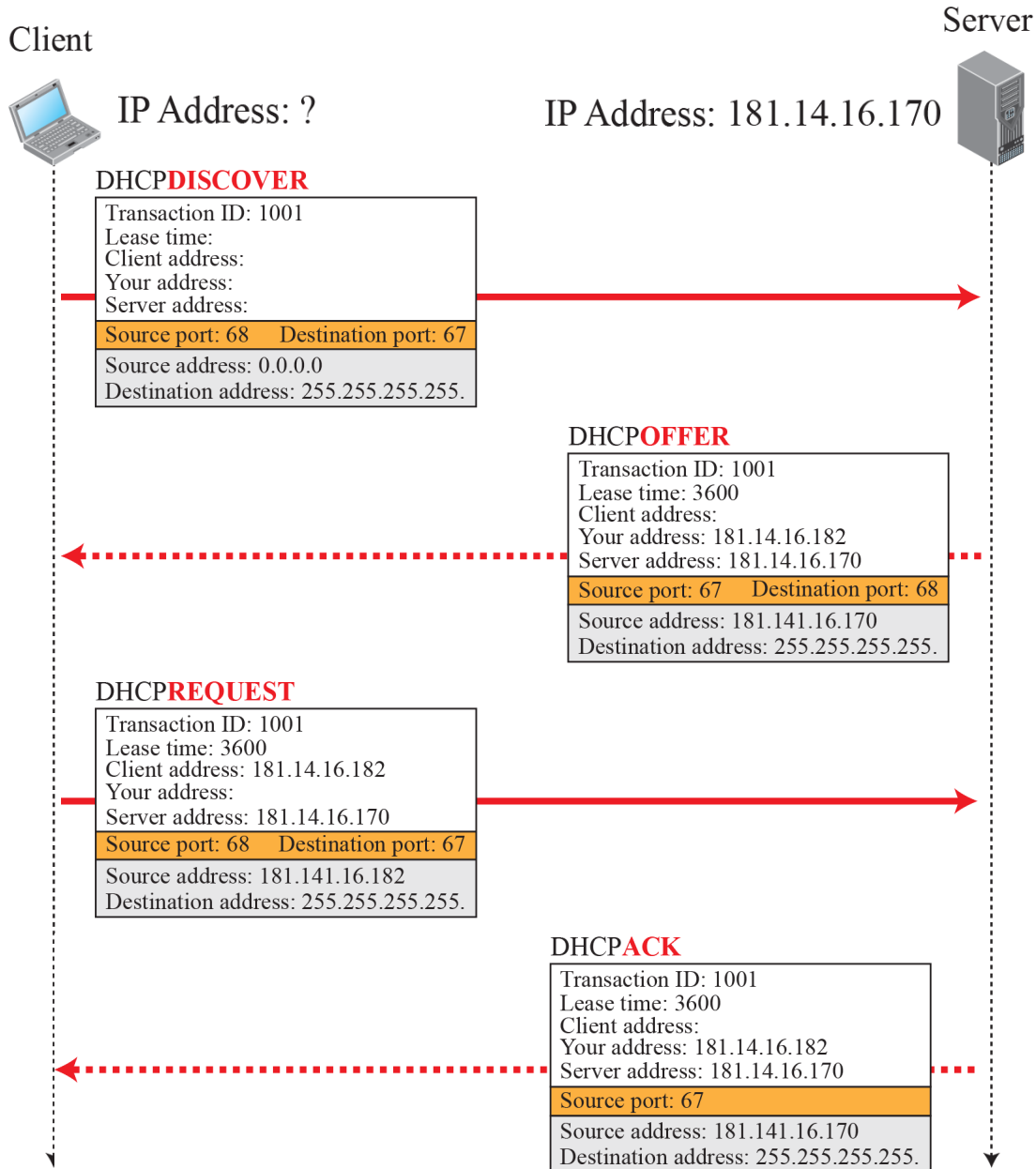
Figure 18.24: Example of address aggregation



DHCP

After a block of addresses are assigned to an organization, the network administration can manually assign addresses to the individual hosts or routers. However, address assignment in an organization can be done automatically using the Dynamic Host Configuration Protocol (DHCP). DHCP is an application-layer program, using the client-server paradigm, that actually helps TCP/IP at the network layer.

