Multicasting And Multicast Routing Protocols

Outline

1 Introduction

2 Multicast Addresses

3 IGMP

4 Multicast Routing

5 Routing Protocols

6 MBONE

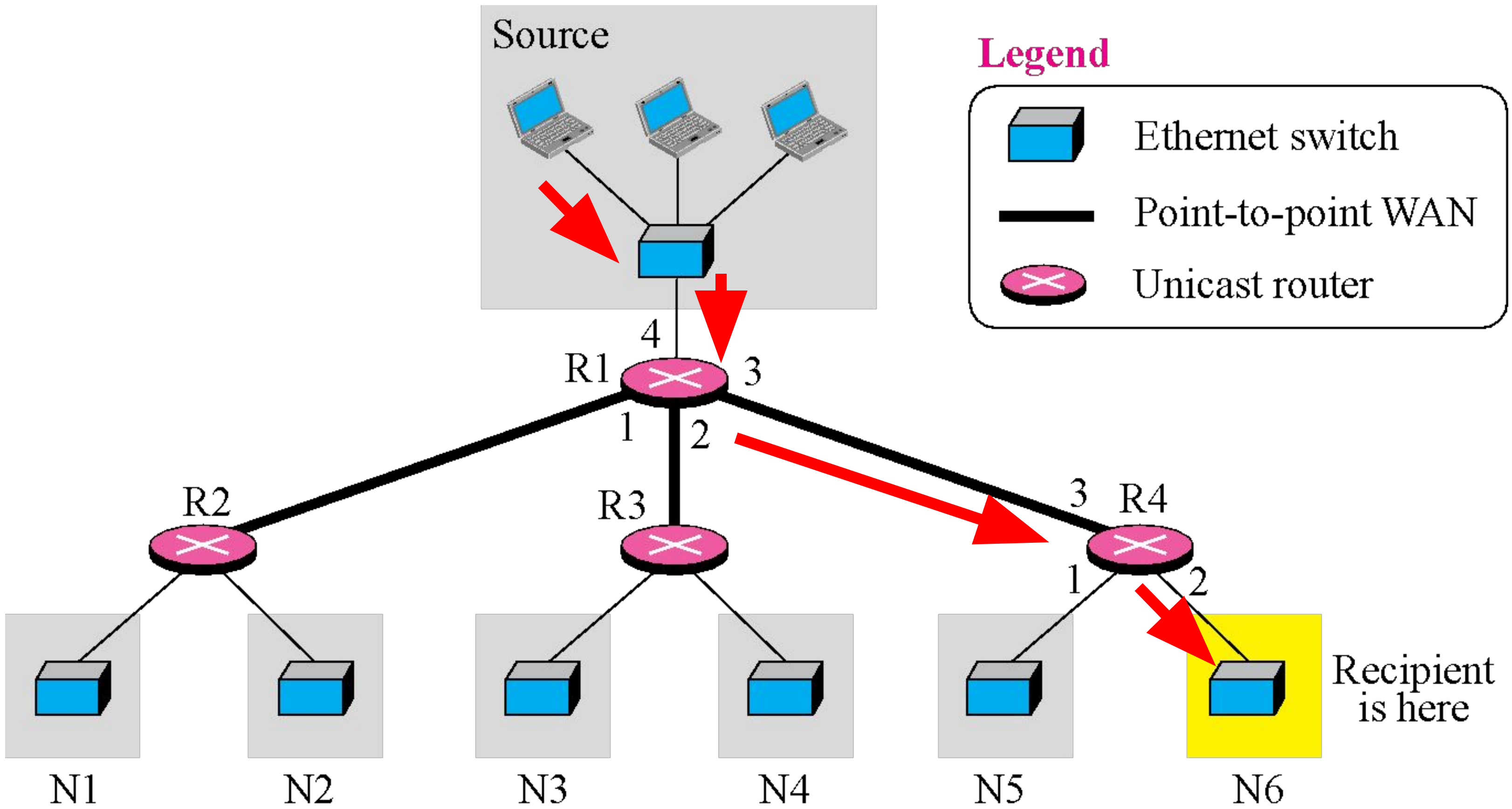
1 INTRODUCTION

We have learned that forwarding a datagram is normally based on the prefix of the destination address in the datagram. Address aggregation mechanism may combine several datagrams to be delivered to an ISP and then separate them to be delivered to their final destination networks, but the principle does not change.

Understanding the above forwarding principle, we can now define unicasting, multicasting, and broadcasting. Let us clarify these terms as they relate to the Internet.

- ✔ Unicasting
- ✔ Multicasting
- ✔ Broadcasting

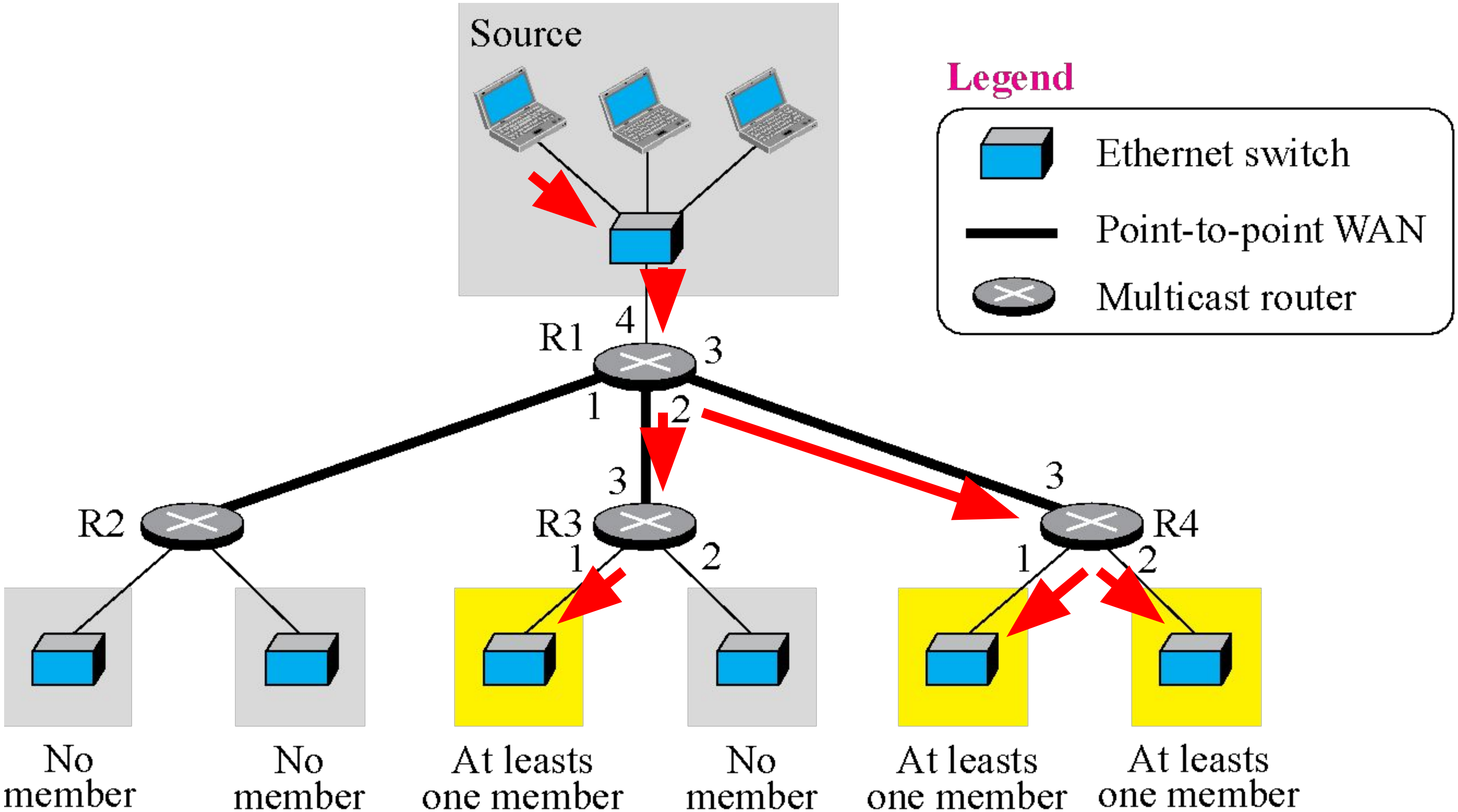
Figure 1 *Unicasting*



Note

In unicasting, the router forwards the received datagram through only one of its interfaces.

