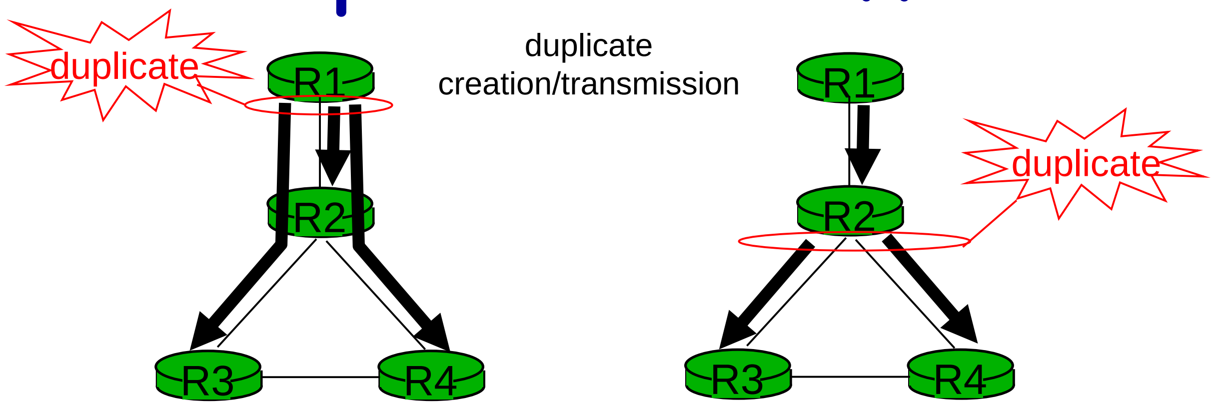
Multicast Routing

Wang zhanquan

Broadcast routing

- deliver packets from source to all other nodes
- source duplication is inefficient:



source duplication

in-network duplication

- source duplication: how does source determine recipient addresses?

9 Multicast Routing

9.1 Multicast on LAN

9.2 Multicast forwarding and routing information

9.3 Multicast forwarding tree

9.4 Multicast routing algorithm

9.5 Multicast routing protocol

9.6 DVMRP

9.7 Multicast open shortest path priority MOSPF

9.8 Core based tree CBT

9.9 PIM - DM

9.10 PIM - SM

9.11 Interdomain multicast technology

9.12 Multicast backbone MBone

9.13 IPv6 multicast technology

9.1Multicast on LAN

Multicast source and multicast group membership

- The multicast source and all members are on the same Ethernet network.Multicast control protocols are not required.HOW?

- The multicast source is not in LAN, and the router determines if there are multicast group members in that LAN. If so, multicast packets are forwarded to the LAN; If not, the multicast packet is not forwarded to this LAN.

Multicast implementation on switched LAN

- The switch LAN is connected to the Internet through a router.

HOW?

- **First**, **the router uses the IGMP message to know if a group member exists on the LAN.If so, multicast packets are forwarded to a switched LAN.**
- **Second**, **the switch forwards the packet to the destination MAC address.However, IGMP is the third layer protocol, and the switch's MAC address forwarding does not have the forwarding item (multicast address, output interface) of this multicast MAC address in the switch's MAC address forwarding, which will result in the switch can only flood multicast packets.For large switched LAN, this will affect the network efficiency.**

Switch LAN to multicast packet forwarding solution

- Manually configure switch to publish.
- General Multicast Register Protocol (GMRP).
- IGMP Snooping (IGMP Snooping) is required.
- the Cisco Group management Protocol.

1 The need for dynamic routing

In multicast routing, even if the network topology does not change (including the failure state of devices in the network), multicast routing changes as an application joins or leaves a multicast group. Unicast routing..

In unicast routing, routing changes occur only when topology changes or devices fail.

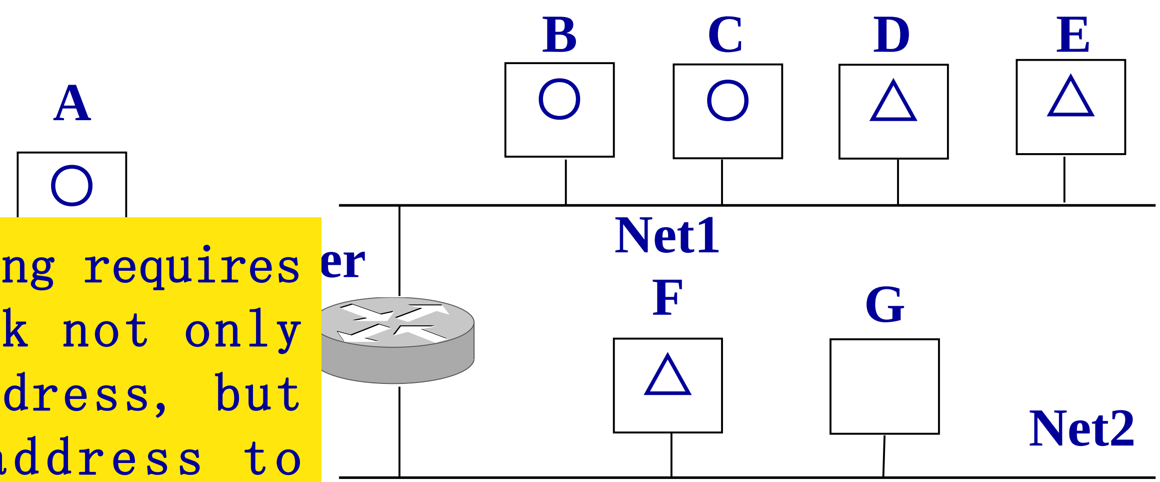
...nd routing

are different

e.g.

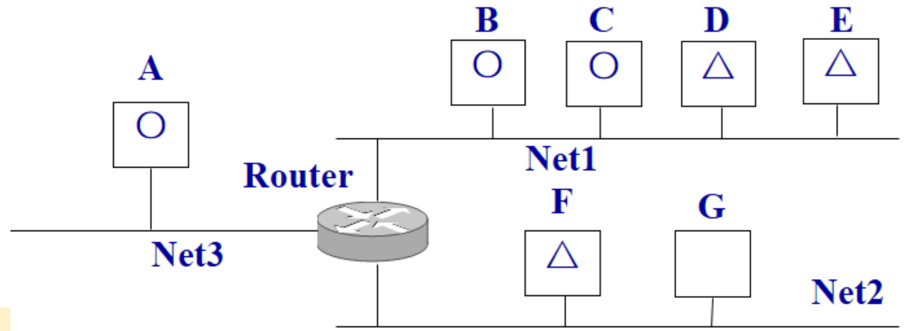
"△" Group2, members are hostD, E, F

Net2 no members of Group1



2 Multicast forwarding requires the router to check not only the destination address, but also the source address to determine when to copy a multicast packet and forward a copy of the multicast packet

3. SENDER



- IP allows any host (not necessarily a member of a multicast group) to forward packets to a multicast group.Host G is not a member of any multicast group, and G is on a network that does not have a member of Group1 multicast group.But G can send a group to Group1.More importantly, when this group crosses the Internet, it is likely to cross other networks that do not have multicast groups.
- multicast groups can be generated by hosts that are not members of a multicast group, and may be over networks that do not have any group members.

How to forward for message?

9.3 Multicast forwarding tree

- **Unicast routing protocol can find the shortest path to a certain destination network.**

- The realization of multicast in WAN is actually the generation of multicast tree in WAN, and the generation of multicast tree is realized through multicast routing protocol.

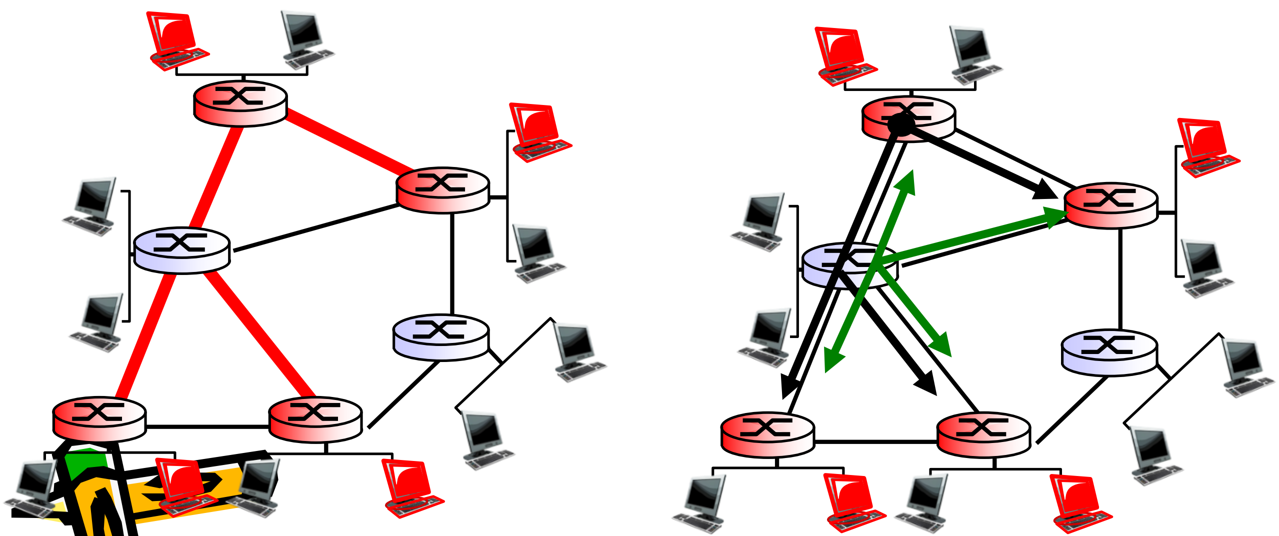
Multicast forwarding tree

- Use the graph theory terminology to describe a path from a specific source node to all members of a multicast group, which defines the trees in the graph theory, namely referred to as forwarding trees.
- ✓ Each multicast router corresponds to a node in the tree.
- ✓ The network connecting the two routers corresponds to an edge in the tree.
- ✓ The source nodes are the root or root nodes of the tree.
- ✓ The last router that follows a path from the source node is called the leaf router.
- ✓ A network connected to a leaf router is called a leaf network.
- ✓ The router responsible for sending multicast packets through its interface to a network is called the parent router of the network.

Multicast routing: problem statement

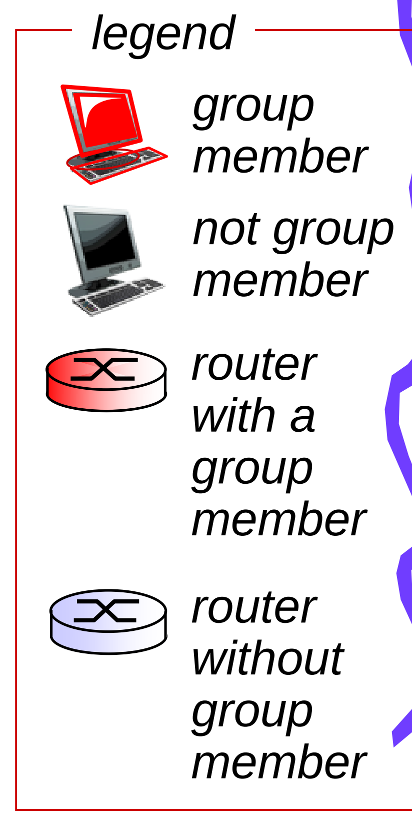
goal: find a tree (or trees) connecting routers having local mcast group members

- ***tree:*** not all paths between routers used
- ***shared-tree:*** same tree used by all group members
- *source-based:* different tree from each sender to members



shared tree

source-based trees



Approaches for building mcast trees

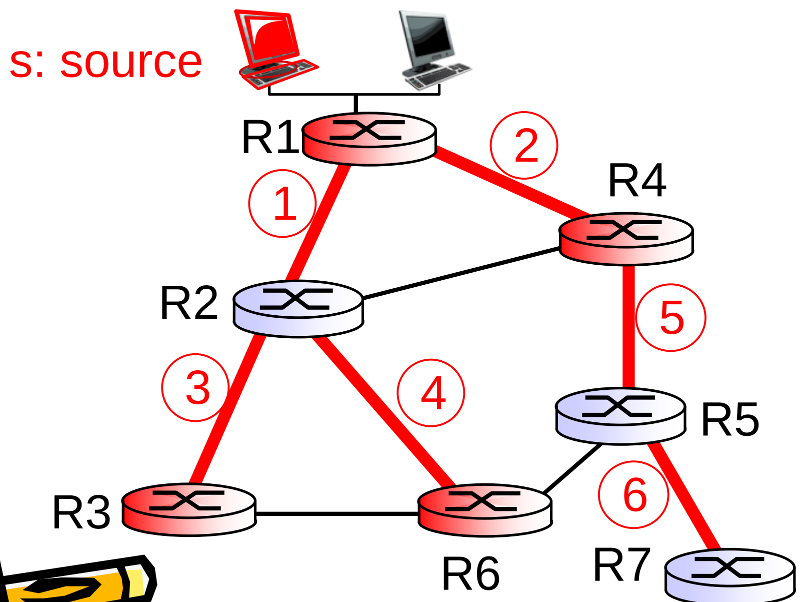
approaches:

- ***source-based tree:*** **one tree per source,** represented by binary groups (S, G).
- **shortest path trees**
  - **reverse path forwarding**
- ***group-shared tree:*** **group uses one tree,** Binary groups (*, G).
  - **minimal spanning (Steiner)**
  - **center-based trees**

…first look at basic approaches, then specific protocols adopting these approaches

Shortest path tree

- mcast forwarding tree: tree of shortest path routes from source to all receivers
  - Dijkstra's algorithm

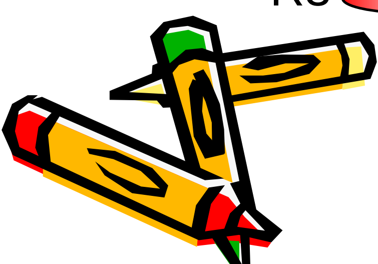


LEGEND

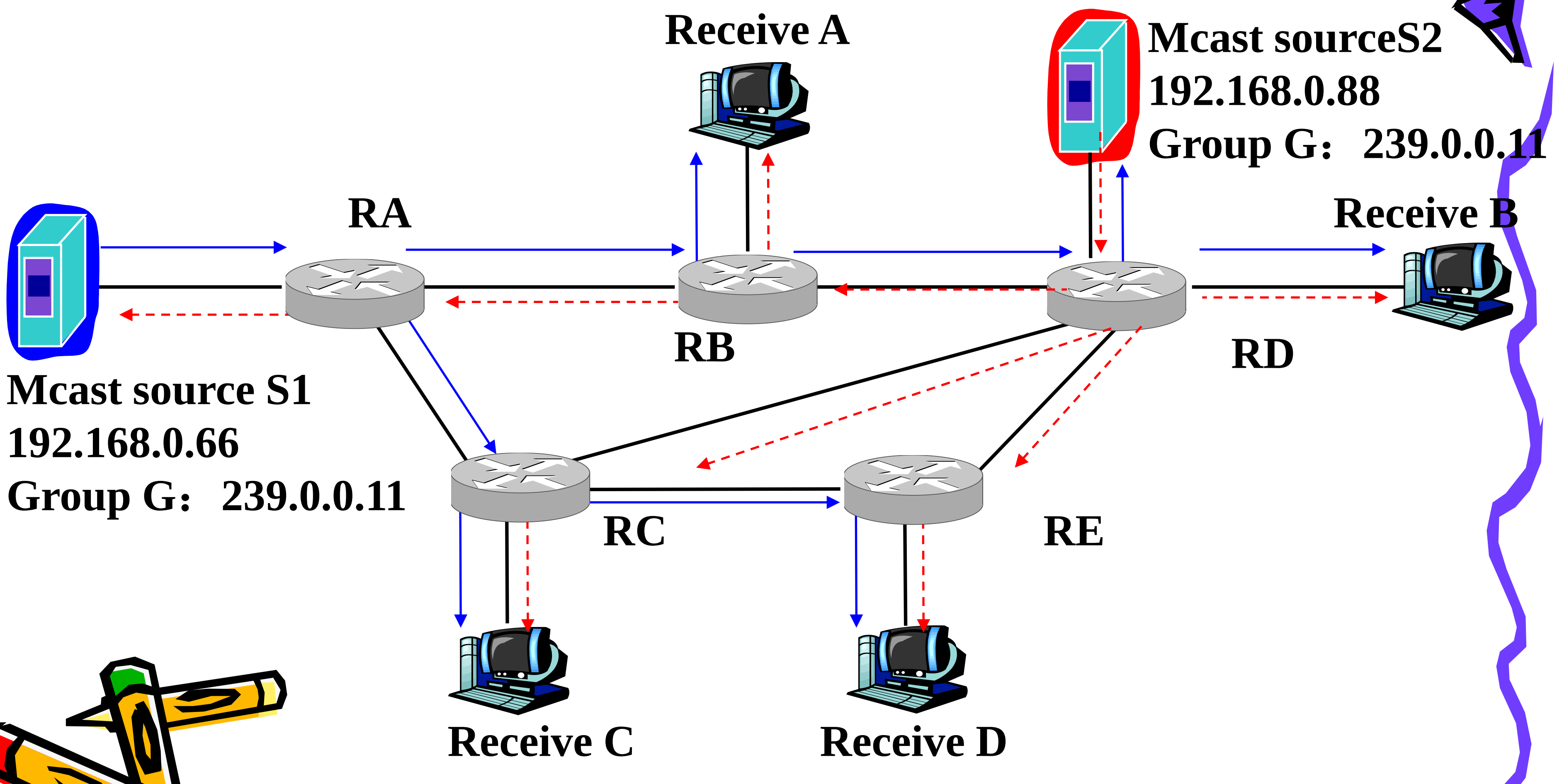
router with attached group member

router with no attached group member

i — link used for forwarding, i indicates order link added by algorithm



Shortest path tree(SPT)



Source Based Tree (SBT)

- **In a source-based tree, a multicast group may have several SPTS without a central multicast router.**
- **If there are N multicast groups and M different source ends in the Internet, there can be at most N x M SPT trees, each SPT tree corresponds to a combination of different sources and multicast groups, that is, the combination of source and multicast groups determines the structure of the tree.**

Reverse path forwarding

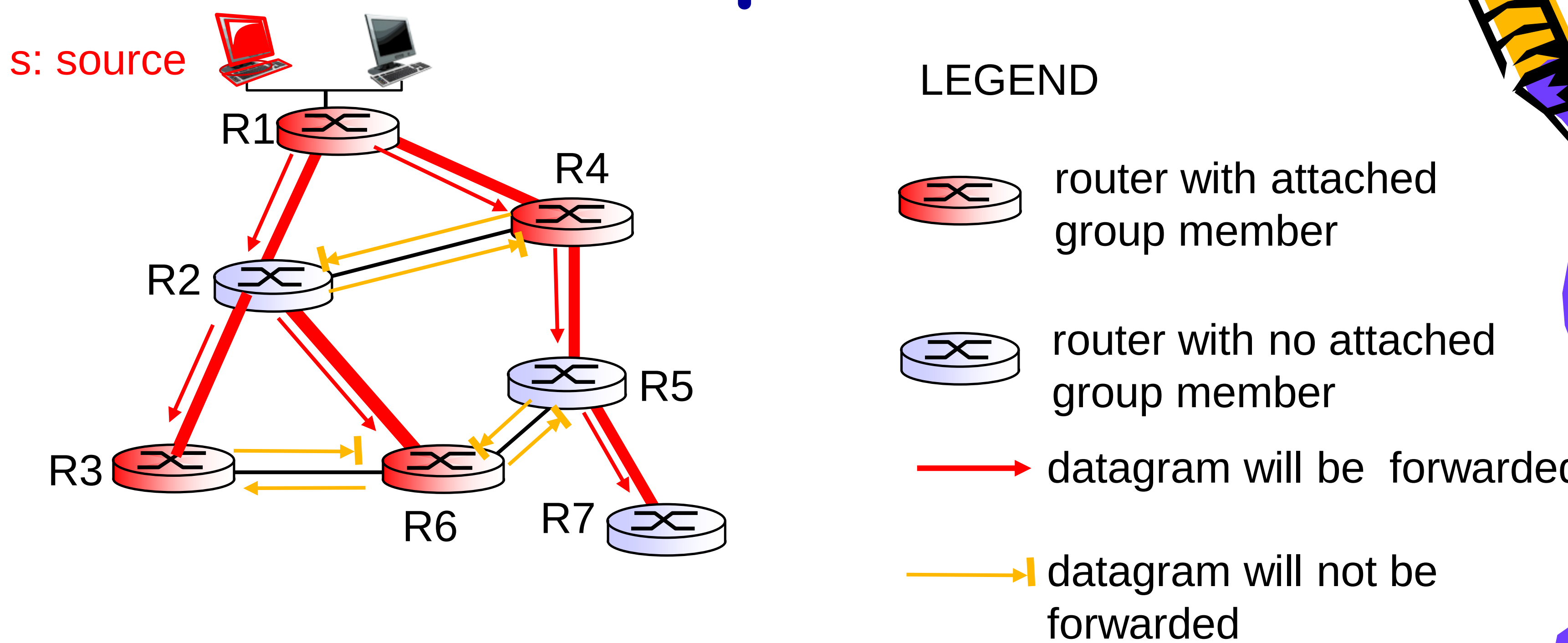
- rely on router's knowledge of unicast shortest path from it to sender
- each router has forwarding behavior:

if (mcast datagram received on incoming link on shortest path back to center)

