UNICAST ROUTING PROTOCOLS

Hierarchical Routing in Internet

The Internet today is made of a huge number of networks and routers that connect them. Routing in the Internet cannot be done using a single protocol for two reasons:
A scalability problem and an administrative issue.

Scalability problem means that the size of the forwarding tables becomes huge, searching for a destination in a forwarding table becomes time-consuming, and updating creates a huge amount of traffic.

Hierarchical routing means considering each ISP as an autonomous system (AS).Each AS can run a routing protocol that meets its needs, but the global Internet runs a global protocol to join and connect all ASs together.The routing protocol run in each AS is referred to as intra-AS routing protocol, intradomain routing protocol, or interior gateway protocol (IGP);The global routing protocol is referred to as inter-AS routing protocol, interdomain routing protocol, or exterior gateway protocol (EGP).

Routing Information Protocol (RIP)

The Routing Information Protocol (RIP) is one of the most widely used intradomain routing protocols based on the distance-vector routing algorithm.

Hop Count

A router in this protocol implements the distance-vector routing algorithm. First, since a router in an AS needs to know how to forward a packet to different networks(subnets) in an AS, RIP routers advertise the cost of reaching different networks instead of reaching other nodes in a theoretical graph.

The cost is defined between a router and the network in which the destination host is located.

Second, to make the implementation of the cost simpler (independent from performance factors of the routers and links, such as delay, bandwidth, and so on), the cost is defined as the number of hops, which means the number of networks (subnets)a packet needs to travel through from the source router to the final destination host.

Note that the network in which the source host is connected is not counted in this calculation because the source host does not use a forwarding table; the packet is delivered to the default router.

Figure 3.3.1 shows the concept of hop count advertised by three routers from a source host to a destination host. In RIP, the maximum cost of a path can be 15, which means 16 is considered as infinity (no connection).For this reason, RIP can be used only in autonomous systems in which the diameter of the AS is not more than 15 hops.

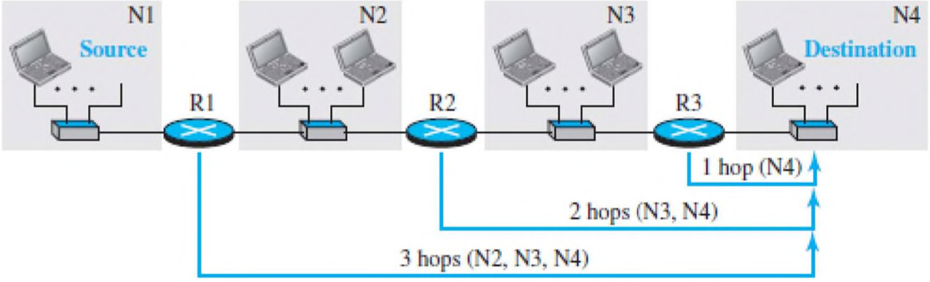
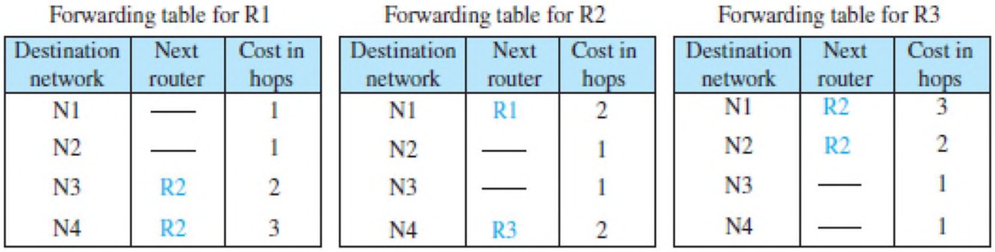


Fig3.3.1: Hop counts in RIP.
[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-613]

Forwarding Table

A forwarding table in RIP is a three-column table in which the first column is the address of the destination network, the second column is the address of the next router to which the packet should be forwarded, and the third column is the cost (the number of hops) to reach the destination network.Figure3.3.2 shows the three forwarding tables for the routers in Figure (above).

Note that the first and the third columns together convey the same information as does a distance vector, but the cost shows the number of hops to the destination networks.



Forwarding table for R1

Destination network	Next router	Cost in hops
N1	——	1
N2	——	1
N3	R2	2
N4	R2	3

Forwarding table for R2

Destination network	Next router	Cost in hops
N1	R1	2
N2	——	1
N3	——	1
N4	R3	2

Forwarding table for R3

Destination network	Next router	Cost in hops
N1	R2	3
N2	R2	2
N3	——	1
N4	——	1

Fig3.3.2:Forwarding tables in RIP.
[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-614]

For example**,** R1 defines that the next router for the path to N4 is R2; R2 defines that the next router to N4 isR3; R3 defines that there is no next router for this path. The tree is then R1 -R2-R3-N4.

The third column is not needed for forwarding the packet, but it is needed for updating the forwarding table when there is a change in the route.

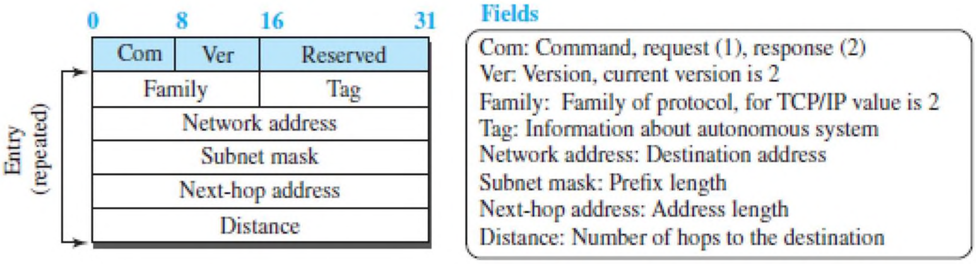
RIP Implementation

RIP is implemented as a process that uses the service of UDP on the port number 520. RIP is a routing protocol to help IP route its datagrams through the AS,the RIP messages are encapsulated inside UDP user datagrams, which in turn are encapsulated inside IP datagrams.