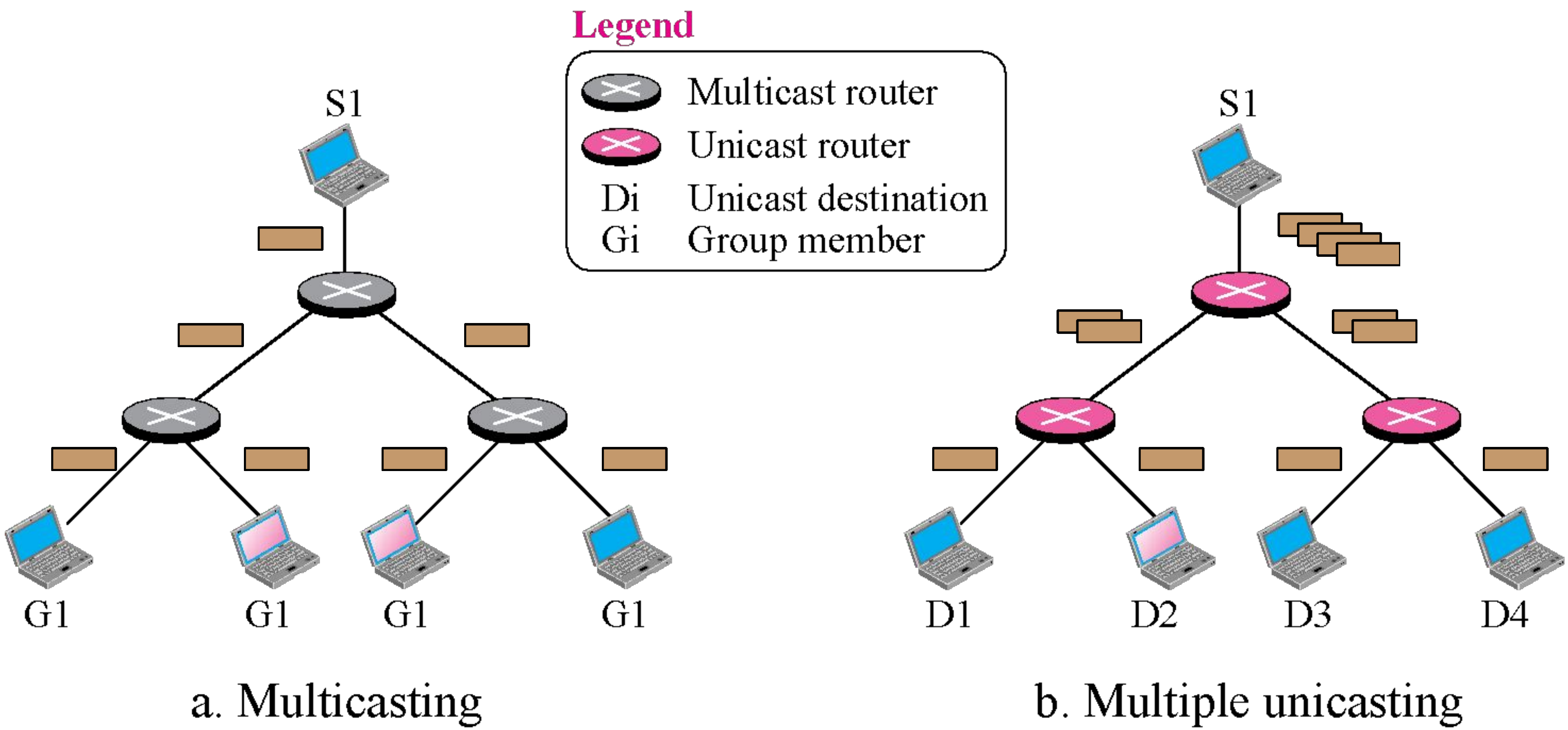
Figure 2 *Multicasting*



Note

In multicasting, the router may forward the received datagram through several of its interfaces.

Figure 3 *Multicasting versus multiple unicasting*



Note

Emulation of multicasting through multiple unicasting is not efficient and may create long delays, particularly with a large group.

2 MULTICAST ADDRESSES

A multicast address is a destination address for a group of hosts that have joined a multicast group.
A packet that uses a multicast address as a destination can reach all members of the group unless there are some filtering restriction by the receiver.

- ✔ **Multicast Addresses in IPv4**
- ✔ **Selecting Multicast Addresses**
- ✔ **Delivery of Multicast Packets at Data Link Layer**

Table 12.1 *Multicast Address Ranges*

CIDR	*Range*	*Assignment*
224.0.0.0/24	224.0.0.0 → 224.0.0.255	Local Network Control Block
224.0.1.0/24	224.0.1.0 → 224.0.1.255	Internetwork Control Block
	224.0.2.0 → 224.0.255.255	AD HOC Block
224.1.0.0/16	224.1.0.0 → 224.1.255.255	ST Multicast Group Block
224.2.0.0/16	224.2.0.0 → 224.2.255.255	SDP/SAP Block
	224.3.0.0 → 231.255.255.255	Reserved
232.0.0.0/8	232.0.0.0 → 224.255.255.255	Source Specific Multicast (SSM)
233.0.0.0/8	233.0.0.0 → 233.255.255.255	GLOP Block
	234.0.0.0 → 238.255.255.255	Reserved
239.0.0.0/8	239.0.0.0 → 239.255.255.255	Administratively Scoped Block

Table 12.2 *Some addresses in Network Control Block*

Address	*Assignment*
224.0.0.0	Base address (reserved)
224.0.0.1	All systems (hosts or routers) on this network
224.0.0.2	All routers on this network
224.0.0.4	DMVRP routers
224.0.0.5	OSPF routers
224.0.0.7	ST (stream) routers
224.0.0.8	ST (stream) hosts
224.0.0.9	RIP2 routers
224.0.0.10	IGRP routers
224.0.0.11	Mobile Agents
224.0.0.12	DHCP servers
224.0.0.13	PIM routers
224.0.0.14	RSVP encapsulation
224.0.0.15	CBT routers
224.0.0.22	IGMPv3

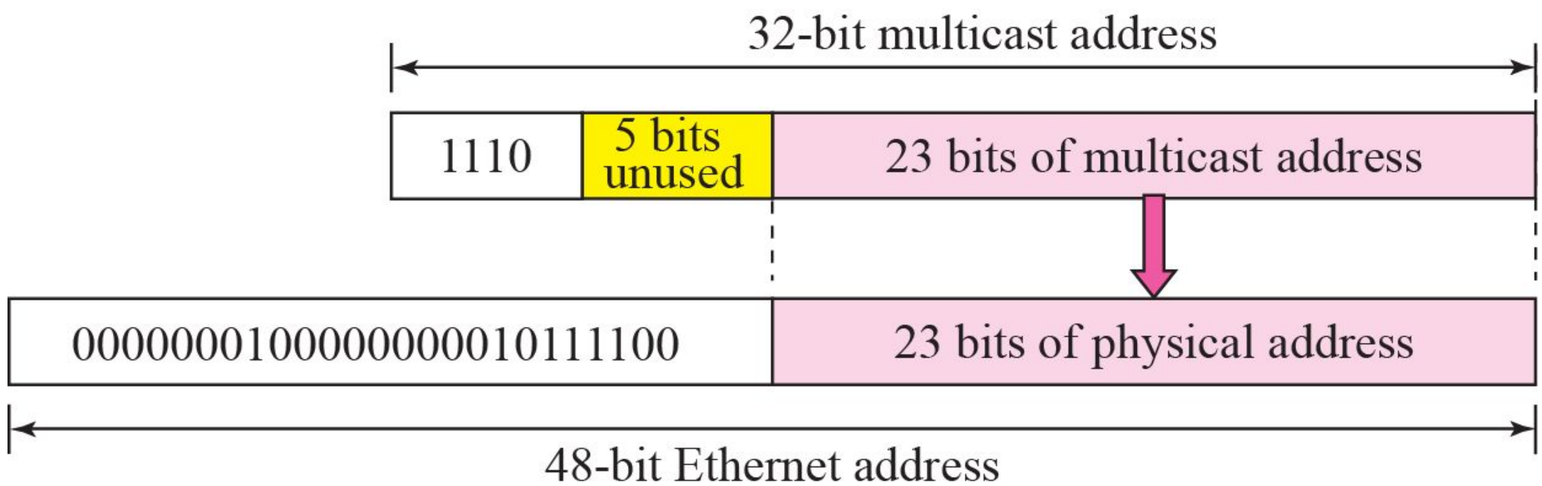
Example 1

We use netstat with three options, -n, -r, and -a. The -n option gives the numeric versions of IP addresses, the -r option gives the routing table, and the -a option gives all addresses (unicast and multicast). Note that we show only the fields relative to our discussion. The multicast address is shown in color.

```
$netstat -nra
Kernel IP routing table
```

Destination	Gateway	Mask	Flags	Iface
153.18.16.0	0.0.0.0	255.255.240.0	U	eth0
169.254.0.0	0.0.0.0	255.255.0.0	U	eth0
127.0.0.0	0.0.0.0	255.0.0.0	U	lo
224.0.0.0	**0.0.0.0**	**224.0.0.0**	**U**	**eth0**
0.0.0.0	153.18.31	0.0.0.0	UG	eth0

Figure 4 *Mapping class D to Ethernet physical address*



Note

An Ethernet multicast physical address is in the range 01:00:5E:00:00:00 to 01:00:5E:7F:FF:FF.

Example 2

Change the multicast IP address 232.43.14.7 to an Ethernet multicast physical address.

Solution

We can do this in two steps:

a. We write the rightmost 23 bits of the IP address in hexadecimal. This can be done by changing the rightmost 3 bytes to hexadecimal and then subtracting 8 from the leftmost digit if it is greater than or equal to 8. In our example the result is 2B:0E:07.

b. We add the result of part a to the starting Ethernet multicast address, which is 01:00:5E:00:00:00. The result is

Example 3

Change the multicast IP address 238.212.24.9 to an Ethernet multicast address.

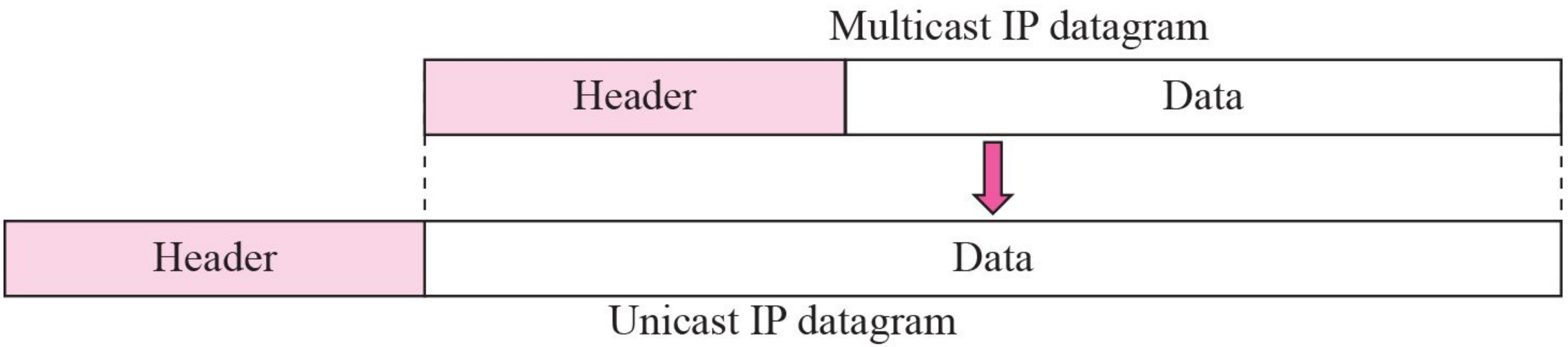
Solution

We can do this in two steps:

a. **The rightmost 3 bytes in hexadecimal are D4:18:09. We need to subtract 8 from the leftmost digit, resulting in 54:18:09.**
b. **We add the result of part a to the Ethernet multicast starting address. The result is**