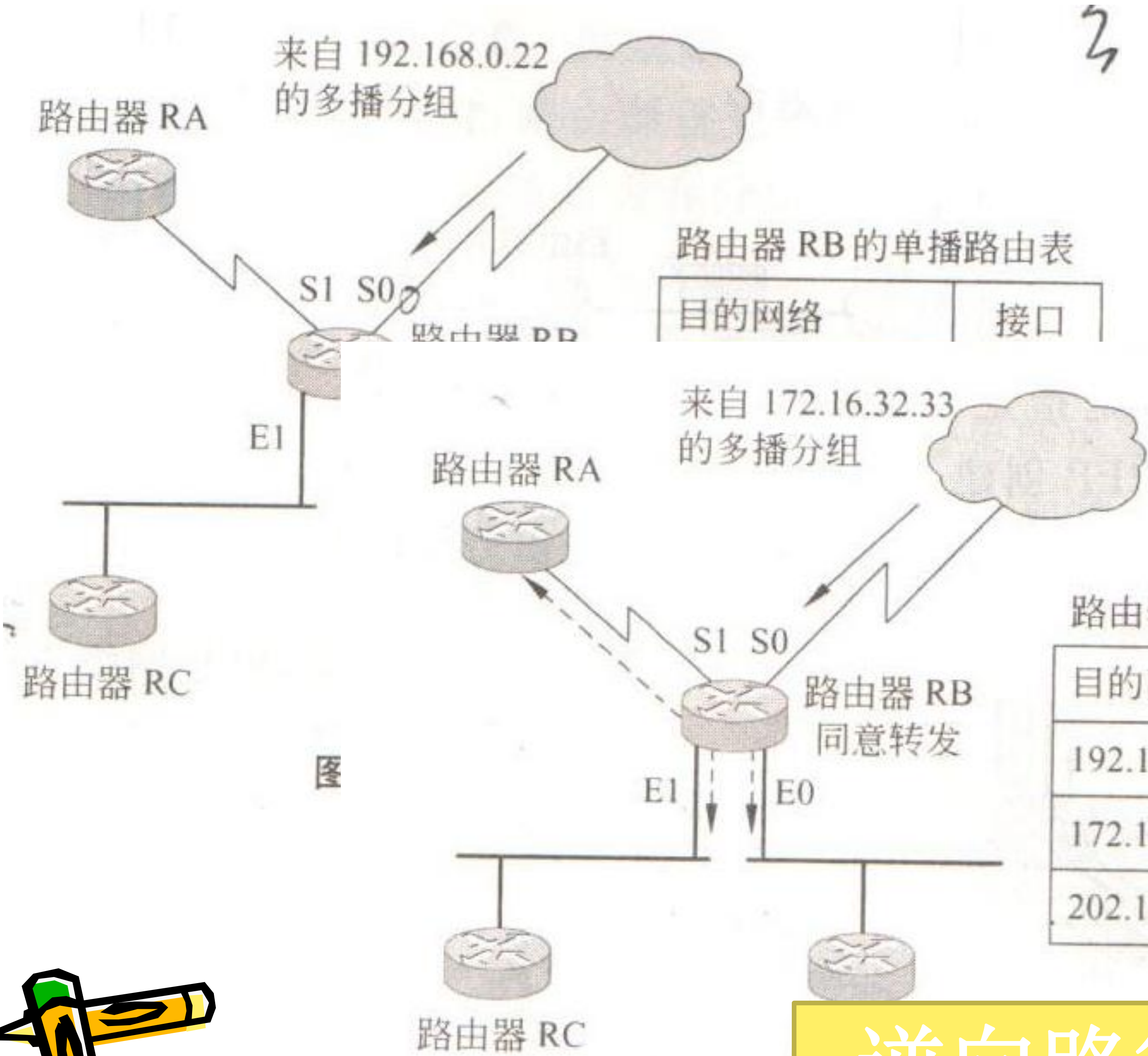
then flood datagram onto all outgoing links

else ignore datagram

Reverse path forwarding: example



- result is a source-specific *reverse* SPT



路由器 RB的单播路由表

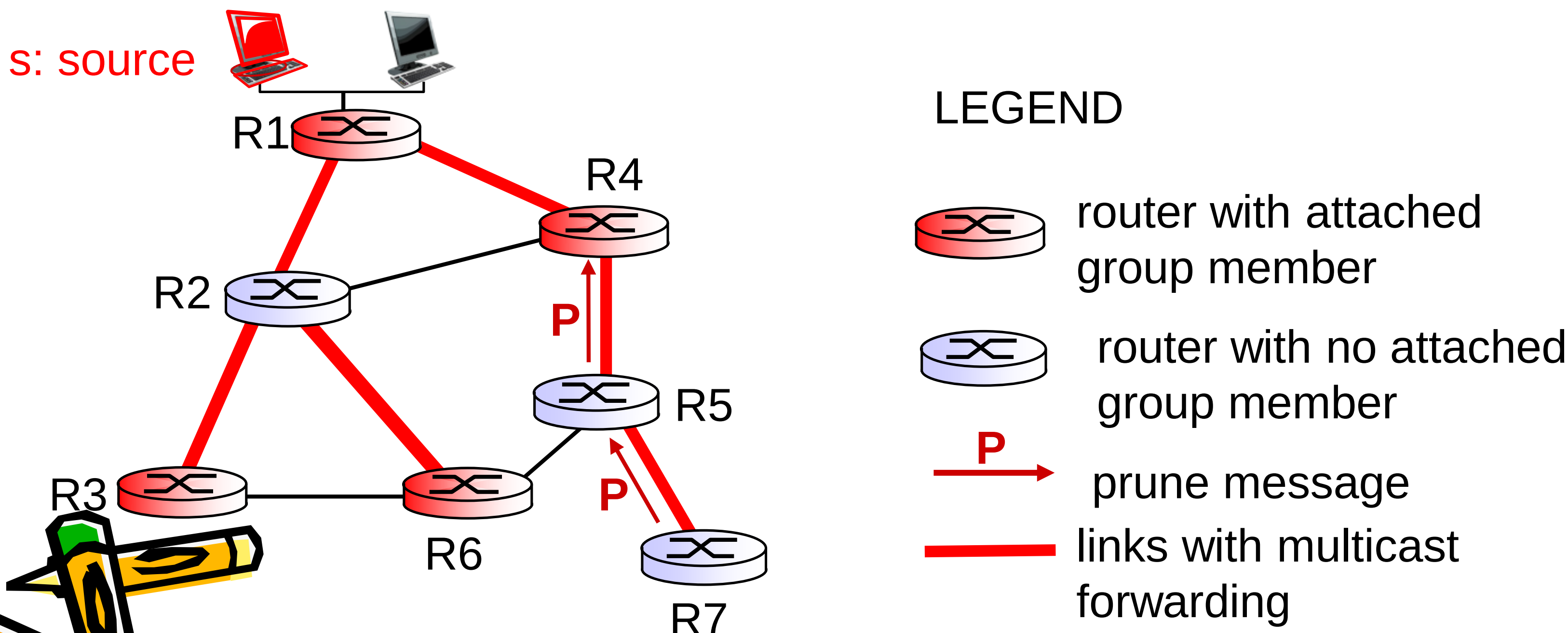
目的网络	接口
192.168.0.0/16	E1
172.16.32.0/24	S0
202.194.210.0/24	E0

图 9-

逆向路径广播?

Reverse path forwarding: pruning

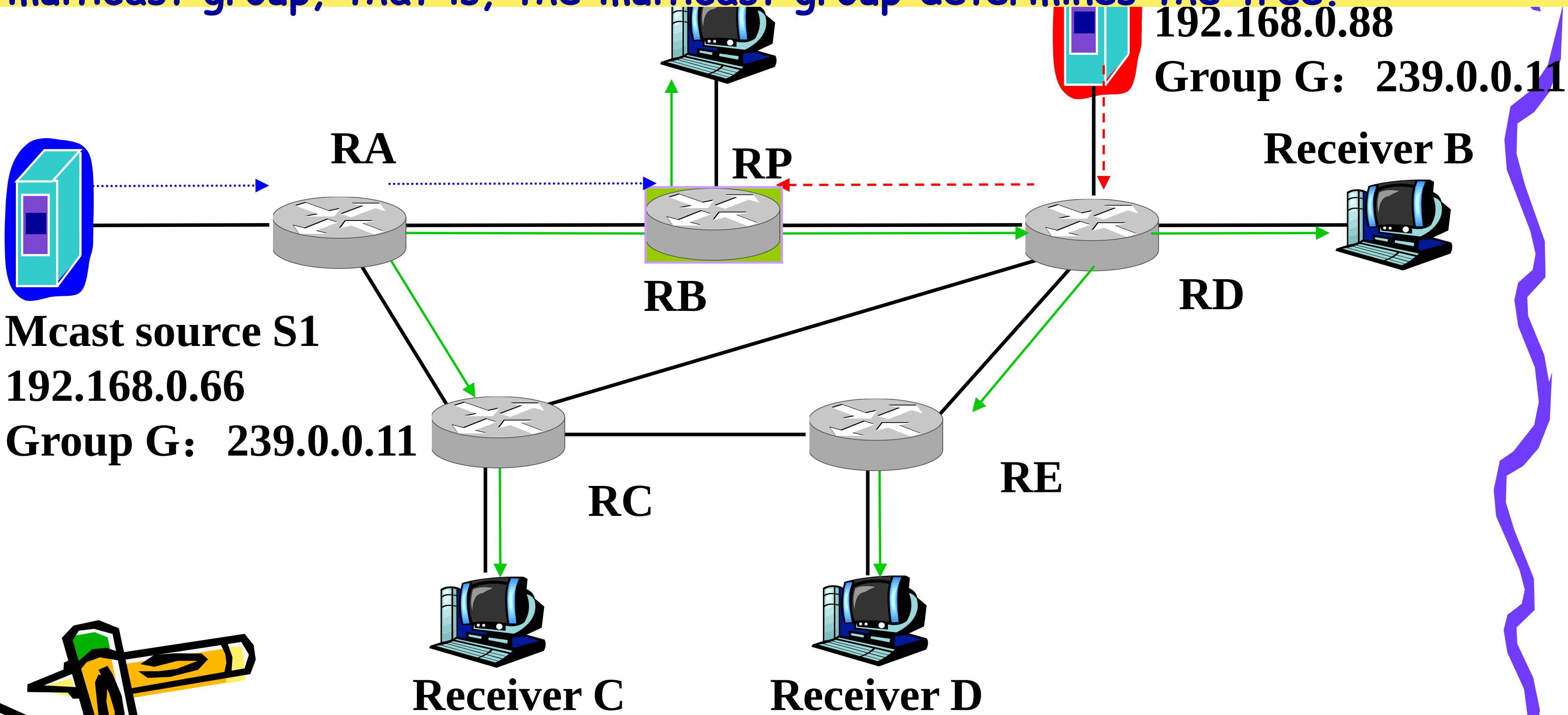
- forwarding tree contains subtrees with no mcast group members
  - no need to forward datagrams down subtree
  - “prune” msgs sent upstream by router with no downstream group members

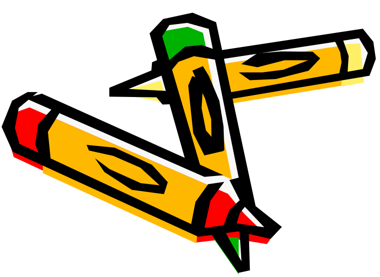


3. Shared-tree

- The Shared Tree is also known as the Rendezous Point Tree (RPT), and the Rendezous Point (RP) serves as the common root of the RPT Tree.
- Unlike the source-based tree SPT, the source host that sends multicast packets does not send multicast packets directly to the network, but first sends the packets to the root RP of the RPT tree, which then sends the multicast packets it receives to all members of the network.
- In the process of sending groups from source to RP and from RP to each receiver, the forwarding is carried out in the shortest path.

- From RP to each receiver, it is the only SPT tree with RP as the multicast source for the corresponding multicast group.
- Shared tree reduces the number of table items in the router multicast routing table, reduces the need for router resources, and makes multicast more scalable.
- Each multicast group in the Shared tree shares its own tree.If there are N multicast groups, there are at most N trees.Each tree corresponds to a multicast group, that is, the multicast group determines the tree.





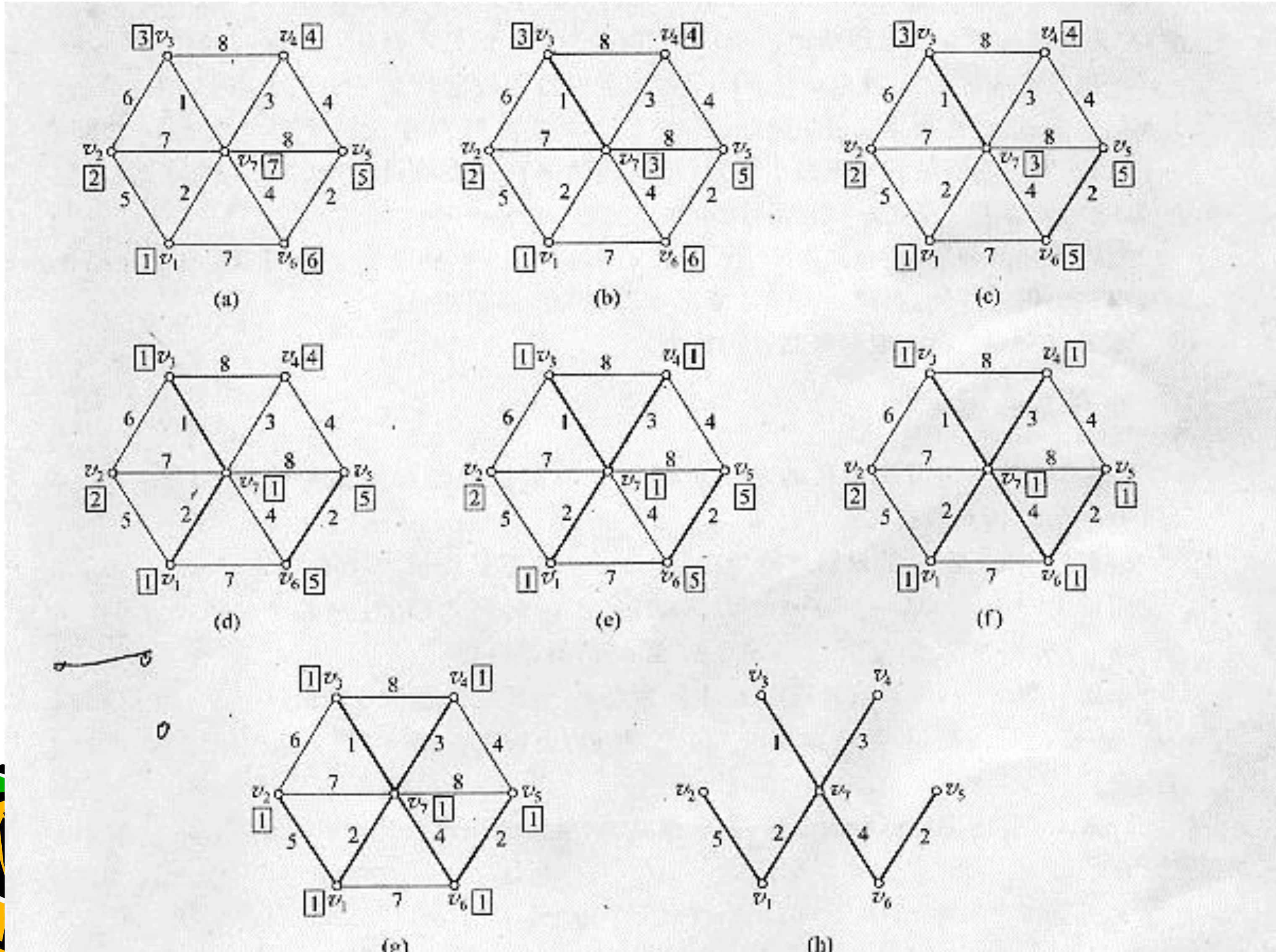
Shared-tree: steiner tree

- ***steiner tree:*** minimum cost tree connecting all routers with attached group members
- problem is NP-complete
- excellent heuristics exists
- not used in practice:
  - computational complexity
  - information about entire network needed
  - monolithic: rerun whenever a router needs to join/leave

9.4 multicast routeing algorithms

- 9.4.1 shortest path tree algorithm
- 9.4.2 minimum spanning tree algorithm
- 9.4.3 Steiner tree algorithm

minimum spanning tree algorithm



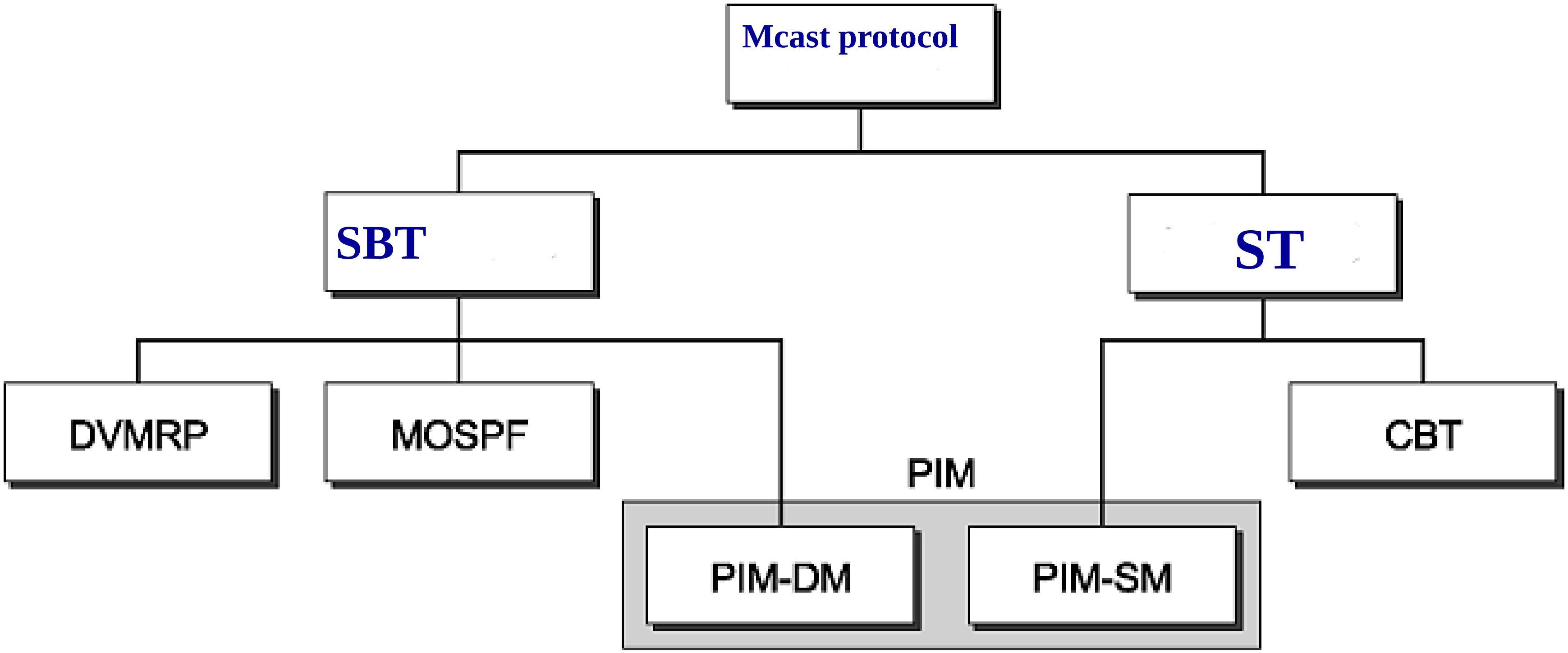
Summary?

Multicast on LAN

Multicast forwarding and routing information etc.

9.5 Multicast routing protocols

Intra-domain multicast routing protocol



9.6 DVMRP
距离向量多播路由选择协议
Distance Vector Multicast Routing Protocol

Internet Multicasting Routing: DVMRP

- **DVMRP:** distance vector multicast routing protocol, RFC1075
- *flood and prune:* reverse path forwarding, source-based tree
  - RPF tree based on DVMRP's own routing tables constructed by communicating DVMRP routers
  - initial datagram to mcast group flooded everywhere via RPF
  - routers not wanting group: send upstream prune msgs

DVMRP: continued…

Largely replaced by PIM

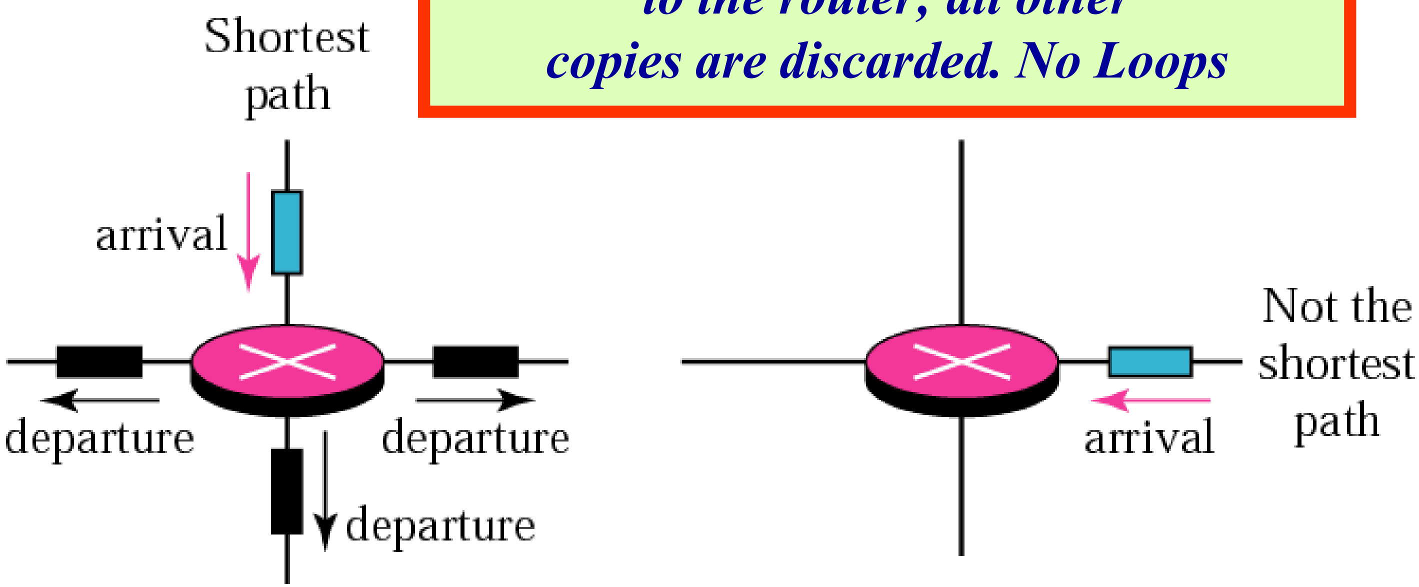
- *soft state:* DVMRP router periodically (1 min.) "forgets" branches pruned:
  - mcast data again flows down unpruned branch
  - downstream router: reprune or else continue to receive data
- routers can quickly regraft to tree
- odds and ends(零碎的东西)
  - commonly implemented in commercial router

Distance Vector Multicast Routing Protocol - DVMRP

- Tree is gradually created by successive routers along the path.
- Uses shortest path (fewest hops)
- Prevent loops: apply Reverse Path Forwarding (RFP)
- Prevent Duplication: apply Reverse Path Broadcasting (RPB)
- Multicast with dynamic membership: apply Reverse Path Multicasting (RPM) with pruning, grafting, and lifetime.

Reverse Path Forwarding

In reverse path forwarding (RPF), the router forwards only the packets that have traveled the shortest path from the source to the router; all other copies are discarded. No Loops



a. Packet is forwarded

Multicast Distance Vector Routing

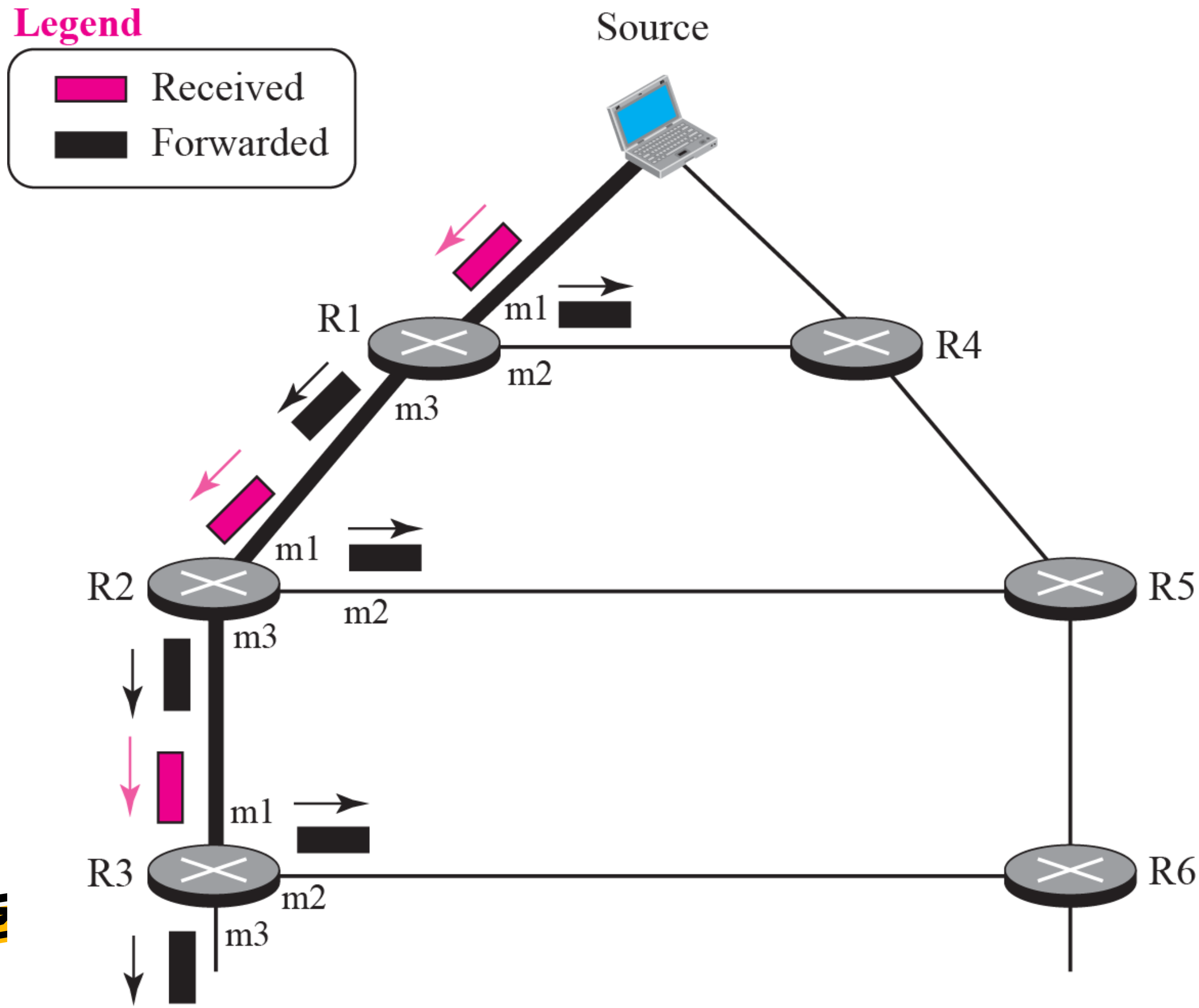
- 4 decision-making strategies

1. Flooding
2. Reverse Path Forwarding (RPF)
3. Reverse Path Broadcasting (RPB)
4. Reverse Path Multicasting (RPM)

Note

Flooding broadcasts packets, but creates loops in the systems.