That is, RIP runs at the application layer, but creates forwarding tables for IP at the network layer.

RIP Messages

Two RIP processes, a client and a server, need to exchange messages. RIP-2 defines the format of the message, as shown in figure3.3.3.The message Entry, can be repeated as needed in a message. Each entry carries the information related to one line in the forwarding table of the router that sends the message.



Com: Command, request (1), response (2)
Ver: Version, current version is 2
Family: Family of protocol, for TCP/IP value is 2
Tag: Information about autonomous system
Network address: Destination address
Subnet mask: Prefix length
Next-hop address: Address length
Distance: Number of hops to the destination

Fig3.3.3: RIP message format.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-615]

RIP has two types of messages:

Request and response. A request message is sent by a router that has just come up or by a router that has some time-out entries.

A request message can ask about specific entries or all entries.

A response (or update)message can be either solicited or unsolicited. A solicited response message is sent only in answer to a request message. It contains information about the destination specified in the corresponding request message.

RIP Algorithm

RIP implements the same algorithm as the distance-vector routing algorithm.

- Instead of sending only distance vectors, a router needs to send the whole contents of its forwarding table in a response message.
- The receiver adds one hop to each cost and changes the next router field to the address of the sending router.
- The received router selects the old routes as the new ones except in the following three cases:
  1.If the received route does not exist in the old forwarding table, it should be added to the route.
  2.If the cost of the received route is lower than the cost of the old one, the received route should be selected as the new one.
  3.If the cost of the received route is higher than the cost of the old one, but the value of the next router is the same in both routes, the received route should be selected as the new one.

Timers in RIP

RIP uses three timers to support its operation.

The periodic timer controls the advertising of regular update messages. Each router has one periodic timer that is randomly set to a number between 25 and 35 seconds (to prevent all routers sending their messages at the same time and creating excess traffic). The timer counts down; when zero is reached, the update message is sent, and the timer is randomly set once again.

The expiration timer governs the validity of a route. When a router receives update information for a route, the expiration timer is set to 180 seconds for that particular route. Every time a new update for the route is received, the timer is reset.

If there is a problem on an internet and no update is received within the allotted 180 seconds, the route is considered expired and the hop count of the route is set to 16, which means the destination is unreachable. Every route has its own expiration timer. The garbage collection timer is used to purge a route from the forwarding table.

The garbage collection timer is used to purge a route from the forwarding table. When the information about a route becomes invalid, the router does not immediately purge that route from its table. Instead, it continues to advertise the route with a metric value of 16. At the same time, a garbage collection timer is set to 120 seconds for that route. When the count reaches zero, the route is purged from the table.

Open Shortest Path First (OSPF)

Open Shortest Path First (**OSPF**) is an intradomain routing protocol like RIP.It is based on the link-state routing protocol.

Metric

In OSPF, like RIP, the cost of reaching a destination from the host is calculated from the source router to the destination network.

However, each link (network) can be assigned a weight based on the throughput, round-trip time, reliability, and so on

Figure 3.3.4 shows the idea of the cost from a router to the destination host network.

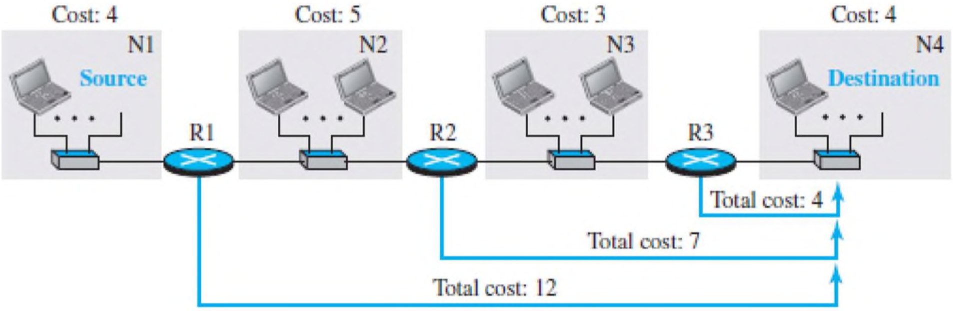
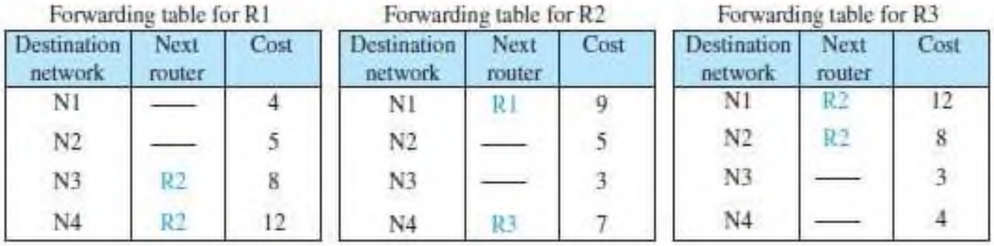


Fig3.3.4:Metric in OSPF.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-618]

Forwarding Tables

Each OSPF router can create a forwarding table as in figure 3.3.5, after finding the shortest-path tree between itself and the destination using Dijkstra's algorithm.



Forwarding table for R1

Destination network	Next router	Cost
N1	——	4
N2	——	5
N3	R2	8
N4	R2	12

Forwarding table for R2

Destination network	Next router	Cost
N1	R1	9
N2	——	5
N3	——	3
N4	R3	7

Forwarding table for R3

Destination network	Next router	Cost
N1	R2	12
N2	R2	8
N3	——	3
N4	——	4

Fig3.3.5:Forwading table in OSPF.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-619]

Areas

OSPF was designed to handle routing in a small or large autonomous system.

The formation of shortest-path trees in OSPF requires that all routers flood the whole AS with their LSPs to create the global LSDB.This may not create a problem in a small AS, but create traffic in large AS.To prevent this, the AS needs to be divided into small sections called areas as shown in figure 3.3.6 .