01:00:5E:54:18:09

Figure 5 *Tunneling*

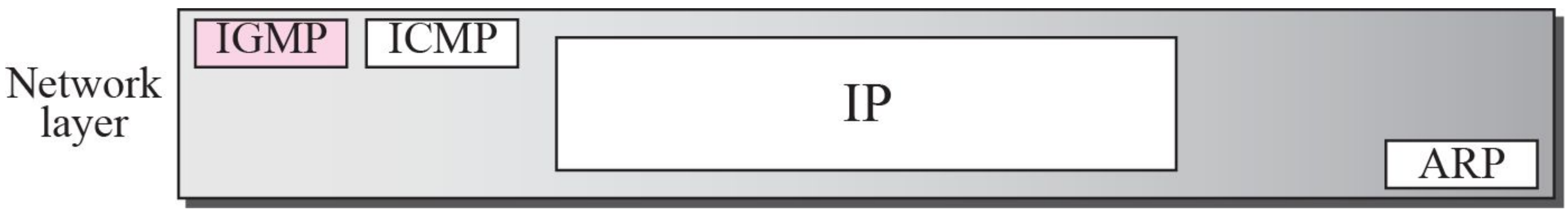


3 IGMP

Multicast communication means that a sender sends a message to a group of recipients that are members of the same group. Each multicast router needs to know the list of groups that have at least one loyal member related to each interface. Collection of this type of information is done at two levels: locally and globally. The first task is done by the IGMP protocol; the second task is done by the multicast routing protocols.

- ✔ **Group Management**
- ✔ **IGMP Messages**
- ✔ **IGMP Protocol Applied to host and Router**
- ✔ **Role of IGMP in Forwarding**
- ✔ **Variables and Timers**
- ✔ **Encapsulation**
- ✔ **Compatibility with other Versions**

Figure 6 *Position of IGMP in the network layer*



Note

IGMP is a group management protocol. It helps a multicast router create and update a list of loyal members related to each router interface.

Figure 7 *IGMP messages*

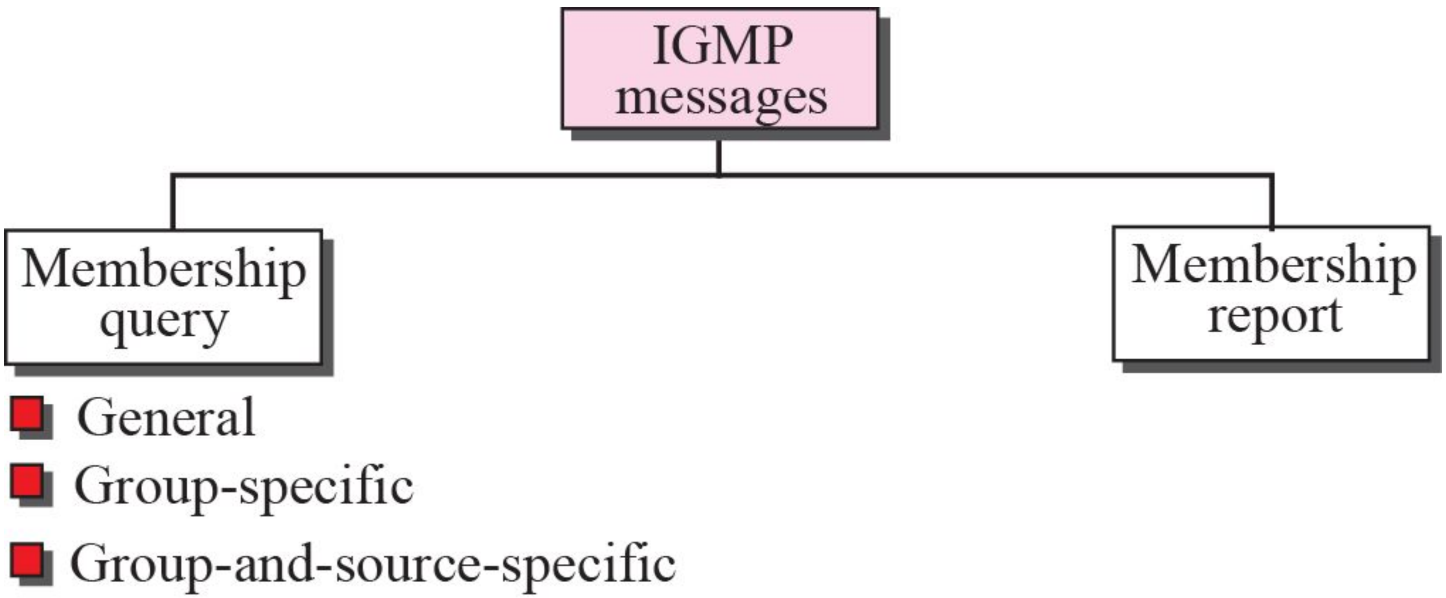


Figure 8 *Membership query message format*

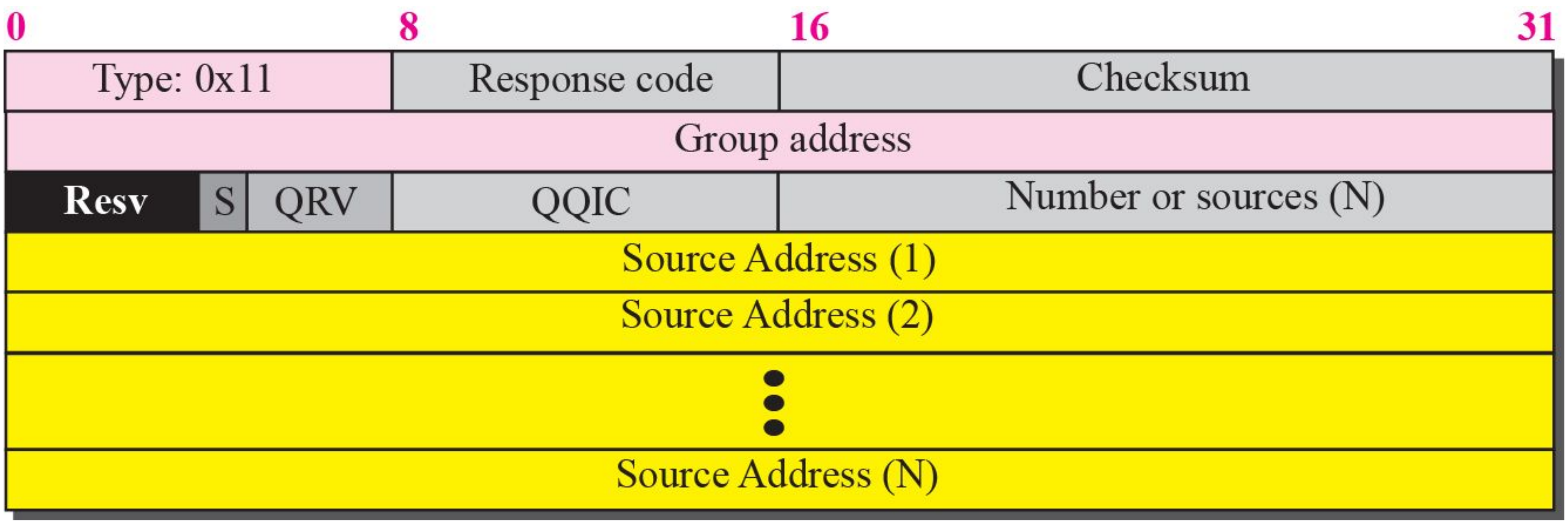


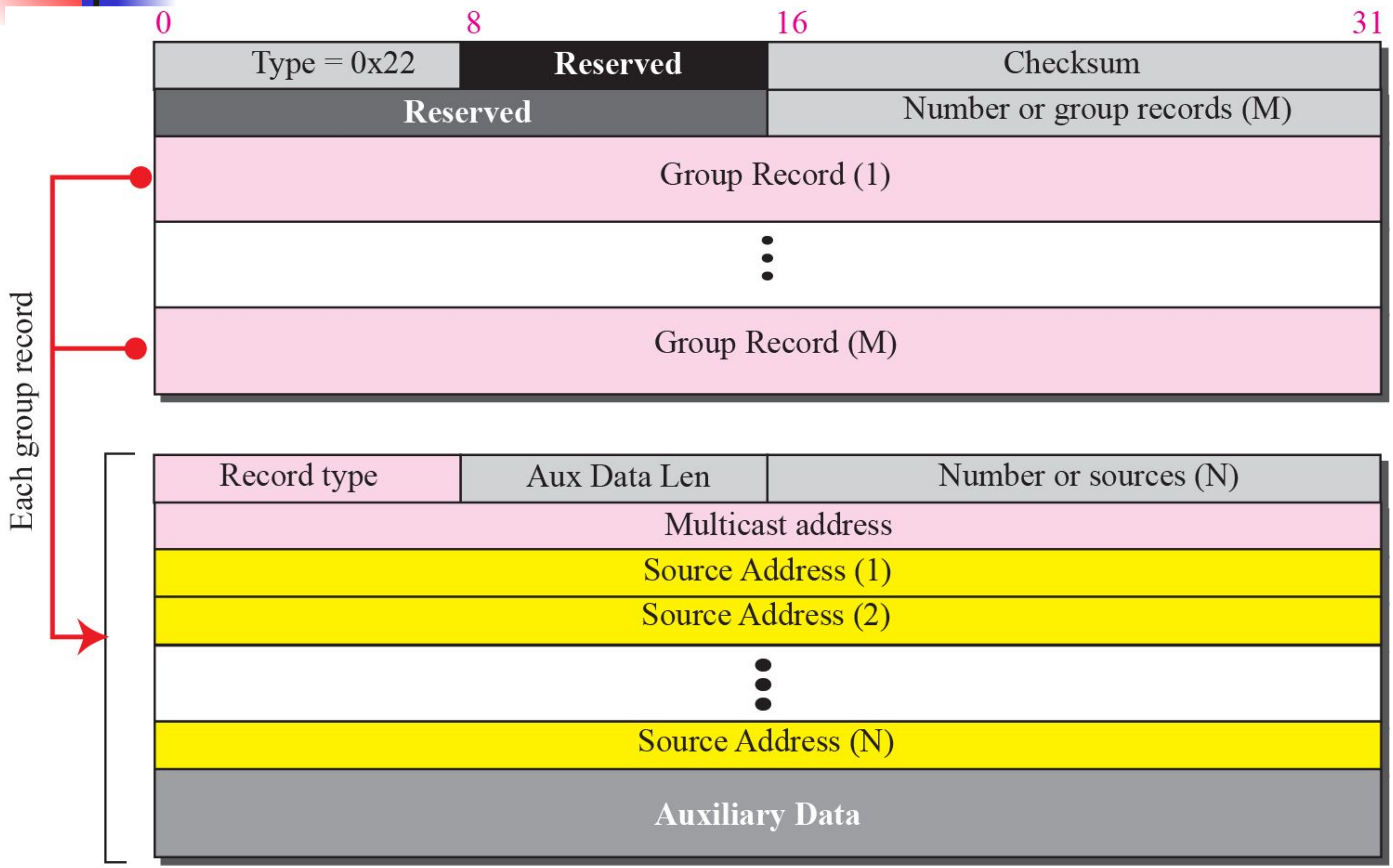
Figure 9 *Three forms of query messages*