Figure 12.22 *RPF*



TCP/IP Proto

Reverse Path Forwarding (1)

- To prevent loops, only one copy is forwarded; the other copies are dropped.
- In RPF, a router forwards only the copy that has traveled the shortest path from the source to the router.
- The router extracts the source address of the multicast packet and consults its unicast routing table.

Reverse Path Forwarding (2)

- If the packet has just come from the hop defined in the table, the packet has traveled the shortest path from the source to the router because the shortest path is reciprocal in unicast distance vector routing protocols.
- If a packet leaves the router and comes back again, it has not traveled the shortest path.

Note

RPF eliminates the loop in the flooding process.

E.g. No Loops in RPF

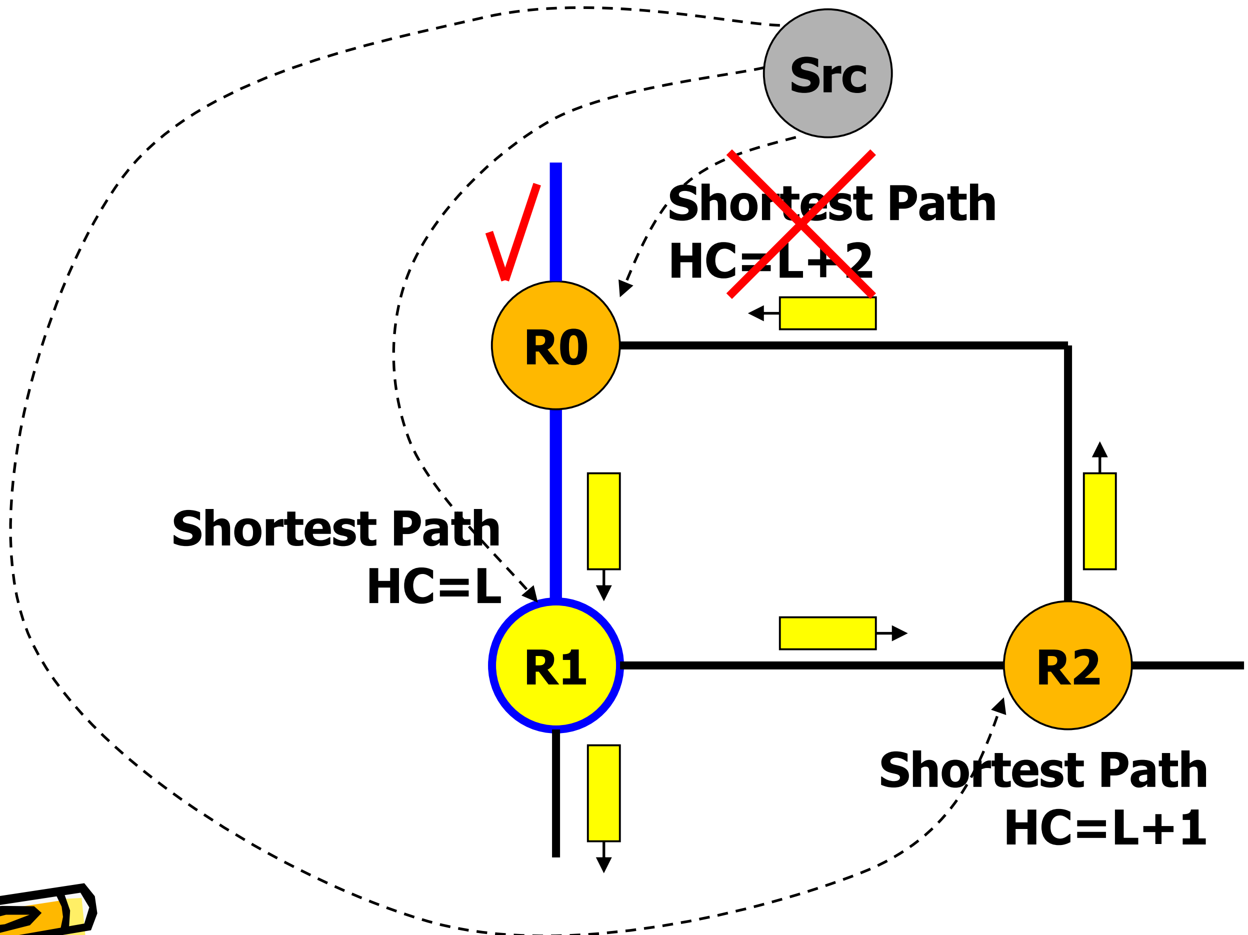
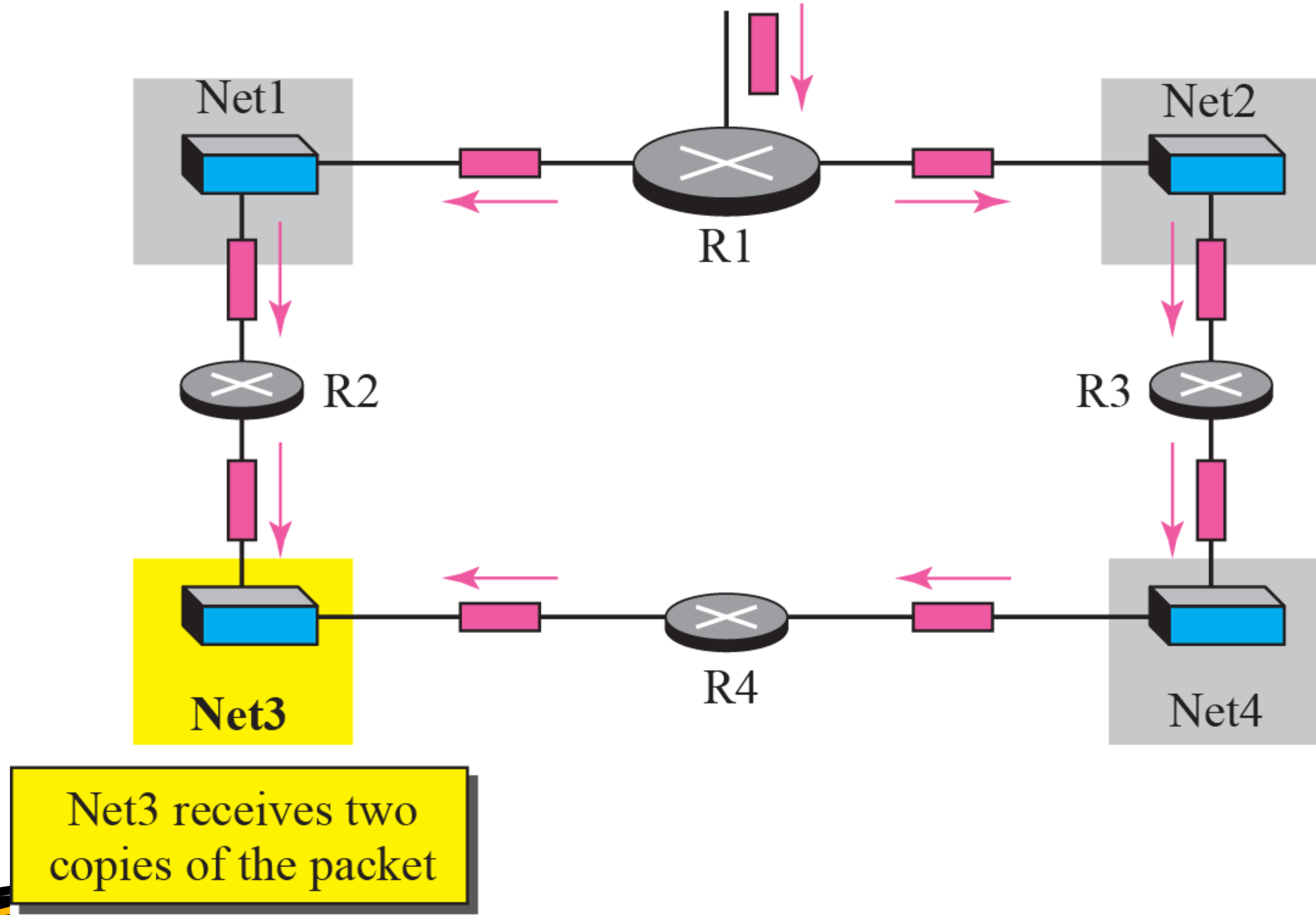
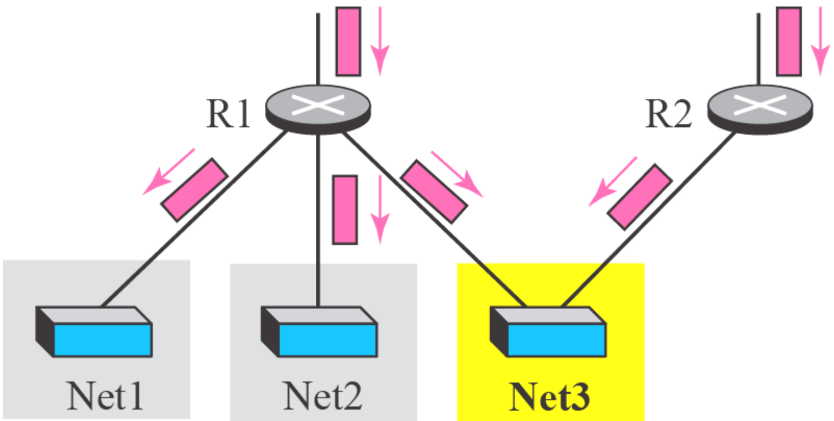


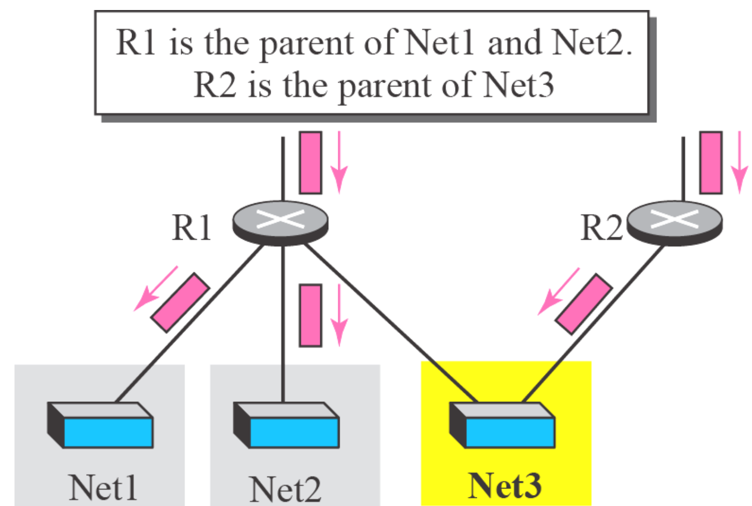
Figure 12.23 Problem with RPF



RPF versus RPB



a. RPF



b. RPB

Reverse Path Broadcasting (1)

- RPF guarantees that each network receives a copy of the multicast packet without formation of loops
- However, RPF does not guarantee that each network receives only one copy
- To eliminate duplication, we must define only one parent router (designated parent router) for each network

Reverse Path Broadcasting (2)

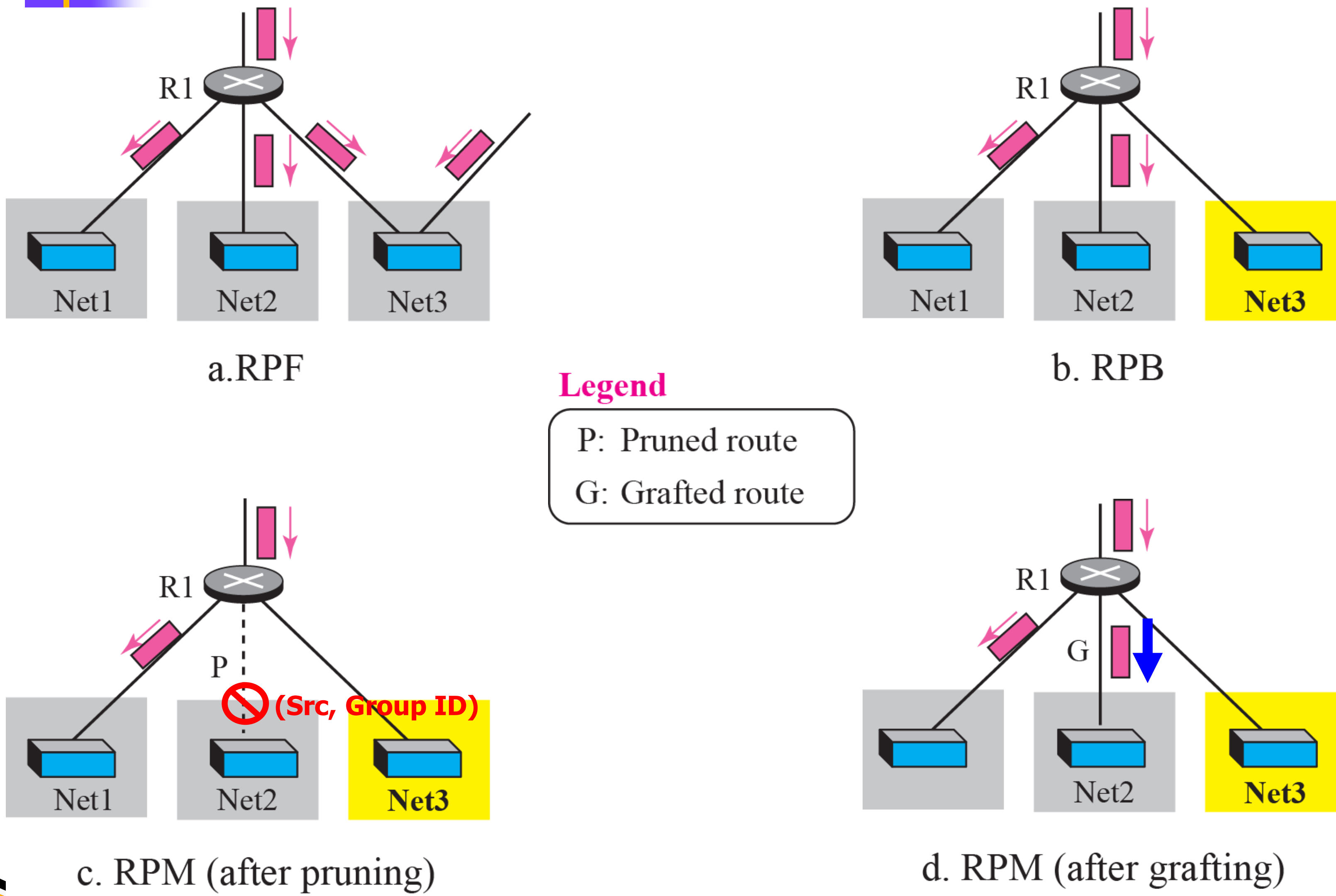
- In RPB, for each source, the router sends the packet only out of those interfaces for which it is the designated parent
- The designated parent router can be the router with the shortest path to the source
  - Because routers periodically send updating packets to each other (in RIP), they can easily determine which router in the neighborhood has the shortest path to the source.

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.

RPF, RPB, and RPM



Reverse Path Multicasting (1)

- To increase efficiency, the multicast packet must reach only those networks that have active members for that particular group
- RPM adopts the procedures of Pruning and Grafting
- Pruning
  - The designated parent router of each network is responsible for holding the membership information (through IGMP)

Reverse Path Multicasting (2)

- The router sends a prune message to the upstream router so that it can prune the corresponding interface
- That is, the upstream router can stop sending multicast message for this group through that interface

- Grafting
  - The graft message forces the upstream router to resume sending the multicast messages

Note

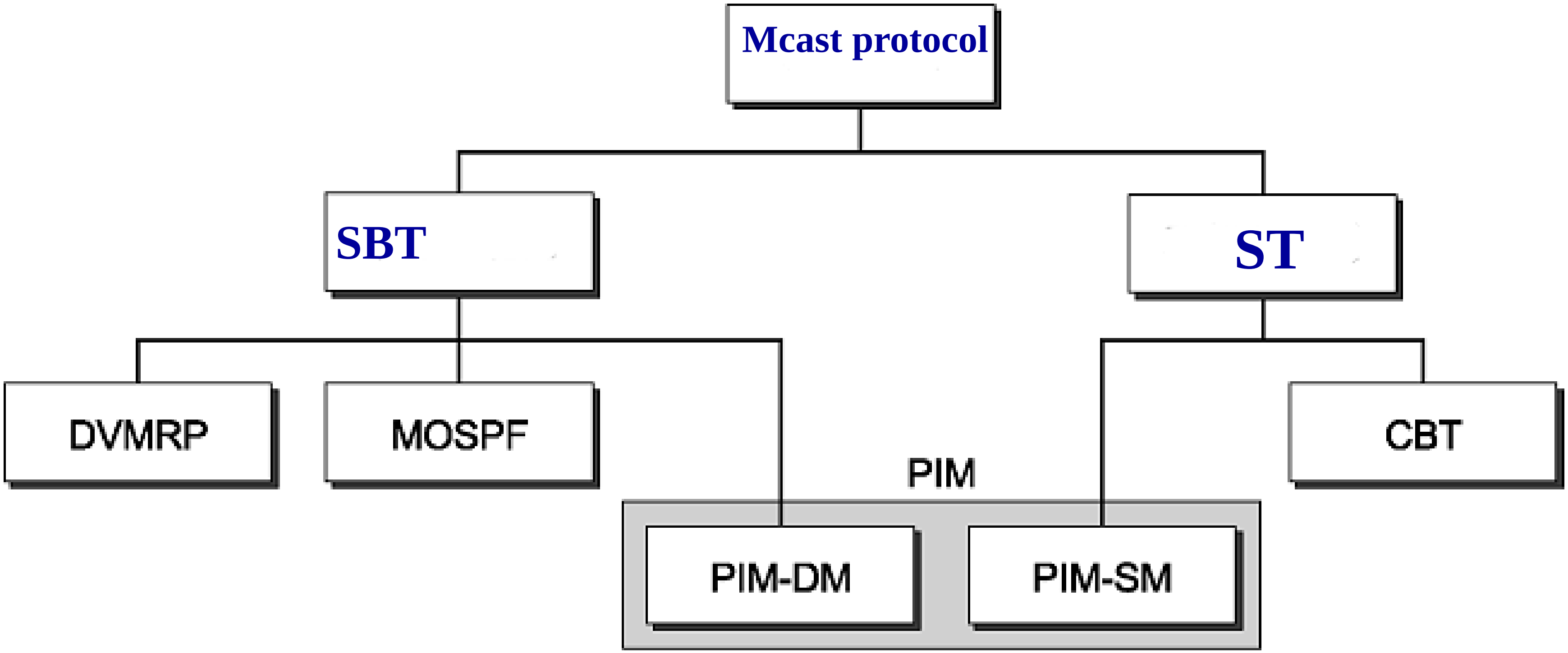
RPM adds pruning and grafting to RPB to create a multicast shortest path tree that supports dynamic membership changes.

Summary?

DVMRP

RPF,RPB,RPM?

Intra-domain multicast routing protocol



9.7 MOSPF
多播开放最短路径优先协议
(Multicast Open Shortest Path First Routing)

MOSPF is an extension of OSPF that uses multicast link-state routing to create a source-side reference tree.

