Multicasting in IOS, IOS XE, IOS XR for IPv4 and IPv6

Disclaimer. I don't pretend to cover everything about the protocols or mechanisms that we have in multicasting. I just explain what we use nowadays, why we use it, how it works and how to configure it.

Introduction

I've started to write this article with the idea to show which bugs I've found while studying multicast topics at IOS XR (particularly IOS XRv). But during the process of writing, it turned into a short overview of multicasting at different Cisco platforms. About three months ago I successfully passed CCIE RS lab exam and finally became CCIE Routing and Switching #49412. From my perspective a person can either develop further or degrade. It's impossible to stay forever with the same knowledge at the same place. Ok, maybe it's possible, but for sure it makes no sense. That's why I've decided to extend my knowledge of IOS and IOS XE to IOS XR. Previously I have had some experience with this platform, but never in the multicast field. Also I think that it can be a good starting point for the future, if I decide to get CCIE Service Providers. So, let's go.

The multicasting technology isn't something in our days. I could even say more, there is a lot of multicast traffic in your network right now, of which you might be not aware. Many network protocols use multicast transport for their operations. For example, there are OSPF, ISIS, EIGRP, SPT, LDP and many others. Multicasting has been already on the market for a long time. However the importance of the technology becomes more and more important every day, as the interactive application with its big amount of voice and video tends to dominate in the Internet and local networks. The basic idea is pretty straightforward:

If there are many clients that want to receive the same content simultaneously, there is no necessity to establish a dedicated session with each one and unicast content to each one. The server sends just one multicast stream in the network instead, and the network itself will replicate and deliver the traffic to the necessary destinations.

The overall architecture of multicasting can be split into three main points:

1) How to deliver multicast traffic in a local segment of the network (basically in the VLAN).
2) How to deliver multicast traffic through the routed network but in the border of the single Autonomous system.
3) How to deliver multicast traffic on the Internet's scale between different autonomous systems.

In this article I'll focus on the first two points. Though I don't like theory very much and would eager to jump directly to the configuration and validation section, I have to provide a short overview in order for you to have an overall understanding of multicasting, which is useful for further configuring and troubleshooting.

Layer 2 multicast destination addresses

In the local segment the transmission of the traffic is done based on the Layer 2 header. Nowadays Ethernet (IEEE 802.3 set of standards) is the only technology that is used in the wired part of LAN. In the wireless part of LAN (WLAN) we use IEEE 802.11 set of standards. They have a little bit different framing due to some nature of wireless operation: less reliability and half-duplex traffic pattern in the one RF channel. But both Ethernet and WLAN standards use the same form of physical

layer addressing – MAC address. It consists of 48 bits that are split into two parts. The first 24 bits represent the vendor of the equipment and are managed by IEEE registration authority. The second 24 bits are generated by vendor and are assigned to the certain device (NIC – network interface card). Coupling together these two parts we get a global unique MAC address. Or at least it must be so, as almost all the operation systems allow you to manually configure the MAC address instead of the one that's burned in the hardware. Let's have a deeper look at the format of MAC address. Usually it's represented as a hexadecimal number 32-10-B3-E9-A9-D2.

Let's translate it in the binary form, as we need it for understanding how multicast MAC address is identified:

00110010-00010000-10110011-11101001-10101001-11010010

The second least significant bit in the first octet, which is the green one at my picture, is U/L bit, which shows whether this MAC is configured locally (value "1") or unique in the world (value "0").

We are mostly interested in the least significant bit in the first octet, which is red on my picture. It's I/G bit, where "I" stands for individual MAC and has a value of "0", and "G" stands for group MAC address and has a value of "1", which is used for broadcast and multicast. Here we come to the first important point about addressing in multicasting. Multicast MAC address always has that bit set to "1". Actually, the most popular multicast MAC addresses that we can see have the following first 24 bits : 01-00-5E or 01-80-C2. Now we are going to explain the Layer 3 (IP) addressing and multicasting and then come back to MAC addresses to show how they are mapped.

Layer 3 multicast destination addresses in IPv4

In IPv4 world the multicast IP addresses are represented by class D IP networks that are covered by 224.0.0.0/8 range. We can consider each IP address from this range as a TV or radio channel. It means that everyone who is listening to this IP will receive the same content. As it usually happens with IP addressing, there are some IP subranges that have specific meaning and shouldn't be used for user traffic, and others that should:

IP Range	Task
224.0.0.0/24	it's used for network protocol to communicate in a local segment; it isn't routed
224.0.1.0/24	it's used for network protocol to communicate in the internetwork, so it's routed
232.0.0.0/8	it's used for source specific multicast (will be described later)
239.0.0.0/8	it's used for user application in enterprise borders.

All the ranges are defined in RFC 5771, so you could look there for the more detailed information [a]. In our article I'll refer mainly to the last range, meaning to 239.0.0.0/8.

Coupling together Layer 2 and Layer 3 destination addresses

Now we know how multicast IPv4 addresses look like and what should be set in MAC address. Let's couple them together. The rule for mapping IPv4 multicast address to MAC multicast address is the following:

Take the 23 least significant bits in IPv4 multicast address and map them to the least significant 23 bits in MAC address. The 24-th least significant bit will be always "0". Then append the resulting number by 01-00-5E in hexadecimal.

Here is just a short example for you to understand it better. We send multicast data stream to the group 239.123.123.123. Let's convert IP to binary view:

11101111.0**1111011.01111011.01111011**

Looks good, now let's take the least significant 23 bits that shown at my picture as red and finalize mapping to MAC Address according to the rule above:

0 + 1111011.01111011.01111011 -> 7B-7B-7B

At the end we just attach "01-00-5E" before our number and get the L2 multicast address 01-00-5E-7B-7B-7B. To this MAC address will be the traffic sent if we send packets to 239.123.123.123. If we look a bit deeper, we could see that there is a potential oversubscription (32:1) when we map IPv4 to MAC. Actually IPs 239.123.123.123, 224.123.123.123 and even 239.251.123.123 are mapped to the only one MAC 01-00-5E-7B-7B-7B. So it's stated not to be a problem as a probability of such overlapping is quite low. Though if it happens, the traffic will be taken to the processing but then it'll be dropped. The CPU/Memory capacity is considered to be very high comparing to the probable amount of traffic.

```
⊞ Frame 180: 118 bytes on wire (944 bits), 118 bytes captured (944 bits)
⊟ Ethernet II, Src: aa:bb:cc:00:01:00 (aa:bb:cc:00:01:00), Dst: IPv4mcast_7b:7b:7b (01:00:5e:7b:7b:7b)
  ⊞ Destination: IPv4mcast_7b:7b:7b (01:00:5e:7b:7b:7b)
  ⊞ Source: aa:bb:cc:00:01:00 (aa:bb:cc:00:01:00)
    Type: 802.1Q Virtual LAN (0x8100)
⊞ 802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 12
⊟ Internet Protocol Version 4, Src: 10.110.0.1 (10.110.0.1), Dst: 239.123.123.123 (239.123.123.123)
    Version: 4
    Header Length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00: Not-ECT (Not ECN-Capable Transport))
    Total Length: 100
    Identification: 0x000b (11)
  ⊞ Flags: 0x00
    Fragment offset: 0
    Time to live: 255
    Protocol: ICMP (1)
  ⊞ Header checksum: 0x4628 [validation disabled]
    Source: 10.110.0.1 (10.110.0.1)
    Destination: 239.123.123.123 (239.123.123.123)
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
```

IPv4 multicast packet

Layer 3 multicast addresses in IPv6 and its mapping

Now let's look into the IPv6 world and how these IP addresses are mapped to MAC addresses. Actually it's also easy, and from my understanding easier than in IPv4, though it isn't so popular and well described. IPv6 address itself is much longer than IPv4 (128 bits against 32 bits). And the probability of oversubscription is also much higher. That's why we copy THE 32 least significant bits in IPv6 multicast address to MAC address. We can state the rule as:

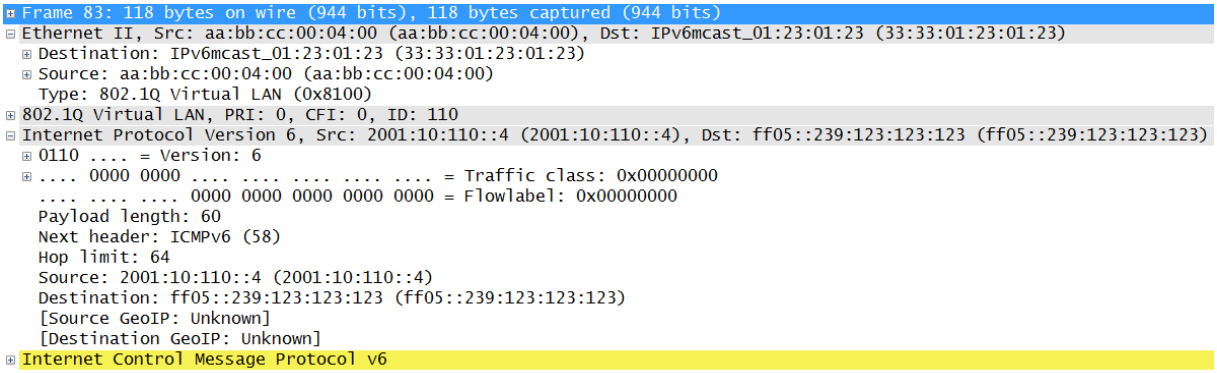
Take the 32 least significant bits in IPv6 multicast address and copy them to multicast MAC address. Then append them by 33-33 in hexadecimal.

In general IPv6 multicast addresses are in the range of ff::/8. There are also some specific subranges as in IPv4, and you can find some references at the end of the article [b]. For user's application we usually use IPv6 addresses, which start with ff05::/16 or ff08::/16.

Here is an example of how we map IPv6 multicast address to MAC address. We send multicast traffic to address ff05::239:123:123:123. Before we go further, we must make an important remark. IPv6 addresses are already in hexadecimal format. This means that we don't have to convert them. We just take the 32 least significant bits (8 hexadecimal digits) and copy them to the corresponding positions in MAC address. So, let's present IPv6 address in the full form:

ff05:0000:0000:0000:0239:0123:**0123:0123**

What we need is just to copy the last 8 hexadecimal digits, which are red on the picture, to MAC address and append them by 33-3". The final MAC address is 33-33-01-23-01-23.



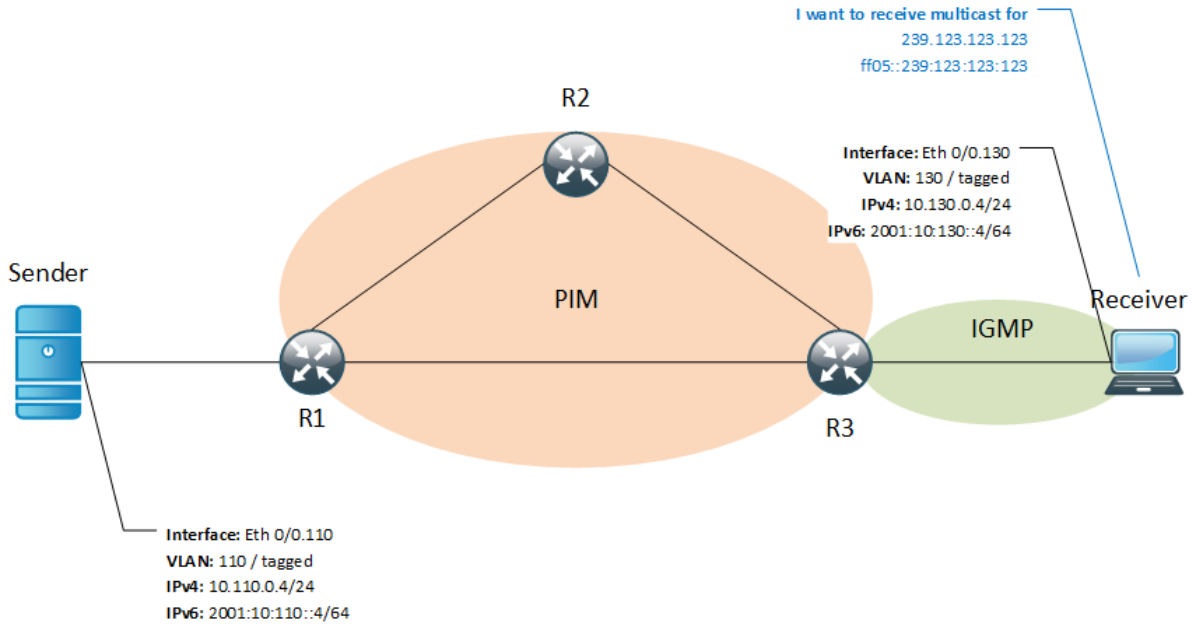
IPv6 Multicast packet

As a short summary of this part we can say that on all the Ethernet links the traffic will be send with the destination multicast IPv4 or IPv6 address, which will map the destination MAC address according to the provided rules. Only destination (IP or MAC) address can be multicast. Source address is always only unicast. If the source address is multicast, it seems to be an attack. Now it's time to see how multicast traffic is transmitted in a routed network, and then we'll provide working solution and some details how to configure multicasting and how to check it.

Delivering Internet traffic through routed network

The general principle of multicast traffic forwarding is quite different from the one we have in unicast routing. In unicast routing we forward traffic to the destination. So, we calculate all the possible ways based on routing protocol's metric and then send the traffic using the best route, which is one with the lowest overall cost. In multicast forwarding we send the traffic from the source. That's why in the literature you can find a name "RPF", which stands for reverse path forwarding. It's fully correct because we just distribute the multicast traffic through the network from the sender. The sender isn't aware of where the receivers are and if they are. It might be the case that there is only one receiver in the network or there is no receiver at all. So we need some protocols and mechanisms how to find the receivers and how to track whether they're alive. Then we need to build a way from the sender to the receiver. After that the multicast traffic can be successfully delivered. Here at this stage come two main protocols that are used in multicasting. The first one in the IPv4 world is called IGMP (Internet Group Management Protocol) and is used to communicate the last-hop router about client's interest to receive multicast traffic for the certain multicast group or multicast IP address, which is the same in this context. In the IPv6 world the same function performs the protocol that is called MLD (Multicast Listener Discovery). The second protocol is called PIM (Protocol Independent Multicasting), which is, despite the wording, actually the protocol that is used to communicate over routed infrastructure to the first hop router the interest of a remote host to

receive the traffic. This protocol exists both in IPv4 and IPv6 world. Here is the sample picture where the areas of usage of IGMP and PIM are shown.



The areas of multicast protocols usage

Now we'll explain a bit how both these protocols together help you to deliver multicast content from the sender to the receivers.

IGMP and MLD – "last-mile" solution

As we already told, IGMP is used to communicate the client's interest from the receiver to the last hop router, which is R3 referring to our topology. There are two options to realize it. The first one is by sending the regular queries (IGMP Query) by R3 on the LAN segment to the multicast IP address 224.0.0.1, which represents all the hosts on the local segment. If the receiver wants to get some traffic, it will answer to multicast IP 224.0.0.2, which represent all multicast-capable routers on a local segment. In the answer the receiver will include the multicast IP, for example 239.123.123.123, for which it wants to receive traffic. Such answer is called IGMP Report, contemporary to IGMP Query sent by R3. Remember that we have mentioned the whole 224.0.0.0/24 range as the one that is used for network control and that isn't routed. Actually this mechanism is also used for tracking whether there is any host that wants to receive. If nobody answers, then the router will stop multicasting on that segment.

The second option of how the receiver can indicate its interest is the explicit request. If you launch any application for receiving multicast traffic and choose the actual channel represented by multicast IP, your PC (the Receiver in ~~the~~ our topology) will immediately send IGMP Report to R3. The same mechanism is also used to show the R3 that you are not interested anymore in receiving multicast traffic. After that R3 will check whether there is anyone else on the local segment who wants to receive the traffic. For that R3 sends the group-specific query to the multicast IP address of the group that is 239.123.123.123 in our case. If no one answers, R3 will stop forwarding multicast on a local subnet.

We have described here overall operation of IGMPv2. But "v2" means that it must be other versions of this protocol. Well, we don't describe the operation of IGMPv1 as it's quite old and can be

considered as obsolete. On the other hand, the most actual version of IGMP is the 3rd. It differs from the IGMPv2 in that it supports the option to include the IP addresses of the source from which the client wants to receive the multicast traffic. Such option is critical both for source-specific multicast (SSM) and for security. SSM will be explained further. Now we'll explain a bit the security issue. In IGMPv2 there is no option to control which is the source of the traffic. Such situation provides the possibility to make a DoS or DDoS attack on the receiver, during which the client won't receive the legitimate traffic. Moreover the source provides a kind of filtering to limit the possibility of attack. Also IGMPv3 supports explicit hosts tracking to improve the quality of delivering the multicast traffic on the end segment. Destination IP address for IGMPv3 queries is the same as for IGMPv2 224.0.0.1, but the IP for IGMPv3 Reports is 224.0.0.22. [c] The latest versions have the compatibility with the lower ones.

By default in Cisco IOS and IOS XE IGMPv2 is used and in Cisco IOS XR the default version is IGMPv3. But you change it in both.

Now let's see how the same task is resolved in the IPv6 world, where we use MLD instead of IGMP. There are two versions of this protocol. MLDv1 is based on IGMPv2. Actually it's stated in the RFC itself [d]. For us it means that the functionality and the logic behind it is the same as ~~it's~~ in IGMPv2. The General query is sent to multicast destination IP ff02::1. In IPv6 the range ff02::/16 is used for the same purposes as the range 224.0.0.0/8 in IPv4, so to say, for local network control. But contemporary to IGMPv2, MLD Reports are sent to group-specific address as well as a group-specific Queries. To communicate that the host doesn't want to receive multicast IPv6 traffic, the MLD Done message is used, which is sent to multicast address of all multicast-capable routers ff02::2. The protocol timers are a bit different, but we think it is neither useful nor interesting to provide here all this stuff. You can always refer to Cisco official command reference guide to the latest information. [e] MLDv2 is an IPv6 version of IGMPv3, meaning that is necessary for SSM, explicit host tracking and improvement of security. Destination IP address for Report messages is ff02::16. Others are the same.