Operation of DHCP



Legend

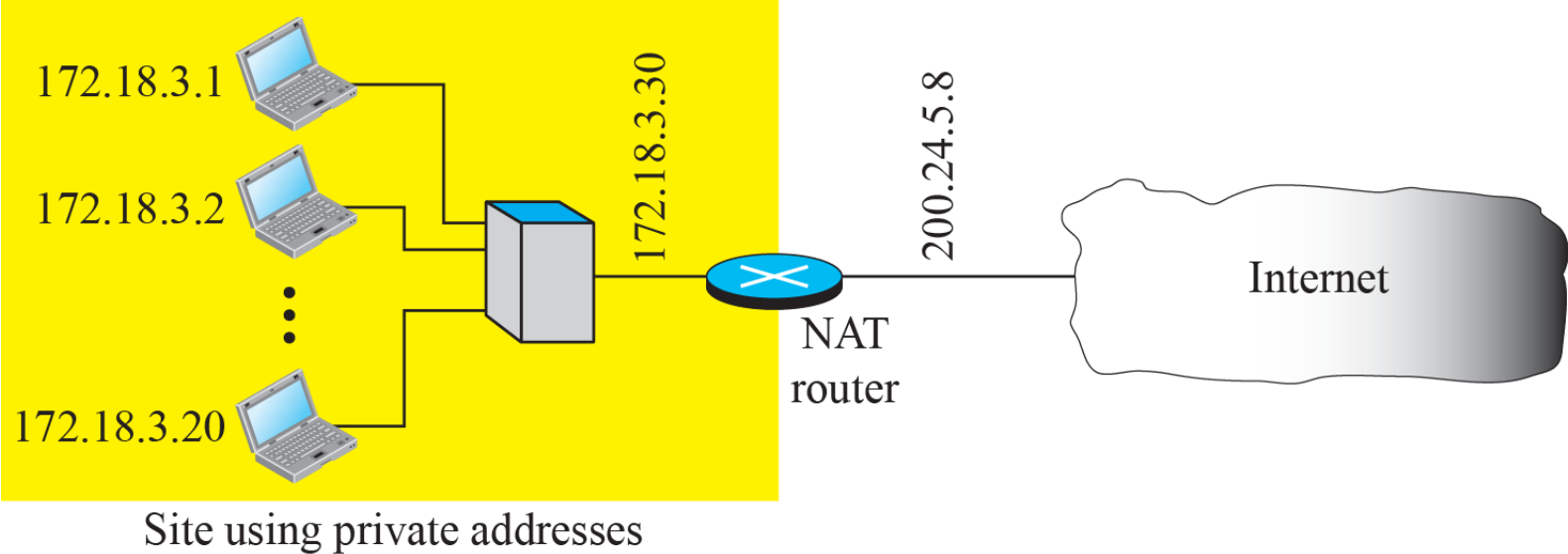
Application
UDP
IP

Note:
Only partial
information
is given.

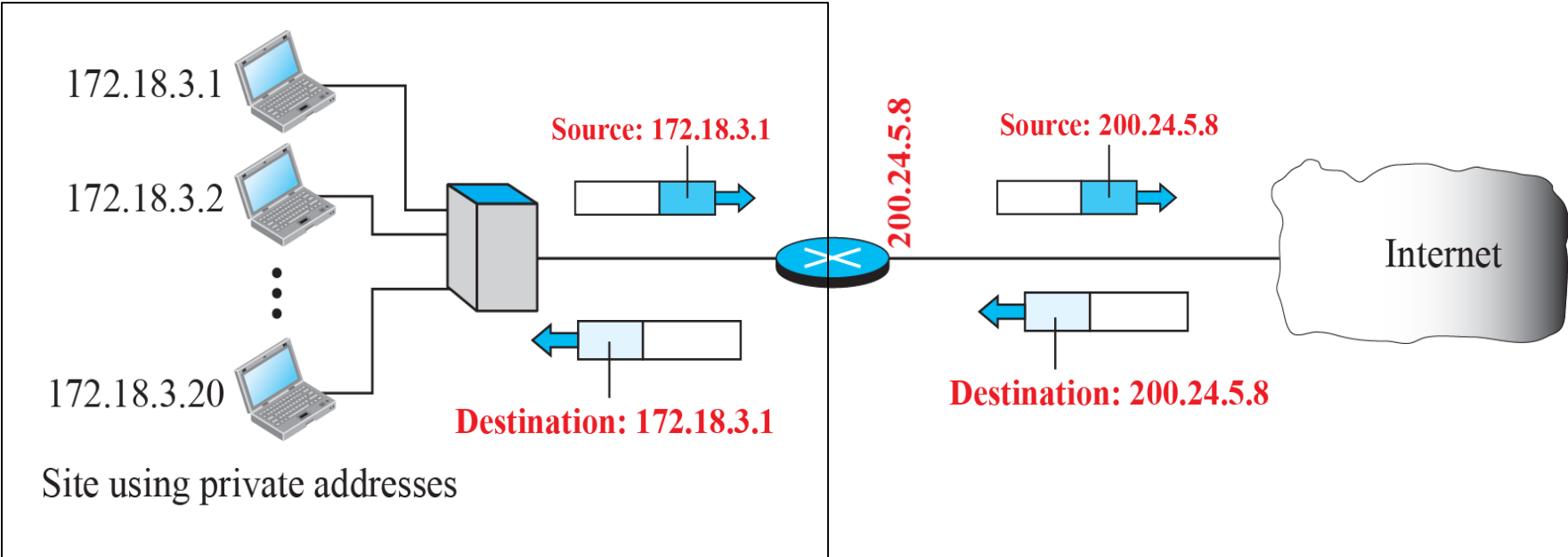
NAT

- *A technology that can provide the mapping between the private and universal addresses, and at the same time support virtual private networks*
- *allows a site to use a set of private addresses for internal communication and a set of global Internet addresses (at least one) for communication with the rest of the world.*