MOSPF Poor scalability

- **When a group member changes, MOSPF issues a link status notification LSA update to all routers in the region, causing all routers in the multicast tree to update their routing status.**
- **If group members change frequently, MOSPF will send a large number of LSA updates and trigger a large number of routing calculations. So MOSPF doesn't scale very well.**
- **MOSPF is not widely used. MOSPF does not support tunneling.**

9.8 CBT

Center-Based Trees核心基干树

- CBT is a shared tree。
- single delivery tree shared by all
- one router identified as *"center"* of tree

9.8.1 formation of trees

9.8.2 send multicast packets

9.8.1 Formation of Trees

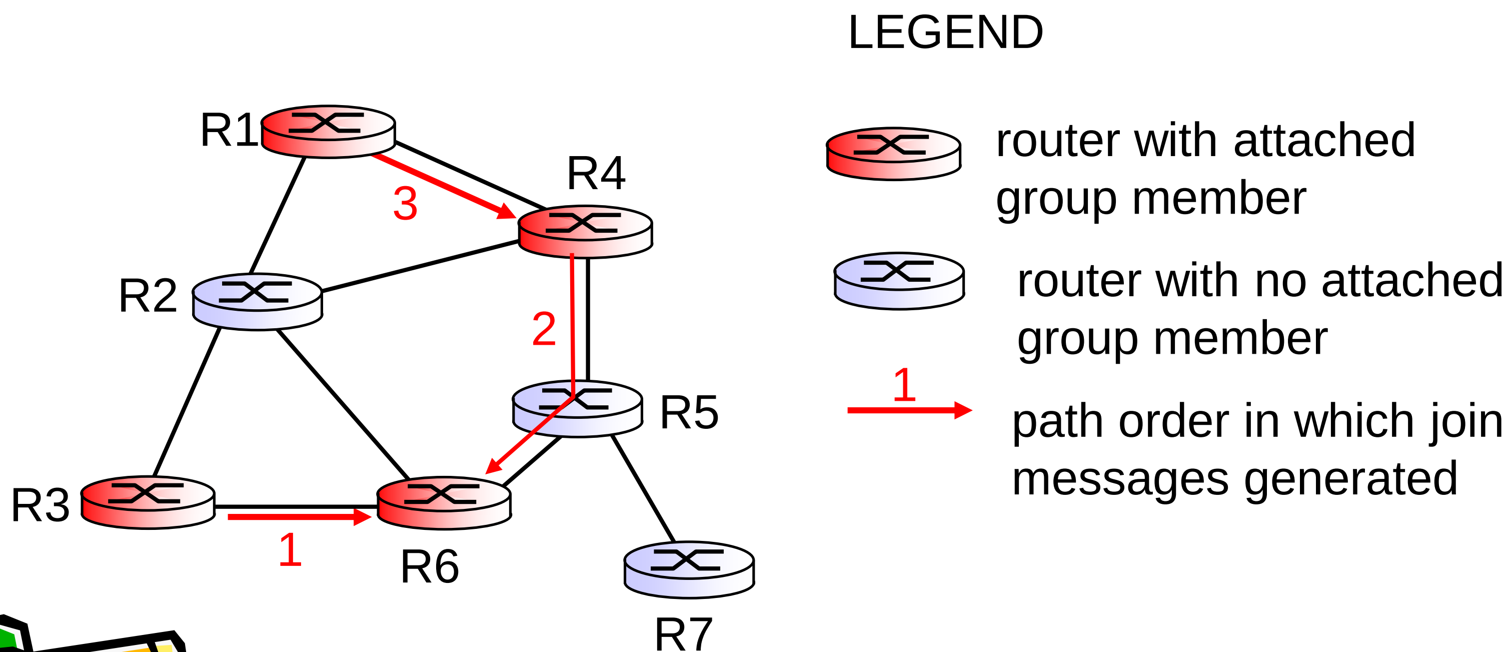
- When the rendezous router is selected, its unicast address is notified to each router.Each router sends a unicast "join message" indicating that it wants to join the group.
- In the path where the "join message" is sent to the rendezous router, all intermediate routers extract the necessary information from the message (for example, unicast address of the sending station, interface to which the message arrives), and then forward the message to the next router.
- A tree is formed when the rendezous router receives all incoming messages from each member of a multicast group.
- Each router knows its upstream router (the router to the root of the tree) and its downstream router (the router to the leaves). 。

Center-based trees

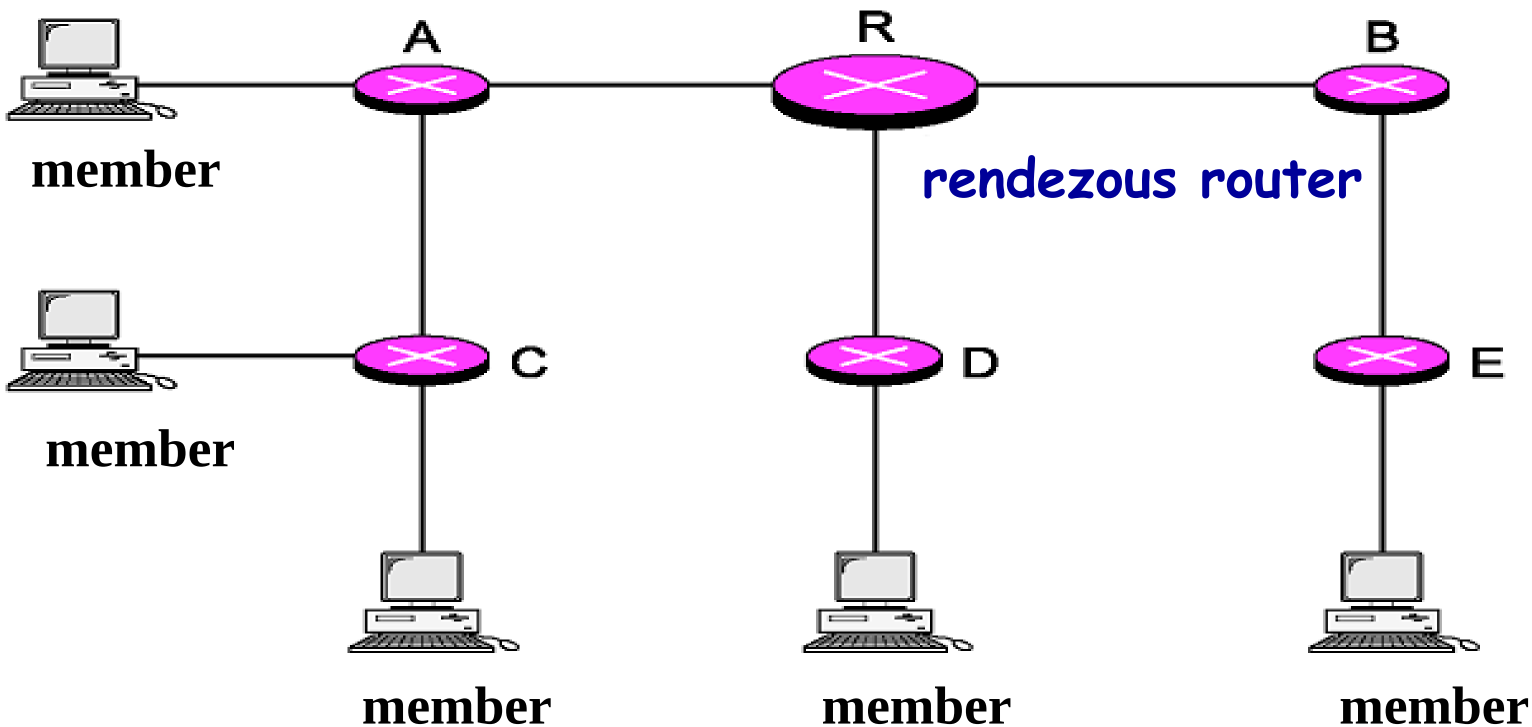
- to join:
  - edge router sends unicast *join-msg* addressed to center router
  - *join-msg* “processed” by intermediate routers and forwarded towards center
  - *join-msg* either hits existing tree branch for this center, or arrives at center
  - path taken by *join-msg* becomes new branch of tree for this router

Center-based trees: example

suppose R6 chosen as center:



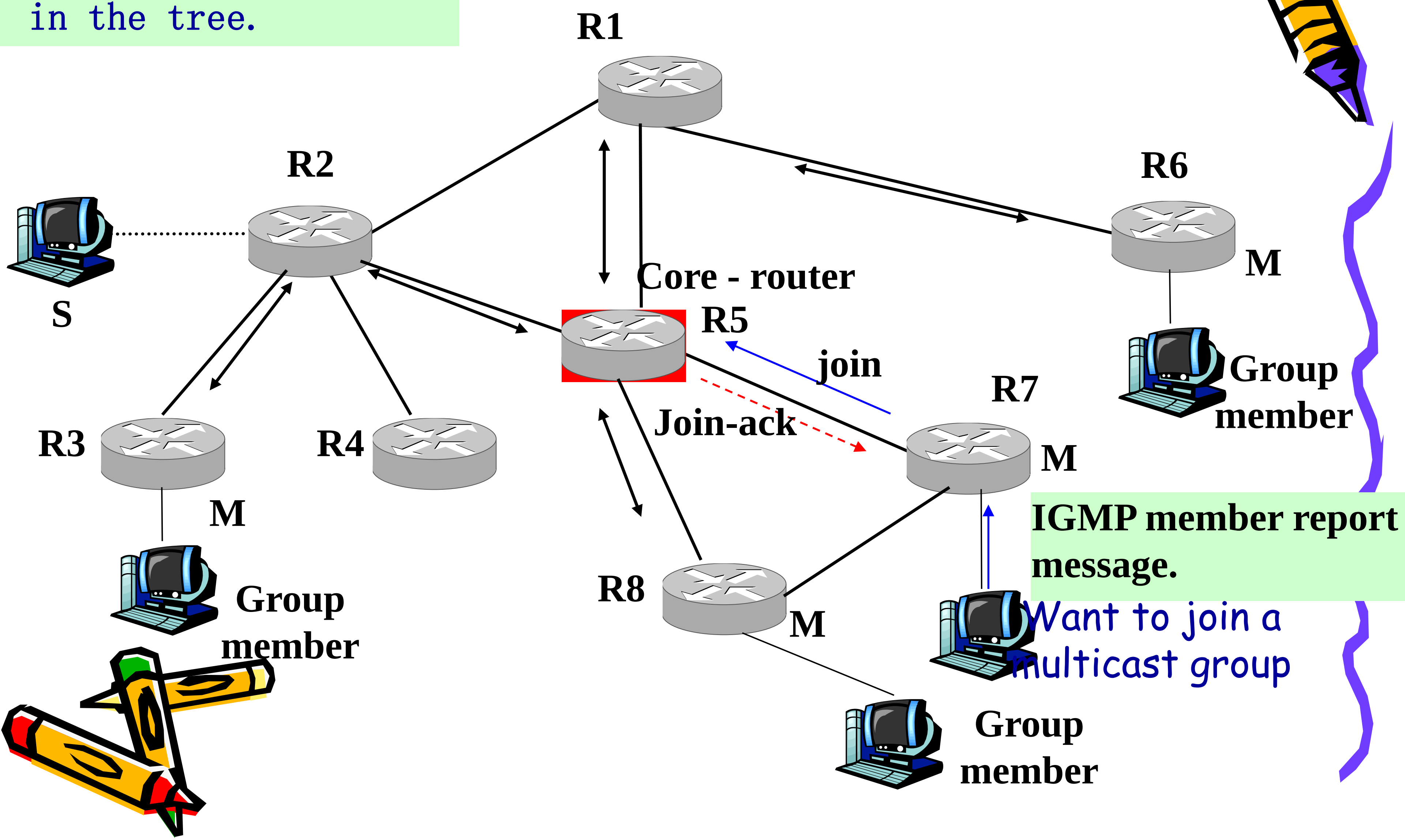
Shared tree



- If a router wants to exit the group, it sends an "exit" message to its upstream router. The upstream router removes the link from the tree to the router and forwards the message to its upstream router.

CBT Construction process

•In CBT, the interface has only two states: either in the tree or not in the tree.



CBT don't RPF technology

- CBT guarantees that the join message and the join-ack message must not loop.
- If the join message and the join-ack message do not follow the same path, CBT considers that a routing loop has occurred and restarts the join process.

The difference among
CBT, MOSPF AND DVMRP

Difference between CBT and DVMRP(MOSPF)

- In the formation of trees,
  - CBT is made from leaves, DVMRP and MOSPF from roots.
  - In DVMRP, broadcast tree is constructed before pruning.In CBT, there are no trees to begin with, and the addition method is used to build trees gradually.
- unicast protocol,
  - CBT uses unicast routing tables to obtain the next hop router information to the converged router, so that CBT can work with any unicast routing protocol.
  - Both DVMRP and MOSPF can only work with *specific* unicast routing protocols.

PIM
协议无关多播
Protocol-independent multicast

- **PIM:** not depend on any specific underlying unicast routing algorithm
- **PIM is PIM-DM（Dense Mode）and PIM-SM（Sparse Mode）**

Consequences of sparse-dense dichotomy:

dense

- *data-driven* construction on mcast tree (e.g., RPF)
- bandwidth and non-group-router processing *profligate*

***sparse*:**

- *receiver- driven* construction of mcast tree (e.g., center-based)
- bandwidth and non-group-router processing *conservative*

PIM- dense mode

flood-and-prune RPF: similar to DVMRP but…

- underlying unicast protocol provides RPF info for incoming datagram
- less complicated (less efficient) downstream flood than DVMRP reduces reliance on underlying routing algorithm
- Independent of any unicast routing protocol, it is assumed that some unicast protocol already constructs the routing table. **Not independent of IP ,independent of routing.**
- PIM-SM is used in a sparse multicast environment such as a WAN.

9.10 PIM-SM

- 9.10.1 selection of RP
- 9.10.2 RP sharing tree construction
- 9.10.3 pruning of Shared trees
- 9.10.4 send multicast packets
- 9.10.5 switch from a Shared tree to a source-based tree
- 9.10.6 establishment of SPT tree from multicast source to multicast group members
- 9.10.7 PIM-SM's features

9.10 PIM-SM

- PIM-SM(RFC 2362) is suitable for sparse mode. PIM-SM protocol combines the advantages of SPT and CBT and is the most promising protocol.
- PIM-SM used a one-way shared tree, and the root node is called RP, which is equivalent to the core router of CBT. All routers in PIM-SM domain must know the RP address.
- CBT(RFC 2189) is similar to PIM-SM, but the two are different:
- CBT only used the Shared tree for data transfer and cannot switch from the Shared tree to the source-based multicast forwarding tree.
- PIM-SM can do that.

PIM-SM support source based tree and shared tree

- First it generates the Shared tree, passing the original multicast group through the Shared tree, and enables multicast group members to discover the active source host for their group.
- Due to the low efficiency of multicast packet transmission caused by Shared tree, multicast group members will switch multicast packets to source-based trees when the rate of multicast group members receiving multicast packets exceeds a certain threshold.

9.10.1 RP's selection

- **PIM-SM is shared treee**
  - **Multicast packet can only transfer multicast's members from shared treee**
- **PIM-SM's RP selection:**
  1. Specifies the RP router statically
  2. Specify and advertise R via an open standard bootstrap protocol
  3. Specify and advertise the RP through Cisco's private protocol, the AUTO-RP protocol
- The AUTO-RP protocol is Cisco's private protocol.

How to select RP?

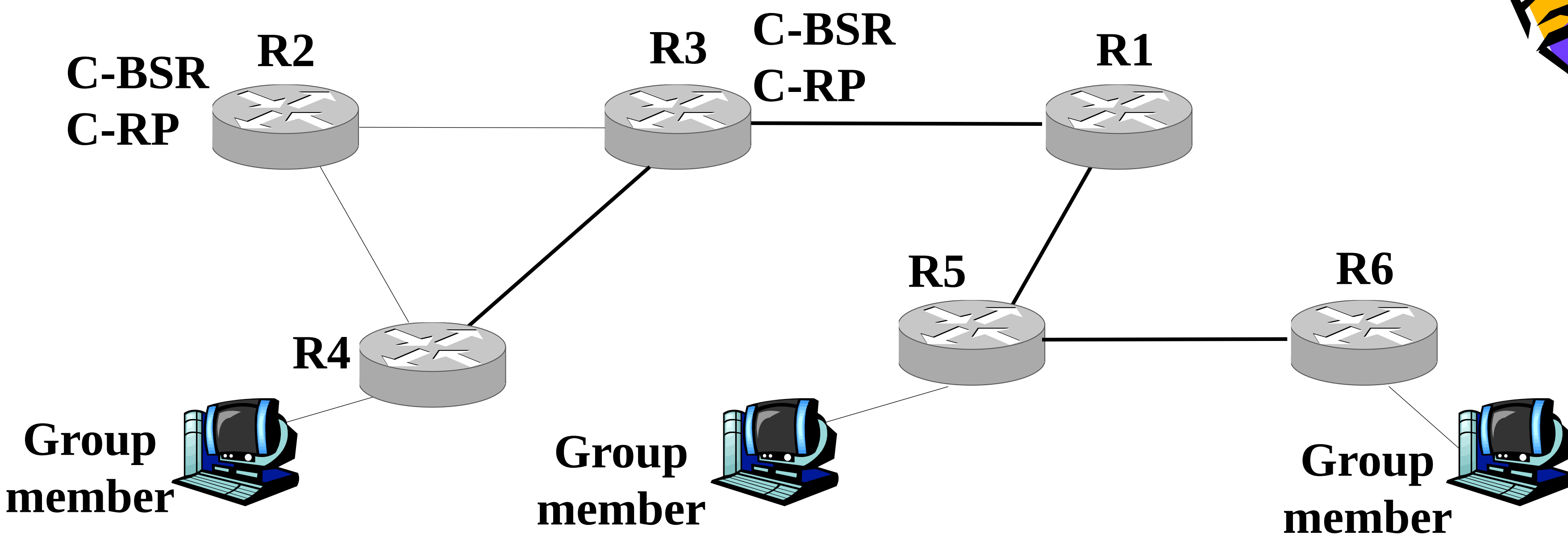
1. Specifies the RP router statically

- **This is done by manually specifying an RP in the PIM-SM domain (a set of PIM routers) to assign an address to the RP, typically using the Loopback interface address. Tells the address of the RP router in its domain.**
- **The biggest weakness of the statically specified RP approach is the existence of a single point of failure for the RP. When an RP fails, the group that this RP is responsible for will not be able to perform normal multicast packet transfer .**

1.2. Specify and advertise R via an open standard bootstrap protocol

- **A few symbols used in this method.**
  - C-BSR represents candidate bootstrap router（候选自举路由器）；
  - BSR is for bootstrap router(自举路由器);
  - C-RP stands for candidate RP.
- **To ensure the robustness of the network, multiple c-bsr and c-rp are generally set on the network, and c-bsr and c-rp are located in the same router and represented by IP address. The address is generally Loopback address of the router.**

BootStrap elect and advertise RP



- ✓ Select BSR from C-BSR
- ✓ Calculation of the RP
- ✓ BSR acts as a mirror
- ✓ Multiple RPS can be set in the PIM-SM domain

9.10.2 RP shared tree contruction

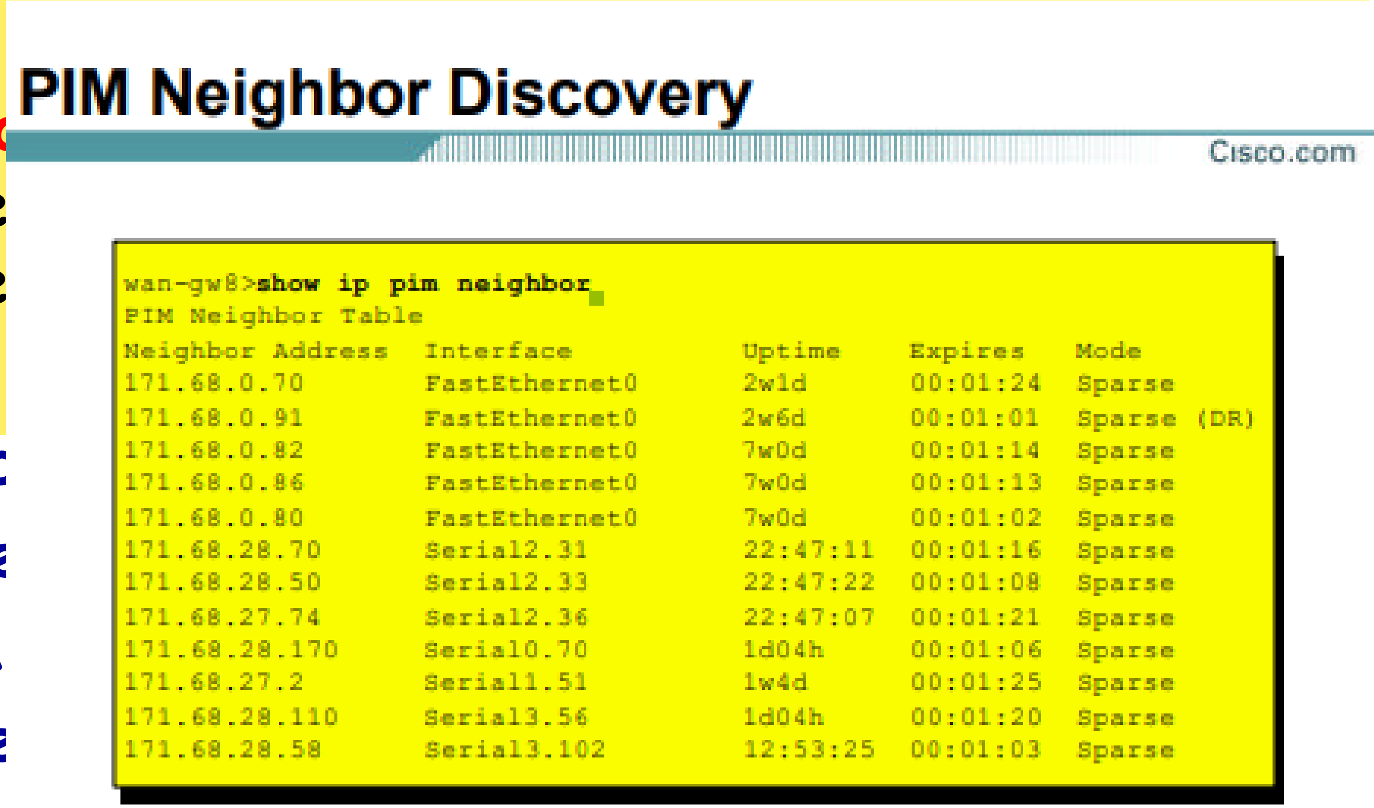
- The multicast routing table maintaines the node state of the multicast tree
- In summary, the multicast routing table is established along with the construction of the multicast tree.

routing table item field meaning

- (S, G) address pair, which is the identification of multicast routing (source, group), is similar to the destination address in unicast routing table, and is the key word to look for it in the routing table;
- RPF neighbor address is the address of the upstream neighbor router connected to the interface;
- The upstream interface, the interface nearest the multicast source, is also called the RPF interface.Used by RPF to check that multicast packets are arriving from the correct interface ;

- The
  Shar
- multi
- Each
  SPT
  items
  - (S
  - RPF neighb
  - The upstre
  - Downstrea
  - Timeout, e

- Downstream interface, the nearest interface to a multicast group member, that is, the output interface of this router's multicast group, is similar to the exit in unicast routing.So, this field is also called the downstream interface list;
- Timeo
  refre
  refre
  table




```
wan-gw8>show ip pim neighbor
PIM Neighbor Table
Neighbor Address   Interface        Uptime    Expires    Mode
171.68.0.70        FastEthernet0    2w1d      00:01:24   Sparse
171.68.0.91        FastEthernet0    2w6d      00:01:01   Sparse (DR)
171.68.0.82        FastEthernet0    7w0d      00:01:14   Sparse
171.68.0.86        FastEthernet0    7w0d      00:01:13   Sparse
171.68.0.80        FastEthernet0    7w0d      00:01:02   Sparse
171.68.28.70       Serial2.31       22:47:11  00:01:16   Sparse
171.68.28.50       Serial2.33       22:47:22  00:01:08   Sparse
171.68.27.74       Serial2.36       22:47:07  00:01:21   Sparse
171.68.28.170      Serial0.70       1d04h     00:01:06   Sparse
171.68.27.2        Serial1.51       1w4d      00:01:25   Sparse
171.68.28.110      Serial3.56       1d04h     00:01:20   Sparse
171.68.28.58       Serial3.102      12:53:25  00:01:03   Sparse
```

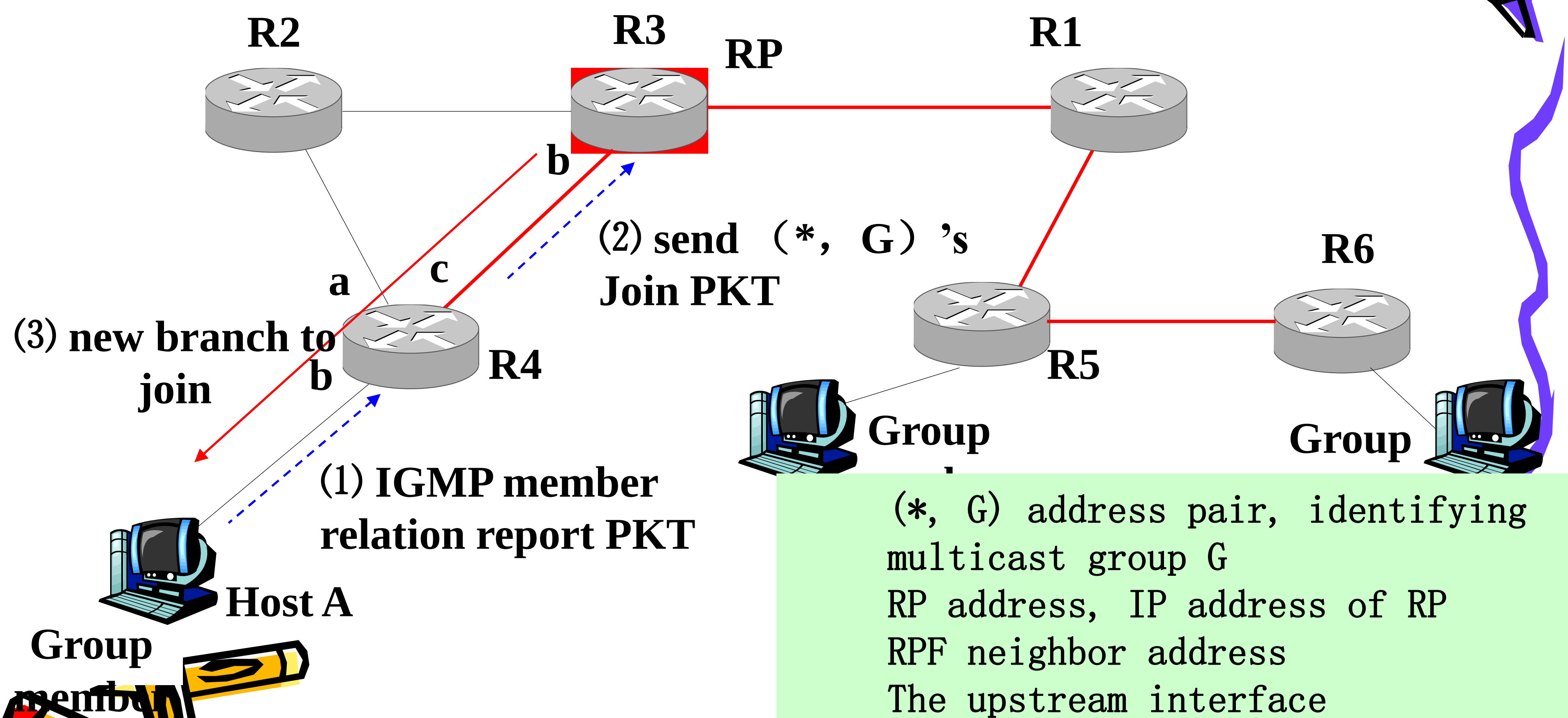
(2) Shared tree multicast routing table

- the multicast routing table item of shared tree:
  - (*, G) address pair, identifying multicast group G
  - RP address, IP address of RP
  - RPF neighbor address
  - Upstream interface
  - Downstream interface
  - timeout

- A network that connects to only one router, which is the DR.
- For a network connected to multiple routers, each interface of the router is a candidate designated router, and each interface corresponds to a DR weight.
  - The higher the DR weight, the higher the priority.
  - The highest weight is selected as DR.
  - If the weights are the same, the one with the highest IP address is selected.