There is one option that is used to improve multicast efficiency in local segment that is called IGMP snooping. The idea behind this feature is to track on the switch the ports that are interested in a certain multicast traffic and then to send L2 multicast only to that ports. This is done by analyzing IGMP Reports from the clients and binding destination multicast MAC address to the ports that have received the corresponding IGMP Report.

Well, we already know how the remote host can say to its router that he wants to receive multicast. Now it's time to see how this info is distributed over routed infrastructure and how the multicast data is transmitted from the sender to the receiver.

PIM – "core" solution

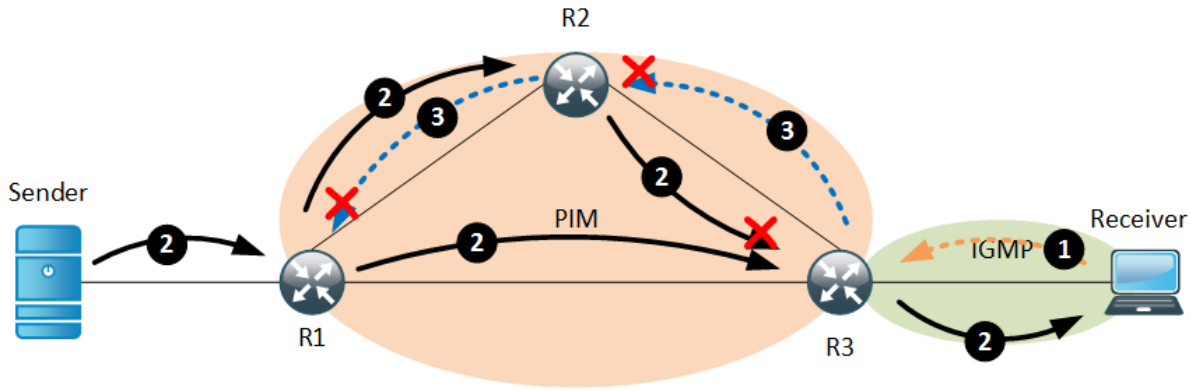
The name PIM may look quite strange at a first glance. Really, we say that it's protocol, it uses PIM Hello messages to establish the adjacency with other PIM-speaking neighbors like OSPF or EIGRP does, though the wording says us "protocol independent multicast". Well, such name PIM has due to its neutrality to unicast routing protocol or IGP. It means that PIM doesn't care which IGP you use in your network. It can be OSPF, ISIS, EIGRP and so on. And even static routes can be used. PIM uses its own set of messages, but it uses underlying IGP to find the best way to the sender from the receiver. This point is crucial. We've already said that multicast forwarding is RPF, meaning that it's

done from the sender rather than to the destination. But to be efficient, RPF must have some mechanisms of loop prevention. Such mechanism is called RPF-check and works as follows:

The router replicates multicast traffic out its interfaces only if it receives the multicast traffic on the interfaces which is also used to get to the sender. It means, that in unicasting routing table we must have a route to the sender that point out that interface. If multicast traffic is received at another interface, it'll be dropped.

Looking in our topology, we can say that such interface at R3 will be in the direction of R1. Also the same interface is used to signal to upstream router that we have clients who are interested in receiving multicast traffic for the certain multicast group (IP address). When the clients don't want to receive the multicast traffic anymore, this mechanism will also be used to stop receiving multicast traffic from upstream router. At the end of the day we'll have a tree starting from the sender and ending at the receivers. Such Tree is called SPT (shortest path tree), because it uses the shortest path from each receiver to the sender. SPT is usually presented with a pair (S,G), where "S" stands for unicast IP address of the sender and "G" is the destination multicast address of the group. There is also another tree that is called rendezvous point three (RPT) or shared tree and is represented with a pair (*,G), where "*" means any source. The RPT will be explained in the next section. It's very rough overview of PIM, but the core functionality and tasks are clear.

Historically there were two main versions, or more correctly to say modes, of PIM: dense mode (PIM-DM) and sparse mode (PIM-SM). In PIM-DM it's considered that there are a lot of receivers in the network. That's why the multicast traffic is distributed to all the routers in the network and then they prune themselves if they don't have any interested receivers. Academically speaking we build SPT from the beginning and then cut it down.



PIM-DM traffic flow

So, let's take a look on what's going on here:

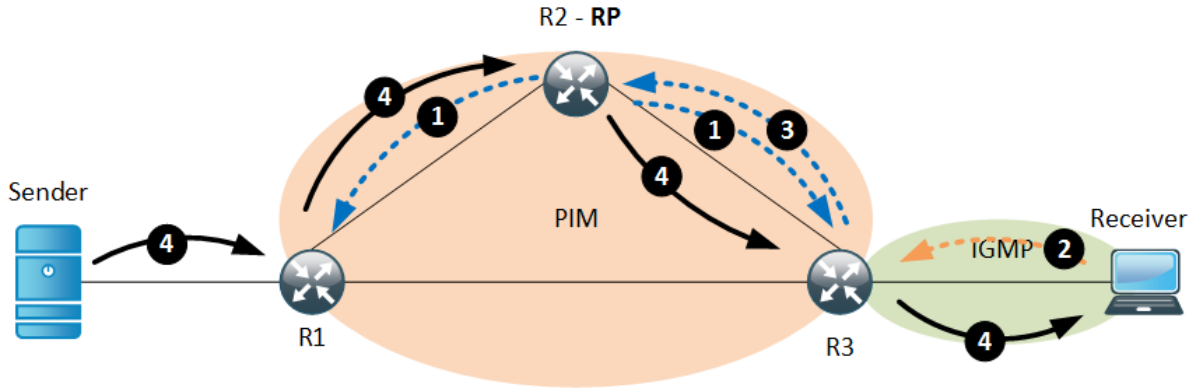
1) At the first step the IGMP Report is received by R3 from the Receiver. This report contains information that the client wants to receive multicast stream for the group 239.123.123.123. In PIM-DM we don't send any PIM messages further as we don't know where the sender is.
2) At the second step the sender starts to send multicast traffic which is then distributed throughout the network, so it reaches the receiver as well. At the end of this step the multicast data from R2 to R3 doesn't pass the RPF check at R3 as the unicast route at R3 to the sender is through R1.

3) At the third step R3 tells R2 to stop sending the traffic using PIM Prune message due to RPF check failure. As R2 doesn't have any clients, it also sends PIM Prune message to R1.

Such approach is considered being inefficient, and now PIM-DM isn't used anymore. To stress this fact we say that there is no PIM-DM for IPv6 at Cisco devices at all, and at Cisco IOS XR you even don't have possibility to configure PIM-DM for IPv4.

What is widely used nowadays and what is recommended to use is PIM-SM. In PIM-SM it's considered that there are few receivers in the network, so we don't have to spam the traffic through the whole network. The core concept of the PIM-SP consists of the introducing the RP (rendezvous point), which is simply a router, where the traffic from the sender and the interest from clients are met. In this case two separate RPF checks are made. From the receivers the RPF-check is made to the IP address of the RP what is usually a loopback of the router, and from the RP the RPF-check is made to the IP address of the sender. Then there are two possible way, what can happen.

It may look strange for you, but I'll start with the second option, because it's easier to explain it. This option is called PIM-bidir or bidirectional PIM. In this case we configure a certain range, for example 239.255.0.0/16, that is used only for bidirectional multicast traffic forwarding. For bidirectional PIM no SPT can be build and all the traffic will always flow through RP. Such approach is useful in many-to-many applications. For example, they are multipoint videoconferencing or stock exchange ticketing applications.



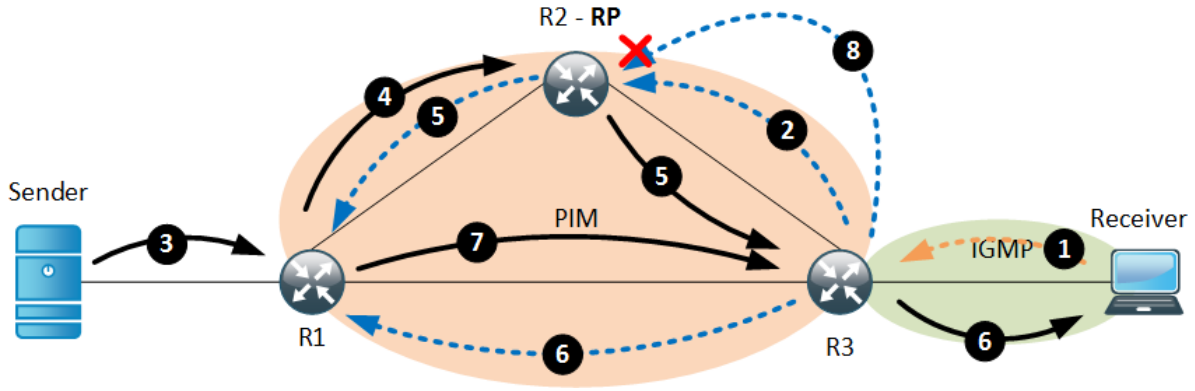
PIM-bidir traffic flow

The operation of the PIM-bidir can be explained as follows:

1) The certain range of multicast IP addresses is configured at the RP and then is sent through the network. For example, it's 239.255.0.0/18. All routers have a group (*, 239.255.0.0/18) that points to the IP address of the RP.
2) Then client reports that it wants to receive traffic for a certain group, for example it's 239.255.123.123.
3) R3 sends PIM Join message to R2 for group (*, 239.255.123.123). A separate (*, G) RPT is built only for this destination multicast IP address and only from R2 to R3.
4) The sender starts to multicast data. In the part of the network between ingress router and RP the traffic is sent to the RP according the RPT for the group (*, 239.255.0.0/18). From the RP the traffic is sent down to the receiver using RPF for the group (*, 239.255.123.123).

In PIM-bidir scenario the placement of the RP is very important as we should consider all possible traffic flows and should avoid not optimal one.

Now let's go back to the first option which is the classical PIM-SM approach, using which the RPT will be switched to the SPT if there is any traffic sender. It means that if there is any receiver and no senders only RPT from clients to RP will be built. It's very important point, because the ingress router where the sender is attached might be not on the path. It means that this ingress router will be unaware of the presence of multicast group. Or there can be another situation when we have a sender and no receivers. To solve such problems in PIM-SM the incoming multicast traffic at the beginning is tunneled in PIM Registration messages from the ingress router to the RP. If there is no receiver, the RP will answer with PIM Register-Stop message to ingress router to stop sending traffic for some time. If there is a client for the multicast stream, meaning that RP has already entry for the group (*, G), the traffic will be forwarded to the client according to the RPT, and the RP itself will build the SPT (S,G) to the sender. When the clients receive first actual multicast data, the last hop router initiates a building of the SPT (S,G) to the unicast IP address of the sender. It can be situations that the RP is not on the actual path between the sender and the receivers. It's actually normal for classical PIM-SM mode as the RP is only a registration point which is used for setup of the multicast streaming. During multicast streaming the RP keeps track of the actual status of the group (S,G) to allow new clients to be quickly added to that stream and to receive multicast content.



PIM-SM traffic flow

Let's bring all the pieces of the puzzle together:

1) The receiver sends IGMP report that it's interested in receiving the traffic for multicast IP address 239.123.123.123.
2) The last hop router (R3) sends PIM Join message to the RP (R2). The RPT for the group (*, 239.123.123.123) is built between R2 and R3.
3) The sender starts to multicast traffic.
4) In the PIM Registration messages the traffic is tunneled to the RP. If this step occurs earlier than the 1st one, the RP will answer with PIM Register-Stop message to postpone the transmission for a certain time.
5) The multicast data stream is forwarded as normal multicast from RP to the R3 following the RPT for the group (*, 239.123.123.123). At the same time the RP initiates a building of the SPT for the group (10.110.0.4, 239.123.123.123) towards the ingress router R1.

6) At this step also two simultaneous actions take place. The multicast data is sent to the receiver and the last hop router build the SPT for the group (10.110.0.4, 239.123.123.123) to R1.
7) The multicast data is streamed from R1 to R3 alongside the built SPT.
8) R3 sends to R2 the message that it doesn't want to receive the multicast traffic from R2 as it receives it through R1.

If we think about the algorithm above, we can see that despite some administrative overhead the PIM-SM helps save a bandwidth in the network and reduce the amount of unnecessary multicast traffic. Completely the same processes as described here for IPv4 for PIM-SM and PIM-bidir exist in IPv6 world. We just replace IGMP with MLD, because PIM for IPv6 is also used.

Options for rendezvous point (RP)

Now let's talk a little bit about the RP itself. Actually there are some options how it can be configured and communicated through the network. Some options are specific for IPv4 or IPv6, so we'll point out such difference. But what is common for all options is that you should configure the loopback interface of the router as the IP address for RP. It guarantees the availability of this address regardless of any failures on the physical interfaces of the RP.

The first one is called Static RP. It's the easiest and the most unreliable way how to configure RP. You just tell all you routers in the network that the RP has a certain IP address, and all multicast traffic will be forward accordingly. But if the RP is down, you have to reconfigure all the routers, just as you do this with static routes for example. This option can be used both for IPv4 and for IPv6.

The second option is called BSR or Boot Strap Router. We have two main components in BSR installation. The first one is the BSR itself which is actually a mapping agent for the RPs (we can have many RPs here). It collects information about a candidate RPs and sends it throughout the network using PIM and its multicast IP address 224.0.0.13 for IPv4 and ff02::13 for IPv6. You can configure many routers as the BSR but only one will be used in the certain moment of time. So, you have a possibility to implement a kind of redundancy. The wording "candidate RP" means that it isn't necessary that the router well be the active RP. As with the BSR there might be many routers configured as the RP. There are some hashing algorithms on a backstage which regulate whether the router is or isn't the RP for a whole multicast range or for the certain group. This hash function provides the opportunity to share the multicasting load as well. In the certain moment of time there is only one RP for the certain group, but different groups can be mapped to the different RPs. Each candidate RP sends its presence and configuration to the unicast IP address of the BSR. Then the BSR distributes this information throughout the network. The BSR can be configured both for IPv4 and for IPv6. It's the most recommended way of multicast configuration, because it's a standard, meaning that you can use it in multivendor environment.

The third option is Auto-RP. It's the Cisco-proprietary feature that exists only in IPv4 world. It was invented before the BSR algorithm that's why it was the first solution for redundancy. The ideas are the same as in the BSR solution. You configure one or some routers as mapping agents and one or some routers as candidate RPs. The main difference between this option and the BSR is that the BSR sends info to the network about all available RPs and their configuration. In Auto-RP the mapping agent chooses the best RP itself and then announces its unicast IP address to the rest of the network. All the candidate RPs send their info to the group with the multicast IP address 239.0.1.39, which is listened to by all mapping agents. Then the elected mapping agent multicasts this info to the IP address 239.0.1.40, which is used by default by all Cisco multicast-aware routers.

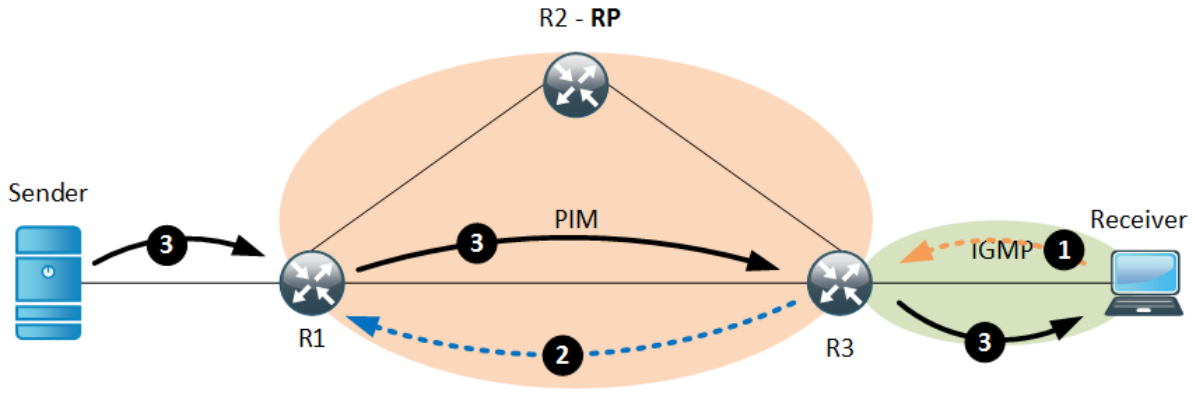
The forth option is called Embedded RP. This is quite specific case from my perspective, because it demands a special IP addressing scheme. Actually the Embedded RP can be configured only in IPv6 environment. The idea here is that the IP address of multicast group contains the information about the RP's unicast prefix. That's why when someone joins the group, the RPT will be built directly to the RP. You can refer to RFC for more details [f]

The fifth option is called Anycast RP. It's the most complicated but the most resilient way to configure multicasting. It isn't a single protocol, but it's a mix of any from the first three options (static RP, BSR or Auto-RP) plus MSDP (Multicast source discovery protocol). The idea here is that we configure the same IP address for the RP on all the routers. This IP is distributed via static RP, BSR or Auto-RP throughout the network. Then MSDP spans all these routers using another loopback IPs. When the receivers informs it last hop router that it wants to receive traffic for a certain multicast group, this request is routed using IGP to the closest RP. Then the sender starts to send multicast stream, and the registration process is done also with the closest RP (router that has the IP of the RP). In order to connect multicast source and destination the MSDP is used. It sends information about registered (S,G) to all the peers. Then the normal SPT is built using described in PIM-SM part algorithm.

It doesn't matter how you configure the RP in your network, but for PIM-SM it must be configured.

PIM-SSM – when we want to receive information only from certain senders

There is also one additional type of PIM which we've already mentioned. It's called PIM-SSM or source specific multicasting. By default the range 232.0.0.0/8 is used for IPv4 PIM-SSM and ff30::/12 for IPv6 PIM-SSM, but this can be reconfigured. As well we should use IGMPv3 or MLDv2 as only they have a possibility to include the unicast IP address of the source of multicast stream in Report messages, because this unicast source is crucial for PIM-SSM. Actually the basic idea in PIM-SSM is to build the SPT (S, G) from the receiver directly to the sender. The tree is always built according the RPF-checks, meaning that it has a shortest path from IGP view as well. That's why we don't need any RP in PIM-SSM.