a. General

b. Group-specific

c. Group-and-source-specific

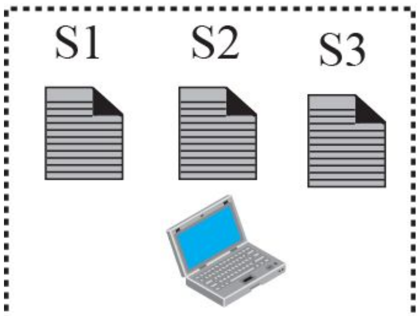
Figure 10 *Membership report message format*



Example 4

Figure 11 shows a host with three processes: S1, S2, and S3. The first process has only one record; the second and the third processes each have two records. We have used lowercase alphabet to show the source address.

Figure 11 *Socket state*



Legend S: Socket; a, b, ...: Source addresses

States Table

Socket	Multicast group	Filter	Source addresses
S1	226.14.5.2	Include	a, b, d, e
S2	226.14.5.2	Exclude	a, b, c
S2	228.24.21.4	Include	b, c, f
S3	226.14.5.2	Exclude	b, c, g
S3	228.24.21.4	Include	d, e, f

Note

Each time there is a change in any socket record, the interface state will change using the above-mentioned rules.

If a record with the same multicast group has two or more different lists of resources, the following two rules need to be followed to combine the list of resources.

- If any of the records to be combined has the *exclusive* filter mode, then the resulting interface record will have the *exclusive* filter mode and the list of the source addresses is made as shown below:

  a. Apply the set intersection operation on all the address lists with *exclusive* filters.

  b. Apply the set difference operation on the result of part *a* and all the address lists with *inclusive* filters.

- If all the records to be combined have the inclusive filter mode, then the resulting interface record will have the inclusive filter mode and the list of the source addresses is found by applying the set union operations on all the address lists.

Example 5

We use the two rules described above to create the interface state for the host in Example 12.4. First we found the list of source address for each multicast group.

a. Multicast group 226.14.5.2 has two exclude lists and one include list. The result is an exclude list as calculated below.

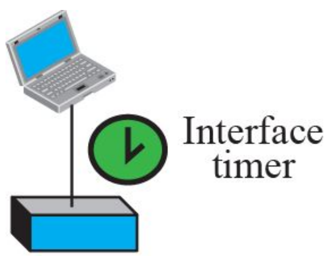
exclude source list = {a, b, c} . {b, c, g} − {a, b, d, e} = {c}

b. Multicast group: 228.24.21.4 has two include lists. The result is an include list as calculated below. We use the plus sign for the union operation.

include source list = {b, c, f} + {d, e, f} = {b, c, d, e, f}

Figure 12 shows the interface state.

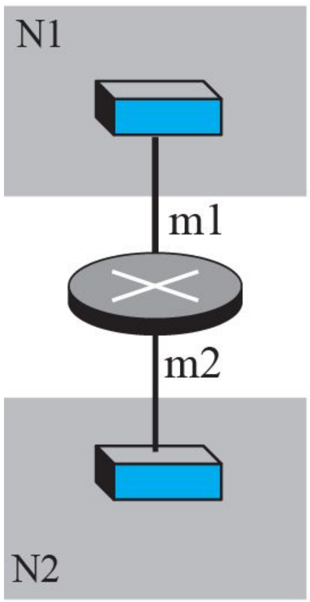
Figure 12 *Interface state*



Interface state

Multicast group	Group timer	Filter	Source addresses
226.14.5.2		Exclude	c
228.24.21.4		Include	b, c, d, e, f

Figure 14 *Router States*



State for interface m1

Multicast group	Timer	Filter	Source addresses
227.12.15.21		Exclude	(a ,) (c ,)
228.21.25.41		Include	(b ,) (d ,) (e ,)

State for interface m2

Multicast group	Timer	Filter	Source addresses
226.10.11.8		Exclude	(b ,)
227.21.25.41		Include	(a ,) (b ,) (c ,)
228.32.12.40		Include	(d ,) (e ,) (f ,)

Table 12.6 *Messages in Versions 1 and 2*

Version	*Type Value*	*Message Type*
1	0x11	Query
	0x12	Membership Report
2	0x11	Query
	0x16	Membership Report
	0x17	Leave Group

4 MULTICAST ROUTING

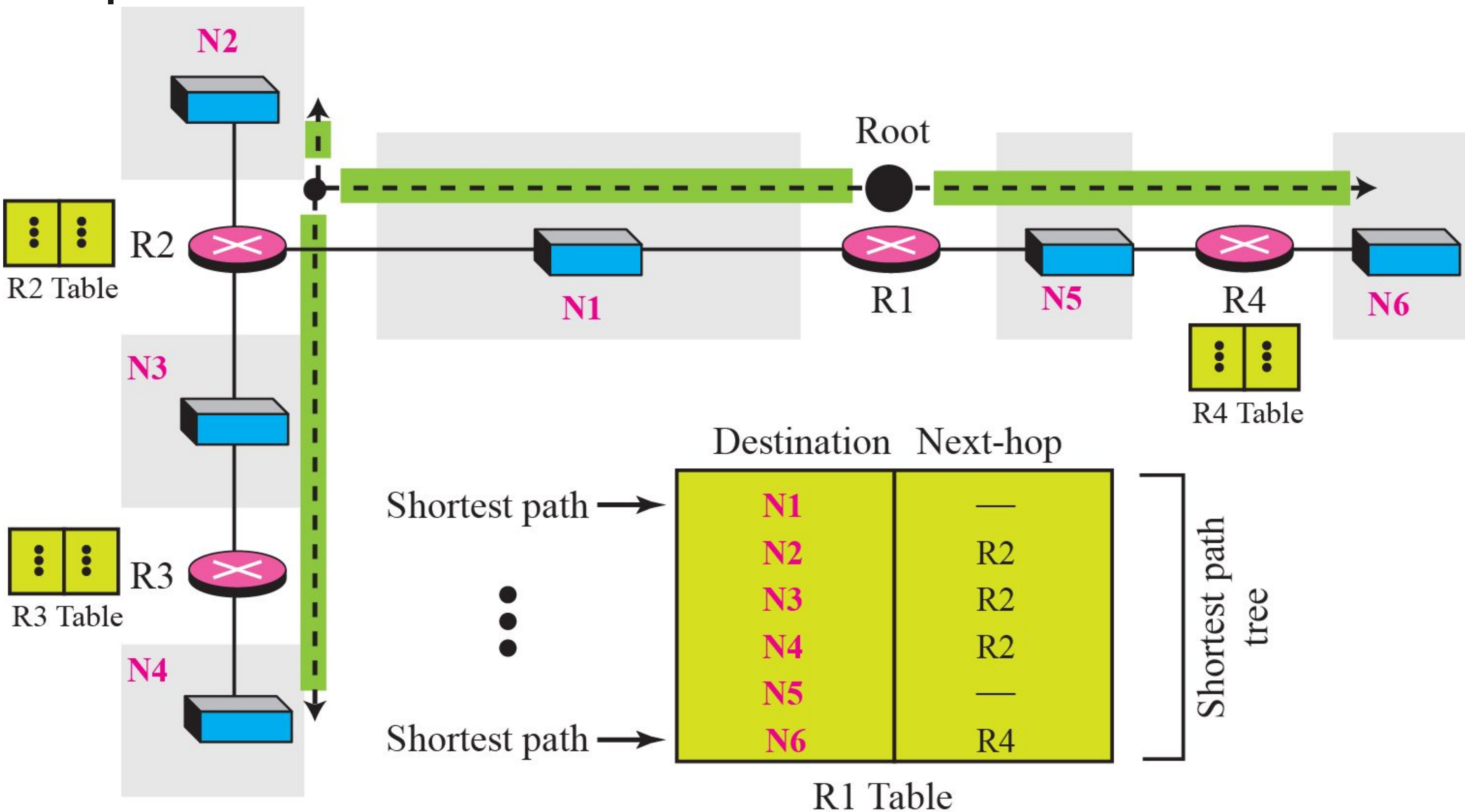
Now we show how information collected by IGMP is disseminated to other routers using multicast routing protocols. However, we first discuss the idea of optimal routing, common in all multicast protocols. We then give an overview of multicast routing protocols.