- In rece the
- The specifying the router.
  - Designed Router (DR) is a Router directly connected to the host. It generates the multicast routing table, processes and forwards the join/prune message and Register message, and forwards the multicast packet.
  - Every network that wants to join a multicast group should have a designated router.
  - Designed Router (DR)?

PIM-SM group member to join



(*， G) address pair， identifying multicast group G

RP address， IP address of RP

RPF neighbor address

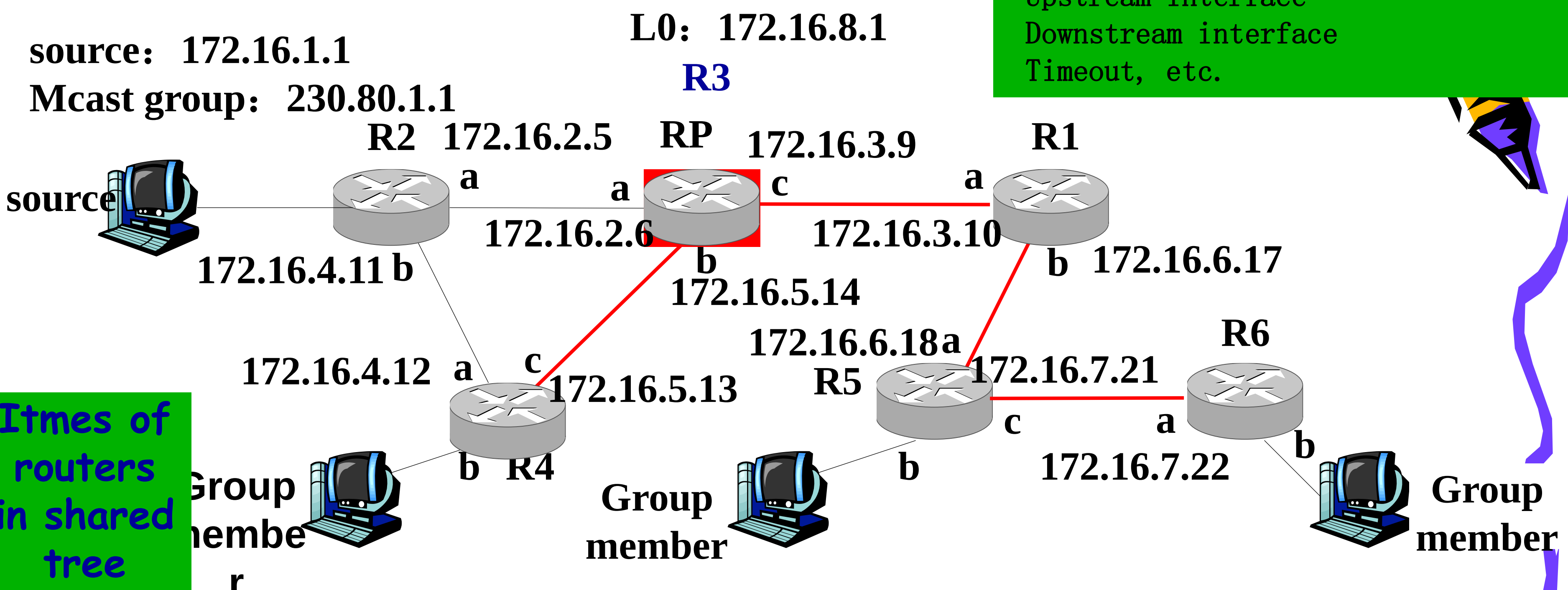
The upstream interface

Downstream interface

Timeout， etc.

各个路由器接口的IP地址

(*, G) address pair, identifying multicast group G
RP address, IP address of RP
RPF neighbor address
Upstream interface
Downstream interface
Timeout, etc.



Itmes of routers in shared tree

	(*, G) ADDR pair	RP ADDR.	RPF neighbor address	Upstream interface	Downstream interface
R4	(*, 230.80.1.1)	172.16.8.1	172.16.5.14	c	b
R5	(*, 230.80.1.1)	172.16.8.1	172.16.6.17	a	b、c
R6	(*, 230.80.1.1)	172.16.8.1	172.16.7.21	a	b
R1	(*, 230.80.1.1)	172.16.8.1	172.16.3.9	a	b

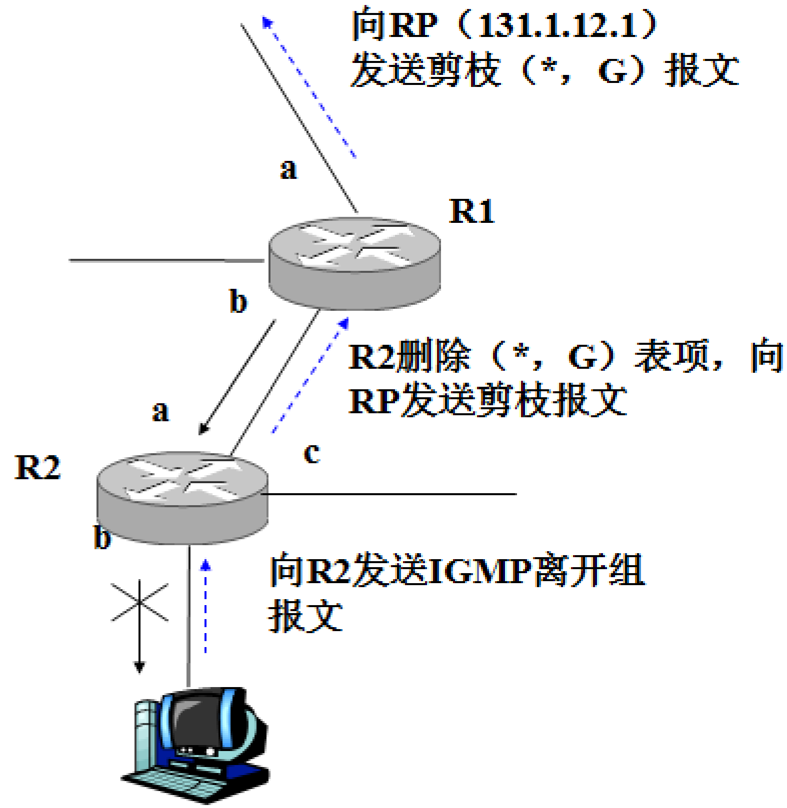
9.10.3 shared tree's pruning

- Once the Shared tree is established, join it or prune it.
- Host X sends an IGMP leave group message to DR.If X is the last member of the multicast group, DR removes the interfaces that DR connects to X's network from the list of downstream interfaces (*, G).
- If the list of downstream interfaces of (*, G) is empty, indicating that there is no receiver of multicast group G on any interface of this router, the router sends a pruned message about (*, G) to the RP.

The transmission of a pruning message

During the transmission of the pruning message, check the downstream interface list of the intermediate node (*, G) if

- Is empty, then the pruning message is sent upstream.
- not empty, it means that the router still has the receiver of (*, G) on other interfaces, and the Shared tree forks here, then the router just deletes the interface and the pruned message is no longer sent upstream.



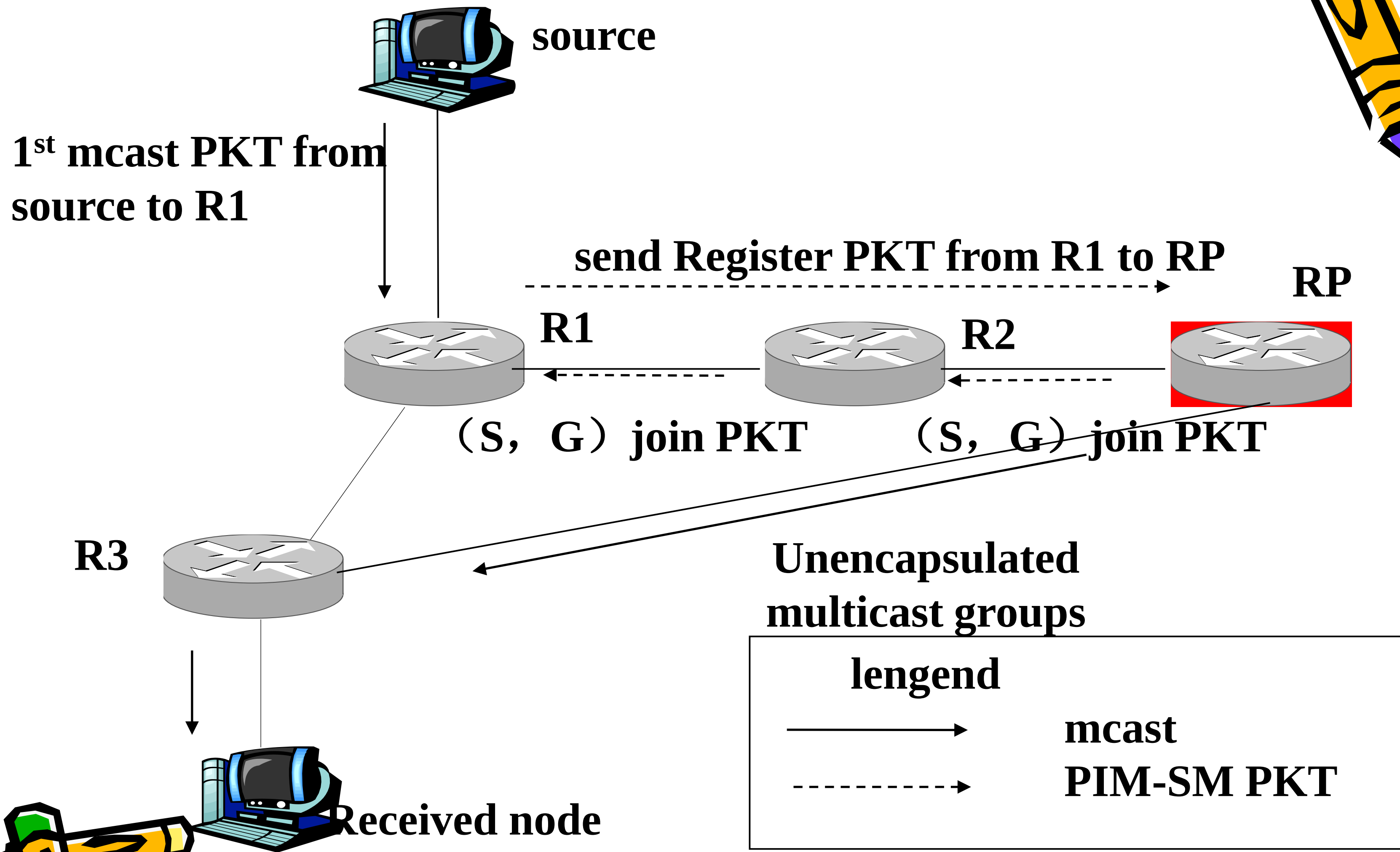
9.10.4 Send multicast packets

- Because PIM-SM uses a one-way Shared tree, multicast information can only be transmitted downstream along the Shared tree.
  - If an active multicast source appears in a multicast group, multicast group transport begins.
  - Multicast packets are first transmitted from the source host to the RP.
  - The RP then forwards along the Shared tree.

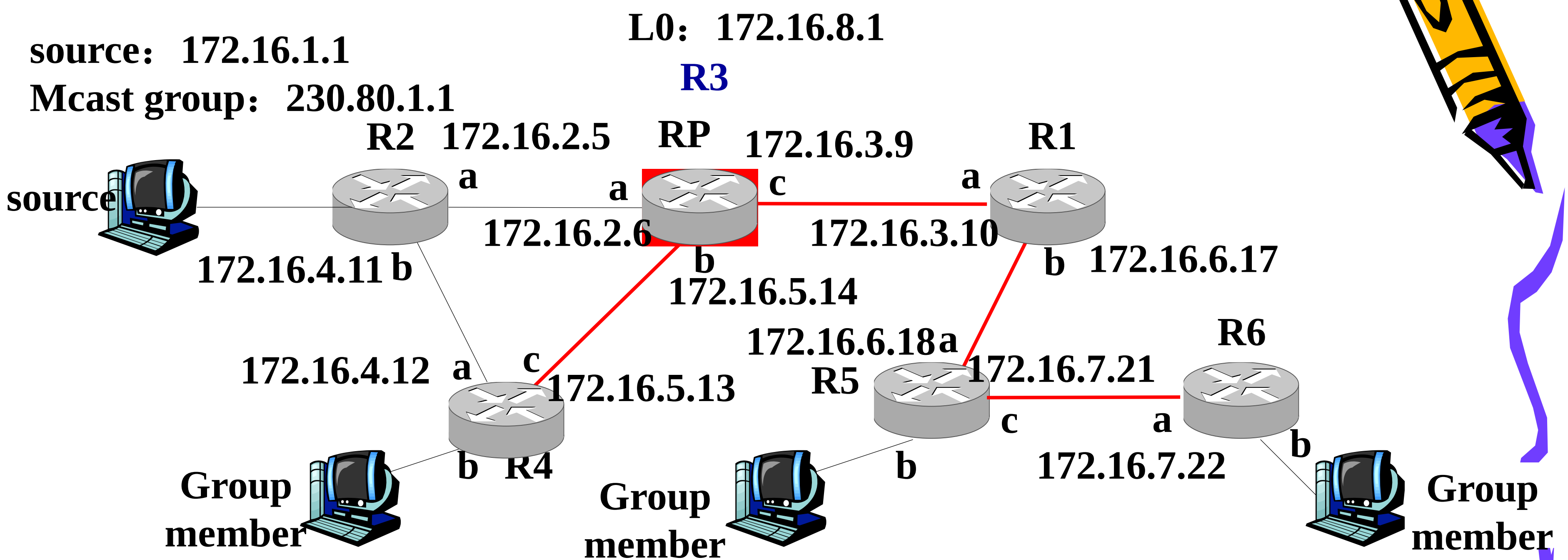
1. Initial transfer of a multicast source to a multicast packet in the RP

- **Since there is no multicast tree from the source host to RP when multicast packet is initially transmitted, multicast packets from the source host to RP cannot be transmitted through the multicast tree.**
- **At this point, PIM-SM uses the Register message to pass the multicast group of the source host to the RP. PIM-SM uses Register message and register-stop message to implement registration mechanism.**

Mcast source Register



IP address of each router interface AND join etc.



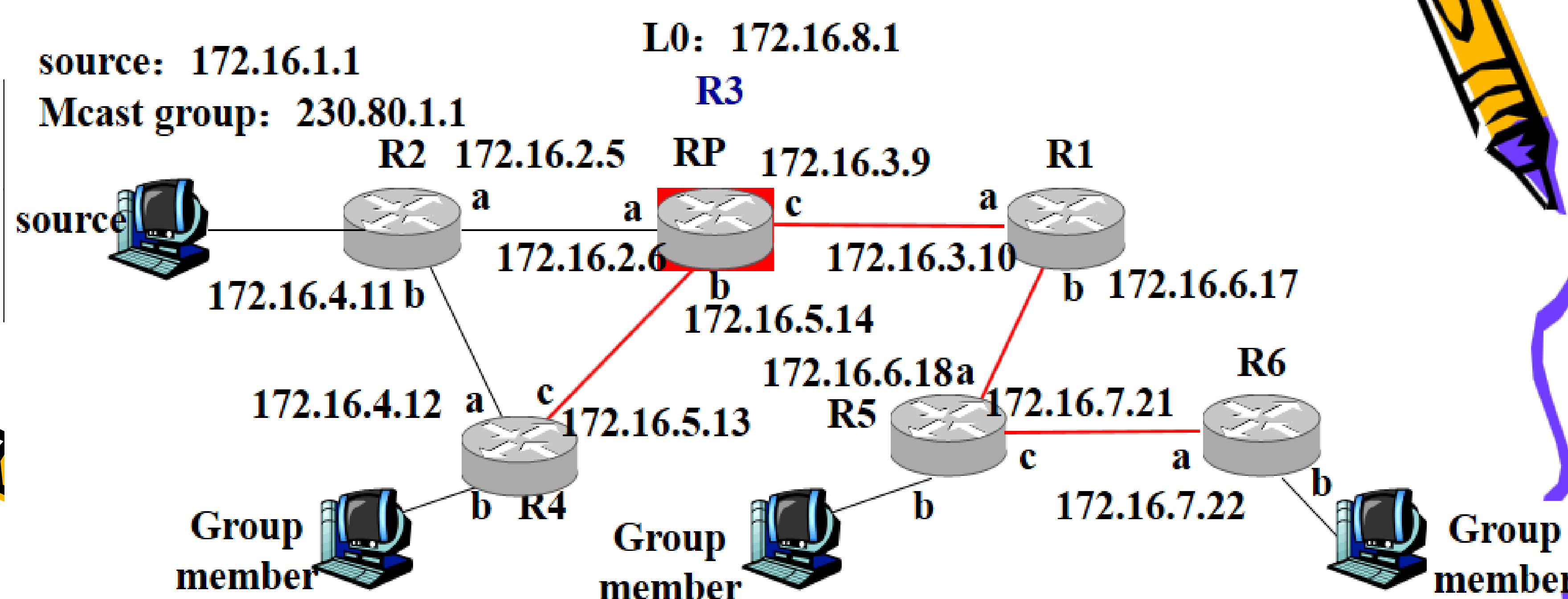
- Registration of multicast sources
- When the multicast source sends a multicast group, the DR of the source host (for example, R2) encapsulates the multicast group in the PIM-SM registration message, which is then encapsulated into the IP group. The IP group is designed for Loopback address of RP (172.16.8.1) and the source address is 172.16.2.5 of interface a of R2.
- This IP packet is then forwarded to RP in unicast mode through R2's unicast routing table. This process is called registration.

2. SPT construction from mcast source to RP

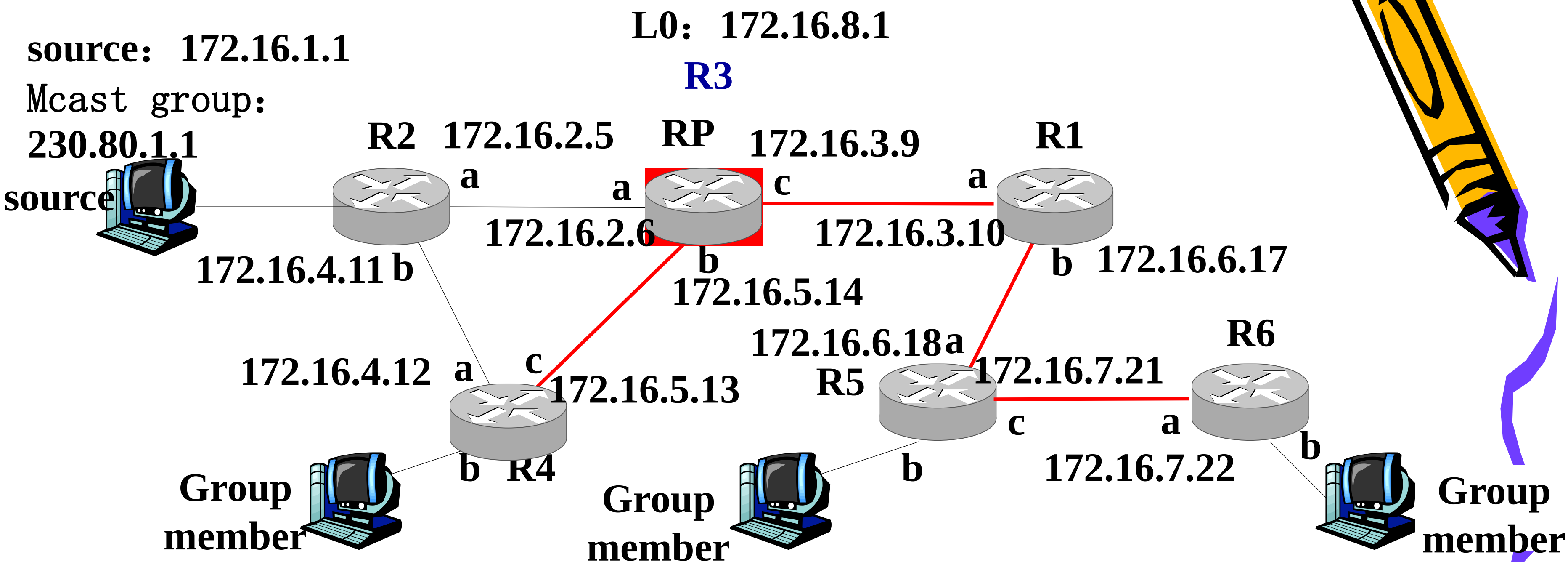
- when the RP receives the first multicast packet sent by the multicast source, the SPT tree is established from the RP to the source host.
- SPT tree is built by PIM-SM join message and prune message.

R2's mcast table

- RP (R3) query the unicast routing table and selects the shortest path to the specified multicast source, 172.16.1.1.
- Then, RPF neighbor R2 along this path sends the join message to the group (172.16.1.1, 230.80.1.1) in unicast mode.
- R2 generates the corresponding (S, G) table entry in the multicast table based on the information of this message, and defines interface "a" of R2 receiving this message as the output interface (downstream interface).