PIM-SSM traffic flow

It works as follows:

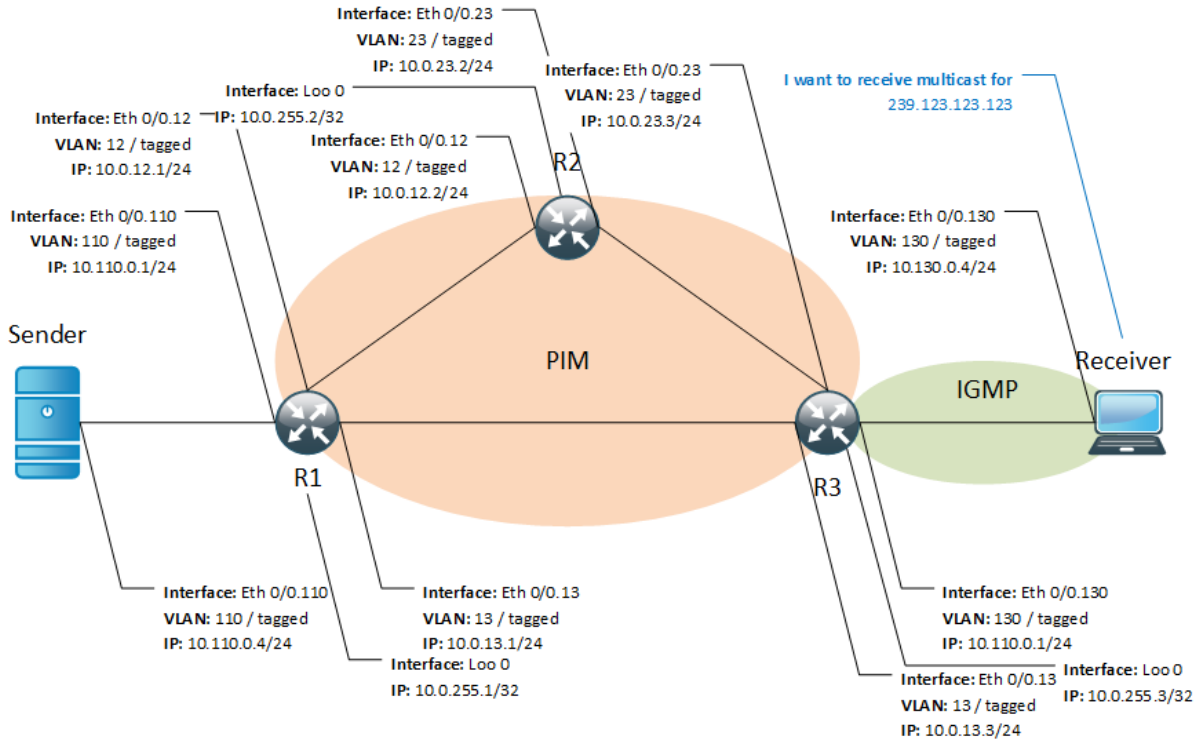
1) The receiver sends IGMPv3 Report to R3 that it wants to receive traffic for the group 232.123.123.123 from the sender with the unicast IP address 10.110.0.4.
2) R3 build the SPT for the group (10.110.0.4, 232.123.123.123) to R1. Despite the fact that there can be no traffic for that group, the tree will be built.

3) When the sender starts to multicast data stream for the group 232.123.123.123, the data will be forwarder along the built SPT to R3 and then to receiver.

Okay… We have explained a main theory that we need know when we speak about multicasting. But it isn't all, of course. Many things were just mentioned or explained in brief words just to provide you the understanding about its operation. Something we haven't said, because we don't want you to run away in a fear due to overwhelming amount of theory and details. From my understanding the best book that you should read about multicast is Routing TCP/IP volume 2, if you want to dig into the details like timers and message format deeper[g]. Though it's quite old, it has very good examples and traces. Now we jump into configuration phase. And here some surprises for you will be, especially at Cisco IOS XR. Despite the big volume of the theory the configuration of multicasting and multicast routing on all Cisco devices is quite quick and easy in general.

Configuration of multicast routing

If i describe all the possible configuration of multicast, it'll take tons of pages. I don't want it, because you'll be bored. I will just provide the configuration and explanation of the most important and/or recent multicast technologies. Due to this aim I will describe the configuration of PIM-SM, PIM-SSM and PIM-bidir both for IPv4 and IPv6 at Cisco IOS, IOS XE and IOS XR platform. The MSDP is also very important, but I won't describe it in this article. It will be described in the separate one, if I write it :-) The most basic configuration of multicast routing on IOS takes 2 commands at all the routers in the network and 4 commands at the router which performs the function of RP. Let's remind the topology in order for you not to scroll the page too far up.



IPv4 addressing for multicast

You can use this topology including the entire addressing schema if you want to reproduce and test it yourself. From the devices perspective, everything can be done in the virtual environment. For IOS XE you can use Cisco CSR 1000v, for IOS XR – Cisco XRv and for IOS you can use IOL, when you

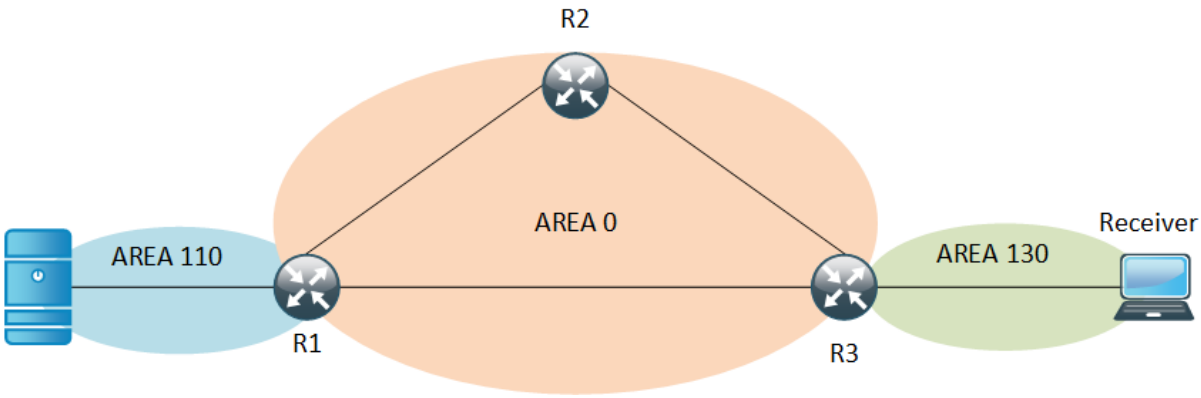
find the necessary image. The first two products can be downloaded from the official Cisco website. Actually you need 4 instances of the equipment, as we'll configure the sender and the receiver on the same router just in different VRFs. Such configuration we do due to minimization of using resources. All the configuration is done using the laptop with Core i7-4810MQ CPU @ 2,80 GHz and 8GB RAM. If you have enough capacity, you can configure everything as separate routers. In terms of RAM usage we have the following parameters:

1) Each Cisco XRv demands at least 2 GB per instance, but actually uses lower depending on configured features/timers. At the official Cisco website it's stated that you have to have at least 3 GB [h]
2) Each Cisco CSR 1000v demands at least 2,5 GB per instance and it usually uses all the provided memory. At the Cisco website it's stated that you need have at least 2,5 Gb RAM for IOS XE 3.12 and 4 Gb for IOS XE 3.14 [i, j]
3) For IOL images the demands are usually low, and as I heard and you can run up to 20 routing instance at just one VM with 5 Gb of RAM. Though you can experience some delays in routers' response.

As you can see, the necessary RAM is lower in reality than in the official documentation. I've written this article with the numbers that I provide. But it can occur that some other feature won't work due to insufficient amount of memory. If you face some problems with your virtual lab, first of all you should allocate more RAM and then check. May be it'll help you. If not, then you should look for a solution in the Internet.

Case #1 – configuration of PIM-SM for IPv4 at Cisco IOS / IOS XE

Before we configure multicast routing we must configure some IGP. As we have said previously, multicast routing is based on the top of the unicast routing. That's why we have to achieve full connectivity between all our addresses at first. You can choose any protocol you like; we'll use OSPF in our example in the following manner.



OSPF topology

A sample config for IOS or IOS XE you can find in Appendix A. I won't explain OSPF configuration, as I assume that you are familiar with it. The initial configuration for IOS XR will be provided further, where I describe how it's configured there.

The first step in the configuration of the multicast routing in the network is activation of multicast routing functionality. You can check whether it's activated or not:


```
R1#show ip mroute
IP Multicast Forwarding is not enabled.
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode
```

It's very important step. During my preparation for CCIE, mainly at the beginning, sometimes I forgot to activate it. Then I had to waste the time, what actually didn't work, though the configuration looked pretty good. The problem is called "show run", because it's the first command which people usually use to find the mistakes in the configuration, though there are many more efficient ways to find the root cause for the problem. I had such problem and think that you also can have it.

The activation is done using a very simple command:

```
R1(config)#ip multicast-routing
```

At the Cisco IOS XE platform you should use "ip multicast-routing distributed" command.

This command activates all the functionality that is related to multicasting. After that you can configure other features like PIM and so on, because by default everything is off. So you should configure all the interfaces to operate in PIM-SM:

```
!Check, that by default everything is off
R1#show ip igmp interface
R1#
R1#show ip pim interface

Address          Interface                Ver/   Nbr    Query  DR     DR
                                          Mode   Count  Intvl  Prior
!Configuring the necessary interfaces
R1(config)#interface eth 0/0.12
R1(config-subif)#ip pim sparse-mode
R1(config-subif)#interface eth 0/0.13
R1(config-subif)#ip pim sparse-mode
R1(config-if)#interface eth 0/0.110
R1(config-subif)#ip pim sparse-mode
R1(config-subif)#ip pim passive
R1(config-subif)#interface lo 0
R1(config-if)#ip pim sparse-mode
```


At the interface level you choose into which mode the PIM should operate. There are some other options, but this is the best one. During the configuration of the router you will see the following messages:

```
000042: *Oct 21 09:07:02.875: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to
10.0.12.1 on interface Ethernet0/0.12
```

At the first configured device the designated router (DR) will be always set to itself. For the others, there will be the election of the DR. The DR is the router who is responsible for registering the sender/receivers with the RP. Here are some remarks about the configuration:

1) PIM must be configured on the interface facing to the receivers and senders. It might be not secure to send PIM messages to the hosts, so you can configure this port as passive for PIM. Think about it like passive interface in OSPF or EIGRP. But you also must remember that this feature works only if you have just one router facing the clients. If there are two routers for redundancy, you mustn't configure this feature as the routers should speak to each other at the LAN segment as well. Configuring this feature in the redundancy scenario will break PIM operation.
2) PIM must be configured at the loopback interface at the Rendezvous Point (RP). In other cases it isn't necessary, though it doesn't break anything. So you can configure it everywhere.

Now let's check that interfaces are working. Look at the interesting fact. Though you haven't configured IGMP explicitly, it's activated together with PIM:

```
R1#show ip pim interface
Address          Interface                Ver/   Nbr    Query  DR     DR
                                          Mode   Count  Intvl  Prior
10.0.12.1        Ethernet0/0.12           v2/S   0      30     1      10.0.12.1
10.0.13.1        Ethernet0/0.13           v2/S   0      30     1      10.0.13.1
10.110.0.1       Ethernet0/0.110          v2/S   0      30     1      10.110.0.1
10.0.255.1       Loopback0                v2/S   0      30     1      10.0.255.1
!
R1#sh ip igmp interface
Ethernet0/0.12 is up, line protocol is up
  Internet address is 10.0.12.1/24
  IGMP is enabled on interface
  Current IGMP host version is 2
  Current IGMP router version is 2
  IGMP query interval is 60 seconds
  IGMP configured query interval is 60 seconds
  IGMP querier timeout is 120 seconds
  IGMP configured querier timeout is 120 seconds
  IGMP max query response time is 10 seconds
  Last member query count is 2
  Last member query response interval is 1000 ms
  Inbound IGMP access group is not set
  IGMP activity: 1 joins, 0 leaves
  Multicast routing is enabled on interface
  Multicast TTL threshold is 0
  Multicast designated router (DR) is 10.0.12.1 (this system)
  IGMP querying router is 10.0.12.1 (this system)
  Multicast groups joined by this system (number of users):
      224.0.1.40(1)
Ethernet0/0.13 is up, line protocol is up
!
```



```
Output is omitted
!
```

Actually the configuration of almost all the routers is done. Sometimes you have to manipulate the DR election in order to configure necessary router as a DR but in many cases it isn't necessary. We just have to configure our RP which in our case will be R2. We'll use the BSR as mechanism to distribute the information about RP in our network. R2 will act both as the candidate RP and as the mapping agent. As well we'll limit the multicasting groups in our network only to the range of 239.0.0.0/8.

```
R2(config)#ip access-list standard R2_MCAST_RANGE_SM
R2(config-std-nacl)#permit 239.0.0.0 0.255.255.255
R2(config-std-nacl)#exit
R2(config)#ip pim bsr-candidate Loopback0 32
R2(config)#ip pim rp-candidate Loopback0 group-list R2_MCAST_RANGE_SM interval 5
```

What also we can do here is to configure priority both for the BSR and the RP, but this parameter works differently. In case of BSR the highest priority wins in the BSR elections. If there is no priority configured, the highest IP address wins. In case of the RP elections, the lowest priority wins. At the second step wins the highest IP, if the priority isn't configured. Before we check the result of our configuration, I'll outline the fact that it's better to deactivate domain-name lookup on all the routers. The router will try to find the DNS name for the IP address of the RP in the output what leads to annoying delays:

```
R2(config)#no ip domain lookup
R2(config)#exit
R2#show ip pim rp mapping
PIM Group-to-RP Mappings
This system is a candidate RP (v2)
This system is the Bootstrap Router (v2)
Group(s) 239.0.0.0/8
  RP 10.0.255.2 (?), v2
    Info source: 10.0.255.2 (?), via bootstrap, priority 0, holdtime 12
         Uptime: 00:09:36, expires: 00:00:10

R1#sh ip pim rp map
PIM Group-to-RP Mappings
Group(s) 239.0.0.0/8
  RP 10.0.255.2 (?), v2
    Info source: 10.0.255.2 (?), via bootstrap, priority 0, holdtime 150
         Uptime: 00:10:31, expires: 00:01:56

R3#sh ip pim rp map
PIM Group-to-RP Mappings
Group(s) 239.0.0.0/8
  RP 10.0.255.2 (?), v2
    Info source: 10.0.255.2 (?), via bootstrap, priority 0, holdtime 150
         Uptime: 00:10:58, expires: 00:01:29
```

You can see interesting messafe, after you have configured a router as the candidate RP or the Mapping Agent:

```
000040: *Oct 21 09:46:48.827: %LINEPROTO-5-UPDOWN: Line protocol on Interface
```



```
Tunnel0, changed state to up
000041: *Oct 21 09:46:48.828: %LINEPROTO-5-UPDOWN: Line protocol on Interface
Tunnel1, changed state to up
```

Though you don't see these tunnels in the configuration, you can check their operational state. As it goes from their name, they are used for the registration of multicast sources with RP.

```
R2#sh ip pim tunnel
Tunnel0
  Type  : PIM Encap
  RP    : 10.0.255.2*
  Source: 10.0.255.2
Tunnel1
  Type  : PIM Decap
  RP    : 10.0.255.2*
  Source: -
```

It might look unbelievable, but it's all. Our network is configured to transmit multicast traffic. So, let's configure R4 right now. We emulate that there is a receiver in the VRF Receiver. To do this we just configure IGMP in the following group:

```
R4(config)#interface eth 0/0.12
R4(config-subif)#ip igmp join-group 239.123.123.123
```

It works. It's really simply, isn't it? Let's have a look on what's going on at the backstage. After we've configured the IGMP group at R4 at the interface Ethernet 0/0.130, R4 registers with R3 as R3 is the only PIM speaking router on the segment. Remember, we don't activate multicast routing at R4 at all.

```
R3#sh ip igmp membership
!
 Channel/Group                  Reporter        Uptime   Exp.  Flags  Interface
 *,239.123.123.123              10.130.0.4      00:05:54 02:22 2A     Et0/0.130
 *,224.0.1.40                   10.0.13.3       01:01:00 02:13 2LA    Et0/0.13
```

This IGMP report is translated to the language of PIM and the interest of the Receiver is signaled to the RP.

```
R3#sh ip pim rp
Group: 239.123.123.123, RP: 10.0.255.2, v2, uptime 00:54:59, expires 00:01:50
R3#
R3#show ip mroute 239.123.123.123
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
```



```
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode
(*, 239.123.123.123), 00:16:01/00:02:58, RP 10.0.255.2, flags: SJC
  Incoming interface: Ethernet0/0.23, RPF nbr 10.0.23.2
  Outgoing interface list:
    Ethernet0/0.130, Forward/Sparse-Dense, 00:16:01/00:02:58


R2#show ip mroute 239.123.123.123
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.123.123.123), 00:17:13/00:03:02, RP 10.0.255.2, flags: S
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/0.23, Forward/Sparse, 00:17:13/00:03:02
```

At this moment there is no information about this group at R1 as it isn't on the path between the last hop router (R3) and the RP (R2).

```
R1#show ip mro 239.123.123.123
Group 239.123.123.123 not found
```

So, it's our moment of the glory. Or the fail. Let's try to test how multicast traffic is sent through our network. We use just a simple ping to the multicast IP address of our group.

```
R4#ping vrf Sender 239.123.123.123 rep 5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 239.123.123.123, timeout is 2 seconds:
Reply to request 0 from 10.130.0.4, 58 ms
Reply to request 1 from 10.130.0.4, 2 ms
Reply to request 1 from 10.130.0.4, 7 ms
Reply to request 2 from 10.130.0.4, 1 ms
Reply to request 3 from 10.130.0.4, 4 ms
Reply to request 4 from 10.130.0.4, 2 ms
```

You can see that one packet is doubled. Remember that the first packet is sent via PIM Tunnel to the RP from the R1. Starting this point RP builds the SPT to the source and sends traffic to the receiver via RPT. As traffic comes to R3 it starts to build the SPT to the source as well. Refer to the algorithm that is provided earlier in the text.

```
R2#show ip mroute 239.123.123.123
```



```
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode
(*, 239.123.123.123), 00:27:50/00:03:12, RP 10.0.255.2, flags: S
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/0.23, Forward/Sparse, 00:27:50/00:03:12
(10.110.0.4, 239.123.123.123), 00:04:39/00:01:58, flags: PT
  Incoming interface: Ethernet0/0.12, RPF nbr 10.0.12.1
  Outgoing interface list: Null
!
R3#show ip mroute 239.123.123.123
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode
(*, 239.123.123.123), 00:28:16/stopped, RP 10.0.255.2, flags: SJC
  Incoming interface: Ethernet0/0.23, RPF nbr 10.0.23.2
  Outgoing interface list:
    Ethernet0/0.130, Forward/Sparse-Dense, 00:28:16/00:02:41
(10.110.0.4, 239.123.123.123), 00:01:59/00:01:00, flags: JT
  Incoming interface: Ethernet0/0.13, RPF nbr 10.0.13.1
  Outgoing interface list:
    Ethernet0/0.130, Forward/Sparse-Dense, 00:01:59/00:02:41
!
R1#show ip mro 239.123.123.123
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
```



```
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode
(*, 239.123.123.123), 00:05:18/stopped, RP 10.0.255.2, flags: SPF
  Incoming interface: Ethernet0/0.12, RPF nbr 10.0.12.2
  Outgoing interface list: Null
(10.110.0.4, 239.123.123.123), 00:05:18/00:03:19, flags: FT
  Incoming interface: Ethernet0/0.110, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/0.13, Forward/Sparse, 00:05:18/00:03:15
```

There is also very useful tool in the multicasting that you will use for troubleshooting or forecasting your multicast flows. You can use it to see the actual flow of the multicast traffic from the source to the receiver:

```
R3#mtrace 10.110.0.4 10.130.0.4 239.123.123.123
Type escape sequence to abort.
Mtrace from 10.110.0.4 to 10.130.0.4 via group 239.123.123.123
From source (?) to destination (?)
Querying full reverse path...
 0  10.130.0.4
-1  10.130.0.3 ==> 10.0.13.3 PIM  [10.110.0.0/16]
-2  10.0.13.1 ==> 10.110.0.1 PIM_MT  [10.110.0.0/24]
-3  10.110.0.4
```

At this point we have configured our network to transmit the multicast user data. It's very good and I'd say that it's an achievement for you, if you really introduce multicast in your network. The configuration for your reference is the Appendix B.