Each area acts as a small independent domain for flooding .Each router in an area needs to know the information about the link states not only in its area but also in other areas.

For this reason, one of the areas in the AS is designated as the backbone area, responsible for gluing the areas together.

The routers in the backbone area are responsible for passing the information collected by each area to all other areas. In this way, a router in an area can receive all LSPs generated in other areas. For the purpose of communication, each area has an area identification.

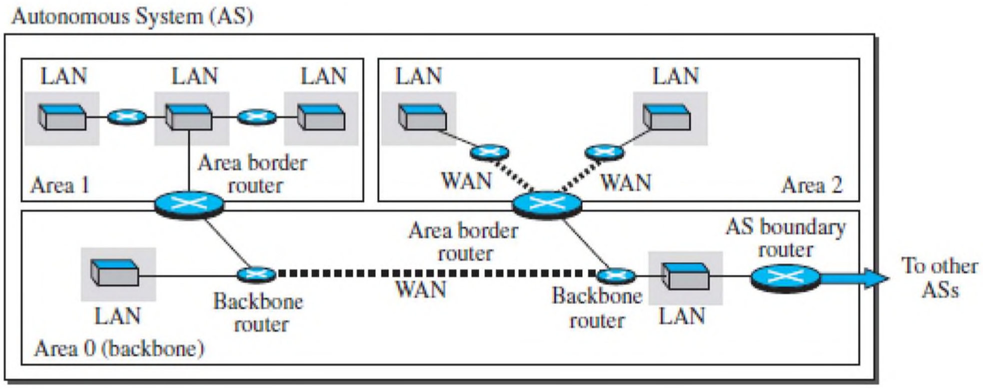


Fig3.3.6:Areas in AS.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-619]

OSPF Implementation

OSPF is implemented as a program in the network layer, using the service of the IP for propagation. An IP datagram that carries a message from OSPF sets the value of the protocol field to 89. This means that, the OSPF messages are encapsulated inside datagrams.

OSPF has two versions: version 1 and version 2.

OSPF Messages

OSPF is a very complex protocol; it has five different types of messages as shown in figure 3.3.7 .

.The hello message (type 1) is used by a router to introduce itself to the neighbors.

The database description message (type 2) is sent in response to the hello message to allow a newly joined router to acquire the full LSDB.The link state request message (type 3) is sent by a router that needs information about a specific LS.The link-state update message (type 4) is the main OSPF message used for building the LSDB. This message, has five different versions (router link, network link, summary link to network, summary link to AS border router, and external link).The link-state acknowledgment message (type 5) is used to create reliability in OSPF; each router that receives a link-state update message needs to acknowledge it.

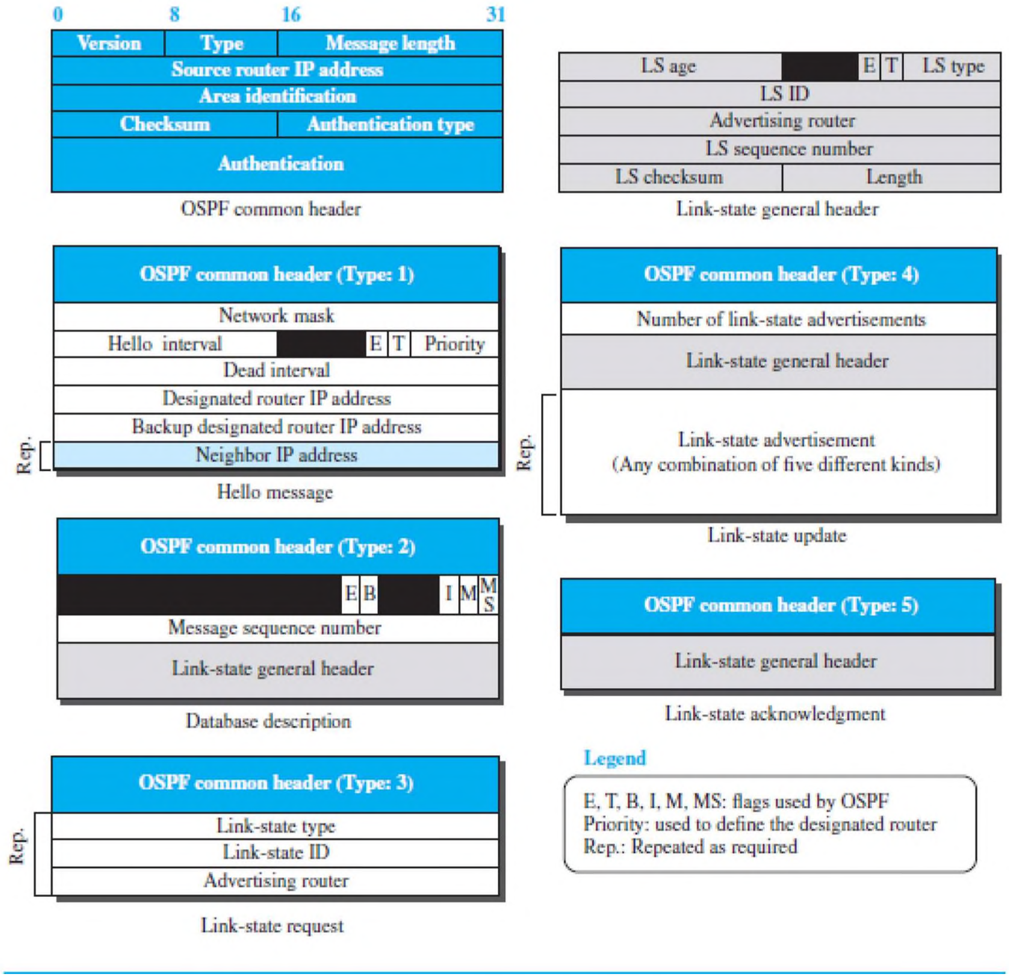

0
8
16
31
Version
Type
Message length
Source router IP address
Area identification
Checksum
Authentication type
Authentication
OSPF common header
LS age
E
T
LS type
LS ID
Advertising router
LS sequence number
LS checksum
Length
Link-state general header
OSPF common header (Type: 1)
Network mask
Hello interval
E
T
Priority
Dead interval
Designated router IP address
Backup designated router IP address
Rep.
Neighbor IP address
Hello message
OSPF common header (Type: 4)
Number of link-state advertisements
Link-state general header
Rep.
Link-state advertisement
(Any combination of five different kinds)
Link-state update
OSPF common header (Type: 2)
E
B
I
M
MS
Message sequence number
Link-state general header
Database description
OSPF common header (Type: 5)
Link-state general header
Link-state acknowledgment
OSPF common header (Type: 3)
Rep.
Link-state type
Link-state ID
Advertising router
Link-state request
Legend
E, T, B, I, M, MS: flags used by OSPF
Priority: used to define the designated router
Rep.: Repeated as required