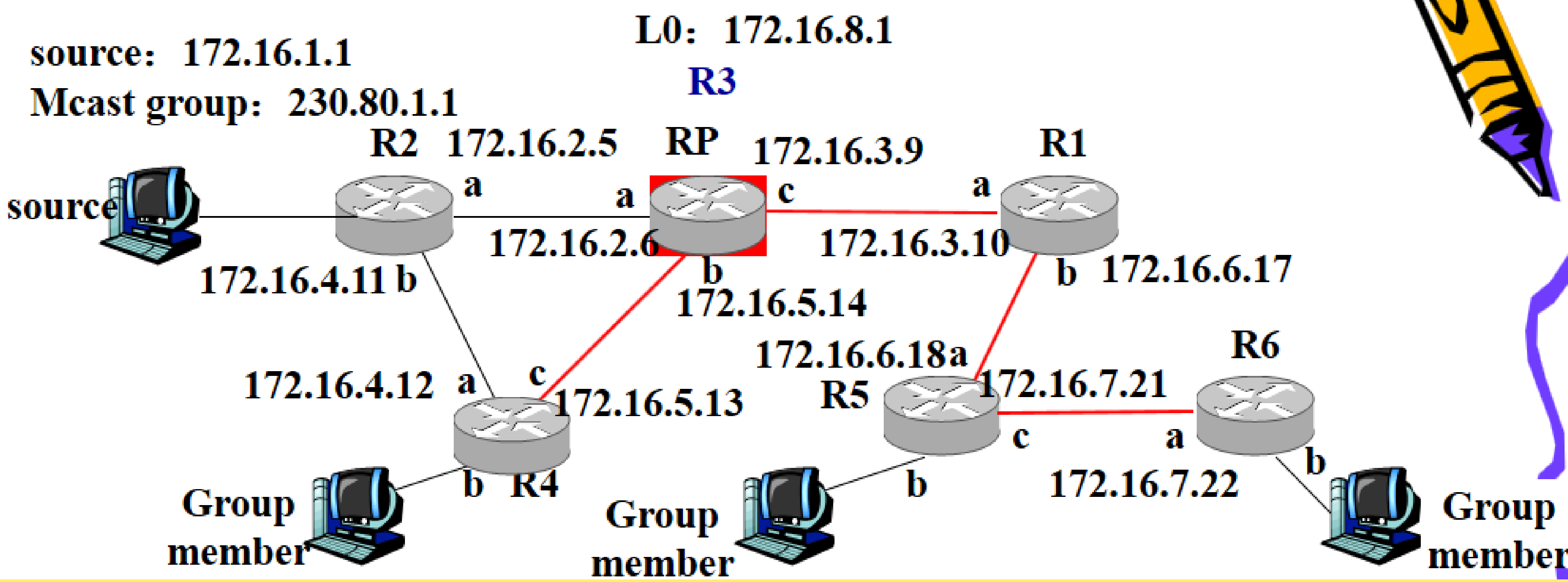
IP address of each router interface



R3's mcast

As RP, R3's multicast routing table is composed of two table entries, one for RPT and one for SPT

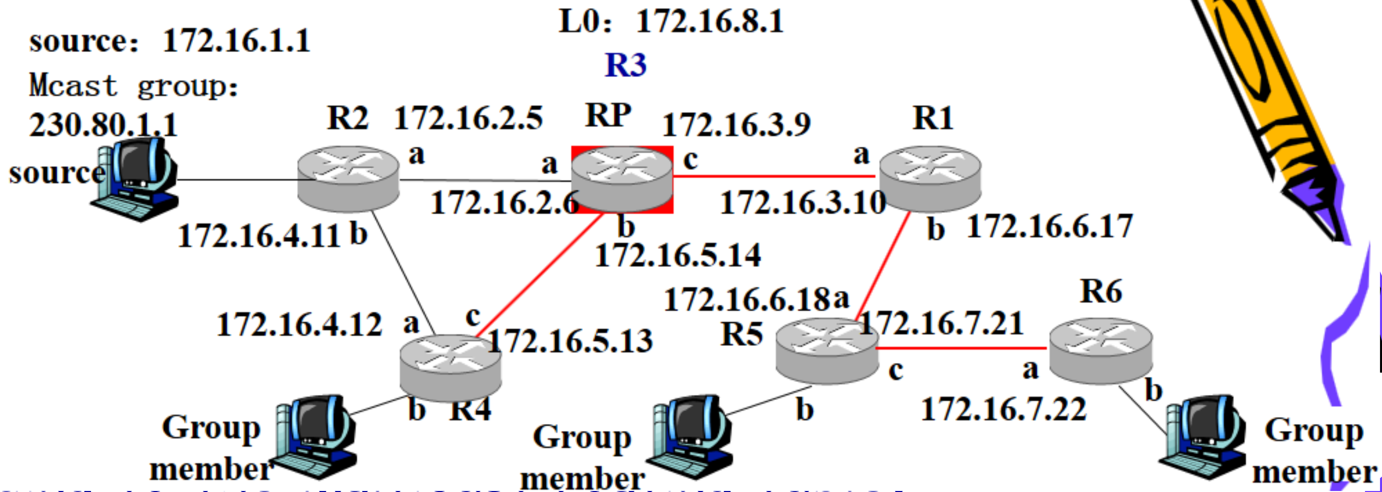
（*, G）ADDR. pair	RP A	address	interface	m interface
（*, 230.80.1.1）	172.16.8.1	0.0.0.0	Null	b、c
（S, G）ADDR. pair	RPF neighbor address		Upstream interface	Downstream interface
（172.16.1.1, 230.80.1.1）	172.16.2.5		a	b、c



- For (172.16.1.1, 230.80.1.1) multicast packets, the longest matching table item on R3 is the second table item, so R3 forwards the multicast packet to interfaces b and c based on this table item.
- The routing table entries for R1, R4, R5, and R6 routers have not changed.

3.

IP address of each router interface

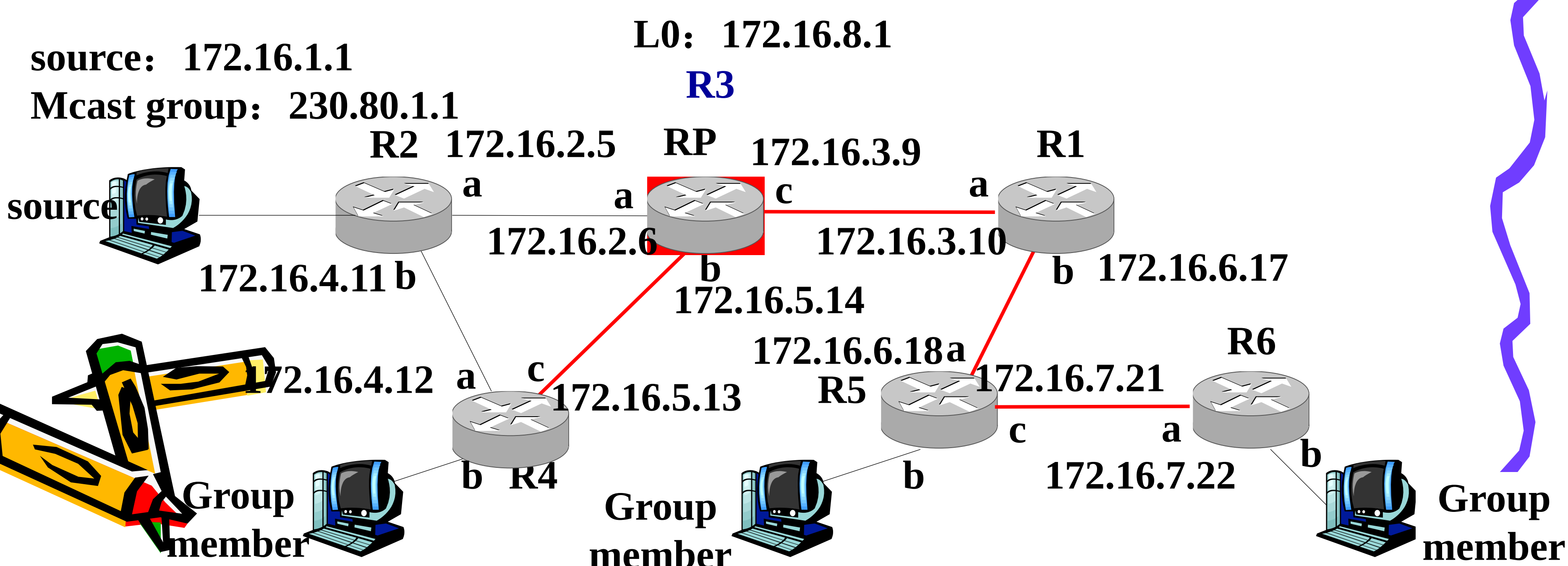


- After rec... takes out ... multicast ... node accor...
- After RP (R3) receives the multicast packet sent by the source host, queries the multicast routing table and decides to forward the packet to interfaces b and c.
- The R1 router performs RPF checks to see if the packet is received from the specified upstream interface a.If so, the packet is forwarded to the specified downstream interface b.
- Routers R5, R6, and R4 do the same, and eventually all multicast group members receive multicast packets from the source host.

Is it the optimal path?

PIM-SM provides a switching mechanism from RPT to SPT

- The Shared tree passes the path to a multicast group, not necessarily the shortest path from the source to the multicast group member host.
  - For example, multicast packet transfer from the source host to R4 follows the R2-R3-R4 Shared tree path, while the shortest path is R2-R4.



9.10.5 Switch from a Shared tree to a source-based tree

- The Shared tree is generally used only to help multicast group members discover the multicast source (S, G) for an activity and for the initial phase of multicast packet transport.
- To reduce network latency and congestion that may occur on RP, when the bit rate of the multicast packet received by the DR of the receiving node exceeds a certain threshold, the DR can start to establish a source-based SPT tree, and establish an SPT tree from this particular multicast source S to the members of the multicast group.
- Thereafter, the delivery of the multicast group switches from the RPT Shared tree to the SPT tree.

PIM-SM RPF check of router

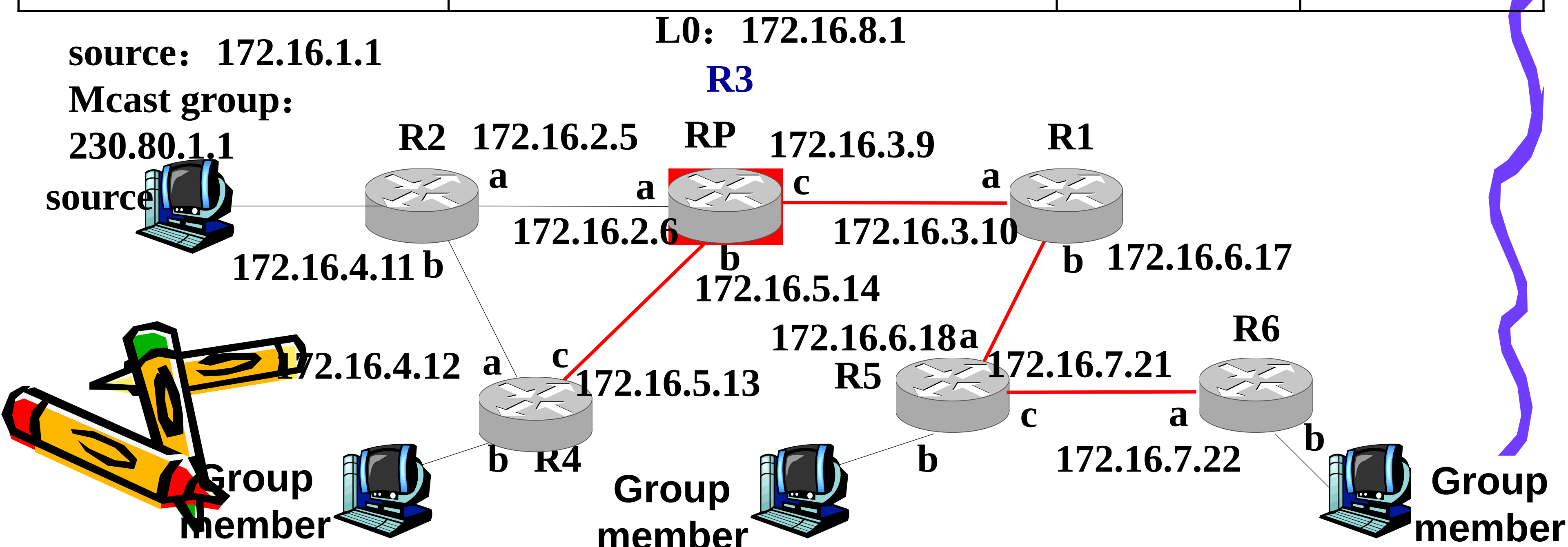
- The PIM-SM router forwards multicast packets to all member hosts. The router performs an RPF check before forwarding multicast packets.
  - If RPT, RPF checks the IP address using RP;
  - If SPT, RPF checks the address of the multicast source used.

9.10.6 Establishment of SPT trees from multicast sources to multicast group members

- DR on the Shared tree, such as R4, R5, and R6, will be established to the SPT tree of the source when the sending rate of a specified (S, G) multicast packet received by R4, R5, and R6 exceeds a threshold value.

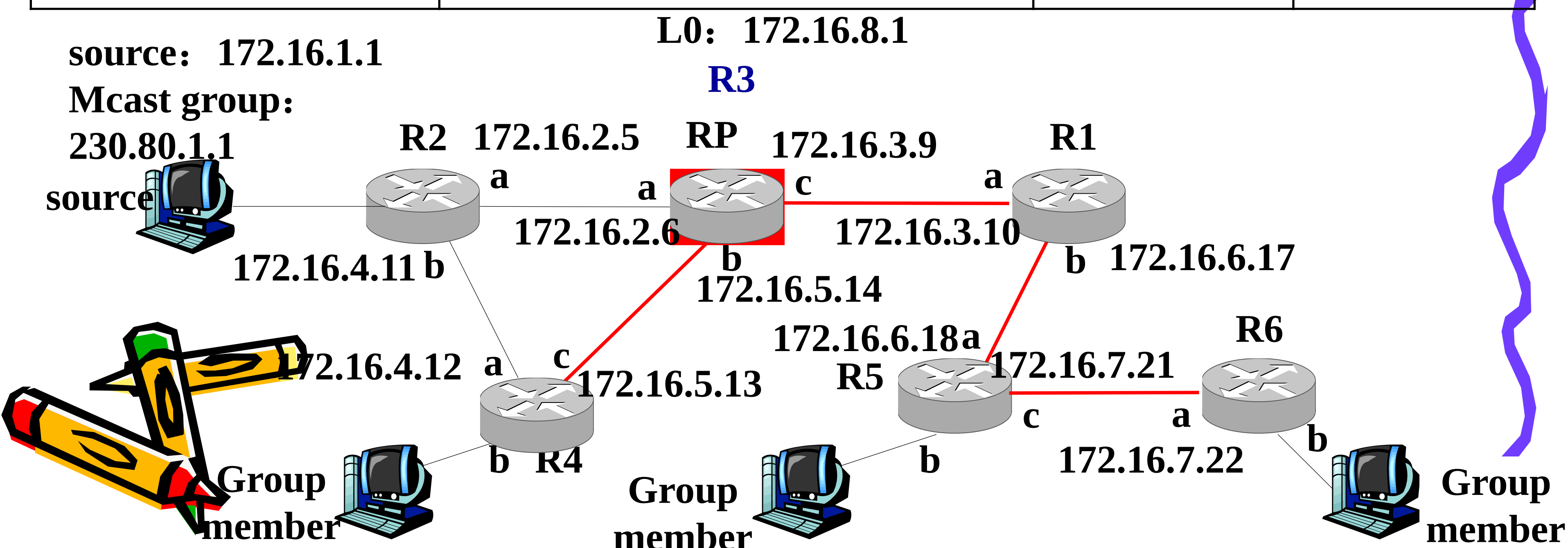
R6 receives (172.16.1.1, 230.80.1.1) multicast packet to get the IP address of the multicast source. Query the unicast routing table of R6 based on the IP address of the multicast source, and get the shortest path to the multicast source, the RPF neighbor and the upstream interface. This generates the corresponding table entry for the multicast routing table.

(*, G) ADDR. pair	RP ADDR.	RPF neighbor address	Upstream interface	Downstream interface
(*, 230.80.1.1)	172.16.8.1	172.16.7.21	a	b
(S, G) ADDR. pair	**RPF neighbor address**		**Upstream interface**	**Downstream interface**
(172.16.1.1, 230.80.1.1)	172.16.7.21		a	b



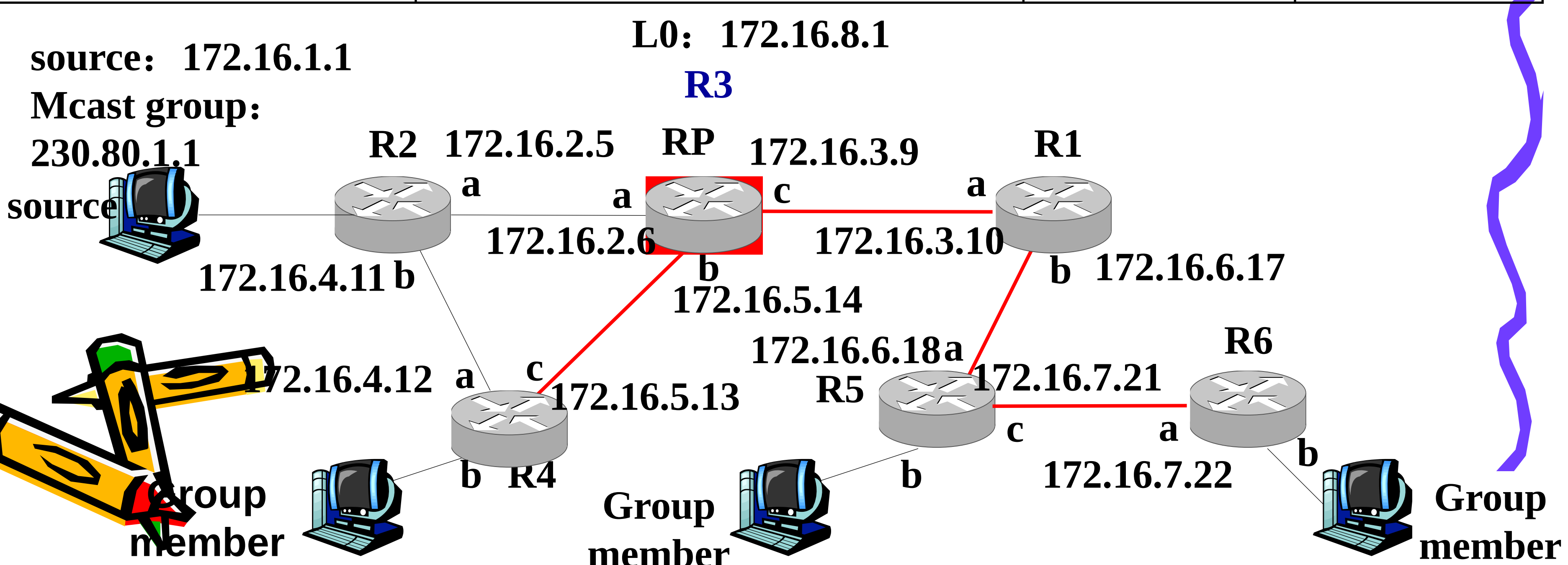
R6 sends join message to its RPF neighbor R5. After R5 receives the join message, interface c receiving this message is defined as the downstream interface, and the join message is sent to the upstream router R1 (its RPF neighbor).

（*，G）ADDR. pair	RP ADDR.	RPF neighbor address	Upstream interface	Downstream interface
（*，230.80.1.1）	172.16.8.1	172.16.6.17	a	b、c
（S，G）ADDR. pair	**RPF neighbor address**		**Upstream interface**	**Downstream interface**
（172.16.1.1，230.80.1.1）	172.16.6.17		a	b、c



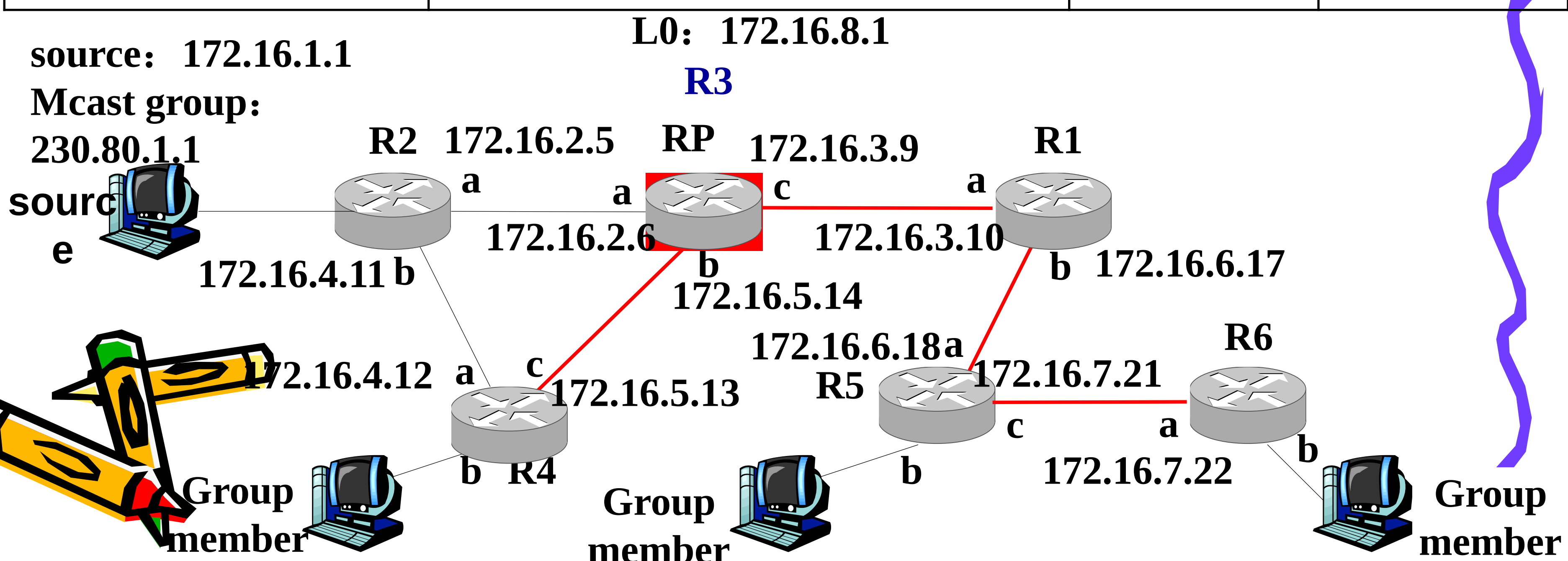
R1's mcast table

（*，G）ADDR. pair	RP ADDR.	RPF neighbor address	Upstream interface	Downstream interface
（*，230.80.1.1）	172.16.8.1	172.16.3.9	a	b
（S，G）ADDR. pair	RPF neighbor address		Upstream interface	Downstream interface
（172.16.1.1，230.80.1.1）	172.16.3.9		a	b