Case #2 – configuration of PIM-bidir for IPv4 at Cisco IOS / IOS XE

Now let's proceed with the configuration of PIM-bidir. We assume that you are looking our article case by case, so you are aware of how to enable multicasting at Cisco routers. If not then take a look into the previous example.

To enable PIM-bidir on top of the previous configuration you should configure on all the routers in the network the support of PIM-bidir. You do it as follows:

```
R3(config)#ip pim bidir-ena
```

The next step is the configuration of the RP for PIM-bidir. The main issue here is that you can't use the same interface as the source IP address as you use for "usual" PIM-SM operation. So first of all you configure the new interface, activate PIM operation in the sparse mode and then configure the candidate RP for bidirectional operation.

Don't forget that this new interface must be added to IGP as well, because it must be available from the any point of your multicast network.

```
R2(config)#interface loopback 21
R2(config-if)# ip add 10.0.255.21 255.255.255.255
R2(config-if)# ip pim sparse-mode
R2(config-if)# ip ospf 1 area 0
R2(config-if)# ipv6 address 2001:10:0:255::21/128
```



```
R2(config-if)# ospfv3 1 ipv6 area 0
R2(config-if)#!
R2(config-if)#ip access-list stan R2_MCAST_RANGE_BIDIR
R2(config-std-nacl)# permit 238.0.0.0 0.255.255.255
R2(config-std-nacl)#!
R2(config-std-nacl)#ip pim rp-candidate loo21  group R2_MCAST_RANGE_BIDIR int 5
bidir
```

The only point where you mention the bidirectional capability is configuration of the candidate RP. We use BSR as our mechanism, that's why this configuration is done at the BSR RP. If you use other mechanism, it will be usual configuration of the RP with just including "bidir" option, nothing special. If you check the outcome you will see that the information about this group is distributed via BSR and the necessary route is added to the multicasting route table (MRIB).

```
R1#sh ip pim rp map
PIM Group-to-RP Mappings
Group(s) 238.0.0.0/8
  RP 10.0.255.21 (?), v2, bidir
    Info source: 10.0.255.2 (?), via bootstrap, priority 0, holdtime 150
         Uptime: 00:14:40, expires: 00:02:05
Group(s) 239.0.0.0/8
  RP 10.0.255.2 (?), v2
    Info source: 10.0.255.2 (?), via bootstrap, priority 0, holdtime 150
         Uptime: 00:40:39, expires: 00:02:03
!
R1#sh ip pim rp map
PIM Group-to-RP Mappings

Group(s) 238.0.0.0/8
  RP 10.0.255.21 (?), v2, bidir
    Info source: 10.0.255.2 (?), via bootstrap, priority 0, holdtime 150
         Uptime: 00:14:40, expires: 00:02:05
Group(s) 239.0.0.0/8
  RP 10.0.255.2 (?), v2
    Info source: 10.0.255.2 (?), via bootstrap, priority 0, holdtime 150
         Uptime: 00:40:39, expires: 00:02:03
R1#
R1#show ip mro
R1#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*,238.0.0.0/8), 00:14:57/-, RP 10.0.255.21, flags: B
  Bidir-Upstream: Ethernet0/0.12, RPF nbr: 10.0.12.2
  Incoming interface list:
```



```
    Loopback0, Accepting/Sparse
    Ethernet0/0.110, Accepting/Sparse-Dense
    Ethernet0/0.12, Accepting/Sparse

(*, 224.0.1.40), 00:41:58/00:02:05, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback0, Forward/Sparse, 00:41:57/00:02:05
```

Well, let's simulate that our receiver also wants to receive multicast for the group 238.123.123.123. We just configure IGMP to join the corresponding group and check what it leads to.

```
R4(config)#int Ethernet0/0.130
R4(config-subif)#ip igmp join-group 238.123.123.123
!
R3#sh ip igmp membership
Flags: A  - aggregate, T - tracked
       L  - Local, S - static, V - virtual, R - Reported through v3
       I - v3lite, U - Urd, M - SSM (S,G) channel
       1,2,3 - The version of IGMP, the group is in
Channel/Group-Flags:
       / - Filtering entry (Exclude mode (S,G), Include mode (G))
Reporter:
       <mac-or-ip-address> - last reporter if group is not explicitly tracked
       <n>/<m>      - <n> reporter in include mode, <m> reporter in exclude
 Channel/Group                  Reporter        Uptime   Exp.  Flags  Interface
 *,238.123.123.123              10.130.0.4      00:00:31 02:58 2A     Et0/0.130
 *,239.123.123.123              10.130.0.4      00:50:02 02:28 2A     Et0/0.130
 *,224.0.1.40                   10.0.255.3      00:50:02 02:02 2LA    Lo0
!
R3#sh ip mroute
IP Multicast Routing Table
!
(*,238.0.0.0/8), 00:23:48/-, RP 10.0.255.21, flags: B
  Bidir-Upstream: Ethernet0/0.23, RPF nbr: 10.0.23.2
  Incoming interface list:
    Ethernet0/0.13, Accepting/Sparse
    Ethernet0/0.130, Accepting/Sparse-Dense
    Loopback0, Accepting/Sparse
    Ethernet0/0.23, Accepting/Sparse

(*, 238.123.123.123), 00:01:18/00:02:11, RP 10.0.255.21, flags: BC
  Bidir-Upstream: Ethernet0/0.23, RPF nbr 10.0.23.2
  Outgoing interface list:
    Ethernet0/0.130, Forward/Sparse-Dense, 00:01:18/00:02:11
    Ethernet0/0.23, Bidir-Upstream/Sparse, 00:01:18/stopped

(*, 239.123.123.123), 00:50:49/00:02:16, RP 10.0.255.2, flags: SJC
  Incoming interface: Ethernet0/0.23, RPF nbr 10.0.23.2
  Outgoing interface list:
    Ethernet0/0.130, Forward/Sparse-Dense, 00:50:48/00:02:16

(*, 224.0.1.40), 00:50:49/00:02:16, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback0, Forward/Sparse, 00:50:48/00:02:16
```


You see, that you have both 238.0.0.0/8 and 239.123.123.123 groups in the MRIB on R3, and the same picture you'll see at the R2. (Refer to the algorithm above for the details). Just send a multicast ping from Receiver to sender and check how the PIM-bidir works.

```
R4%Sender#ping 238.123.123.123 rep 5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 238.123.123.123, timeout is 2 seconds:

Reply to request 0 from 10.130.0.4, 1 ms
Reply to request 1 from 10.130.0.4, 1 ms
Reply to request 2 from 10.130.0.4, 1 ms
Reply to request 3 from 10.130.0.4, 1 ms
Reply to request 4 from 10.130.0.4, 3 ms

R1#sh ip mroute
IP Multicast Routing Table
!
(*,238.0.0.0/8), 00:30:18/-, RP 10.0.255.21, flags: B
  Bidir-Upstream: Ethernet0/0.12, RPF nbr: 10.0.12.2
  Incoming interface list:
    Loopback0, Accepting/Sparse
    Ethernet0/0.110, Accepting/Sparse-Dense
    Ethernet0/0.12, Accepting/Sparse

(*, 224.0.1.40), 00:57:19/00:02:47, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    Loopback0, Forward/Sparse, 00:57:18/00:02:47
```

You see that R1 has only the same group as it had earlier. No additional groups are added at any router in the network and the RP is in the actual traffic path. Let's have a look at this traffic path. You see that tree is built only to the RP, because the traffic is send always according to the RPT.

```
R3#mtrace 10.110.0.4 10.130.0.4 238.123.123.123
Type escape sequence to abort.
Mtrace from 10.110.0.4 to 10.130.0.4 via group 238.123.123.123
From source (?) to destination (?)
Querying full reverse path...
 0  10.130.0.4
-1  10.130.0.3 ==> 10.0.23.3 PIM  [using shared tree]
-2  10.0.23.2 ==> 0.0.0.0 PIM_MT Reached RP/Core [using shared tree]
```

We are going further. The last thing about multicasting for IPv4 at Cisco IOS / IOS XE platform is the configuration of source-specific multicasting or PIM-SSM.

Case #3 – configuration of PIM-SSM for IPv4 at Cisco IOS / IOS XE

As we already told the source-specific multicasting eliminates the necessity of having any RP, because it builds the SPT directly from the receiver to the host as the unicast IP address of the source is included in IGMP registration message. You can look into the algorithm above to refresh its process.

In terms of configuration we need activate the support of PIM-SSM on all the routers in the network. We do it as follows:


```
R3(config)#ip pim ssm default
```

The keyword “default” means that the default range for SSM will be used which is 232.0.0.0/8. If you want to use another group to SSM, you should use keyword “range” and configure the access-list that allows the necessary multicast IP address range.

The next and the last point in the configuration of PIM-SSM in the core multicast network is the configuration of the last hop router with IGMPv3 on the interface that faces the client. Only IGMPv3 supports INCLUDE reports that is reports with definite unicast IP address of source. Referring to our topology, we configure the interface Eth0/0.130 of R3.

Just to outline again: this step is specific for IOS / IOS XE, as IOS XR has all the interfaces configured with IGMPv3 by default.

```
R3(config)#int eth0/0.130
R3(config-subif)#ip igmp version 3
!
R3#sh ip igmp interface eth 0/0.130
Ethernet0/0.130 is up, line protocol is up
  Internet address is 10.130.0.3/24
  IGMP is enabled on interface
  Current IGMP host version is 3
  Current IGMP router version is 3
!
```

Now we’ll simulate the interest of the receiver to get the multicast traffic from the source with IP address 10.110.0.4 for the group 232.123.123.123.

```
R4(config)#int eth 0/0.130
R4(config-subif)#ip igmp join-group 232.123.123.123 source 10.110.0.4
R4(config-subif)#ip igmp version 3
```

Let’s check our last hop router.

```
R3#sh ip igmp membership
Flags: A  - aggregate, T - tracked
       L  - Local, S - static, V - virtual, R - Reported through v3
       I - v3lite, U - Urd, M - SSM (S,G) channel
       1,2,3 - The version of IGMP, the group is in
Channel/Group-Flags:
       / - Filtering entry (Exclude mode (S,G), Include mode (G))
Reporter:
       <mac-or-ip-address> - last reporter if group is not explicitly tracked
       <n>/<m>      - <n> reporter in include mode, <m> reporter in exclude

 Channel/Group                 Reporter        Uptime   Exp.  Flags  Interface
/*,232.123.123.123              10.130.0.4      00:00:45 stop  3MA    Et0/0.130
 10.110.0.4,232.123.123.123                    00:00:45 02:17 A      Et0/0.130
 *,238.123.123.123             10.130.0.4      00:23:37 02:17 2A     Et0/0.130
 *,239.123.123.123             10.130.0.4      00:23:36 02:17 2A     Et0/0.130
 *,224.0.1.40                  10.0.255.3      00:23:38 02:31 2LA    Lo0
!
R3#sh ip igmp groups 232.123.123.123 detail
```



```
Flags: L - Local, U - User, SG - Static Group, VG - Virtual Group,
       SS - Static Source, VS - Virtual Source,
       Ac - Group accounted towards access control limit

Interface:      Ethernet0/0.130
Group:          232.123.123.123
Flags:          SSM
Uptime:         00:01:06
Group mode:     INCLUDE
Last reporter:  10.130.0.4
Group source list: (C - Cisco Src Report, U - URD, R - Remote, S - Static,
                    V - Virtual, M - SSM Mapping, L - Local,
                    Ac - Channel accounted towards access control limit)
  Source Address   Uptime     v3 Exp   CSR Exp   Fwd  Flags
  10.110.0.4       00:01:06   00:02:59  stopped   Yes  R
```

You see here that your group is SSM and that the IP address of the source is provided as well. The group mode is INCLUDE comparing to the mode EXCLUDE that is by default for IGMPv2 and for IGMPv3, if you not include the IP address of the sender. What is about PIM operation?

```
R3#show ip mroute 232.123.123.123
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(10.110.0.4, 232.123.123.123), 00:07:37/00:02:27, flags: sTI
  Incoming interface: Ethernet0/0.13, RPF nbr 10.0.13.1
  Outgoing interface list:
    Ethernet0/0.130, Forward/Sparse-Dense, 00:07:37/00:02:27
!
R1#show ip mroute 232.123.123.123
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       G - Received BGP C-Mroute, g - Sent BGP C-Mroute,
       N - Received BGP Shared-Tree Prune, n - BGP C-Mroute suppressed,
       Q - Received BGP S-A Route, q - Sent BGP S-A Route,
       V - RD & Vector, v - Vector, p - PIM Joins on route
Outgoing interface flags: H - Hardware switched, A - Assert winner, p - PIM Join
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode
```



```
(10.110.0.4, 232.123.123.123), 00:07:59/00:03:22, flags: sT
  Incoming interface: Ethernet0/0.110, RPF nbr 0.0.0.0
  Outgoing interface list:
    Ethernet0/0.13, Forward/Sparse, 00:07:59/00:03:22
```

As you can see here there is no shared tree (RPT) for group 232.123.123.123. Instead of it you have a usual source-specific tree (SPT) which is built from the receiver to the sender. Also you can find a mentioning that the tree relates to SSM and is built due to source-specific IGMP report. Let's make just a short test of our topology:

```
R4#ping vrf Sender 232.123.123.123 sou 10.110.0.4 rep 5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 232.123.123.123, timeout is 2 seconds:
Packet sent with a source address of 10.110.0.4

Reply to request 0 from 10.130.0.4, 5 ms
Reply to request 1 from 10.130.0.4, 2 ms
Reply to request 2 from 10.130.0.4, 4 ms
Reply to request 3 from 10.130.0.4, 3 ms
Reply to request 4 from 10.130.0.4, 7 ms
```

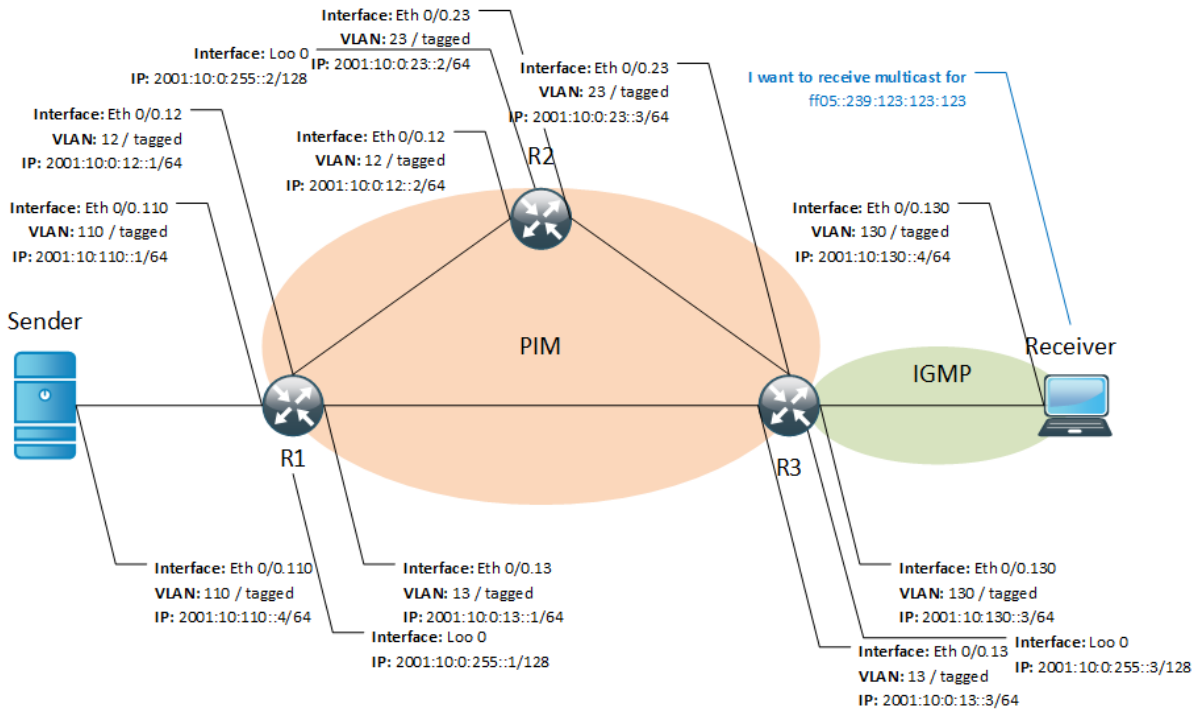
Summary for Cases 1, 2, 3 (IPv4 multicasting on Cisco IOS and IOS XE)

Let's make a short conclusion to our findings in the first three cases. The main one is that the configuration of multicasting is pretty straightforward. But you have to understand the theory well, if you want to be a good multicasting guy. Without such background you'll be like a blind kitten in the world of evil multicast. The configuration itself doesn't spend much time and you can add some features later (like PIM-SSM or PIM-bidir) as their configuration a completely separated from PIM-SM, though all the interfaces must operate in the PIM-SM mode from the beginning, as it's the only technology you should deploy today.