✔ **Optimal Routing: Shortest Path Trees**

Note

In unicast routing, each router in the domain has a table that defines a shortest path tree to possible destinations.

Figure 18 *Shortest path tree in unicast routing*



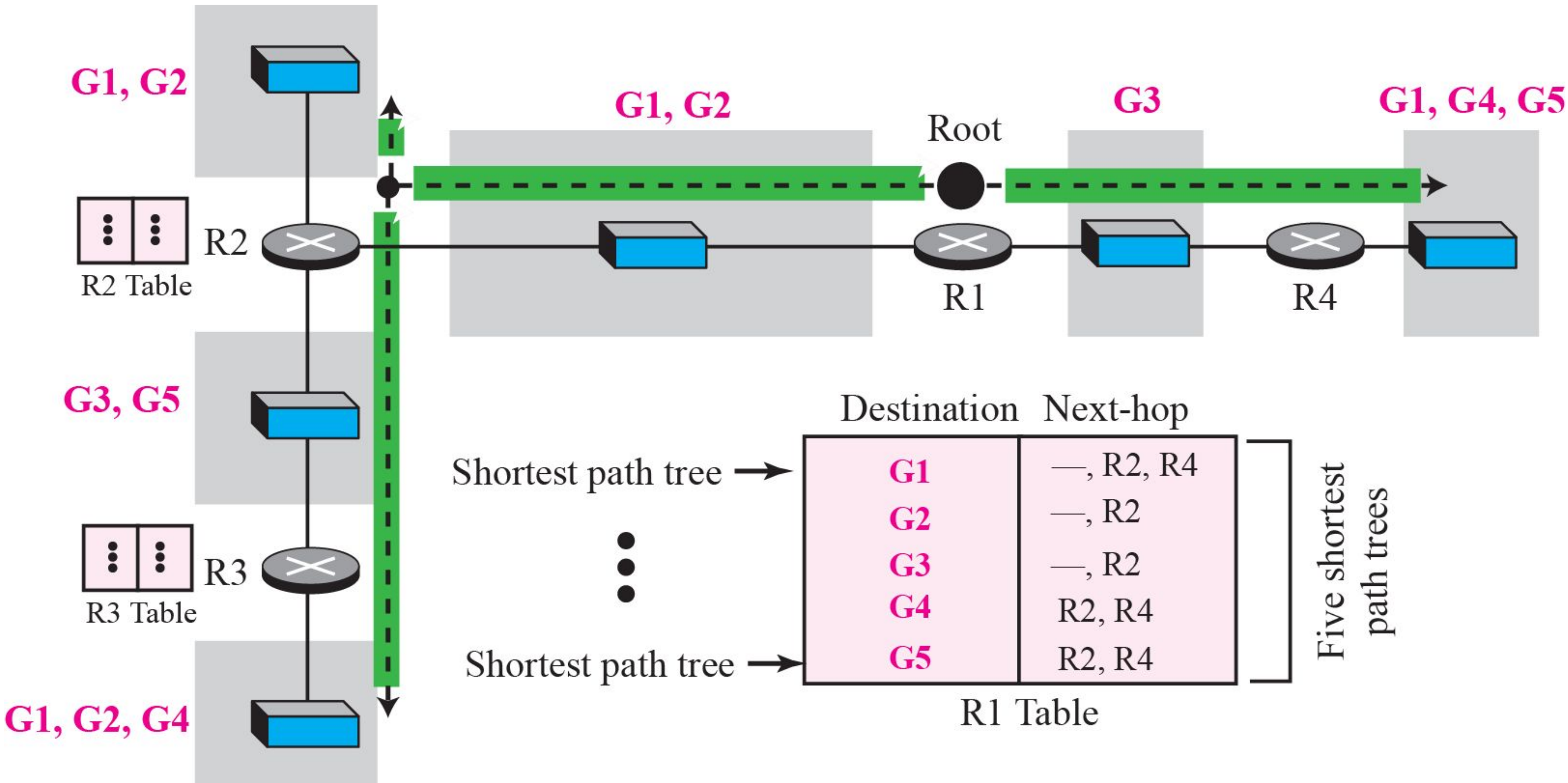
Note

In multicast routing, each involved router needs to construct a shortest path tree for each group.

Note

In the source-based tree approach, each router needs to have one shortest path tree for each group.

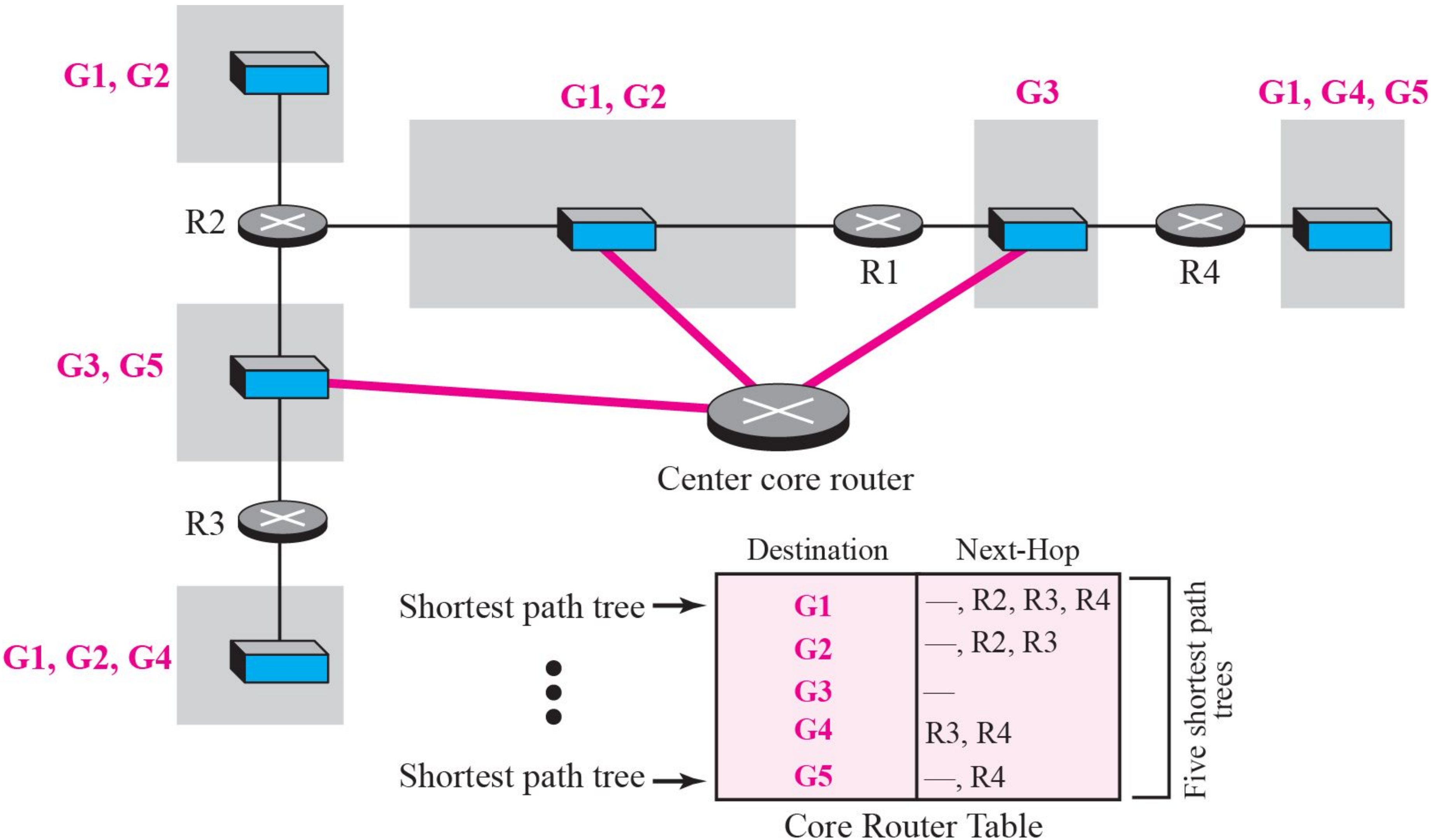
Figure 19 *Source-based tree approach*



Note

In the group-shared tree approach, only the core router, which has a shortest path tree for each group, is involved in multicasting.

Figure 20 *Group-shared tree approach*

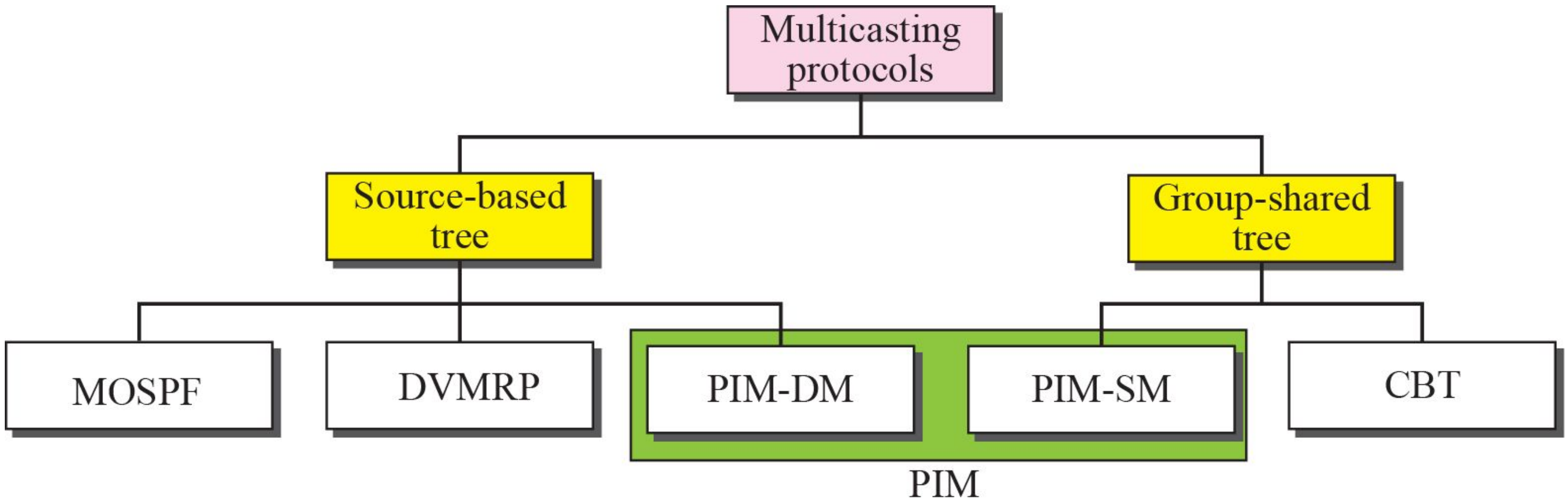


4 ROUTING PROTOCOLS

During the last few decades, several multicast routing protocols have emerged. Some of these protocols are extensions of unicast routing protocols; some are totally new. Different protocols are given below:

- ✔ **Multicast Link State Routing: MOSPF**
- ✔ **Multicast Distance Vector: DVMRP**
- ✔ **Core-Based Tree: CBT**
- ✔ **Protocol Independent Multicast: PIM**

Figure 21 *Taxonomy of common multicast protocols*



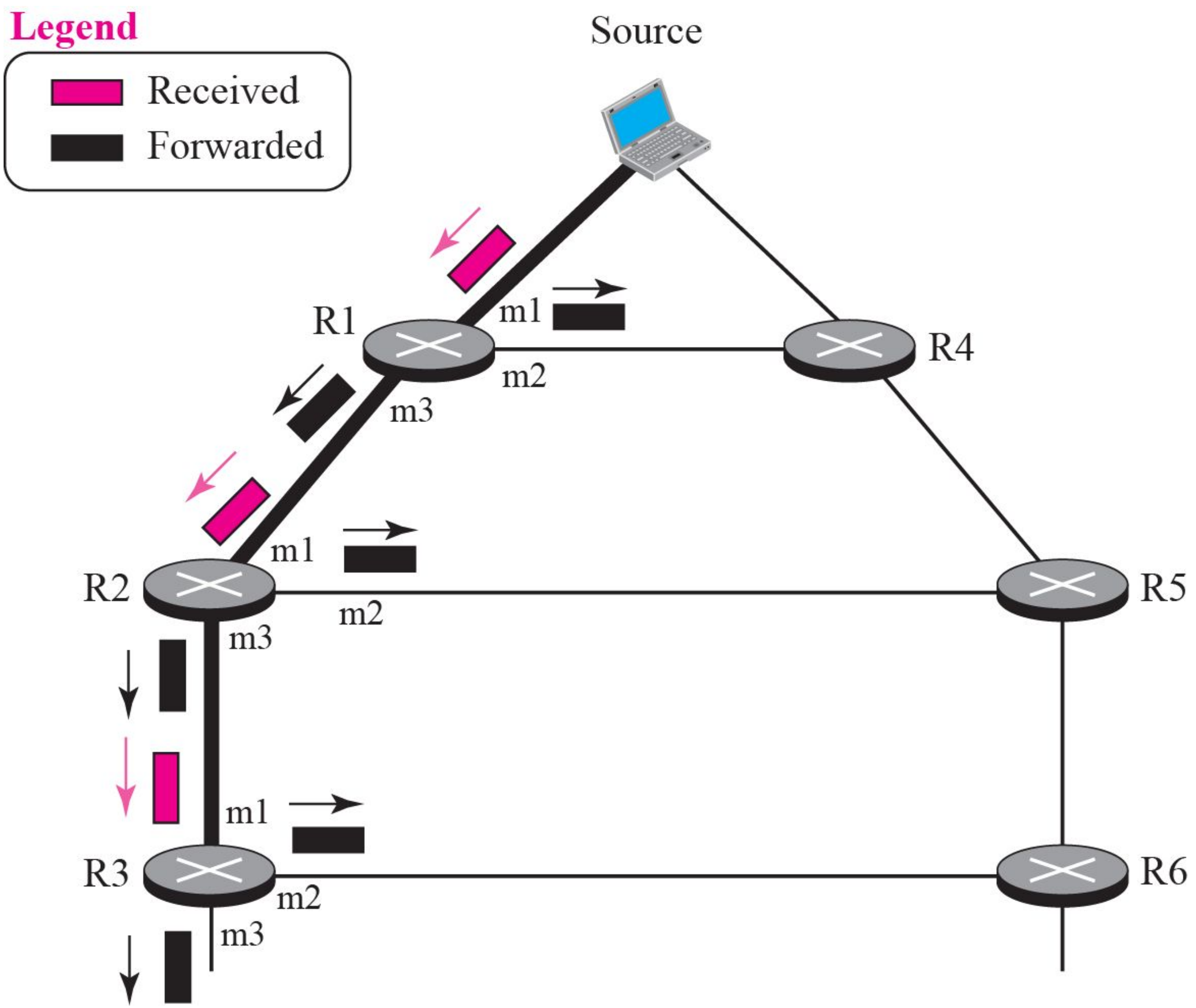
Note

Multicast link state routing uses the source-based tree approach.

Note

Flooding broadcasts packets, but creates loops in the systems.

Figure 22 *RPF*



Note

RPF eliminates the loop in the flooding process.

Figure 23 *Problem with RPF*

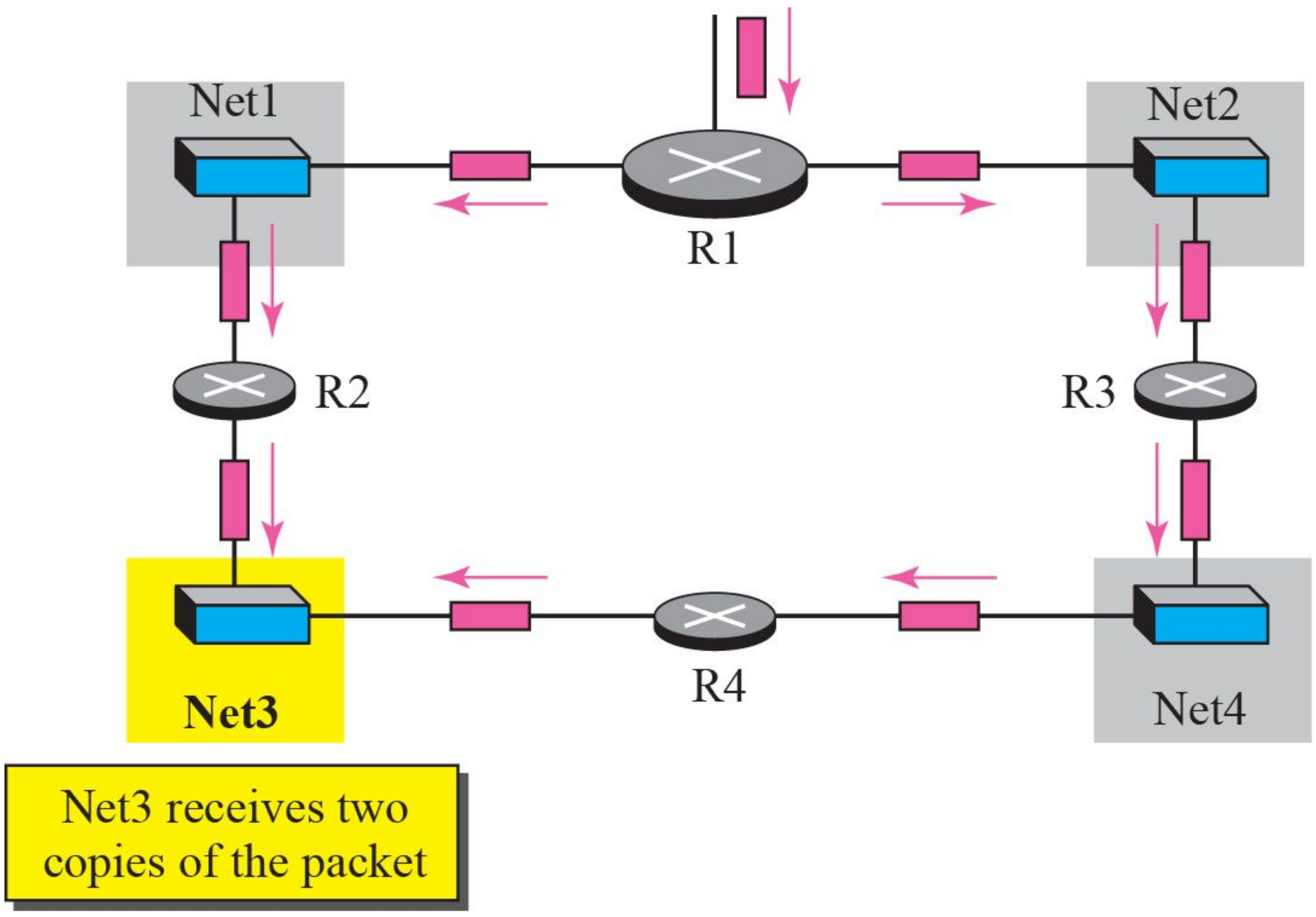
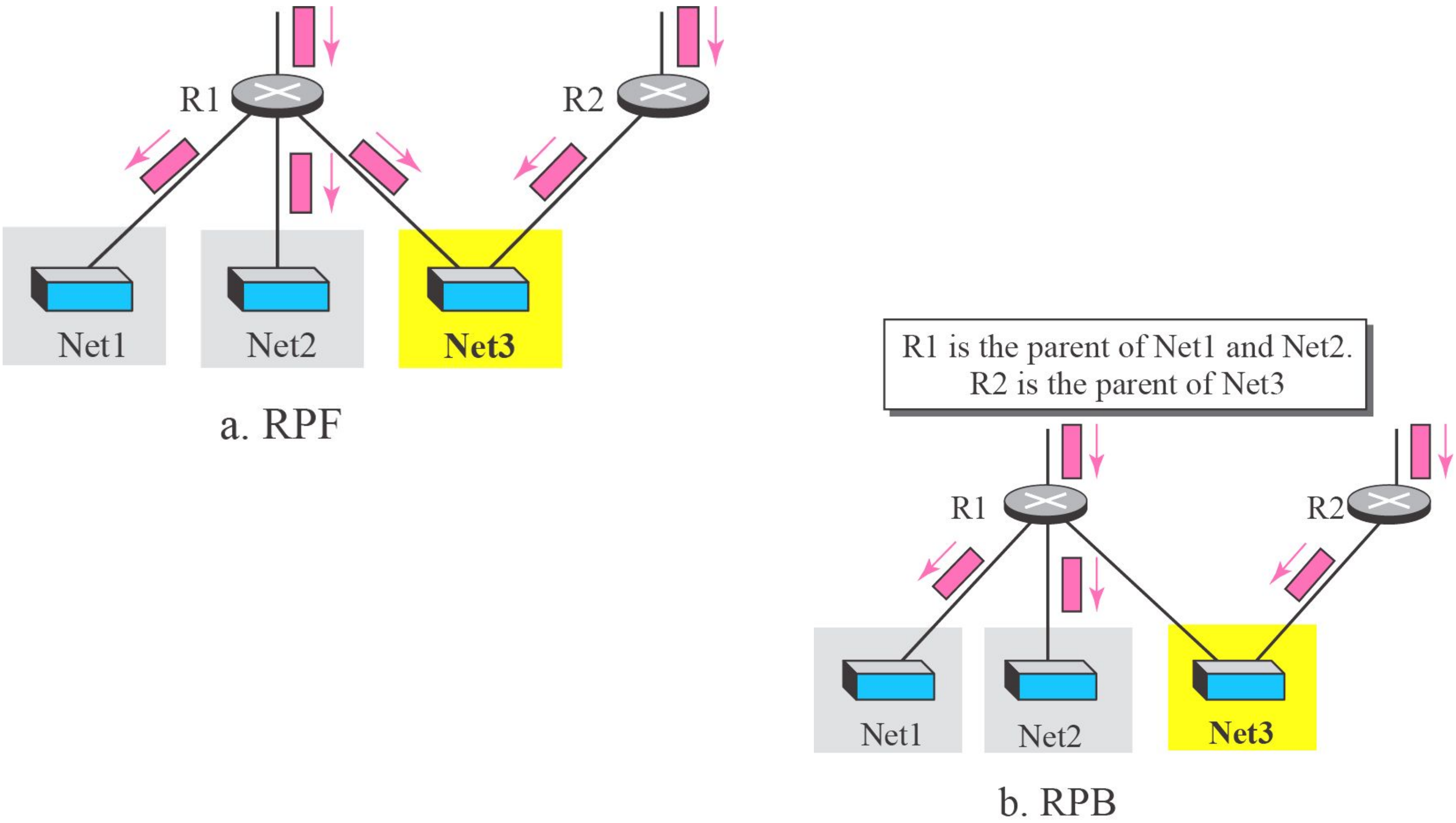