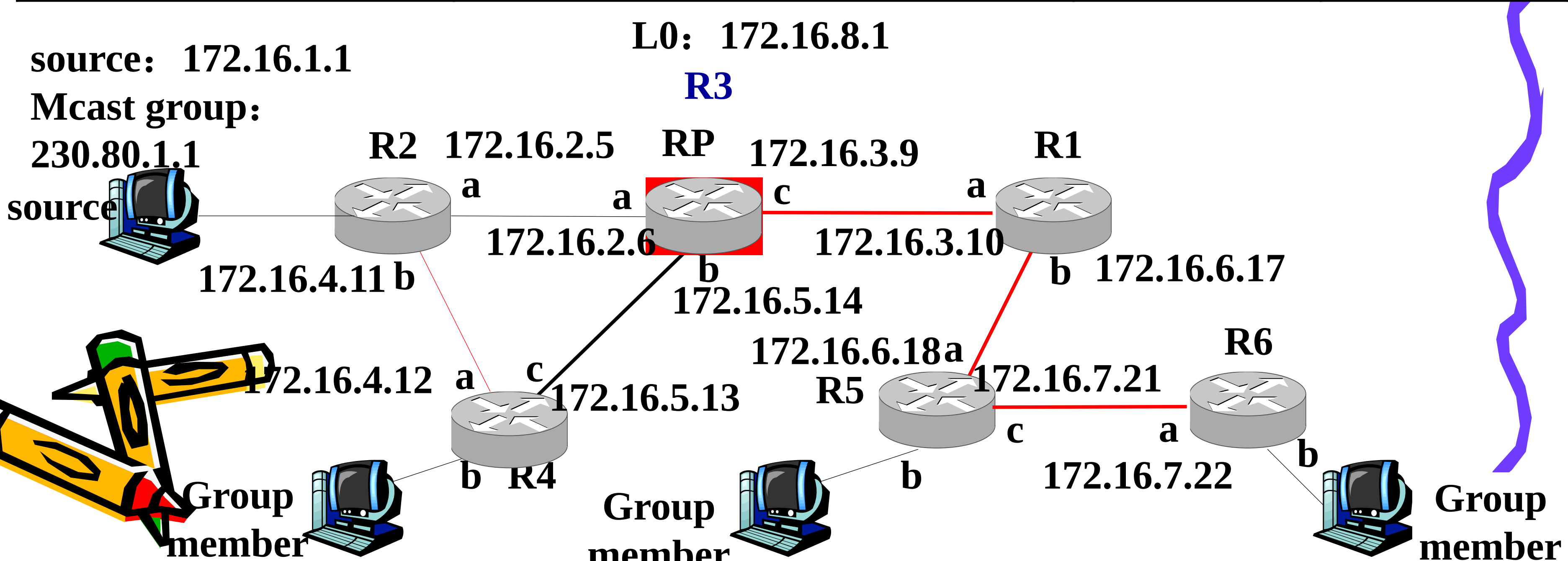
R3's mcast table

（*，G）ADDR. pair	RP ADDR.	RPF neighbor address	Upstream interface	Downstream interface
（*，230.80.1.1）	172.16.8.1	0.0.0.0	Null	b、c
（S，G）ADDR. pair	**RPF neighbor address**		**Upstream interface**	**Downstream interface**
（172.16.1.1，230.80.1.1）	172.16.2.5		a	c



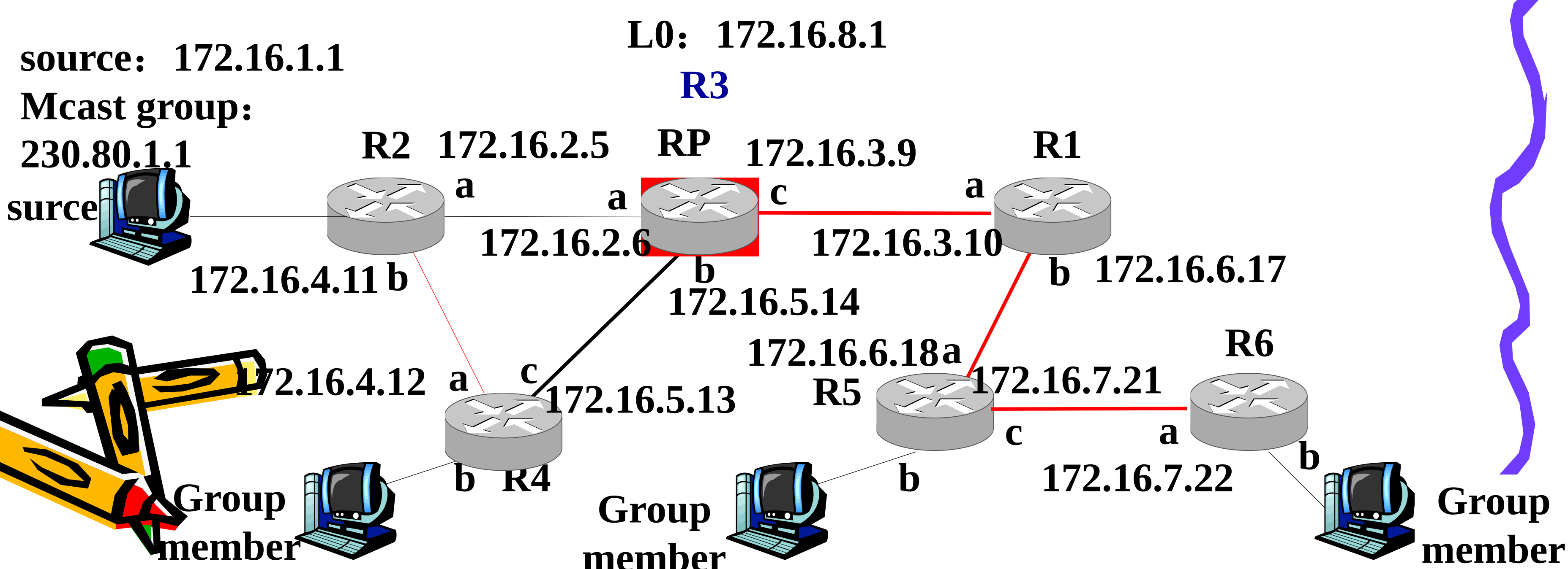
R4的多播表

（*，G）ADDR. pair	RP ADDR.	RPF neighbor address	Upstream interface	Downstream interface
（*，230.80.1.1）	172.16.8.1	172.16.5.14	c	b
（S，G）ADDR. pair	**RPF neighbor address**		**Upstream interface**	**Downstream interface**
（172.16.1.1，230.80.1.1）	172.16.4.11		a	b



R2's mcast table

（S，G）ADDR. pair	RPF neighbor address		Upstream interface
（172.16.1.1，230.80.1.1）	0.0.0.0	Null	a、b



9.10.7 PIM-SM's features

- The main features of PIM-SM are:
- Don't need to own a separate multicast routing table, do not have to send multicast routing update message, low overhead.
- The PIM-SM is more flexible than CBT.PIM-SM enables routers to switch from a Shared tree to a source-based tree to reduce network latency associated with the Shared tree.
- Multicast group membership using explicit mode, is more suitable for WAN connection at the end of the potential members of the multicast network, multicast group has fewer members, sender and receiver are isolated or sparse.

9.11 Interdomain multicast technology

- 9.11.1 inter-domain multicast problem
- 9.11.2 MBGP agreement
- 9.11.3 examples of inter-domain multicast

9.11 Interdomain multicast technology

- **What protocols are used?A solution uses three protocols:**
  - **MBGP is used to exchange multicast routing information between autonomous domains.**
  - **Multicast source discovery protocol (MSDP) is used by ISP to exchange multicast source information.**
  - **PIM-SM is used as an intra-domain multicast routing protocol.**

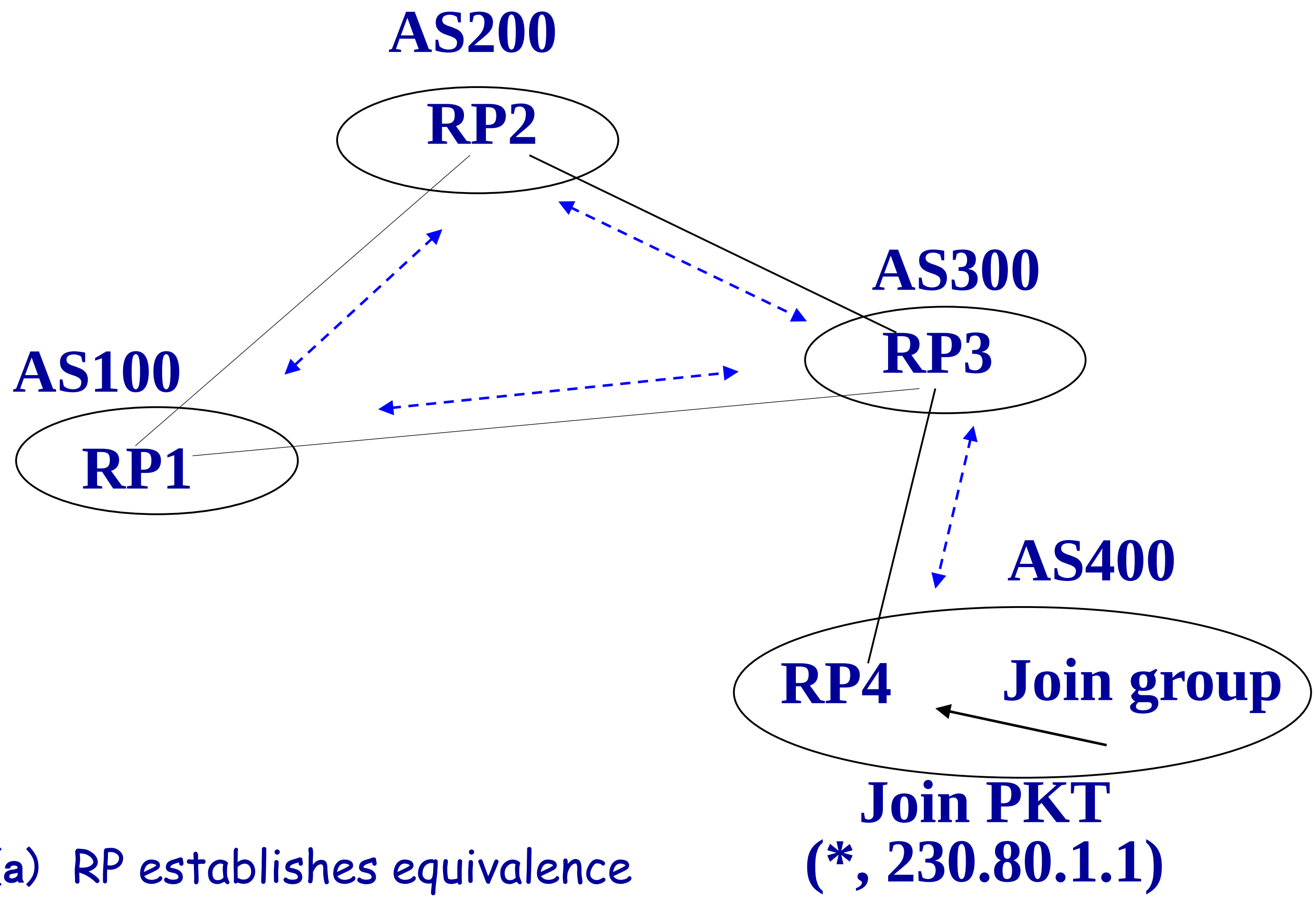
9.11.2 MBGP

- MBGP provides a way to check for multicast RPF.
- BGP-4 is an effective and stable unicast inter-domain routing protocol. MBGP is an enhancement and extension of the BGP protocol.
- Multicast BGP is defined in RFC 2858 。

MBGP is an enhancement and extension of BGP

- **MBGP carries not only IPv4 unicast routing information, but also the routing information of other network layer protocols (such as multicast, IPv6, etc.). Carrying multicast routing information is only one of the extended functions.**
- **MBGP notifies the adjacent autonomous system that "sender S can be reached from me".**
- **When an RP or multicast group member sends a join message to another AS multicast source S, the message needs to follow the reverse path to the multicast source S, and RPF checking can be implemented with the route provided by MBGP.**

9.11.3 examples of inter-domain multicast

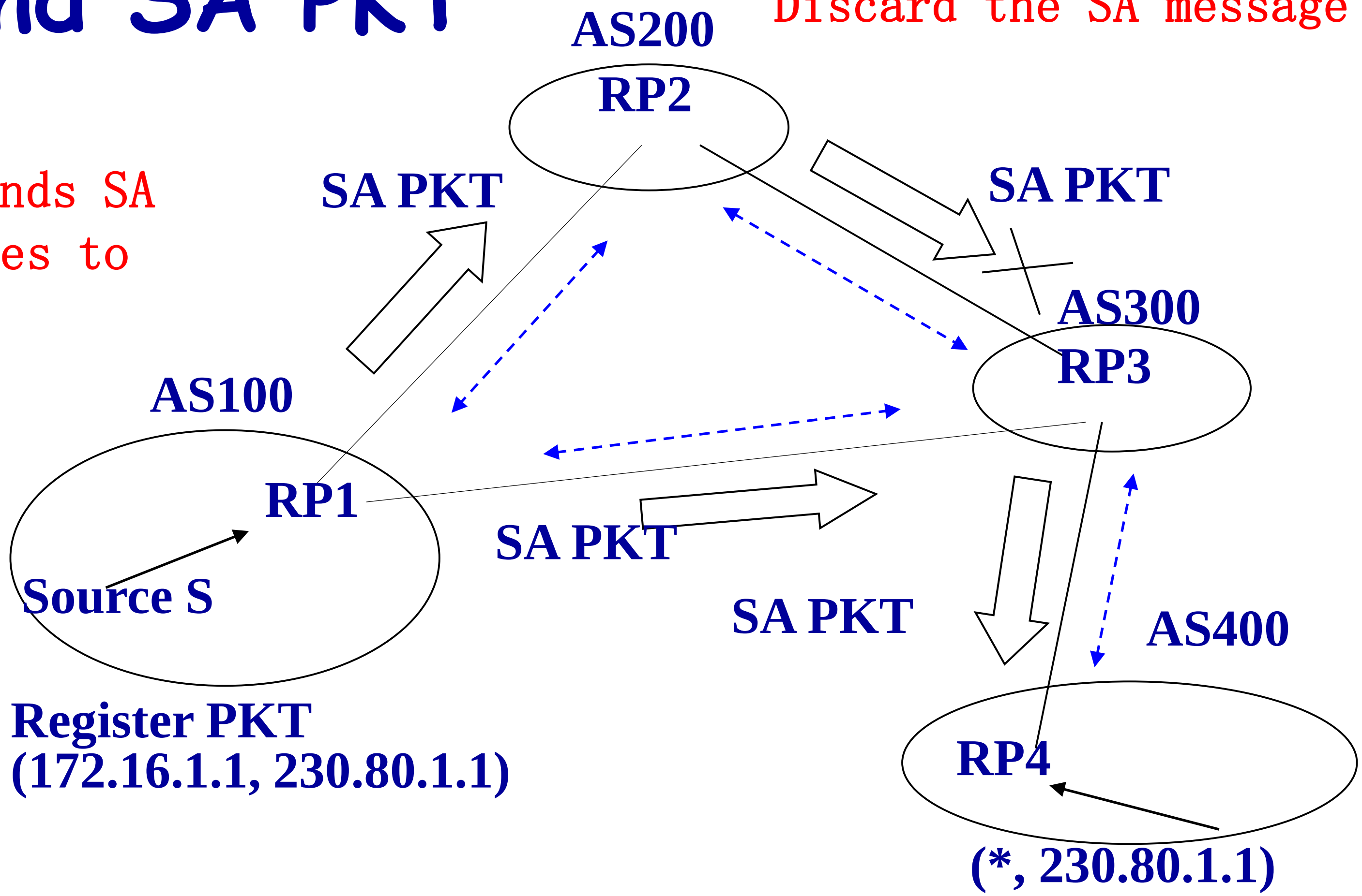


(a) RP establishes equivalence

Send SA PKT

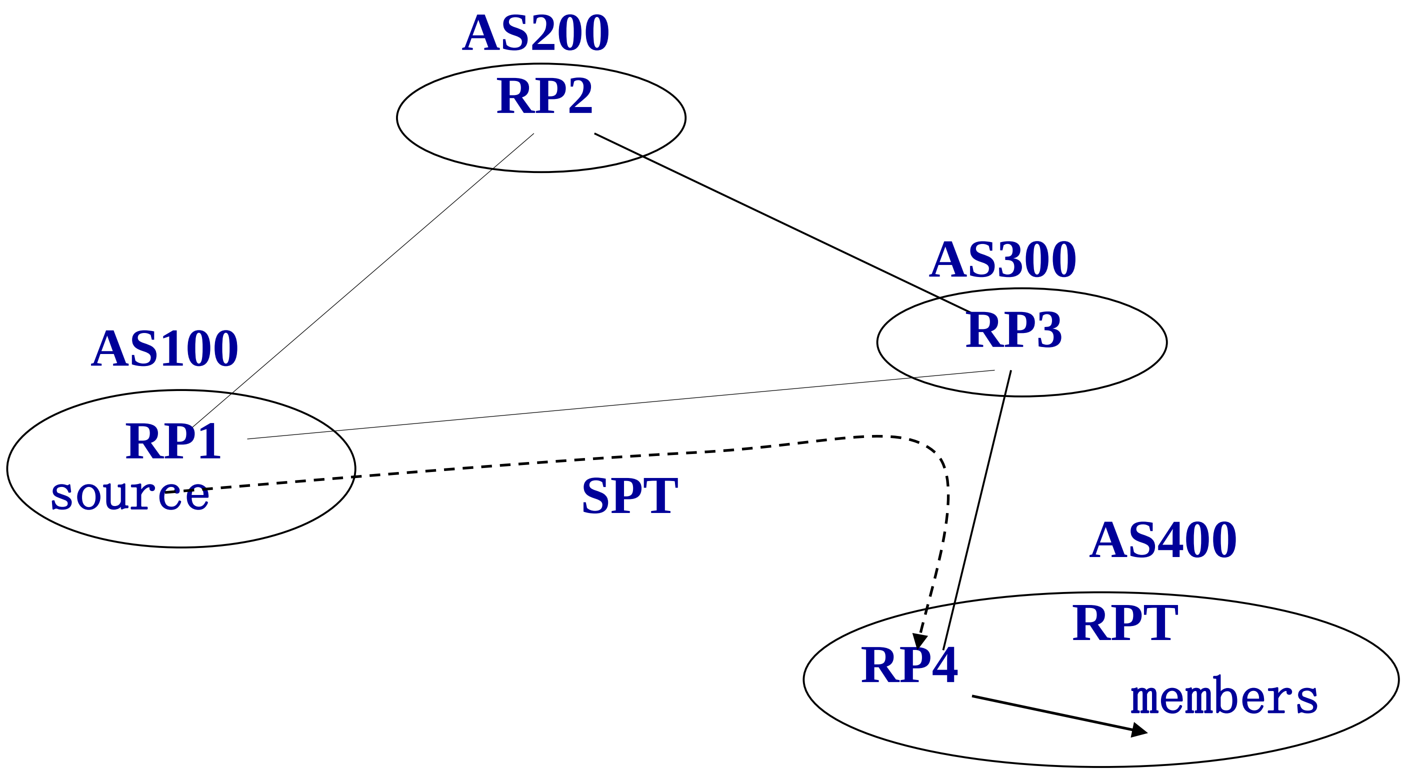
RP3 performs RPF check,
Receive the SA message of AS100,
Discard the SA message of AS200

RP1 sends SA messages to peers



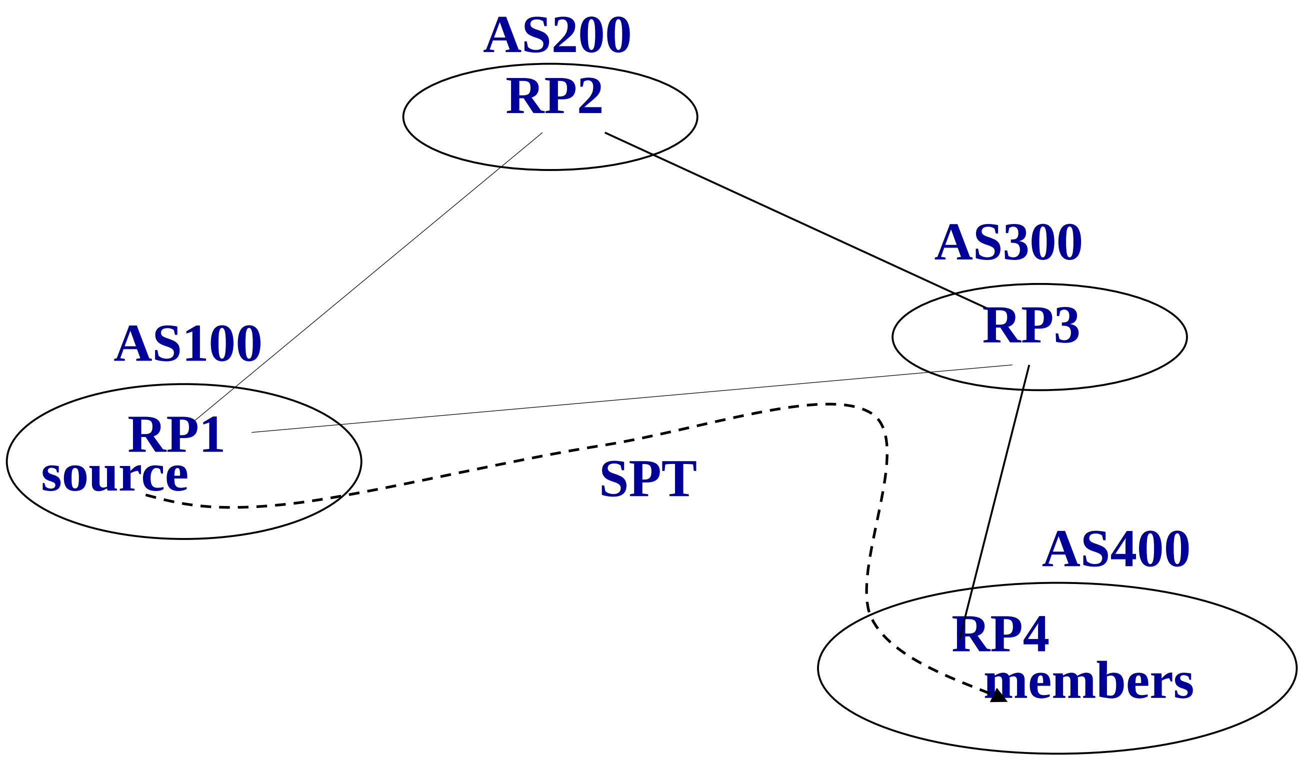
In AS400, members of a multicast group applied to join the group (*, 230.80.1.1), joined the join message through PIIM-SM, and established a Shared tree with RP4 as the root in AS400

SPT from mcast source to RP



Establish an SPT tree from AS100 to RP4, and then transfer the multicast group (172.16.1.1, 230.80.1.1) along this SPT tree to RP4. RP4 forwards to the multicast group members in this domain through the AS400 Shared tree RPT.