In Appendix C you can find the configuration file for the first three cases.

Case #4 – configuration of PIM-SM for IPv6 at Cisco IOS / IOS XE

We are going forward and now it's time to take a look on the IPv6 world. We have chosen BSR technology for the distribution of the information about the IP address of the RP and the mapping for IPv4. The same mechanism exists in the IPv6 world and we use it as well. It's quite good opportunity, because the underlying logic is the same and it's easier for you to support the network.



IPv6 addressing scheme for multicast

Everything is the same as it was for IPv4; we've just added new IPv6 addresses and configured IGP that is OSPFv3 in our case in the same manner as it was done for IPv4.

Now let's proceed with the configuration of the multicasting for IPv6 itself. Actually there are not too many differences from what we've done before. The first step is also to enable support of the multicasting and we must do it on all the routers in our network.

```
R1(config)#ipv6 multicast-routing
```

Then we come to the first difference in operation. As you remember you have to enable PIM per interfaces in IPv4, whereas PIM and MLD is on by default at all the IPv6 enabled interfaces after you activate multicasting.

```
R1#sh ipv6 pim interface state-on
Interface          PIM   Nbr   Hello  DR
                         Count Intvl  Prior

Ethernet0/0.12     on    1     30     1
    Address: FE80::A8BB:CCFF:FE00:100
    DR     : FE80::A8BB:CCFF:FE00:200
Ethernet0/0.110    on    0     30     1
    Address: FE80::A8BB:CCFF:FE00:100
    DR     : this system
Ethernet0/0.13     on    1     30     1
    Address: FE80::A8BB:CCFF:FE00:100
    DR     : FE80::A8BB:CCFF:FE00:300
Loopback0          on    0     30     1
    Address: FE80::A8BB:CCFF:FE00:100
    DR     : this system
!
R1#sh ipv6 mld interface
```



```
Ethernet0/0.12 is up, line protocol is up
  Internet address is FE80::A8BB:CCFF:FE00:100/10
  MLD is enabled on interface
  Current MLD version is 2
  MLD query interval is 125 seconds
  MLD querier timeout is 255 seconds
  MLD max query response time is 10 seconds
  Last member query response interval is 1 seconds
  MLD activity: 7 joins, 0 leaves
  MLD querying router is FE80::A8BB:CCFF:FE00:100 (this system)
Ethernet0/0.110 is up, line protocol is up
  Internet address is FE80::A8BB:CCFF:FE00:100/10
  MLD is enabled on interface
  Current MLD version is 2
  MLD query interval is 125 seconds
  MLD querier timeout is 255 seconds
  MLD max query response time is 10 seconds
  Last member query response interval is 1 seconds
  MLD activity: 7 joins, 0 leaves
  MLD querying router is FE80::A8BB:CCFF:FE00:100 (this system)
Ethernet0/0.13 is up, line protocol is up
  Internet address is FE80::A8BB:CCFF:FE00:100/10
  MLD is enabled on interface
  Current MLD version is 2
  MLD query interval is 125 seconds
  MLD querier timeout is 255 seconds
  MLD max query response time is 10 seconds
  Last member query response interval is 1 seconds
  MLD activity: 7 joins, 0 leaves
  MLD querying router is FE80::A8BB:CCFF:FE00:100 (this system)
Loopback0 is up, line protocol is up
  Internet address is FE80::A8BB:CCFF:FE00:100/10
  MLD is enabled on interface
  Current MLD version is 2
  MLD query interval is 125 seconds
  MLD querier timeout is 255 seconds
  MLD max query response time is 10 seconds
  Last member query response interval is 1 seconds
  MLD activity: 7 joins, 0 leaves
  MLD querying router is FE80::A8BB:CCFF:FE00:100 (this system)
```

Here we can also outline that MLDv2 is on by default. It's important, because you don't have to do any modification in order to configure SSM. As PIM works on all the interfaces already, we just need to configure the candidate RP and the BSR for IPv6. We do it as follows:

```
R2(config)#ipv6 pim bsr candidate bsr 2001:10:0:255::2 128
R2(config)#ipv6 pim bsr candidate rp 2001:10:0:255::2 group-list
IPV6_MCAST_RANGE_SM interval 5
R2(config)#ipv6 access-list IPV6_MCAST_RANGE_SM
R2(config-ipv6-acl)#permit ipv6 any FF05::239:0:0:0/80
```

To check that information is distributed in the network, you use a little bit other command in IPv6 than in IPv4.

```
R1#sh ipv pim group-map
IP PIM Group Mapping Table
(* indicates group mappings being used)
```



```
FF05::239:0:0:0/80*
    SM, RP: 2001:10:0:255::2
    RPF: Et0/0.12,FE80::A8BB:CCFF:FE00:200
    Info source: BSR From: 2001:10:0:255::2(00:01:34), Priority: 192
    Uptime: 00:02:36, Groups: 0
!
R1#sh ipv6 mroute
No mroute entries found.
```

So you have the information about potential mapping of the IPv6 multicast groups to the RP, though there is nothing in the multicast routing table as there is no interest for such traffic. Let's provide such interest by configuring MLD group at our receiver.

```
R4(config)#int eth 0/0.130
R4(config-subif)#ipv6 mld join-group ff05::239:123:123:123
!
R3#sh ipv6 mld groups
MLD Connected Group Membership
Group Address                           Interface          Uptime    Expires
FF05::239:123:123:123                   Ethernet0/0.130    00:05:06  00:03:20
!
R3#sh ipv mroute
Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group,
       C - Connected, L - Local, I - Received Source Specific Host Report,
       P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
       J - Join SPT, Y - Joined MDT-data group,
       y - Sending to MDT-data group
       g - BGP signal originated, G - BGP Signal received,
       N - BGP Shared-Tree Prune received, n - BGP C-Mroute suppressed,
       q - BGP Src-Active originated, Q - BGP Src-Active received
       E - Extranet
Timers: Uptime/Expires
Interface state: Interface, State
(*, FF05::239:123:123:123), 00:05:07/never, RP 2001:10:0:255::2, flags: SCJ
  Incoming interface: Ethernet0/0.23
  RPF nbr: FE80::A8BB:CCFF:FE00:200
  Immediate Outgoing interface list:
    Ethernet0/0.130, Forward, 00:05:07/never
!
R2#sh ipv6 mroute
Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group,
       C - Connected, L - Local, I - Received Source Specific Host Report,
       P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
       J - Join SPT, Y - Joined MDT-data group,
       y - Sending to MDT-data group
       g - BGP signal originated, G - BGP Signal received,
       N - BGP Shared-Tree Prune received, n - BGP C-Mroute suppressed,
       q - BGP Src-Active originated, Q - BGP Src-Active received
       E - Extranet
Timers: Uptime/Expires
Interface state: Interface, State
(*, FF05::239:123:123:123), 00:05:24/00:03:05, RP 2001:10:0:255::2, flags: S
  Incoming interface: Tunnel4
  RPF nbr: 2001:10:0:255::2
  Immediate Outgoing interface list:
    Ethernet0/0.23, Forward, 00:05:24/00:03:05
```


It looks very similar to the configuration of IPv4, but in the check phase there are some differences. The first one is that you have to explicitly define outgoing interface for the multicast traffic. The second one is that output of ping result is very strange:

```
R4#ping vrf Sender ff05::239:123:123:123 source 2001:10:110::4%Sender rep 5
Output Interface: Ethernet0/0.110
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FF05::239:123:123:123, timeout is 2 seconds:
Packet sent with a source address of 2001:10:110::4%Sender

Request 0 timed out
Request 1 timed out
Request 2 timed out
Request 3 timed out
Request 4 timed out
Success rate is 0 percent (0/5)
```

It seems that we've missed something in the configuration. Well it may be, but first of all we should check the building of SPTs:

```
R1#sh ipv6 mroute
Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group,
       C - Connected, L - Local, I - Received Source Specific Host Report,
       P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
       J - Join SPT, Y - Joined MDT-data group,
       y - Sending to MDT-data group
       g - BGP signal originated, G - BGP Signal received,
       N - BGP Shared-Tree Prune received, n - BGP C-Mroute suppressed,
       q - BGP Src-Active originated, Q - BGP Src-Active received
       E - Extranet
Timers: Uptime/Expires
Interface state: Interface, State

(2001:10:110::4, FF05::239:123:123:123), 00:13:56/00:00:31, flags: SFT
  Incoming interface: Ethernet0/0.110
  RPF nbr: FE80::A8BB:CCFF:FE00:400
  Immediate Outgoing interface list:
    Ethernet0/0.13, Forward, 00:04:03/00:03:26
!
R3#sh ipv6 mroute
Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group,
       C - Connected, L - Local, I - Received Source Specific Host Report,
       P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
       J - Join SPT, Y - Joined MDT-data group,
       y - Sending to MDT-data group
       g - BGP signal originated, G - BGP Signal received,
       N - BGP Shared-Tree Prune received, n - BGP C-Mroute suppressed,
       q - BGP Src-Active originated, Q - BGP Src-Active received
       E - Extranet
Timers: Uptime/Expires
Interface state: Interface, State

(*, FF05::239:123:123:123), 00:38:08/never, RP 2001:10:0:255::2, flags: SCJ
  Incoming interface: Ethernet0/0.23
```



```
  RPF nbr: FE80::A8BB:CCFF:FE00:200
  Immediate Outgoing interface list:
    Ethernet0/0.130, Forward, 00:38:08/never

(2001:10:110::4, FF05::239:123:123:123), 00:04:28/00:00:08, flags: SJT
  Incoming interface: Ethernet0/0.13
  RPF nbr: FE80::A8BB:CCFF:FE00:100
  Inherited Outgoing interface list:
    Ethernet0/0.130, Forward, 00:38:08/never
```

Actually the SPT is built. And moreover if we look into the actual amounts of packets, which were sent along the tree, you'll see all of them.

```
R3#show ipv6 mfib ff05::239:123:123:123 count
Forwarding Counts: Pkt Count/Pkts per second/Avg Pkt Size/Kilobits per second
Other counts:      Total/RPF failed/Other drops(OIF-null, rate-limit etc)
Default
 57 routes, 9 (*,G)s, 47 (*,G/m)s
Group: FF05::239:123:123:123
  RP-tree,
   SW Forwarding: 0/0/0/0, Other: 0/0/0
  Source: 2001:10:110::4,
   SW Forwarding: 11/0/100/0, Other: 0/0/0
  Totals - Source count: 1, Packet count: 11
!
R1#show ipv6 mfib ff05::239:123:123:123 count
Forwarding Counts: Pkt Count/Pkts per second/Avg Pkt Size/Kilobits per second
Other counts:      Total/RPF failed/Other drops(OIF-null, rate-limit etc)
Default
 56 routes, 8 (*,G)s, 47 (*,G/m)s
Group: FF05::239:123:123:123
  Source: 2001:10:110::4,
   SW Forwarding: 10/0/100/0, Other: 0/0/0
  Totals - Source count: 1, Packet count: 10
Groups: 1, 1.00 average sources per group
```

Looks very strange, yes? Furthermore you can see the actual packets, if you debug the operation of ICMPv6.

```
R4#deb ipv6 icmp
  ICMPv6 Packet debugging is on
R4#ping vrf Sender ff05::239:123:123:123 source 2001:10:110::4%Sender rep 5
Output Interface: Ethernet0/0.110
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FF05::239:123:123:123, timeout is 2 seconds:
Packet sent with a source address of 2001:10:110::4%Sender

000097: *Oct 27 11:06:01.657: ICMPv6: Sent echo request, Src=2001:10:110::4,
Dst=FF05::239:123:123:123
000098: *Oct 27 11:06:01.659: ICMPv6: Received echo request, Src=2001:10:110::4,
Dst=FF05::239:123:123:123
000099: *Oct 27 11:06:01.659: ICMPv6: Sent echo reply, Src=2001:10:130::4,
Dst=2001:10:110::4
000100: *Oct 27 11:06:01.659: ICMPv6: Received echo reply, Src=2001:10:130::4,
Dst=2001:10:110::4
Request 0 timed out
```


In the debug output you can see the following:

1) ICMPv6 request is sent by the Sender (000097 entry in syslog)
2) ICMPv6 request is received by the Receiver (000098 entry in syslog)
3) ICMPv6 reply is sent by the Sender (000099 entry in syslog)
4) ICMPv6 reply is received by the Sender (000097 entry in syslog)

Collecting all the info we see that multicast works, though there are some problems during verification in case of VRF. In the sake of consistency we've add additional virtual router to the segment 2001:10:110::0/64 with the simplest configuration and we've got the working result.

```
R5#sh run
!
hostname R5
!
ip cef
ipv6 unicast-routing
ipv6 cef
!
interface Ethernet0/0
 ip address 10.110.0.5 255.255.255.0
 ipv6 address 2001:10:110::5/64
!
ip route 0.0.0.0 0.0.0.0 Ethernet0/0 10.110.0.1
!
ipv6 route ::/0 Ethernet0/0 2001:10:110::1
!
End

R5#ping ff05::239:123:123:123
Output Interface: Ethernet0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FF05::239:123:123:123, timeout is 2 seconds:
Packet sent with a source address of 2001:10:110::5

Reply to request 0 received from 2001:10:130::4, 1 ms
Reply to request 1 received from 2001:10:130::4, 1 ms
Reply to request 2 received from 2001:10:130::4, 1 ms
Reply to request 3 received from 2001:10:130::4, 2 ms
Reply to request 4 received from 2001:10:130::4, 2 ms
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/2 ms
5 multicast replies and 0 errors.
```

Case #5 – configuration of PIM-bidir for IPv6 at Cisco IOS / IOS XE

We go further and come to the second option for IPv6 multicasting that is PIM-bidir. Here the configuration is simpler than in IPv4 as well, because PIM-bidir operation is on by default. You just need configure the RP for it (remember, it must be another address, not the one you use for PIM-SM).

```
R2(config)#interface Loopback21
R2(config-if)# ipv6 address 2001:10:0:255::21/128
R2(config)#ipv6 pim bsr candidate rp 2001:10:0:255::21 group-list
IPV6_MCAST_RANGE_BIDIR interval 5 bidir
R2(config)#ipv6 access-list IPV6_MCAST_RANGE_BIDIR
R2(config-ipv6-acl)#permit ipv6 any FF05::238:0:0:0/80
!
```



```
R1#sh ipv6 pim group-map
IP PIM Group Mapping Table
(* indicates group mappings being used)
FF05::238:0:0:0/80*
    BD, RP: 2001:10:0:255::21
    RPF: Et0/0.12,FE80::A8BB:CCFF:FE00:200
    Info source: BSR From: 2001:10:0:255::2(00:01:18), Priority: 192
    Uptime: 00:01:51, Groups: 0
FF05::239:0:0:0/80*
    SM, RP: 2001:10:0:255::2
    RPF: Et0/0.12,FE80::A8BB:CCFF:FE00:200
    Info source: BSR From: 2001:10:0:255::2(00:01:18), Priority: 192
    Uptime: 00:15:08, Groups: 1
!
R1#show ipv6 mroute
No mroute entries found.
```

In the output of group-mapping you see “BD” in the description of group ff05:238:0:0:0/8 what means bidirectional capability. At the same time there is no entry in the actual multicast routing table, though in IPv4 it’s added at the time of the learning info from the RP. Now our receiver wants to get traffic for this bidirectional group.

```
R4(config)#int eth 0/0.130
R4(config-subif)#ipv6 mld join-group ff05::238:123:123:123
```

There is nothing special, everything is the same as we configured in the previous example. Check the R3:

```
R3#show ipv6 mld groups
MLD Connected Group Membership
Group Address                           Interface          Uptime    Expires
FF05::238:123:123:123                   Ethernet0/0.130    00:01:23  00:04:08
FF05::239:123:123:123                   Ethernet0/0.130    00:27:45  00:04:08

R3#show ipv6 mroute
Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group,
       C - Connected, L - Local, I - Received Source Specific Host Report,
       P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
       J - Join SPT, Y - Joined MDT-data group,
       y - Sending to MDT-data group
       g - BGP signal originated, G - BGP Signal received,
       N - BGP Shared-Tree Prune received, n - BGP C-Mroute suppressed,
       q - BGP Src-Active originated, Q - BGP Src-Active received
       E - Extranet
Timers: Uptime/Expires
Interface state: Interface, State

(*, FF05::238:123:123:123), 00:01:31/never, RP 2001:10:0:255::21, flags: BC
  Bidir-Upstream: Ethernet0/0.23
  RPF nbr: FE80::A8BB:CCFF:FE00:200
  Immediate Outgoing interface list:
    Ethernet0/0.130, Forward, 00:01:31/never

(*, FF05::239:123:123:123), 00:27:53/never, RP 2001:10:0:255::2, flags: SCJ
  Incoming interface: Ethernet0/0.23
  RPF nbr: FE80::A8BB:CCFF:FE00:200
```



```
  Immediate Outgoing interface list:
    Ethernet0/0.130, Forward, 00:27:53/never
```

At this step the behavior is the same as it was in IPv4 or a usual PIM-SM. This group is added in MRIB at R2 and R3. The verification will be done from R5, as we've found a problem with VRF.

```
R5#ping ff05::238:123:123:123 rep 5
Output Interface: Ethernet0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FF05::238:123:123:123, timeout is 2 seconds:
Packet sent with a source address of 2001:10:110::5
Reply to request 0 received from 2001:10:130::4, 6 ms
Reply to request 1 received from 2001:10:130::4, 2 ms
Reply to request 2 received from 2001:10:130::4, 7 ms
Reply to request 3 received from 2001:10:130::4, 6 ms
Reply to request 4 received from 2001:10:130::4, 2 ms
Success rate is 100 percent (5/5), round-trip min/avg/max = 2/4/7 ms
5 multicast replies and 0 errors.
!
R1#show ipv6 mroute
No mroute entries found.
```

The interesting fact is that you don't have an entry in multicast routing table at R1, though the traffic is delivered pretty well.