Figure 24 *RPF versus RPB*

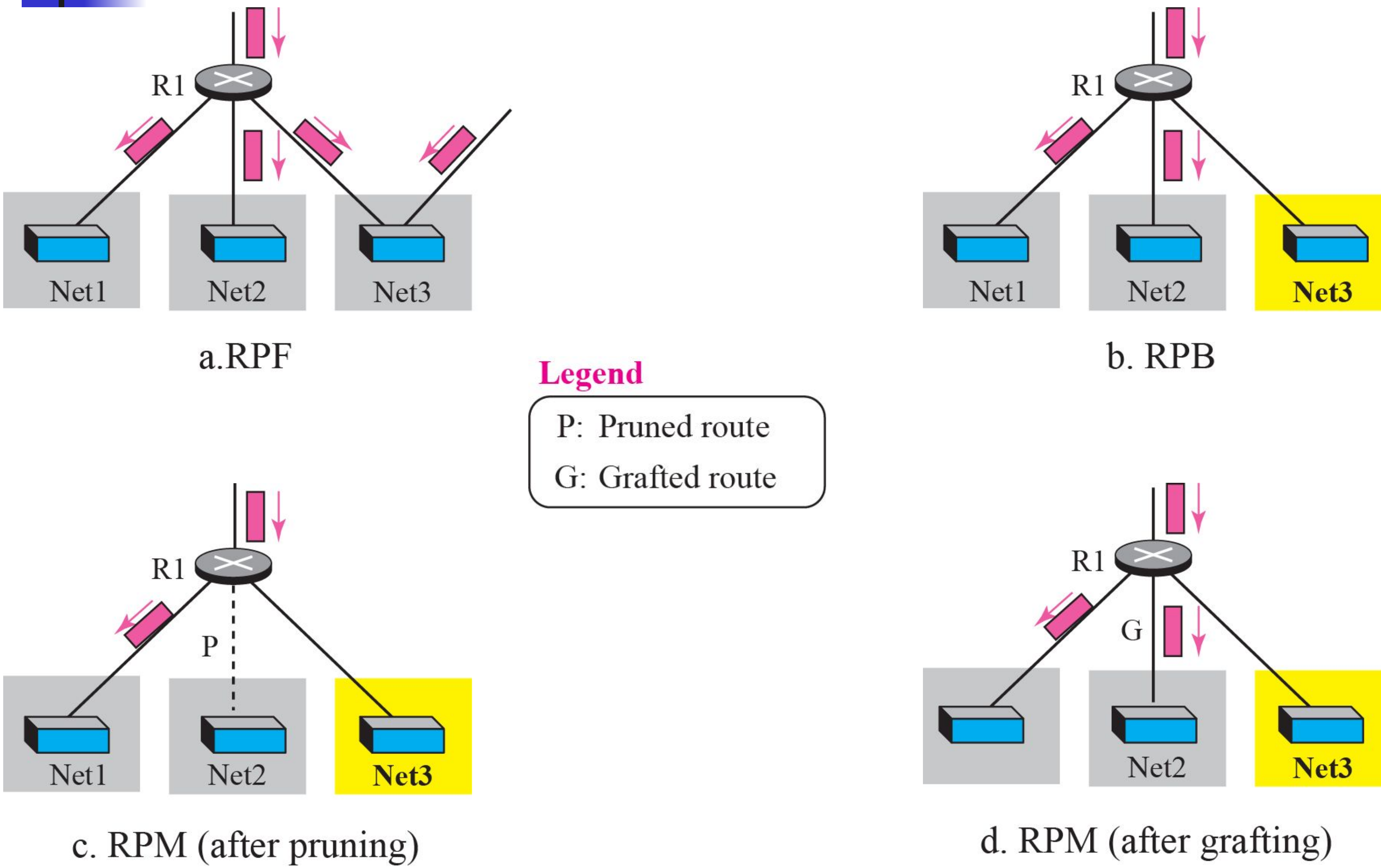


Note

RPB creates a shortest path broadcast tree from the source to each destination.

It guarantees that each destination receives one and only one copy of the packet.

Figure 25 *RPF, RPB, and RPM*



Note

RPM adds pruning and grafting to RPB to create a multicast shortest path tree that supports dynamic membership changes.