Fig3.3.7: OSPF message format.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-622]

OSPF Algorithm

OSPF implements the link-state routing algorithm .

After each router has created the shortest-path tree, the algorithm needs to use it to create the corresponding routing algorithm.The algorithm needs to be augmented to handle sending and receiving all five types of messages.

Border Gateway Protocol Version 4 (BGP4)

The Border Gateway Protocol version 4 (BGP4) is the only inter domain routing protocol used in the Internet today.

Consider an example of an internet with four autonomous systems. AS2, AS3, and AS4 are stub autonomous systems; AS1 is a transient one as shown in figure 3.3.8 .

. Here,data exchange between AS2, AS3, and AS4 should pass through AS1.

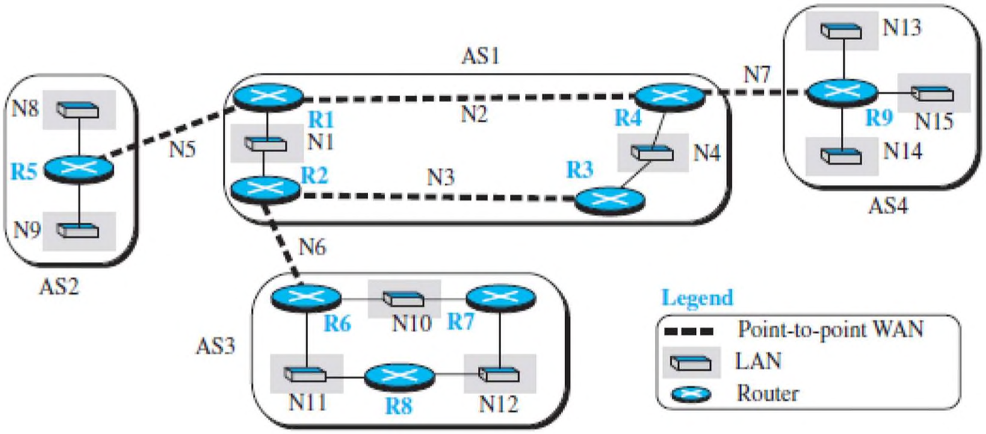


Fig3.3.8:Sample internet with four AS.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-623]

Each router in each AS knows how to reach a network that is in its own AS, but it does not know how to reach a network in another AS.

To enable each router to route a packet to any network in the internet, we first install a variation of BGP4, called external BGP (eBGP), on each border router (the one at the edge of each AS which is connected to a router at another AS).We then install the second variation of BGP, called internal BGP (iBGP), on all routers.

The border routers will be running three routing protocols (intradomain, eBGP, and iBGP), but other routers are running two protocols (intradomain and iBGP).

Operation of External BGP (eBGP)

BGP is a point-to-point protocol. When the software is installed on two routers, they try to create a TCP connection using the well-known port 179.

The two routers that run the BGP processes are called BGP peers or BGP speakers.The eBGP variation of BGP allows two physically connected border routers in two different ASs to form pairs of eBGP speakers and exchange messages.

The routers that we use has three pairs: R1-R5, R2-R6, and R4-R9. The connection between these pairs is established over three physical WANs (N5,N6, and N7). There is a need for a logical TCP connection to be created over the physical connection to make the exchange of information possible. Each logical connection in BGP is referred to as a session. This means that we need three sessions, as shown in Figure 3.3.9.

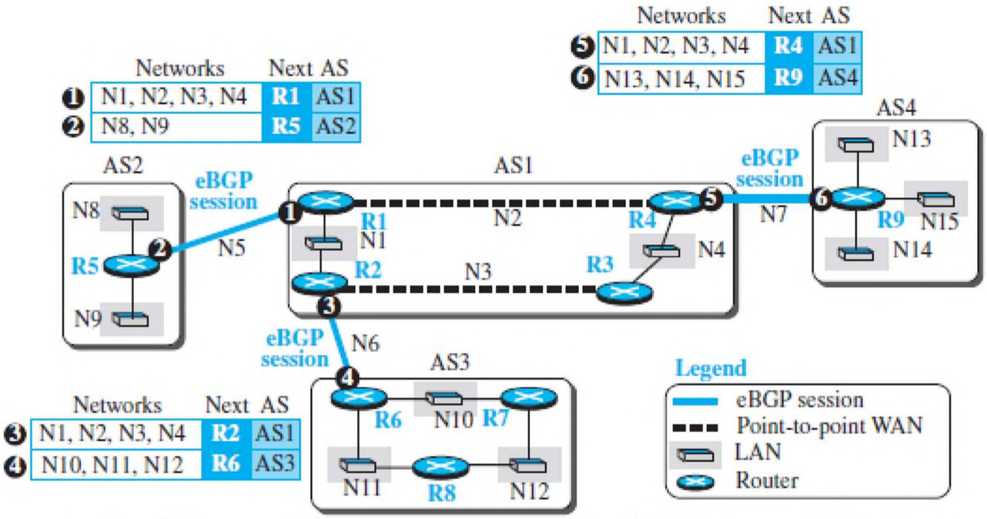


Fig3.3.9: EBGP operation.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-624]

The circled number defines the sending router in each case.