Case #6 – configuration of PIM-SSM for IPv6 at Cisco IOS / IOS XE

The last part of our configuration at Cisco IOS and IOS XE platform will be configuration of the source-specific multicasting. As with PIM-bidir, the operation of PIM-SSM is on by default for IPv6. Also we've already mentioned that the default version of MLD is 2. It means that you just need to receive the report at the last hop router, which includes the IPv6 unicast address of the sender and the SPT will be built. But before we jump into configuration, let's take a quick look at group mapping.

```
R1#sh ipv6 pim group-map
!
FF33::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF34::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF35::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF36::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF37::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF38::/32*
```



```
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF39::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF3A::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF3B::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF3C::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF3D::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF3E::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
FF3F::/32*
    SSM
    Info source: Static
    Uptime: 00:03:00, Groups: 0
!
```

You see that there is a predefined range of IPv6 address, which should be used for IPv6 PIM-SSM. Initially it was an idea that the forth number in the address will mention the scope of traffic. For example in the address ff35::/32 we have “5” which point to site-scope multicasting, whereas in address ff38::/32 the “8” represents the organizational scope. There are no preconfigured dependencies between TTL (officially it’s called “hop limit” in IPv6 header), but you should consider these guidelines during designing your multicast network. Let’s configure out sender in the way it wants to receive traffic group for the group ff35::232:123:123:123 from 2001:10:110::5 (considering the found problems):

```
R4(config)#int eth 0/0.130
R4(config-subif)#ipv6 mld join ff35::232:123:123:123 2001:10:110::5
```

At R3 we see the registration for that group including information about source.

```
R3#sh ipv mld groups
MLD Connected Group Membership
Group Address                           Interface          Uptime    Expires
FF05::238:123:123:123                   Ethernet0/0.130    00:30:51  00:03:07
FF05::239:123:123:123                   Ethernet0/0.130    00:30:51  00:03:07
FF35::232:123:123:123                   Ethernet0/0.130    00:06:57  not used
!
R3#sh ipv mld groups ff35::232:123:123:123 detail
Interface:      Ethernet0/0.130
```



```
Group:          FF35::232:123:123:123
Uptime:         00:07:15
Router mode:    INCLUDE
Host mode:      INCLUDE
Last reporter:  FE80::A8BB:CCFF:FE00:400
Group source list:
Source Address                          Uptime    Expires   Fwd  Flags
2001:10:110::5                          00:07:13  00:02:49  Yes  Remote 4
```

The next point in our verification is checking of multicast routing for IPv6 configuration.

```
R3#show ipv6 mroute
Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group,
       C - Connected, L - Local, I - Received Source Specific Host Report,
       P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
       J - Join SPT, Y - Joined MDT-data group,
       y - Sending to MDT-data group
       g - BGP signal originated, G - BGP Signal received,
       N - BGP Shared-Tree Prune received, n - BGP C-Mroute suppressed,
       q - BGP Src-Active originated, Q - BGP Src-Active received
       E - Extranet
Timers: Uptime/Expires
Interface state: Interface, State
(*, FF05::238:123:123:123), 02:52:55/never, RP 2001:10:0:255::21, flags: BC
  Bidir-Upstream: Ethernet0/0.23
  RPF nbr: FE80::A8BB:CCFF:FE00:200
  Immediate Outgoing interface list:
    Ethernet0/0.130, Forward, 02:52:55/never
(*, FF05::239:123:123:123), 02:52:55/never, RP 2001:10:0:255::2, flags: SCJ
  Incoming interface: Ethernet0/0.23
  RPF nbr: FE80::A8BB:CCFF:FE00:200
  Immediate Outgoing interface list:
    Ethernet0/0.130, Forward, 02:52:55/never
(2001:10:110::5, FF35::232:123:123:123), 02:29:00/never, flags: sTI
  Incoming interface: Ethernet0/0.13
  RPF nbr: FE80::A8BB:CCFF:FE00:100
  Immediate Outgoing interface list:
    Ethernet0/0.130, Forward, 02:29:00/never
!
R1#show ipv6 mroute
Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group,
       C - Connected, L - Local, I - Received Source Specific Host Report,
       P - Pruned, R - RP-bit set, F - Register flag, T - SPT-bit set,
       J - Join SPT, Y - Joined MDT-data group,
       y - Sending to MDT-data group
       g - BGP signal originated, G - BGP Signal received,
       N - BGP Shared-Tree Prune received, n - BGP C-Mroute suppressed,
       q - BGP Src-Active originated, Q - BGP Src-Active received
       E - Extranet
Timers: Uptime/Expires
Interface state: Interface, State
(2001:10:110::5, FF35::232:123:123:123), 02:28:49/00:02:42, flags: sT
  Incoming interface: Ethernet0/0.110
  RPF nbr: 2001:10:110::5
  Immediate Outgoing interface list:
    Ethernet0/0.13, Forward, 02:28:49/00:02:42
```


The last step in verification is multicast ping as usual:

```
R5#ping ff35::232:123:123:123 rep 5
Output Interface: Ethernet0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FF35::232:123:123:123, timeout is 2 seconds:
Packet sent with a source address of 2001:10:110::5

Reply to request 0 received from 2001:10:130::4, 23 ms
Reply to request 1 received from 2001:10:130::4, 1 ms
Reply to request 2 received from 2001:10:130::4, 6 ms
Reply to request 3 received from 2001:10:130::4, 2 ms
Reply to request 4 received from 2001:10:130::4, 9 ms
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/8/23 ms
5 multicast replies and 0 errors.
```

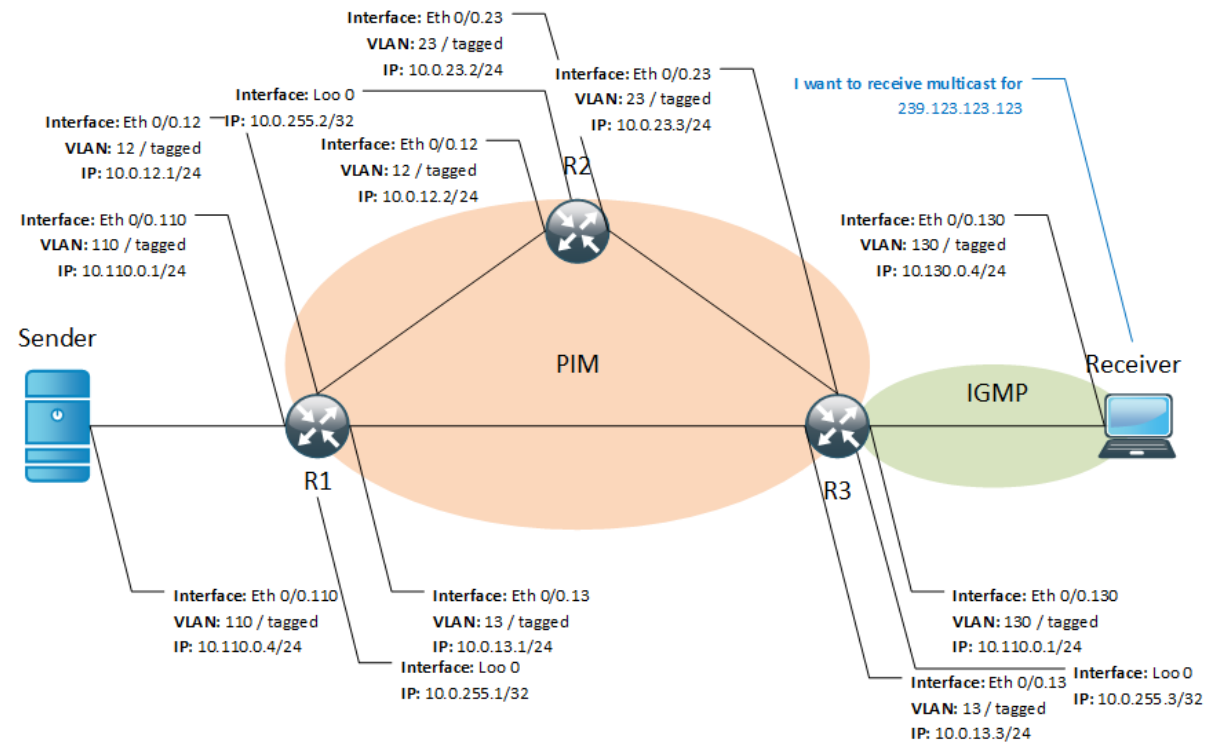
Summary for Cases 4, 5, 6 (IPv6 multicasting on Cisco IOS and IOS XE)

The configuration of multicasting for IPv6 is easier, because many advanced features are on by default and you can just use them. Despite the bigger size of IPv6 multicast address the technologies on the backstage are the same. And actually it's very good, because you can introduce IPv6 as a feature-reach technology and make migration from IPv4 quite simple and seamless.

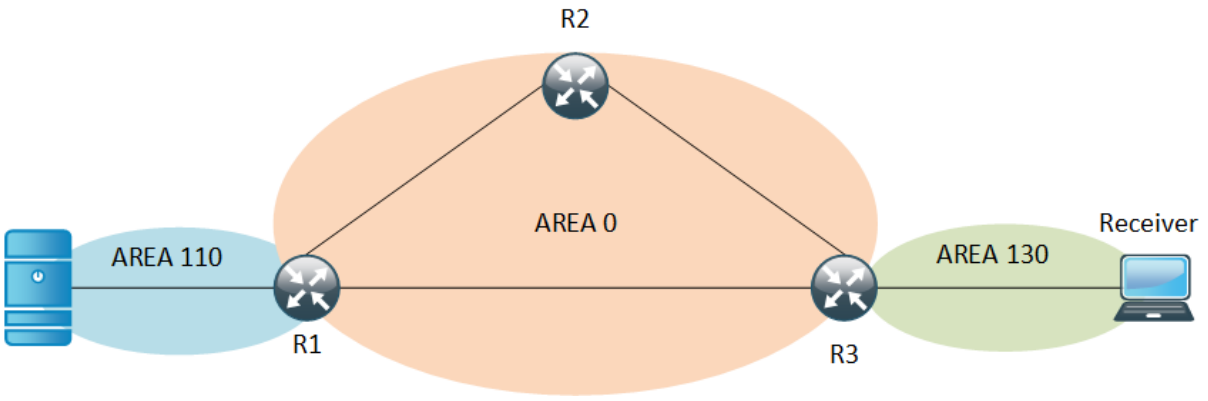
Also we've found a strange behavior regarding multicast ping from VRF. And you can find the configuration files in Appendix D.

Configuration of multicasting on Cisco IOS XR

Well done, my friends. We've described main cases that you'll meet in the network. Actually, we've provided almost all cases in terms of multicasting, which can be met in the enterprise network beside anycast RP. But anycast RP is topic for separate article. Now we'll see how we can configure the same features on Cisco IOS XR platform. This platform is mainly used in Service Provider networks, though some big enterprises can also benefit from it. The main difference in the configuration of Cisco IOS XR is that it's complete different operation system. It has strict separation between configuration of data plane related parameters and control plane related parameters. At the beginning it's quite confusing, but then you'll like it, I promise. So, let's proceed with the first step like it was for Cisco IOS XE. Let's proceed with PIM-SM for IPv4. But before we begin, we'll remind the addressing scheme.



IPv4 addressing for multicasting



OSPF topology

Case #7 – configuration of PIM-SM for IPv4 at Cisco IOS XR

As Cisco IOS XR has a strict separation of the data plane and the control plane configurations, we'll focus solely on the control plane. The control plane stands for all the signaling in the network which helps to build the actual path for data forwarding.

The first step in configuration of the multicasting on Cisco IOS XR platform is activation of this feature. But contrasting to IOS XE, you should also chose interfaces which will be involved in multicasting process, so you do following configuration.

```
RP/0/0/CPU0:R1(config-mcast-default-ipv4)#show configuration
Wed Oct 28 09:04:12.206 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
multicast-routing
 address-family ipv4
  interface all enable
```



```
 !
!
multicast-routing
!
end
```

As it was with IOS or IOS XE, before you activate multicast routing, you don't see any routes in MRIB.

```
RP/0/0/CPU0:R1#show mrib ipv4 route
Wed Oct 28 09:02:27.793 UTC
No matching routes in MRIB route-DB
```

But just after activation you see something. Take a look at the command syntax: it's changed.

```
RP/0/0/CPU0:R1#show mrib ipv4 route
Wed Oct 28 09:10:08.831 UTC

IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
    C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
    IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
    MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface handle
    CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
    MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
    MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
    NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
    II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
    LD - Local Disinterest, DI - Decapsulation Interface
    EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
    EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
    MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE MDT Interface
    IRMI - IR MDT Interface

(*,224.0.0.0/24) Flags: D P
  Up: 00:03:52

(*,224.0.1.39) Flags: S P
  Up: 00:03:52

(*,224.0.1.40) Flags: S P
  Up: 00:03:52
  Outgoing Interface List
    Loopback0 Flags: II LI, Up: 00:03:52

(*,232.0.0.0/8) Flags: D P
  Up: 00:03:52
```

The second step is activation of PIM and IGMP. Or more correctly to say, it must be so, because after the enabling of the multicast routing on the interfaces, both PIM and IGMP are activated on the same interfaces as well. If it's necessary, you can disable PIM per interface. But it's better to deactivate multicasting on all the interfaces and then explicitly configure them only as you need. Let's check what we have.

```
RP/0/0/CPU0:R1#show pim ipv4 interface
```



```
Wed Oct 28 09:17:44.140 UTC
PIM interfaces in VRF default
Address               Interface                PIM   Nbr    Hello  DR     DR
                                                     Count  Intvl  Prior
10.0.255.1            Loopback0                on    1      30     1      this
system
10.0.12.1             GigabitEthernet0/0/0/0.12    on    2      30     1
10.0.12.2
10.0.13.1             GigabitEthernet0/0/0/0.13    on    2      30     1
10.0.13.3
10.110.0.1            GigabitEthernet0/0/0/0.110   on    1      30     1      this
system
!
RP/0/0/CPU0:R1#show igmp interface
Wed Oct 28 09:17:50.280 UTC
Loopback0 is up, line protocol is up
  Internet address is 10.0.255.1/32
  IGMP is enabled on interface
  Current IGMP version is 3
  IGMP query interval is 60 seconds
  IGMP querier timeout is 125 seconds
  IGMP max query response time is 10 seconds
  Last member query response interval is 1 seconds
  IGMP activity: 4 joins, 0 leaves
  IGMP querying router is 10.0.255.1 (this system)
  Time elapsed since last query sent 00:00:25
  Time elapsed since IGMP router enabled 00:11:34
  Time elapsed since last report received 00:00:22
GigabitEthernet0/0/0/0.12 is up, line protocol is up
!
GigabitEthernet0/0/0/0.13 is up, line protocol is up
!
GigabitEthernet0/0/0/0.110 is up, line protocol is up
!
```

You can see that here the commands are also a bit different. This is always with IOS XR, because it's just another operation system. It's also interesting that IOS XR has a little bit different logic in the counters. You can seem that the number of the PIM neighbors is bigger than it should be by 1. Even at the loopback interface we have PIM neighbor. So you must think about it, as our router is included in this number as well. And the only neighbor at the loopback interface is our router itself. Also as we've described it many times, default version for IGMP is 3 at Cisco IOS XR. The last step in the configuration of the multicasting for PIM-SM is configuring the RP. We'll use BSR as we've done it previously.

```
RP/0/0/CPU0:R2(config-ipv4-acl)#show conf
Wed Oct 28 09:39:45.800 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
ipv4 access-list R2_MACST_SM
 10 permit ipv4 any 239.0.0.0/8
!
router pim
 address-family ipv4
  bsr candidate-bsr 10.0.255.2 hash-mask-len 32 priority 1
  bsr candidate-rp 10.0.255.2 group-list R2_MACST_SM priority 192 interval 30
 !
!
```



```
router pim
!
end
```

There are two differences from the IOS configuration. The first one doesn't relate to the multicasting itself, but rather it relates to overall IOS XR architecture. There are no standard access-lists which were used in IOS or IOS XE. That's why you have to configure access-lists properly, as they are always extended.

But if you have a mix of devices in your network where some are IOS and some are IOS XR, don't think about using the same configuration of access-lists for multicasting. On a regular IOS you are not allowed to use extended access-lists for group mapping.

The second difference is syntax. You can see that it is completely different from IOS. But you'll see later that such syntax is much better, because the config is more structured and easier to read. Besides, the configuration of IPv6 uses the same commands and there is no diversity in configuration of multicasting as it was in IOS and IOS XE. The only one negative thing is that the timers for PIM convergence here is much bigger, but I can assume this relates to the virtual environment. In the real life you'd use BFD, which is not supported on Cisco IOS XRv.