Figure 26 *Group-shared tree with rendezvous router*

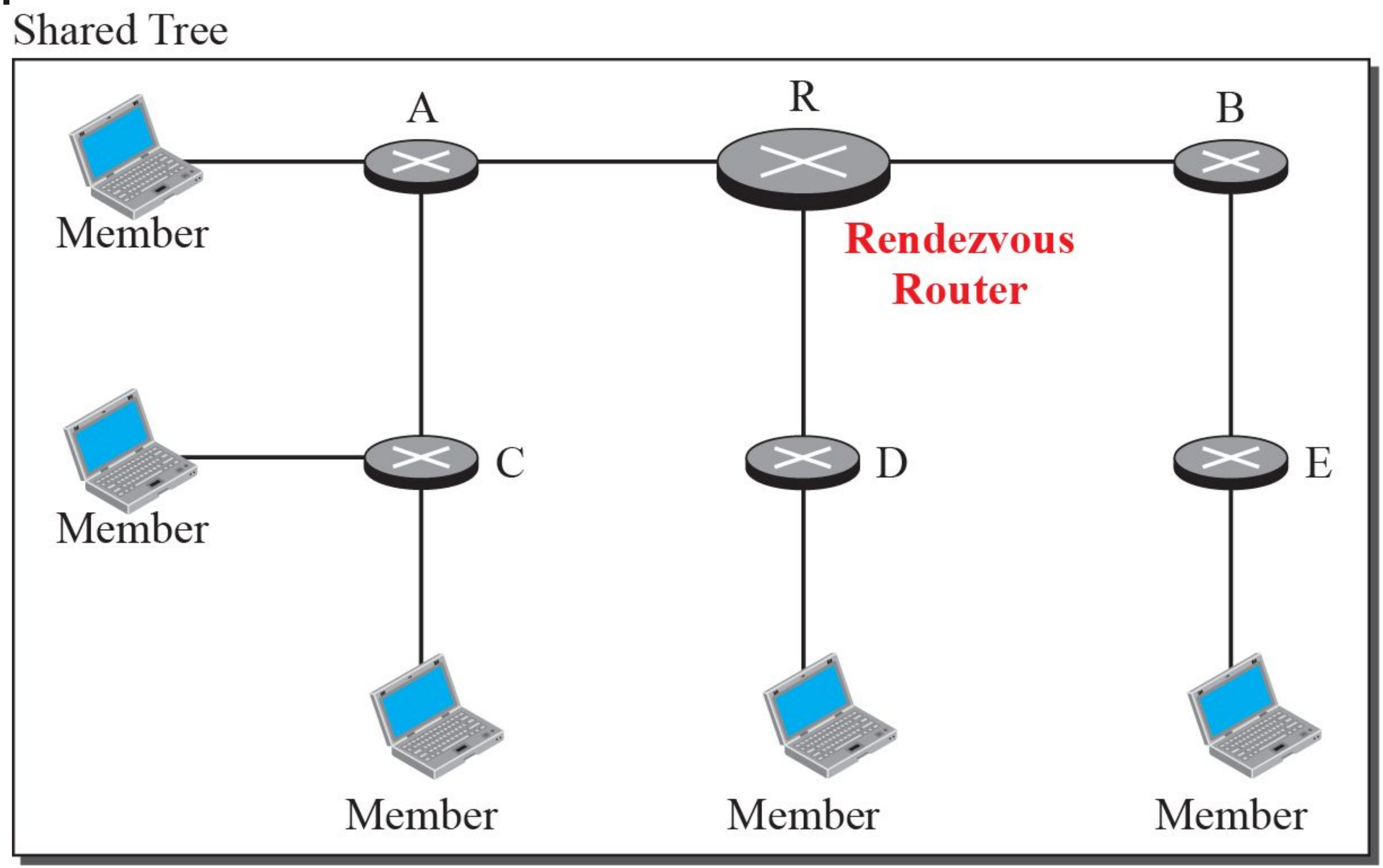
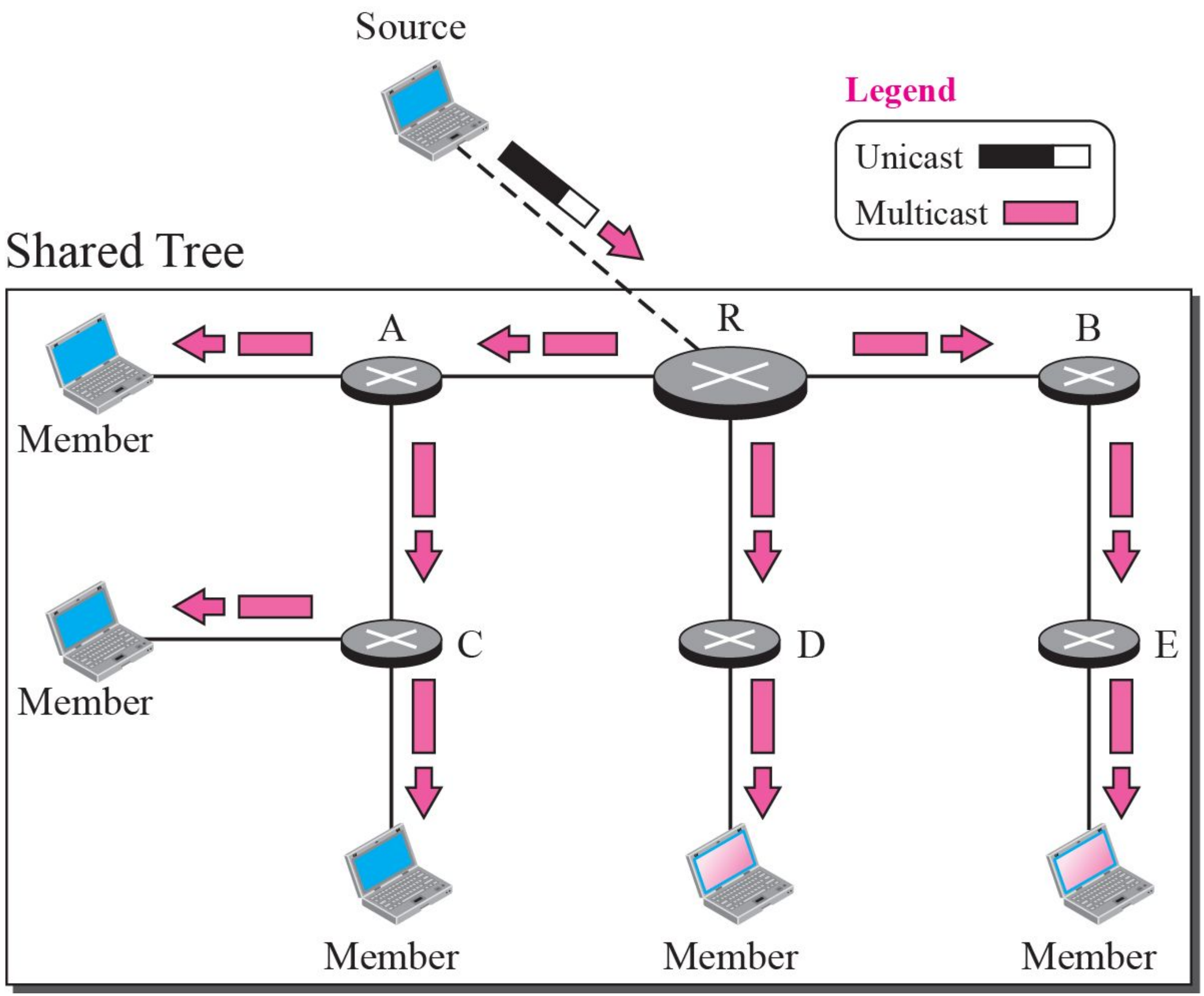


Figure 27 *Sending a multicast packet to the rendezvous router*



Note

In CBT, the source sends the multicast packet (encapsulated in a unicast packet) to the core router. The core router decapsulates the packet and forwards it to all interested interfaces.

Note

PIM-DM is used in a dense multicast environment, such as a LAN.

Note

PIM-DM uses RPF and pruning/grafting strategies to handle multicasting.

However, it is independent from the underlying unicast protocol.

Note

PIM-SM is used in a sparse multicast environment such as a WAN.

Note

PIM-SM is similar to CBT but uses a simpler procedure.

6 MBONE

Multimedia and real-time communication have increased the need for multicasting in the Internet. However, only a small fraction of Internet routers are multicast routers. Although this problem may be solved in the next few years by adding more and more multicast routers, there is another solution for this problem. The solution is tunneling. The multicast routers are seen as a group of routers on top of unicast routers. The multicast routers may not be connected directly, but they are connected logically.

Figure 28 *Logical tunneling*

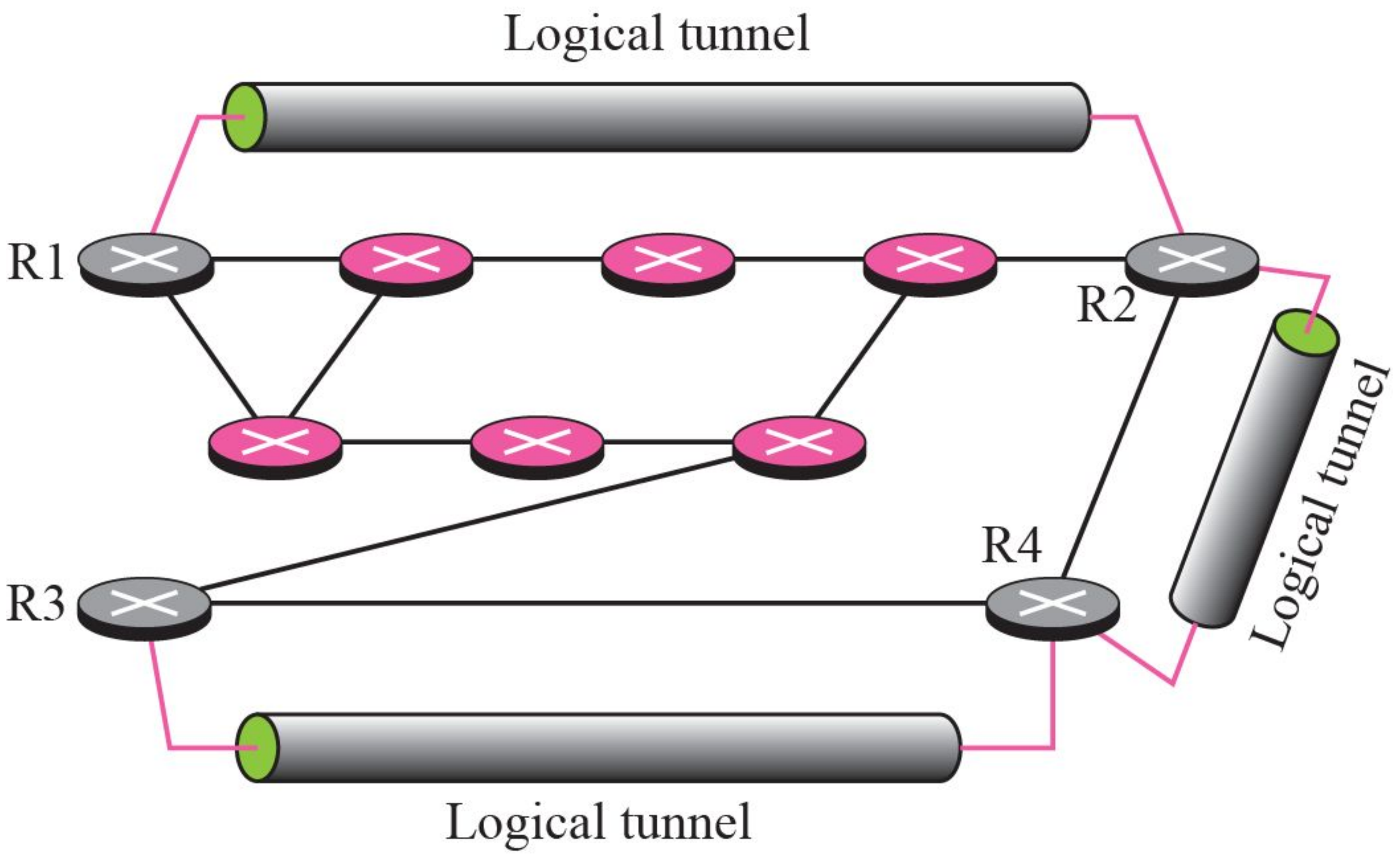


Figure 29 *MBONE*