For example, message number 1 is sent by router R1 and tells router R5 that N1, N2, N3,and N4 can be reached through router R1 (R1 gets this information from the corresponding intradomain forwarding table).

Router R5 can now add these pieces of information at the end of its forwarding table. When R5 receives any packet destined for these four networks, it can use its forwarding table and find that the next router is R1.

Messages

BGP four types of messages for communication between the BGP speakers across the ASs and inside an AS:

Four messages are open, update, keep alive, and notification .

All BGP packets share the same common header.

Open Message. To create a neighborhood relationship, a router running BGP opens a TCP connection with a neighbor and sends an open message.

Update Message.

The update message is used by a router to withdraw destinations that have been advertised previously, to announce a route to a new destination, or both.

Note that BGP can withdraw several destinations that were advertised before, but it can only advertise one new destination in a single update message.

Keep alive Message. The BGP peers that are running exchange keep alive messages regularly (before their hold time expires) to tell each other that they are alive.

Notification. A notification message is sent by a router whenever an error condition is detected or a router wants to close the session.

Performance

BGP performance can be compared with RIP. BGP speakers exchange a lot of messages to create forwarding tables, but BGP is free from loops and count-to-infinity.

3.4 MULTICAST ROUTING

In multicasting, there is one source and a group of destinations. The relationship is one to many.In this type of communication, the source address is a unicast address,but the destination address is a group address, a group of one or more destination networks in which there is at least one member of the group that is interested in receiving the multicast datagram.

Multicasting starts with a single packet from the source that is duplicated by the routers. The destination address in each packet is the same for all duplicates.Note that only a single copy of the packet travels between any two routers.

Multicast Applications

Access to Distributed Databases.

Most of the large databases today are distributed.That is, the information is stored in more than one location, usually at the time of production.The user who needs to access the database does not know the location of the information. A user's request is multicast to all the database locations, and the location that has the information responds.

Information Dissemination.

Businesses often need to send information to their customers.If the nature of the information is the same for each customer, it can be multicast. In this way a business can send one message that can reach many customers.

Teleconferencing. Teleconferencing involves multicasting. The individuals attending a teleconference all need to receive the same information at the same time.

Distance Learning. One growing area in the use of multicasting is distance learning.

MULTICASTING BASICS

In multicast communication, the sender is only one, but the receiver is many, sometimes thousands or millions spread all over the world. It should be clear that we cannot include the addresses of all recipients in the packet.The destination address of a packet, as described in the Internet Protocol (IP) should be only one. For this reason,we need multicast addresses. A multicast address defines a group of recipients, not a single one.

A multicast address is an identifier for a group. If a new group is formed with some active members, an authority can assign an unused multicast address to this group to uniquely define it.

Multicast Forwarding

Important issue in multicasting is the decision a router needs to make to forward a multicast packet.Forwarding in unicast and multicast communication is different in two aspects:

In unicast communication, the destination address of the packet defines one single destination. The packet needs to be sent only out of one of the interfaces, the interface which is the branch in the shortest-path tree reaching the destination with the minimum cost.

In multicast communication, the destination of the packet defines one group, but that group may have more than one member in the internet.To reach all of the destinations, the router may have to send the packet out of more than one interface. Figure (below) shows the concept.

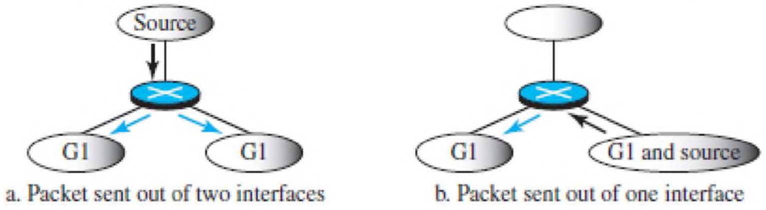

Source
G1
G1
a. Packet sent out of two interfaces
G1
G1 and source
b. Packet sent out of one interface

Fig3.4.1: Forwarding depends on destination and source.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-649]

In part a of the figure3.4.1, the source is in a section of the internet where there is no group member. In part b, the source is in a section where there is a group member. In part a, the router needs to send out the packet from two interfaces; in part b, the router should send the packet only from one interface to avoid sending a second copy of the packet from the interface it has arrived at.

Two Approaches to Multicasting

Source-Based Tree Approach

In the source-based tree approach to multicasting, each router needs to create a separate tree for each source-group combination. If there are m groups and n sources in the internet, a router needs to create (mxn) routing trees. In each tree,the corresponding source is the root, the members of the group are the leaves, and the router itself is somewhere on the tree.

Group-Shared Tree Approach

In the group-shared tree approach, a router act like a source for each group. The designated router, which is called the core router or the rendezvous point router, acts as the representative for the group. Any source that has a packet to send to a member of that group sends it to the core center (unicast communication) and the core center is responsible for multicasting.The core center creates one single routing tree with itself as the root and any routers with active members in the group as the leaves.In this approach, there are m core routers (one for each group) and each core router has a routing tree, for the total of m trees. Therefore the number of routing trees is reduced from (m x n) in the source-based tree approach to m in this approach.

INTRADOMAIN MULTICAST PROTOCOLS

Multicast Distance Vector (DVMRP)

The Distance Vector Multicast Routing Protocol (DVMRP) is the extension of the Routing Information Protocol (RIP) which is used in unicast routing. It uses the source based tree approach to multicasting.

Multicast tree in three steps:

1.The router uses an algorithm called reverse path forwarding (RPF) to simulate creating part of the optimal source-based tree between the source and itself.

2.The router uses an algorithm called reverse path broadcasting (RPB) to create a broadcast (spanning) tree whose root is the router itself and whose leaves are all networks in the internet.

3.The router uses an algorithm called reverse path multicasting (RPM) to create a multicast tree by cutting some branches of the tree that end in networks with no member in the group.