After the configuration of BSR, it's meaningful to check its operation.

```
RP/0/0/CPU0:R1#show pim ipv4 rp mapping
Wed Oct 28 09:51:27.121 UTC
PIM Group-to-RP Mappings
Group(s) 239.0.0.0/8
  RP 10.0.255.2 (?), v2
    Info source: 10.0.12.2 (?), elected via bsr, priority 192, holdtime 75
      Uptime: 00:10:52, expires: 00:01:07
```

This output is familiar to you. I just want to point out one interesting fact. In RFC about BSR it's stated, that default priority for candidate-RP is 192. The RP is elected based on this value, and wins the one with the lowest priority. If the priority is the same, the highest IP wins. If you will scroll back to the Case#1, you'll find in the same output from regular IOS that there priority is 0 by default. So the default values of priorities are different on IOS and IOS XR platforms. And if you have a mixed set of equipment, you must take care of these values in order to get desired operation of multicasting.

Now it's time to emulate the interest of the Receiver in the multicast traffic and see what's going on.

```
RP/0/0/CPU0:R4(config-igmp-default-if)#show configuration
Wed Oct 28 10:06:01.904 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
multicast-routing
 vrf Receiver
  address-family ipv4
   interface GigabitEthernet0/0/0/0.130
    enable
   !
  !
 !
```



```
!
router igmp
 vrf Receiver
  interface GigabitEthernet0/0/0/0.130
   join-group 239.123.123.123
  !
 !
!
router igmp
!
end
```

The next difference between regular IOS and IOS XR is that you have to activate multicasting on the R4, which emulates our Receiver. Without such configuration IGMP will be disabled despite its configuration can be done separately.

You can see that you configure interfaces under separate processes. They are configured separately in multicast, in PIM, in IGMP, in IGPs and so on. This relates to the described fact that the control plane is completely separated from the data plane. And the configuration of physical interface parameters like IP, speed, encapsulation and so on is done for the data plane, whereas logical parameters of different signaling protocols are configured at the control plane.

Let's have a look at IGMP registration at R3 and MRIB at all our routers.

```
RP/0/0/CPU0:R3#sh igmp groups gig 0/0/0/0.130
Wed Oct 28 10:16:54.259 UTC
IGMP Connected Group Membership
Group Address   Interface                      Uptime    Expires   Last Reporter
224.0.0.2       GigabitEthernet0/0/0/0.130     01:09:55  never     10.130.0.1
224.0.0.13      GigabitEthernet0/0/0/0.130     01:09:55  never     10.130.0.1
224.0.0.22      GigabitEthernet0/0/0/0.130     01:09:55  never     10.130.0.1
224.0.1.40      GigabitEthernet0/0/0/0.130     00:01:49  00:01:26  10.130.0.4
239.123.123.123 GigabitEthernet0/0/0/0.130     00:01:49  00:01:26  10.130.0.4
!
RP/0/0/CPU0:R3#sh mrib ipv4 route 239.123.123.123
Wed Oct 28 10:17:56.345 UTC
IP Multicast Routing Information Base
Entry flags: L - Domain-Local Source, E - External Source to the Domain,
    C - Directly-Connected Check, S - Signal, IA - Inherit Accept,
    IF - Inherit From, D - Drop, ME - MDT Encap, EID - Encap ID,
    MD - MDT Decap, MT - MDT Threshold Crossed, MH - MDT interface handle
    CD - Conditional Decap, MPLS - MPLS Decap, EX - Extranet
    MoFE - MoFRR Enabled, MoFS - MoFRR State, MoFP - MoFRR Primary
    MoFB - MoFRR Backup, RPFID - RPF ID Set, X - VXLAN
Interface flags: F - Forward, A - Accept, IC - Internal Copy,
    NS - Negate Signal, DP - Don't Preserve, SP - Signal Present,
    II - Internal Interest, ID - Internal Disinterest, LI - Local Interest,
    LD - Local Disinterest, DI - Decapsulation Interface
    EI - Encapsulation Interface, MI - MDT Interface, LVIF - MPLS Encap,
    EX - Extranet, A2 - Secondary Accept, MT - MDT Threshold Crossed,
    MA - Data MDT Assigned, LMI - mLDP MDT Interface, TMI - P2MP-TE MDT Interface
    IRMI - IR MDT Interface
(*,239.123.123.123) RPF nbr: 10.0.23.2 Flags: C RPF
  Up: 00:02:51
  Incoming Interface List
    GigabitEthernet0/0/0/0.23 Flags: A NS, Up: 00:02:51
```



```
  Outgoing Interface List
    GigabitEthernet0/0/0/0.130 Flags: F NS LI, Up: 00:02:51
!
RP/0/0/CPU0:R2#show mrib ipv4 route 239.123.123.123
!
(*,239.123.123.123) RPF nbr: 10.0.255.2 Flags: C RPF
  Up: 00:09:56
  Incoming Interface List
    Decapstunnel0 Flags: A, Up: 00:09:56
  Outgoing Interface List
    GigabitEthernet0/0/0/0.23 Flags: F NS, Up: 00:09:56
!
RP/0/0/CPU0:R1#show mrib ipv4 route 239.123.123.123
Wed Oct 28 10:25:46.930 UTC
No matching routes in MRIB route-DB
```

You see that R4's vrf Receiver has registered with R3 and RPT is built towards R2, which is our RP. Everything looks fine and we can test our network with multicast ping from our Sender.

```
RP/0/0/CPU0:R4#ping vrf Sender 239.123.123.123 source 10.110.0.4 count 5
Wed Oct 28 10:34:32.407 UTC
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 239.123.123.123, timeout is 2 seconds:
..
Reply to request 2 from 10.130.0.4, 9 ms
Reply to request 3 from 10.130.0.4, 19 ms
Reply to request 4 from 10.130.0.4, 29 ms
```

Here is the important hint. You have to mention the source of multicast or you can receive and error.

```
RP/0/0/CPU0:R4#ping vrf Sender 239.123.123.123 count 5
Wed Oct 28 10:34:16.548 UTC
Mdef cons get failed for VRF 0x60000002 - No such process
```

So take care about possible problem. As you see ping is going and the replies are being received from the correct IP. The topology for PIM also looks good.

```
RP/0/0/CPU0:R1#show mrib ipv4 route 239.123.123.123
(10.110.0.4,239.123.123.123) RPF nbr: 10.110.0.4 Flags: RPF
  Up: 00:04:28
  Incoming Interface List
    GigabitEthernet0/0/0/0.110 Flags: A, Up: 00:04:28
  Outgoing Interface List
    GigabitEthernet0/0/0/0.13 Flags: F NS, Up: 00:04:24
!
RP/0/0/CPU0:R2#show mrib ipv4 route 239.123.123.123
(*,239.123.123.123) RPF nbr: 10.0.255.2 Flags: C RPF
  Up: 00:24:11
  Incoming Interface List
    Decapstunnel0 Flags: A, Up: 00:24:11
  Outgoing Interface List
    GigabitEthernet0/0/0/0.23 Flags: F NS, Up: 00:24:11
(10.110.0.4,239.123.123.123) RPF nbr: 10.0.255.2 Flags: L RPF
  Up: 00:04:58
  Incoming Interface List
    Decapstunnel0 Flags: A, Up: 00:04:54
!
```



```
RP/0/0/CPU0:R3#sh mrib ipv4 route 239.123.123.123
(*,239.123.123.123) RPF nbr: 10.0.23.2 Flags: C RPF
  Up: 00:25:07
  Incoming Interface List
    GigabitEthernet0/0/0/0.23 Flags: A NS, Up: 00:25:07
  Outgoing Interface List
    GigabitEthernet0/0/0/0.130 Flags: F NS LI, Up: 00:25:07
(10.110.0.4,239.123.123.123) RPF nbr: 10.0.13.1 Flags: RPF
  Up: 00:05:34
  Incoming Interface List
    GigabitEthernet0/0/0/0.13 Flags: A, Up: 00:05:34
  Outgoing Interface List
    GigabitEthernet0/0/0/0.130 Flags: F NS, Up: 00:05:34
```

Case #8 – configuration of PIM-bidir for IPv4 at Cisco IOS XR

Very pleasant thing in working with IOS XR is that many annoying commands you don't have to enter. Like it was for IPv6 at IOS / IOS XE platforms, where all advanced features are on by default and you just need make some small pieces of configuration to get them working. At IOS XR it's so both for IPv4 and IPv6. The configuration of PIM-bidir consists of just two points at RP. There are configuration of the new interface and announcing it as a RP for bidirectional group.

```
RP/0/0/CPU0:R2(config-pim-default-ipv4)#show configuration
Wed Oct 28 10:48:07.919 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
ipv4 access-list R2_MCAST_BIDIR
 10 permit ipv4 any 238.0.0.0/8
!
interface Loopback21
 ipv4 address 10.0.255.21 255.255.255.255
 ipv6 address 2001:10:0:255::21/128
!
router ospf IPV4_CORE
 area 0
  interface Loopback21
   passive enable
  !
 !
!
router ospfv3 IPV6_CORE
 area 0
  interface Loopback21
   passive
  !
 !
!
router pim
 address-family ipv4
  bsr candidate-rp 10.0.255.21 group-list R2_MCAST_BIDIR priority 192 interval 30
bidir
 !
!
router pim
!
end
```


As with usual PIM mapping, it makes sense to check, what we see on other routers regarding this bidirectional group.

```
RP/0/0/CPU0:R1#show pim ipv4 rp mapping
Wed Oct 28 10:52:01.702 UTC
PIM Group-to-RP Mappings
Group(s) 238.0.0.0/8
  RP 10.0.255.21 (?), v2, bidir
    Info source: 10.0.12.2 (?), elected via bsr, priority 192, holdtime 75
      Uptime: 00:03:32, expires: 00:01:05
Group(s) 239.0.0.0/8
  RP 10.0.255.2 (?), v2
    Info source: 10.0.12.2 (?), elected via bsr, priority 192, holdtime 75
      Uptime: 01:11:26, expires: 00:01:05
!
RP/0/0/CPU0:R1#show mrib ipv4 route 238.0.0.0/8
(*,238.0.0.0/8) RPF nbr: 10.0.12.2 Flags: IF RPF P
  Up: 00:04:55
  Incoming Interface List
    Loopback0 Flags: A, Up: 00:04:54
    GigabitEthernet0/0/0/0.12 Flags: F A, Up: 00:04:54
    GigabitEthernet0/0/0/0.110 Flags: A, Up: 00:04:54
  Outgoing Interface List
    GigabitEthernet0/0/0/0.12 Flags: F A, Up: 00:04:54
```

We see that al the routers have information about mapping and they install the route to the group 238.0.0.0/8 pointing towards RP. Now it's time to add to our Receiver's configuration request to join a bidirectional group.

```
RP/0/0/CPU0:R4#show configuration
Wed Oct 28 10:57:52.001 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
router igmp
 vrf Receiver
  interface GigabitEthernet0/0/0/0.130
   join-group 238.123.123.123
  !
 !
!
router igmp
```

And what's going on further.

```
RP/0/0/CPU0:R3#show igmp groups gig 0/0/0/0.130
Wed Oct 28 10:59:20.395 UTC
IGMP Connected Group Membership
Group Address   Interface                 Uptime    Expires   Last Reporter
224.0.0.2       GigabitEthernet0/0/0/0.130    01:52:21  never     10.130.0.1
224.0.0.13      GigabitEthernet0/0/0/0.130    01:52:21  never     10.130.0.1
```



```
224.0.0.22      GigabitEthernet0/0/0/0.130    01:52:21  never     10.130.0.1
224.0.1.40      GigabitEthernet0/0/0/0.130    00:44:16  00:02:03  10.130.0.4
238.123.123.123 GigabitEthernet0/0/0/0.130    00:01:52  00:02:03  10.130.0.4
239.123.123.123 GigabitEthernet0/0/0/0.130    00:44:16  00:02:03  10.130.0.4
!
RP/0/0/CPU0:R3#show mrib ipv4 route
(*,238.0.0.0/8) RPF nbr: 10.0.23.2 Flags: IF RPF P
  Up: 00:11:14
  Incoming Interface List
    Loopback0 Flags: A, Up: 00:11:14
    GigabitEthernet0/0/0/0.13 Flags: A, Up: 00:11:14
    GigabitEthernet0/0/0/0.23 Flags: F A, Up: 00:11:14
    GigabitEthernet0/0/0/0.130 Flags: A, Up: 00:11:14
  Outgoing Interface List
    GigabitEthernet0/0/0/0.23 Flags: F A, Up: 00:11:14
(*,238.123.123.123) RPF nbr: 10.0.23.2 Flags: IA RPF Inherit: 238.0.0.0/8
  Up: 00:02:17
  Outgoing Interface List
    GigabitEthernet0/0/0/0.23 Flags: F, Up: 00:02:17
    GigabitEthernet0/0/0/0.130 Flags: F LI, Up: 00:02:17
!
```

At the RP we'll see also both these routes, whereas at R1 only the first one. Such behavior is the same as it was at IOS platform and as it must be according to the algorithm of PIM-bidir. Let's make a test from our Sender.

```
RP/0/0/CPU0:R4#ping vrf Sender 238.123.123.123 source 10.110.0.4 count 5
Wed Oct 28 11:02:59.740 UTC
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 238.123.123.123, timeout is 2 seconds:
Reply to request 0 from 10.130.0.4, 19 ms
Reply to request 1 from 10.130.0.4, 19 ms
Reply to request 2 from 10.130.0.4, 19 ms
Reply to request 3 from 10.130.0.4, 19 ms
Reply to request 4 from 10.130.0.4, 9 ms
```

The further observation of MRIB won't show any new groups, and all the traffic will be sent through RP.

Case #9 – configuration of PIM-SM for IPv6 at Cisco XR

I'd say that it's the easiest part of configuration. If you look into MRIB just after activation of the multicasting, you'll find the IP range which is reserved for SSM.

```
RP/0/0/CPU0:R1#show mrib ipv4 route 232.0.0.0/8
(*,232.0.0.0/8) Flags: D P
  Up: 02:01:48
```

Everything what we need to do is just to register our Receiver with the last hop router.

```
RP/0/0/CPU0:R4(config-igmp-Receiver-if)#show configuration
Wed Oct 28 11:10:01.021 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
router igmp
 vrf Receiver
```



```
  interface GigabitEthernet0/0/0/0.130
   join-group 232.123.123.123 10.110.0.4
  !
 !
!
router igmp
!
end
```

That's it. We are ready to receive a multicast data from the source with IP address 10.110.0.4. We can check the path.

```
RP/0/0/CPU0:R3#show igmp groups 232.123.123.123 gig 0/0/0/0.130 detail
Wed Oct 28 11:12:36.770 UTC
Interface:      GigabitEthernet0/0/0/0.130
Group:          232.123.123.123
Uptime:         00:02:32
Router mode:    INCLUDE
Host mode:      INCLUDE
Last reporter:  10.130.0.4
Group source list:
  Source Address   Uptime    Expires   Fwd  Flags
  10.110.0.4       00:02:32  00:01:48  Yes  Remote 4
!
RP/0/0/CPU0:R3#show mrib ipv4 route 232.123.123.123
(10.110.0.4,232.123.123.123) RPF nbr: 10.0.13.1 Flags: RPF
  Up: 00:02:50
  Incoming Interface List
    GigabitEthernet0/0/0/0.13 Flags: A, Up: 00:02:50
  Outgoing Interface List
    GigabitEthernet0/0/0/0.130 Flags: F NS LI, Up: 00:02:50
!
RP/0/0/CPU0:R1#show mrib ipv4 route 232.123.123.123
(10.110.0.4,232.123.123.123) RPF nbr: 10.110.0.4 Flags: RPF
  Up: 00:03:14
  Incoming Interface List
    GigabitEthernet0/0/0/0.110 Flags: A, Up: 00:03:14
  Outgoing Interface List
    GigabitEthernet0/0/0/0.13 Flags: F NS, Up: 00:03:14
```

In this table you don't see any mentions about SSM or other group-specific attributes. They can be seen in another place.

```
RP/0/0/CPU0:R3#show pim ipv4 topology
Wed Oct 28 11:14:49.731 UTC

IP PIM Multicast Topology Table
Entry state: (*/S,G)[RPT/SPT] Protocol Uptime Info
Entry flags: KAT - Keep Alive Timer, AA - Assume Alive, PA - Probe Alive
    RA - Really Alive, IA - Inherit Alive, LH - Last Hop
    DSS - Don't Signal Sources,  RR - Register Received
    SR - Sending Registers, SNR - Sending Null Registers
    E - MSDP External, EX - Extranet
    MFA - Mofrr Active, MFP - Mofrr Primary, MFB - Mofrr Backup
    DCC - Don't Check Connected, ME - MDT Encap, MD - MDT Decap
    MT - Crossed Data MDT threshold, MA - Data MDT Assigned
    SAJ - BGP Source Active Joined, SAR - BGP Source Active Received,
    SAS - BGP Source Active Sent, IM - Inband mLDP, X - VxLAN
```



```
Interface state: Name, Uptime, Fwd, Info
Interface flags: LI - Local Interest, LD - Local Dissinterest,
    II - Internal Interest, ID - Internal Dissinterest,
    LH - Last Hop, AS - Assert, AB - Admin Boundary, EX - Extranet,
    BGP - BGP C-Multicast Join, BP - BGP Source Active Prune,
    MVS - MVPN Safi Learned, MV6S - MVPN IPv6 Safi Learned

(*,224.0.1.40) DM Up: 02:07:50 RP: 0.0.0.0
JP: Null(never) RPF: Null,0.0.0.0 Flags: LH DSS
  Loopback0                   02:07:50  off LI II LH
  GigabitEthernet0/0/0/0.130  00:59:45  off LI LH

(10.110.0.4,232.123.123.123)SPT SSM Up: 00:04:45
JP: Join(00:00:04) RPF: GigabitEthernet0/0/0/0.13,10.0.13.1 Flags:
  GigabitEthernet0/0/0/0.130  00:04:45  fwd LI LH

(*,238.123.123.123) BD Up: 00:17:22 RP: 10.0.255.21
JP: Join(00:00:24) RPF: GigabitEthernet0/0/0/0.23,10.0.23.2 Flags: LH DSS
  GigabitEthernet0/0/0/0.130  00:17:22  fwd LI LH

(*,239.123.123.123) SM Up: 00:59:45 RP: 10.0.255.2
JP: Join(00:00:24) RPF: GigabitEthernet0/0/0/0.23,10.0.23.2 Flags: LH
  GigabitEthernet0/0/0/0.130  00:59:45  fwd LI LH
```

Actually in this output you can also see information about bidirectional capability of the group 238.123.123.123 as well.