directly to the SPT of a multicast group member

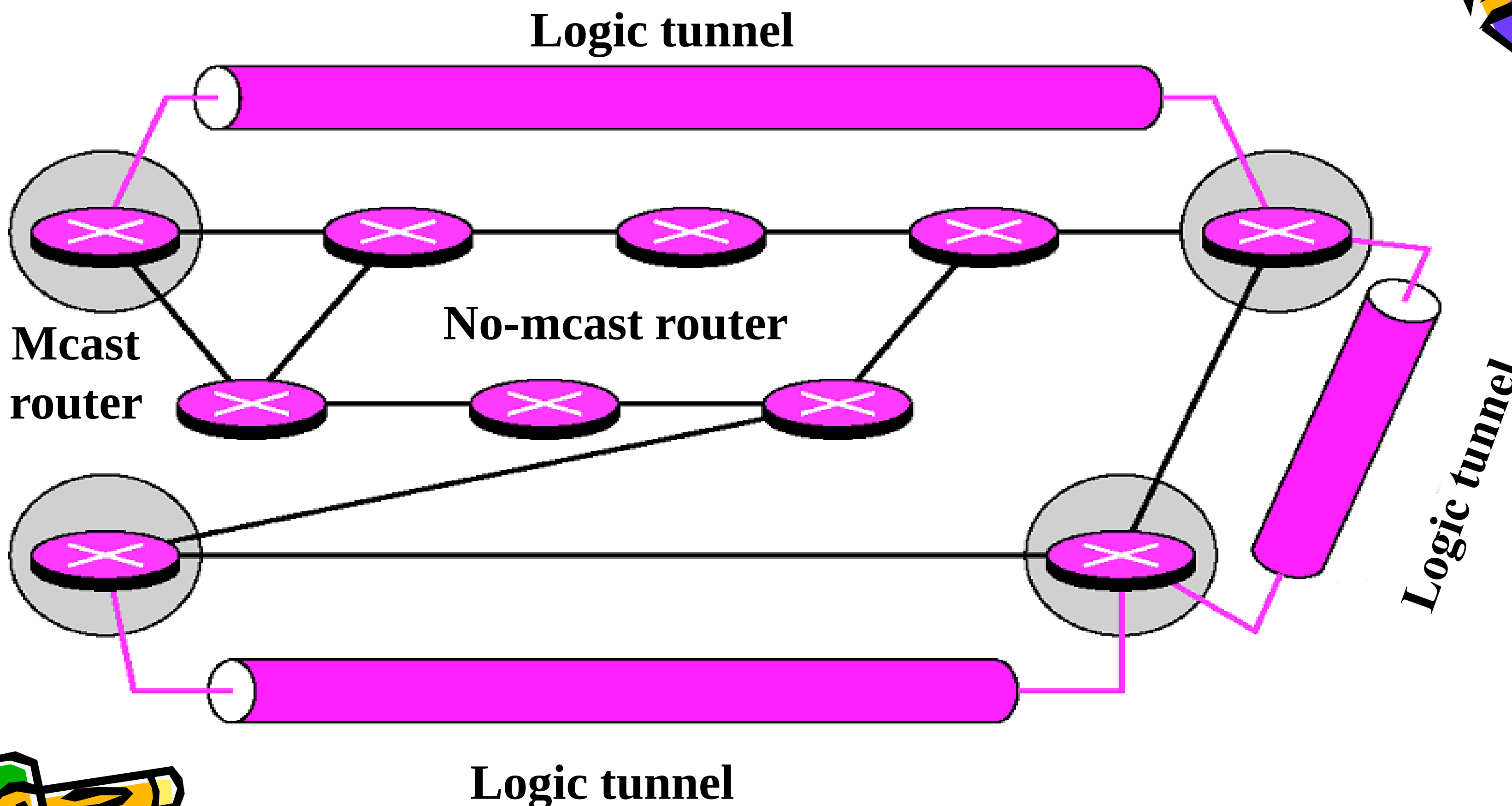


After the multicast group members of AS400 receive the multicast group, according to the IP address of the source, establish the SPT tree directly from the source in AS100 domain to the multicast group members in AS400. Multicast groups are passed directly from the multicast source to multicast group members along this SPT tree. This SPT tree can go through RP1, RP3, and RP4 without going through them

9.12 Multicast the backbone MBONE

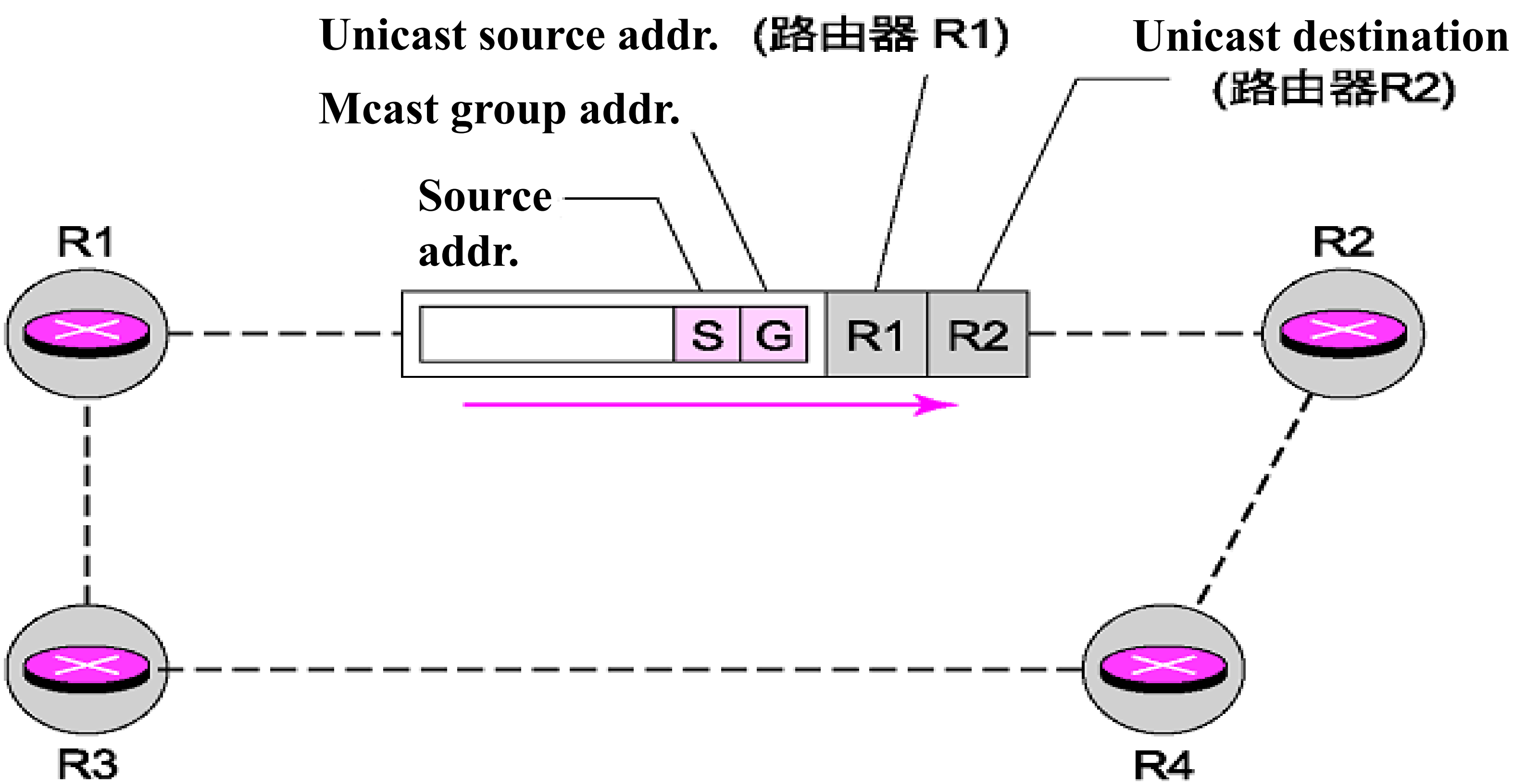
- In Internet, only a small proportion of routers are multicast routers, and one multicast router may not find another multicast router nearby when forwarding multicast packets.
- Tunneling technology was used to establish a multicast backbone MBONE outside the isolated multicast router.

Logic tunnel



Encapsulation of multicast groups in unicast groups

- By encapsulating multicast packets in unicast packets, a logic tunnel is established and multicast packets become the payload of unicast packets. The intermediate router forwards the packet as a unicast router.



9.13 IPv6 mcast technology

- 9.13.1 IPv6 multicast new features
- 9.13.2 IPv6 multicast receiver discovery protocol MLD
- 9.13.3 IPv6 multicast routing protocol
- 9.13.4 multicast in IPv6 experimental network

9.13 IPv6 mcast technology

- The IETF made IPv6 protocol with multicast preserved and broadcast cancelled.
- Multicast applications require that the vast majority of devices in the network support multicast, and many IPv4 network devices do not support multicast functions.
- IPv6 brings a new opportunity to the wide application of multicast technology.

9.13.1 IPv6 mcast new features

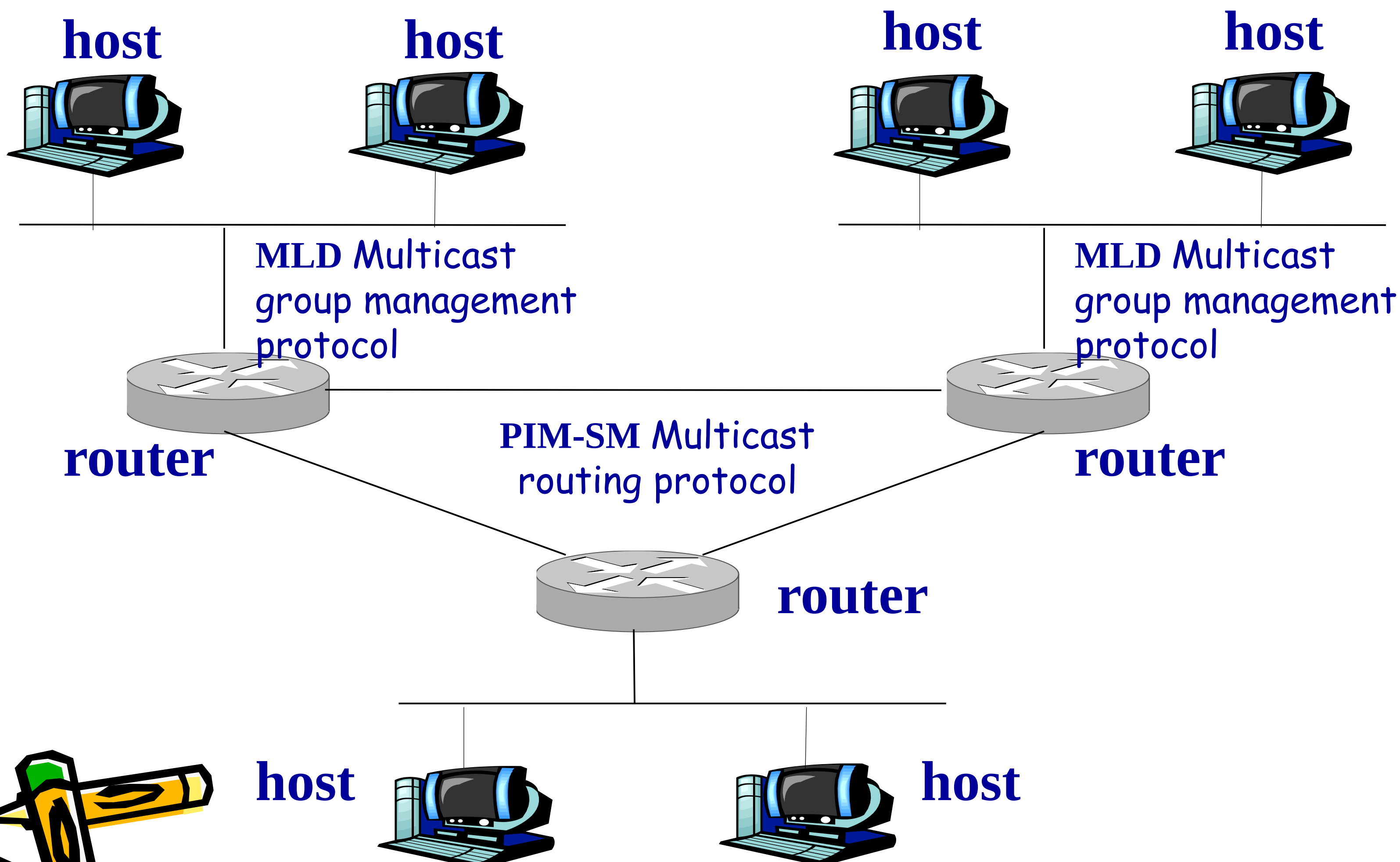
- Multicast address improvements.Advantages of IPv6 over IPv4:
    - With larger multicast address space.IPv6 reserves 112 bit group identifiers.
    - The application of the scope field. IPv6 addresses specify scoping fields that facilitate the division of multicast domains and control the propagation range of multicast applications based on the multicast domain.
    - The new multicast address type is defined.IPv6 defines the multicast address type of the requested node, which is used for ICMPv6 packets, instead of ARP protocol and so on.

Mcast addr.	1111 1111	1/256

9.13.2 IPv6 multicast receiver discovery protocol MLD

- **The two basic protocols for IPv6 multicast are the MLD protocol and the PIM-SM protocol.**
  - **Multicast Listener Discovery for IPv6**
  - **PIM-SM multicast routing protocol is used between routers**

PIM-SM IPv6 Multicast protocol



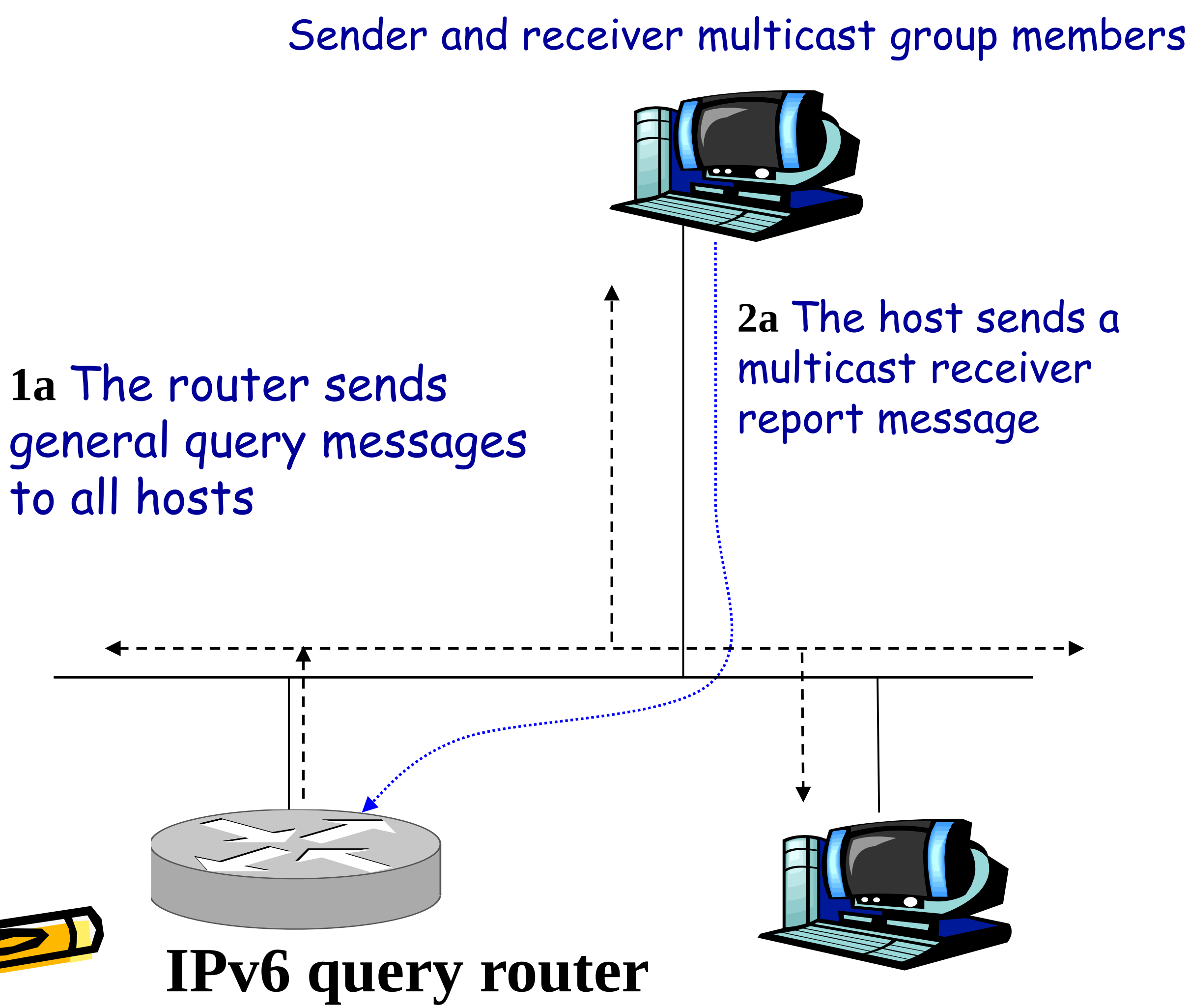
MLD protocol

- MLDv1 is derived from the IGMPv2 protocol in IPv4, and is used for IPv6 multicast group management. It exchanges multicast group member information between the host and router, so that IPv6 router can find the directly connected group member and the group member of the specific multicast address in the adjacent nodes.
- MLDv2 adds source-specific multicast capabilities similar to those in IGMPv3, allowing receivers to join a multicast group that specifies a multicast source, that is, only the group of that multicast source will be accepted.
- The MLD protocol does not use IGMP message format, but ICMPv6 message format.

MLD protocol defines three message types

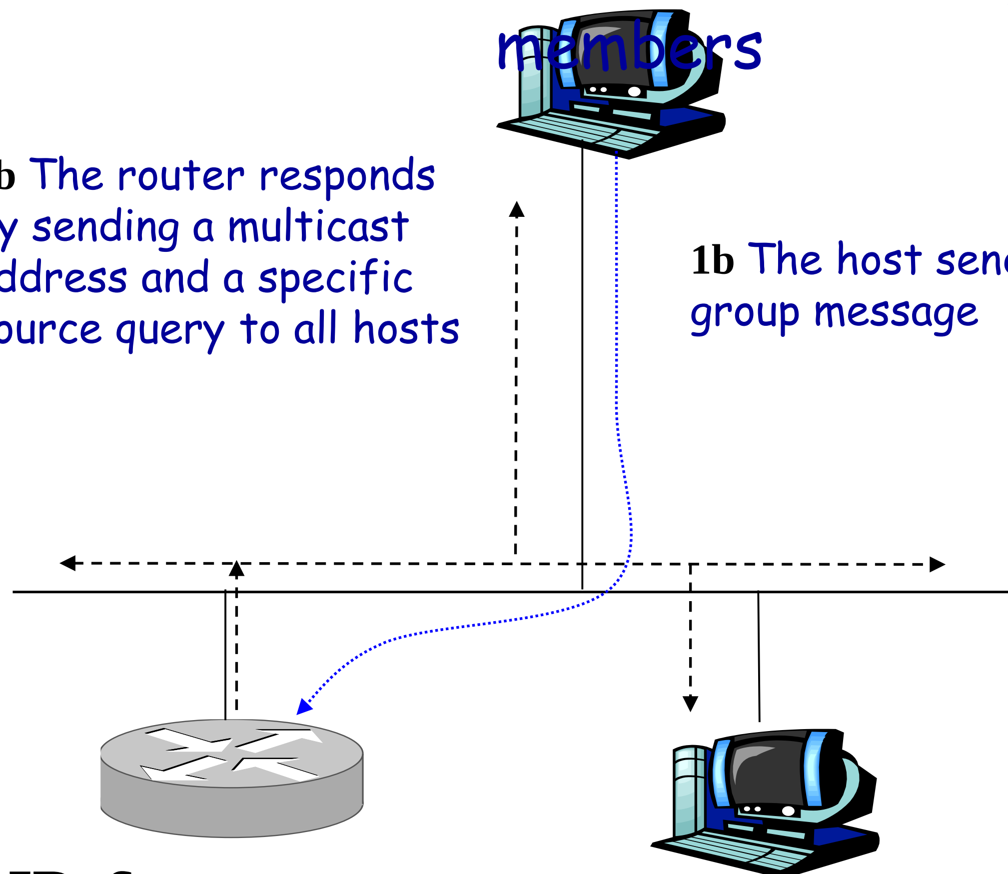
- Group receiver query message (Type=130) : the general query PKT and specific mcast query PKT.Multicast Multicast Address Specific Query used to discover which multicast addresses have multicast receivers on a direct link.
- Group receiver report message (Type=131)
- Group receiver exits message (Type=132)
- MLDv2 also has one class of Multicast packets, Multicast Source and source-specific queries

(a) The router sends general query messages periodically

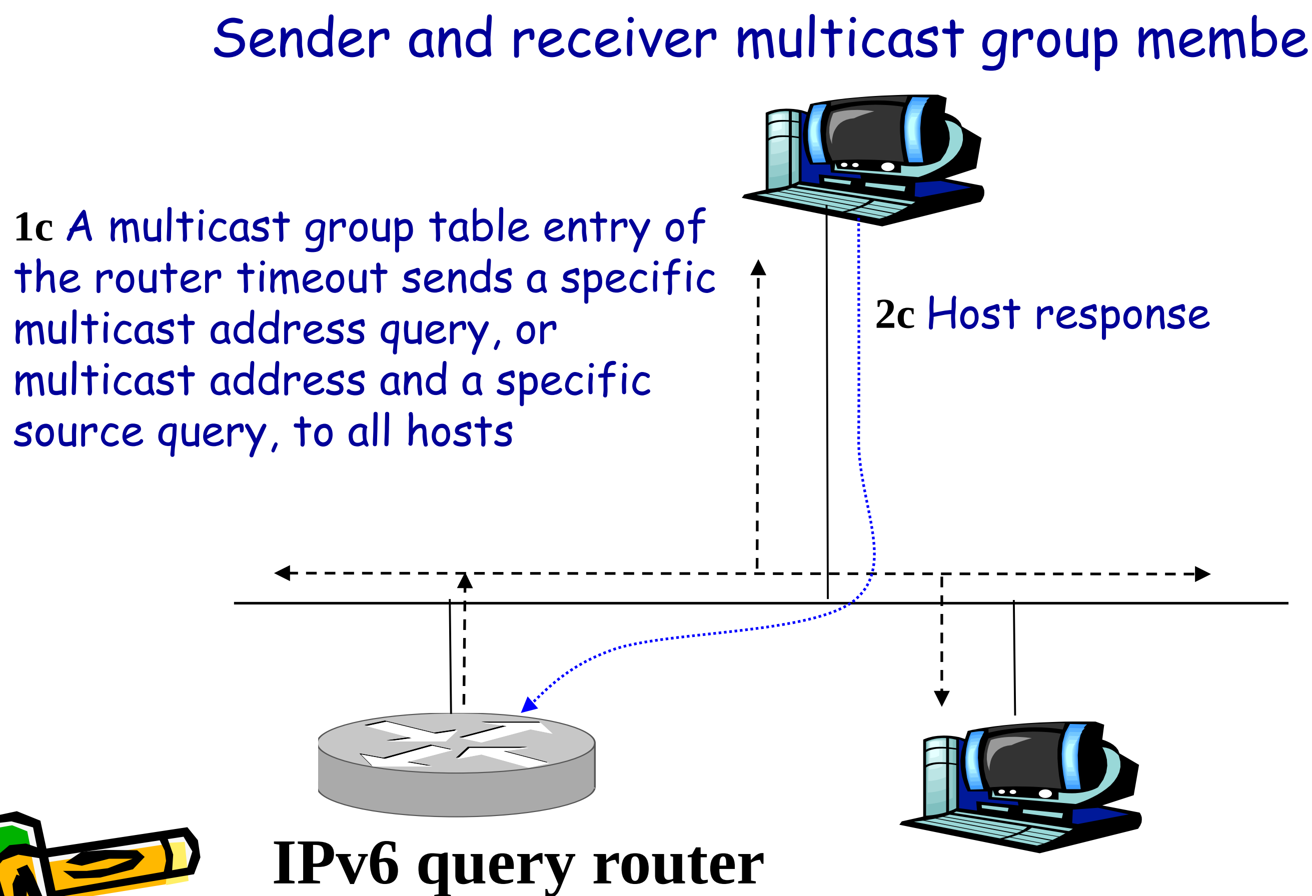


(b) The host sends an leave group message

Sender and receiver multicast group members



(c) The router sends a particular multicast address query message, or multicast address and a specific source query message



9.13.3 IPv6 Multicast routing protocol

- Compared with IPv4, IPv6 multicast routing protocol has not changed in principle.However, IPv6 multicast routing protocol can use IPv6 multicast address features.the routing protocol has better support.
- PIM-SM multicast routing protocol can be used between IPv6 routers.
- DR, the designated router of PIM-SM, is the edge router in the multicast tree, which is the bridge connecting the host and the upstream router. It can process both MLD packets and PIM packets.
- DR finds the multicast receiver on the link directly connected to it through MLD protocol, and then DR sends the join/prune message to RP to maintain the RP tree of multicast group G.

目录

07-PIM配置

目 录