Reverse Path Forwarding (RPF)

The first algorithm, reverse path forwarding (RPF), forces the router to forward a multicast packet from one specific interface: the one which has come through the shortest path from the source to the router.The router does not know the shortest path from the source to itself, but it can find which is the next router in the shortest path from itself to the source (reverse path).

The router simply consults its unicast forwarding table, pretending that it wants to send a packet to the source; the forwarding table gives the next router and the interface the message that the packet should be sent out in this reverse direction.

The router uses this information to accept a multicast packet only if it arrives from this interface. This is needed to prevent looping. In multicasting, a packet may arrive at the same router that has forwarded it.If the router does not drop all arrived packets except the one, multiple copies of the packet will be circulating in the internet.

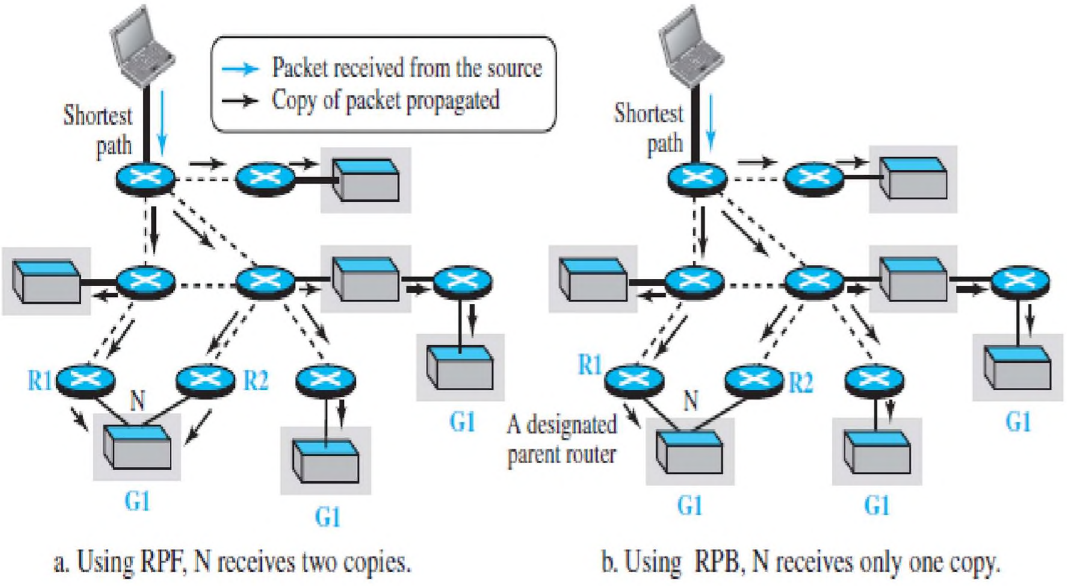
Reverse Path Broadcasting (RPB)

The RPF algorithm helps a router to forward only one copy received from a source and drop the rest. When we think about broadcasting in the second step, we need to remember that destinations are all the networks (LANs) in the internet. To be efficient,we need to prevent each network from receiving more than one copy of the packet.

If a network is connected to more than one router, it may receive a copy of the packet from each router. RPF cannot help here, because a network does not have the intelligence to apply the RPF algorithm; we need to allow only one of the routers attached to a network to pass the packet to the network.

One way to do so is to designate only one router as the parent of a network related to a specific source. When a router that is not the parent of the attached network receives a multicast packet, it simply drops the packet.There are several ways that the parent of the network related to a network can be selected; one way is to select the router that has the shortest path to the source (using the unicast forwarding table, again in the reverse direction).

Every packet started from the source reaches all LANs in the internet travelling the shortest path. Figure 3.4.2 shows how RPB can avoid duplicate reception in a network by assigning a designated parent router, R1, for network N.The difference between RPB and RPF is shown in figure 3.4.3.


Packet received from the source
Copy of packet propagated
Shortest path
R1
R2
N
G1
G1
G1
Shortest path
R1
R2
N
A designated parent router
G1
G1
G1

a. Using RPF, N receives two copies.

b. Using RPB, N receives only one copy.

Fig3.4.2: Reverse path broadcasting.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-652]

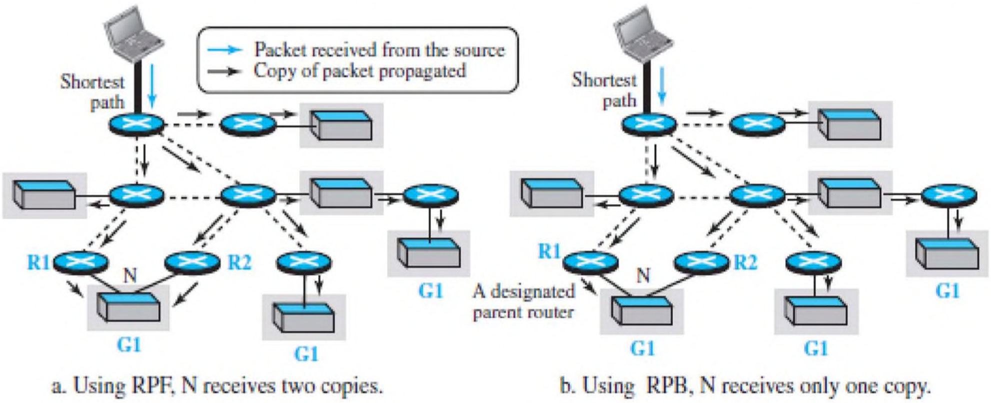
Reverse Path Multicasting (RPM)

To increase efficiency, the multicast packet must reach only those networks that have active members for that particular group. This is called reverse path multicasting (RPM).

To change the broadcast shortest-path tree to a multicast shortest-path tree, each router needs to prune (make inactive) the interfaces that do not reach a network with active members corresponding to a particular source-group combination.

This step can be done bottom-up, from the leaves to the root. At the leaf level, the routers connected to the network collect the membership information using the IGMP protocol.

The parent router of the network can then disseminate this information upward using the reverse shortest-path tree from the router to the source, the same way as the distance vector messages are passed from one neighbor to another.