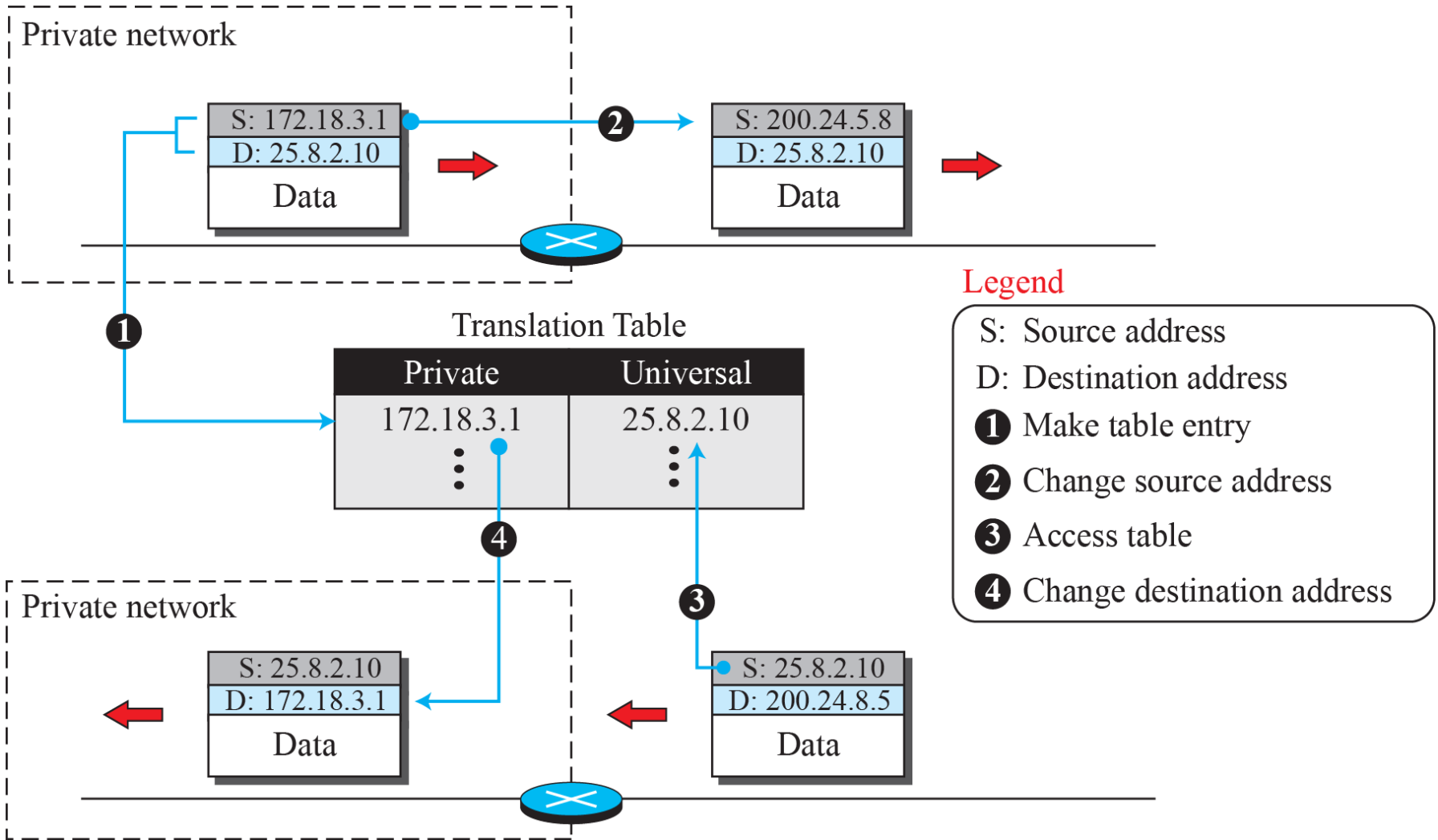
NAT



Address translation



Translation



Five-column translation table

<i>Private address</i>	<i>Private port</i>	<i>External address</i>	<i>External port</i>	<i>Transport protocol</i>
172.18.3.1	1400	25.8.3.2	80	TCP
172.18.3.2	1401	25.8.3.2	80	TCP
⋮	⋮	⋮	⋮	⋮