Packet received from the source
Copy of packet propagated
Shortest path
R1
R2
N
G1
A designated parent router

a. Using RPF, N receives two copies.

b. Using RPB, N receives only one copy.

Fig3.4.3:RPB vs RPF.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-653]

Multicast Link State (MOSPF)

Multicast Open Shortest Path First (MOSPF) is the extension of the Open Shortest Path First (OSPF) protocol, which is used in unicast routing as shown in figure 3.4.4. It uses the source based tree approach to multicasting.

In multicasting, each router needs to have a database, as with the case of unicast distance-vector routing, to show which interface has an active member in a particular group.

A router follow these steps to forward a multicast packet received from source S and to be sent to destination G (a group of recipients):

The router uses the Dijkstra algorithm to create a shortest-path tree with S as the root and all destinations in the internet as the leaves. Note that this shortest-path tree is different from the one the router normally uses for unicast forwarding, in which the root of the tree is the router itself.

Here, the root of the tree is the source of the packet defined in the source address of the packet The router finds itself in the shortest-path tree created in the first step. In otherwords, the router creates a shortest-path subtree with itself as the root of the subtree.The shortest-path subtree is actually a broadcast subtree with the router as the root and all networks as the leaves.

The IGMP protocol is used to find the information at the leaf level. The router can now forward the received packet out of only those interfaces that correspond to the branches of the multicast tree.

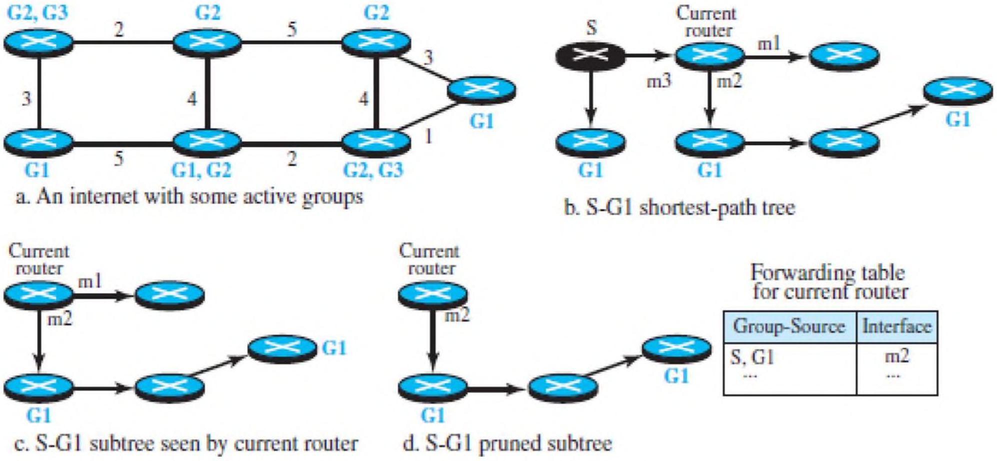


Fig3.4.4: Tree formation in MOSPF.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-654]

Protocol Independent Multicast (PIM)

Protocol Independent Multicast (PIM) is the name given to a common protocol that needs a unicast routing protocol for its operation, but the unicast protocol can be either a distance-vector protocol or a link-state protocol .PIM uses the forwarding table of a unicast routing protocol to find the next router in a path to the destination, but it does not matter how the forwarding table is created.

Feature of PIM: It can work in two different modes: dense and sparse.

The term dense means that the number of active members of a group in the internet is large;the probability that a router has a member in a group is high.For example, in a popular teleconference that has a lot of members.

The term sparse, means that only a few routers in the internet have active members in the group; the probability that a router has a member of the group is low.For example, in a technical teleconference where a number of members are spread somewhere in the internet. When the protocol is working in the dense mode, it is referred to as PIM-DM; when it is working in the sparse mode, it is referred to as PIM-SM.

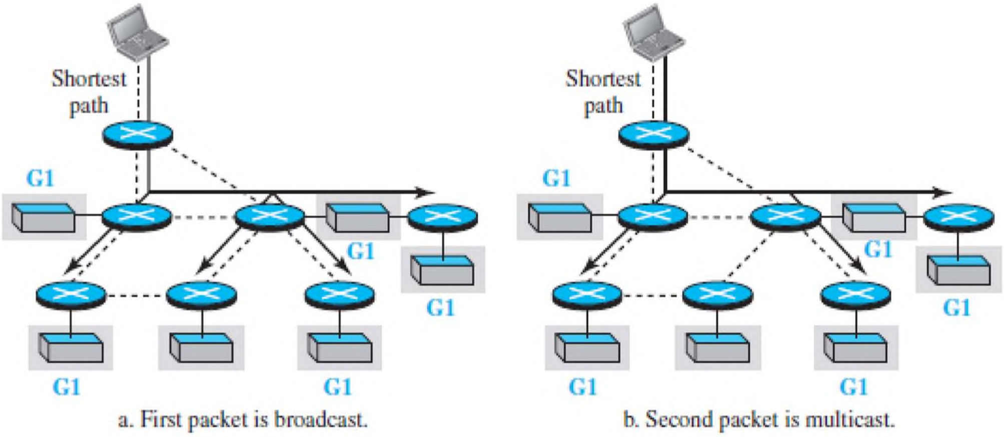
Protocol Independent Multicast-Dense Mode (PIM-DM)

When the number of routers with attached members is large relative to the number of routers in the internet, PIM works in the dense mode and is called PIM-DM. In this mode, the protocol uses a source-based tree approach as shown in figure 3.4.5.

PIM-DM uses only two strategies described in DVMRP: RPF and RPM.

The two steps used in PIM-DM .

1.A router that has received a multicast packet from the source S destined for the group G first uses the RPF strategy to avoid receiving a duplicate of the packet. It consults the forwarding table of the unicast protocol to find the next router if it wants to send a message to the source S (in the reverse direction).If the packet has not arrived from the next router in the reverse direction, it drops the packet and sends a prune (remove things which are not needed) message in that direction to prevent receiving future packets related to (S, G).



a. First packet is broadcast.

b. Second packet is multicast.

Fig3.4.5: Idea behind PIM- DM.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-656]

2. If the packet in the first step has arrived from the next router in the reverse direction, the receiving router forwards the packet from all its interfaces except the one from which the packet has arrived . Note that this is broadcasting instead of a multicasting if the packet is the first packet from the source S to group G.Each router downstream that receives an unwanted packet sends a prune

message to the router upstream, and eventually the broadcasting is changed to multicasting.

Figure (above) PIM-DM. The first packet is broadcast to all networks, which have or do not have members. After a prune message arrives from a router with no member, the second packet is only multicast.

Protocol Independent Multicast-Sparse Mode (PIM-SM)

When the number of routers with attached members is small relative to the number of routers in the internet, PIM works in the sparse mode and is called PIM-SM as shown in figure 3.4.6.

In this environment, PIM-SM uses a group-shared tree approach to multicasting.The core router in PIM-SM is called the rendezvous point (RP). Multicast communication is achieved in two steps.

Any router that has a multicast packet to send to a group of destinations first encapsulates the multicast packet in a unicast packet (tunneling) and sends it to the RP. The RP then decapsulates the unicast packet and sends the multicast packet to its destination.

PIM-SM uses a complex algorithm to select one router among all routers in the internet as the RP for a specific group. This means that if we have m active groups, we need m RPs, although a router may serve more than one group.

After the RP for each group is selected, each router creates a database and stores the group identifier and the IP address of the RP for tunneling multicast packets to it.

PIM-SM uses a spanning multicast tree rooted at the RP with leaves pointing to designated routers connected to each network with an active member. A very interesting point in PIM-SM is the formation of the multicast tree for a group.

To create a multicast tree rooted at the RP, PIM-SM uses join and prune messages.

Figure (below) shows the operation of join and prune messages in PIM-SM. First, three networks join group G1 and form a multicast tree. Later, one of the networks leaves the group and the tree is pruned.The join message is used to add possible new branches to the tree; the prune message is used to cut branches that are not needed.

When a designated router finds out that a network has a new member in the corresponding group (via IGMP), it sends a join message in a unicast packet destined for the RP.The packet travels through the unicast shortest-path tree to reach the RP. Any router in the path receives and forwards the packet, but at the same time, the router adds two pieces of information to its multicast forwarding table.

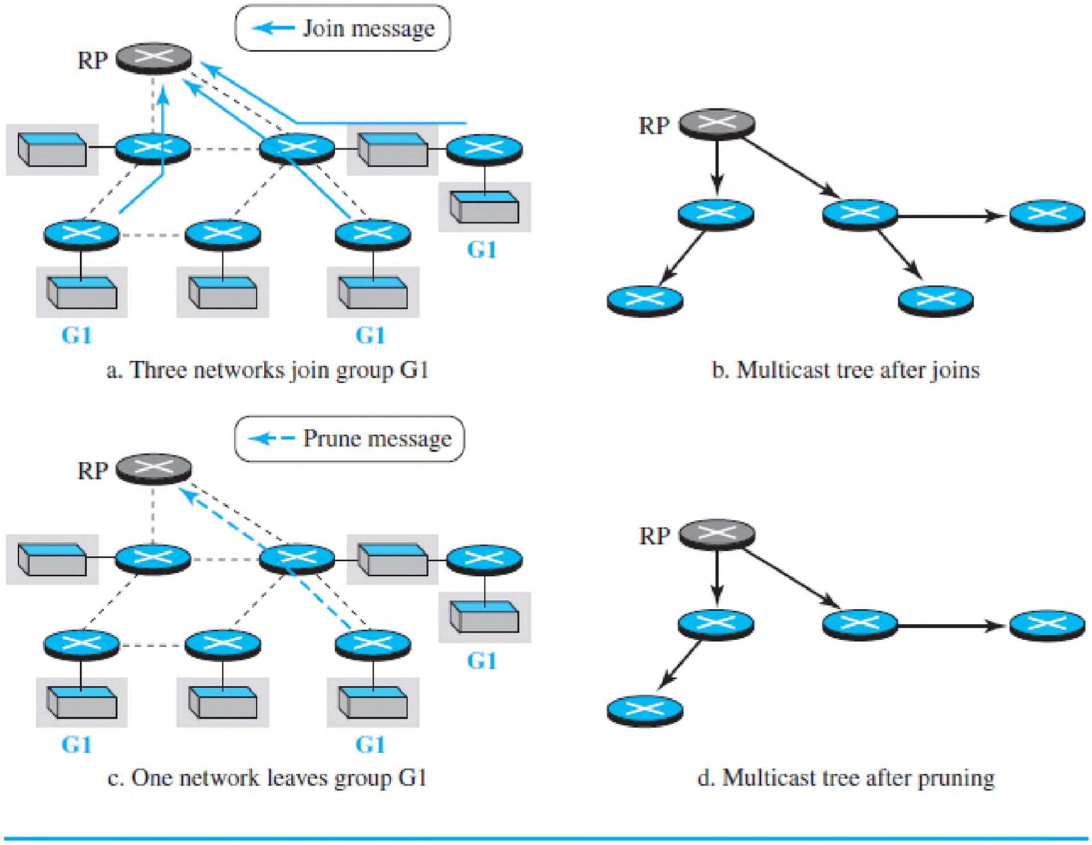

Join message
RP
G1
G1
G1
a. Three networks join group G1
RP
b. Multicast tree after joins
Prune message
RP
G1
G1
G1
c. One network leaves group G1
RP
d. Multicast tree after pruning

Fig3.4.6: Idea behind PIM-SM.

[Source : "Data Communications and Networking" by Behrouz A. Forouzan,Page-657]

The number of the interface through which the join message was sent to the RP is marked(if not already marked) as the only interface through which the multicast packet destined for the same group should be received.In this way, the first join message sent by a designated router creates a path from the RP to one of the networks with group members.To avoid sending multicast packets to networks with no members, PIM-SM uses the prune message.