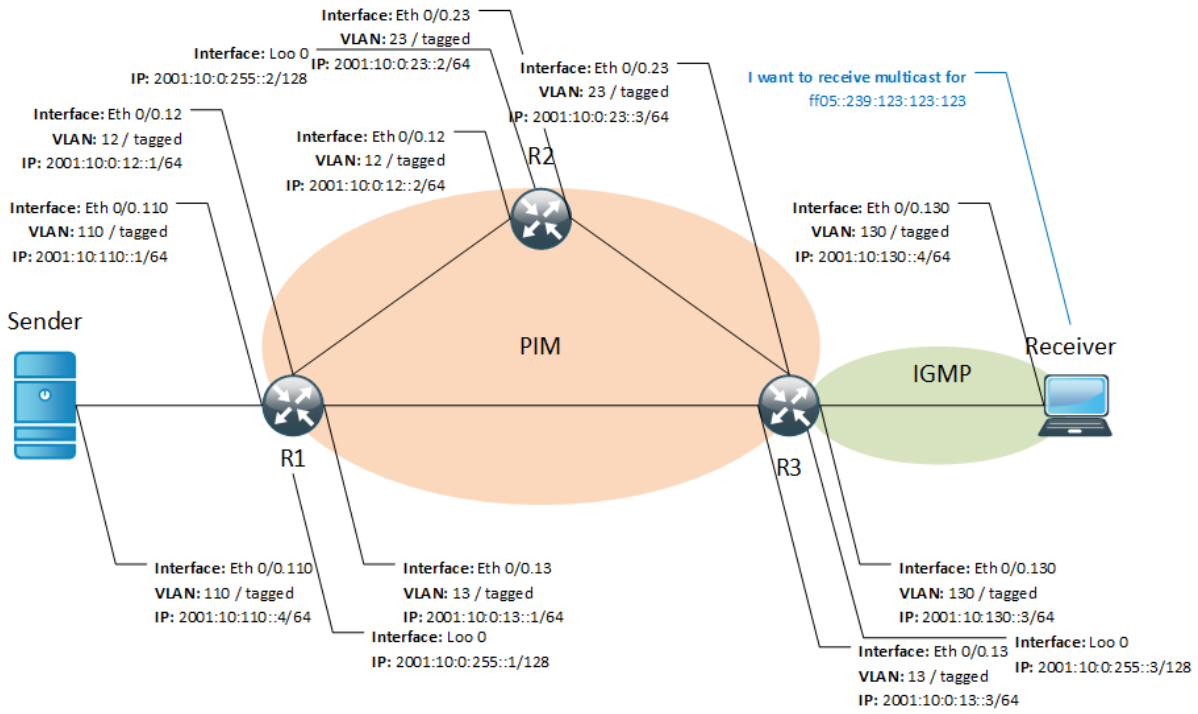
Summary for Cases 7, 8, 9 (IPv4 multicasting on Cisco IOS XR)

Comparing to IOS / IOS XE, you can see a significant simplification of multicasting configuration at IOS XR platform. The approach here is more structured and doesn't need for additional features activation, as they are on by default.

You can find the configuration file for IPv4 multicasting at IOS XR in Appendix E.

Case #10 – configuration of PIM-SM for IPv6 at Cisco IOS XR

By default the IPv6 unicast routing is activated at Cisco IOS XR platform, that's why you just need to configure and verify IPv6 connectivity between all parts of your network. Just to remind you the addressing and the topology of our lab we provide the scheme.



IPv6 addressing for multicasting

After establishing the connectivity for IPv6 the next step will be activating of multicasting for it. You have mentioned in the previous cases for IOS XR that we've made a lot of configuration in address families. That's one of the architectural concepts to simplify configuration and operation. So we just need add the new address family for IPv6 to configuration of multicasting. You remember that PIM and MLD will be activated simultaneously automatically.

```
RP/0/0/CPU0:R2#show configuration commit changes last 1
Wed Oct 28 11:36:52.318 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
multicast-routing
 address-family ipv6
  interface all enable
 !
!
multicast-routing
!
End
!
RP/0/0/CPU0:R1#show pim ipv6 interface
Wed Oct 28 11:30:41.893 UTC
PIM interfaces in VRF default
Interface                  PIM  Nbr    Hello  DR
                                Count  Intvl  Prior
Loopback0                   on   1      30     1
    Primary Address : fe80::58d1:1bff:fe5b:9f6d
                  DR : this system
GigabitEthernet0/0/0/0.12   on   2      30     1
    Primary Address : fe80::a00:27ff:fe20:b1b
                  DR : fe80::a00:27ff:feba:b01b
GigabitEthernet0/0/0/0.13   on   2      30     1
    Primary Address : fe80::a00:27ff:fe20:b1b
                  DR : this system
```



```
GigabitEthernet0/0/0/0.110  on   1     30     1
    Primary Address : fe80::a00:27ff:fe20:b1b
                 DR : this system

!
RP/0/0/CPU0:R1#show ml
mlacp  mld  mlib
RP/0/0/CPU0:R1#show mld interface
Loopback0 is up, line protocol is up
  Internet address is fe80::58d1:1bff:fe5b:9f6d
  MLD is enabled on interface
  Current MLD version is 2
  MLD query interval is 125 seconds
  MLD querier timeout is 255 seconds
  MLD max query response time is 10 seconds
  Last member query response interval is 1 seconds
  MLD activity: 3 joins, 0 leaves
  MLD querying router is fe80::58d1:1bff:fe5b:9f6d (this system)
  Time elapsed since last query sent 00:00:36
  Time elapsed since IGMP router enabled 00:07:16
  Time elapsed since last report received 00:00:34
GigabitEthernet0/0/0/0.12 is up, line protocol is up
!
GigabitEthernet0/0/0/0.13 is up, line protocol is up
!
GigabitEthernet0/0/0/0.110 is up, line protocol is up
!
```

The next and the last step in the configuration of PIM-SM is the configuring the RP. And here comes very good advantage of IOS XR. The syntax is the same as for IPv4.

```
RP/0/0/CPU0:R2#show configuration commit changes last 1
Wed Oct 28 11:44:58.265 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
ipv6 access-list R2_IPV6_MCAST_SM
 10 permit ipv6 any ff05::239:0:0:0/80
!
router pim
 address-family ipv6
  bsr candidate-bsr 2001:10:0:255::2 hash-mask-len 128 priority 1
  bsr candidate-rp 2001:10:0:255::2 group-list R2_IPV6_MCAST_SM priority 192
interval 30
 !
!
router pim
!
end
```

At the Cisco IOS XR platform you have the possibility to check mapping of groups with the same command as for ipv4 or with the command, which was used at Cisco IOS XE. You can use any you like.

```
RP/0/0/CPU0:R1#show pim ipv6 group-map
IP PIM Group Mapping Table
(* indicates group mappings being used)
(+ indicates BSR group mappings active in MRIB)
```



```
!
ff05::239:0:0:0/80*                                     SM    bsr+     0
  RP: 2001:10:0:255::2
  RPF: Gi0/0/0/0.12,fe80::a00:27ff:feba:b01b
!
RP/0/0/CPU0:R1#show pim ipv6 rp mapping
PIM Group-to-RP Mappings
!
Group(s) ff05::239:0:0:0/80
  RP 2001:10:0:255::2 (?), v2
    Info source: fe80::a00:27ff:feba:b01b (?), elected via bsr, priority 192,
holdtime 75
      Uptime: 00:02:45, expires: 00:01:14
```

So in both commands you see the RP and the interface through which this info was received. Now we need our Receiver to register with R3. Remember that we have to enable multicasting in corresponding VRF in order to bring up MLD.

```
RP/0/0/CPU0:R4(config-mld-Receiver-if)#show configuration
Wed Oct 28 15:05:19.020 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
multicast-routing
 vrf Receiver
  address-family ipv6
   interface all enable
  !
 !
!
multicast-routing
!
router mld
 vrf Receiver
  interface GigabitEthernet0/0/0/0.130
   join-group ff05::239:123:123:123
  !
 !
!
router mld
!
End
```

Now we need check, whether it's registered and the RPT is built.

```
RP/0/0/CPU0:R3#show mld groups gigabitEthernet 0/0/0/0.130
Wed Oct 28 15:09:16.497 UTC
MLD Connected Group Membership
GigabitEthernet0/0/0/0.130
Group Address : ff02::2
Last Reporter : fe80::a00:27ff:fe01:2bef
       Uptime : 00:12:53
      Expires : never
Group Address : ff02::d
Last Reporter : fe80::a00:27ff:fe01:2bef
       Uptime : 00:12:53
      Expires : never
Group Address : ff02::16
Last Reporter : fe80::a00:27ff:fe01:2bef
```



```
       Uptime : 00:12:53
      Expires : never
Group Address : ff05::239:123:123:123
Last Reporter : fe80::a00:27ff:fee1:f9a
       Uptime : 00:00:20
      Expires : 00:04:00
!
RP/0/0/CPU0:R3#show mrib ipv6 route
!
(*,ff05::239:123:123:123)
  RPF nbr: fe80::a00:27ff:feba:b01b Flags: C RPF
  Up: 00:00:56
  Incoming Interface List
    GigabitEthernet0/0/0/0.23 Flags: A NS, Up: 00:00:56
  Outgoing Interface List
    GigabitEthernet0/0/0/0.130 Flags: F NS LI, Up: 00:00:56
!
```

We see that group is successfully registered and RPT is built. That's what we need and now we test our connectivity. Actually we've faced the same problem regarding ping from vrf for IPv6. It might be just the bug of the Cisco IOS XRv, but still it adds some inconvenience. So we've just removed vrf Sender and configure its interface and routes in the default VRF which is also called global. Let's make a ping test.

Comparing to IPv6 ping at Cisco IOS / IOS XE platform, you don't have to mention outgoing interface for you ping.

```
RP/0/0/CPU0:R4#ping ff05::239:123:123:123 count 5
Wed Oct 28 15:25:14.748 UTC
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to ff05::239:123:123:123, timeout is 2 seconds:
Reply to request 0 from 2001:10:130::4, 9 ms
Reply to request 1 from 2001:10:130::4, 9 ms
Reply to request 2 from 2001:10:130::4, 9 ms
Reply to request 3 from 2001:10:130::4, 9 ms
Reply to request 4 from 2001:10:130::4, 29 ms
```

There is usual check of SPT.

```
RP/0/0/CPU0:R3#show mrib ipv6 route
!
(2001:10:110::4,ff05::239:123:123:123)
  RPF nbr: fe80::a00:27ff:fe20:b1b Flags: RPF
  Up: 00:04:00
  Incoming Interface List
    GigabitEthernet0/0/0/0.13 Flags: A NS, Up: 00:04:00
  Outgoing Interface List
    GigabitEthernet0/0/0/0.130 Flags: F NS, Up: 00:04:00
!
RP/0/0/CPU0:R1#show mrib ipv6 route ff05::239:123:123:123
!
(2001:10:110::4,ff05::239:123:123:123)
  RPF nbr: 2001:10:110::4 Flags: RPF
  Up: 00:05:01
  Incoming Interface List
    GigabitEthernet0/0/0/0.110 Flags: A NS, Up: 00:00:00
```



```
  Outgoing Interface List
    GigabitEthernet0/0/0/0.12 Flags: F NS, Up: 00:00:00
```

Case #11 – configuration of PIM-bidir for IPv6 at Cisco IOS XR

You just have to configure at the RP an additional interface with IPv6 address and announce it with the corresponding PIM mapping. The procedure is 100% the same as for IPv4.

```
RP/0/0/CPU0:R2(config-pim-default-ipv6)#do show configuration commit changes 1$
Wed Oct 28 15:34:12.564 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
ipv6 access-list R2_IPV6_MCAST_BIDIR
 10 permit ipv6 any ff05::238:0:0:0/80
!
router pim
 address-family ipv6
  bsr candidate-rp 2001:10:0:255::21 group-list R2_IPV6_MCAST_BIDIR priority 192
interval 30 bidir
 !
!
router pim
!
end
```

Let's check our MRIB and mapping table.

```
RP/0/0/CPU0:R1#show pim ipv6 rp mapping
Group(s) ff05::238:0:0:0/80
  RP 2001:10:0:255::21 (?), v2, bidir
    Info source: fe80::a00:27ff:feba:b01b (?), elected via bsr, priority 192,
holdtime 75
!
RP/0/0/CPU0:R1#show mrib ipv6 route
!
(*,ff05::238:0:0:0/80)
  RPF nbr: fe80::a00:27ff:feba:b01b Flags: IF RPF P
  Up: 00:32:31
  Incoming Interface List
    Loopback0 Flags: A, Up: 00:00:25
    GigabitEthernet0/0/0/0.12 Flags: F A, Up: 00:00:25
    GigabitEthernet0/0/0/0.13 Flags: A, Up: 00:00:25
    GigabitEthernet0/0/0/0.110 Flags: A, Up: 00:00:25
  Outgoing Interface List
    GigabitEthernet0/0/0/0.12 Flags: F A, Up: 00:00:25
```

We see our bidirectional group as it was in IPv4 bidirectional. But do you remember that at regular IOS platform we didn't see this group? At Cisco IOS XR you see them. Let's signal the interest from R4's vrf Sender to receive the traffic for the group ff05::238:123:123:123.

```
RP/0/0/CPU0:R4#show configuration commit changes last 1
Wed Oct 28 15:56:18.050 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
router mld
 vrf Receiver
  interface GigabitEthernet0/0/0/0.130
```



```
   join-group ff05::238:123:123:123
  !
 !
!
router mld
!
end
```

We see that right now we have the RPT from R3 to R2. As well there is information in the PIM topology table about bidirectional capability of our group.

```
RP/0/0/CPU0:R3#show mld groups gig 0/0/0/0.130
Group Address : ff05::238:123:123:123
Last Reporter : fe80::a00:27ff:fee1:f9a
       Uptime : 00:02:02
      Expires : 00:03:27
!
RP/0/0/CPU0:R3#show mrib ipv6 route ff05::238:123:123:123
(*,ff05::238:123:123:123)
  RPF nbr: fe80::a00:27ff:feba:b01b Flags: IA RPF Inherit: ff05::238:0:0:0/80
  Up: 00:11:52
  Outgoing Interface List
    GigabitEthernet0/0/0/0.23 Flags: F, Up: 00:02:03
    GigabitEthernet0/0/0/0.130 Flags: F LI, Up: 00:11:52
!
RP/0/0/CPU0:R3#show pim ipv6 topology
(*,ff05::238:123:123:123)
BD Up: 00:12:32 JP: Join(00:01:04) Flags: LH DSS
RP: 2001:10:0:255::21
RPF: GigabitEthernet0/0/0/0.23,fe80::a00:27ff:feba:b01b
  GigabitEthernet0/0/0/0.130  00:12:32  fwd LI LH
!
```

ICMP test shows that everything works good form our Sender.

```
RP/0/0/CPU0:R4#ping ff05::238:123:123:123 count 5
Wed Oct 28 16:11:13.009 UTC
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to ff05::238:123:123:123, timeout is 2 seconds:
Reply to request 0 from 2001:10:130::4, 29 ms
Reply to request 1 from 2001:10:130::4, 9 ms
Reply to request 2 from 2001:10:130::4, 39 ms
Reply to request 3 from 2001:10:130::4, 19 ms
Reply to request 4 from 2001:10:130::4, 29 ms
```

Case #12 – configuration of PIM-SSM for IPv6 at Cisco IOS XR

As with IPv4 multicasting at this platform, IPv6 PIM-SSM is the easiest case from the configuration point of view. We just need to register our Receiver with the last hop router in the corresponding group (ff33::/32 – ff3f::/32), check the SPT and make an ICMP test.

```
RP/0/0/CPU0:R4(config-mld-Receiver-if)#show configuration
Wed Oct 28 16:17:52.942 UTC
Building configuration...
!! IOS XR Configuration 5.3.2
router mld
 vrf Receiver
```



```
  interface GigabitEthernet0/0/0/0.130
   join-group ff35::232:123:123:123 2001:10:110::4
  !
 !
!
router mld
!
end
```

At the R3 and R1 we see predictable picture.

```
RP/0/0/CPU0:R3#show mld groups ff35::232:123:123:123 gigabitEthernet 0/0/0/0.130
Interface:      GigabitEthernet0/0/0/0.130
Group:          ff35::232:123:123:123
Uptime:         00:00:03
Router mode:    INCLUDE
Host mode:      INCLUDE
Last reporter:  fe80::a00:27ff:fee1:f9a
Group source list:
  Source Address                          Uptime    Expires   Fwd  Flags
  2001:10:110::4                        00:00:03  00:04:17  Yes  Remote 4
!
RP/0/0/CPU0:R3# show mrib ipv6 route ff35::232:123:123:123
(2001:10:110::4,ff35::232:123:123:123)
  RPF nbr: fe80::a00:27ff:fe20:b1b Flags: RPF
  Up: 00:00:28
  Incoming Interface List
    GigabitEthernet0/0/0/0.13 Flags: A, Up: 00:00:28
  Outgoing Interface List
    GigabitEthernet0/0/0/0.130 Flags: F NS LI, Up: 00:00:28
!
RP/0/0/CPU0:R3#show pim ipv6 topology ff35::232:123:123:123
(2001:10:110::4,ff35::232:123:123:123) SPT
SSM Up: 00:00:56 JP: Join(00:00:46) Flags:
RPF: GigabitEthernet0/0/0/0.13,fe80::a00:27ff:fe20:b1b
  GigabitEthernet0/0/0/0.130  00:00:56  fwd LI LH
!
RP/0/0/CPU0:R1#show mrib ipv6 route ff35::232:123:123:123
(2001:10:110::4,ff35::232:123:123:123)
  RPF nbr: 2001:10:110::4 Flags: RPF
  Up: 00:01:34
  Incoming Interface List
    GigabitEthernet0/0/0/0.110 Flags: A, Up: 00:01:34
  Outgoing Interface List
    GigabitEthernet0/0/0/0.13 Flags: F NS, Up: 00:01:34
```

We've reached the final point of our multicast journey. There is final ICMPv6 ping test in our article.

```
RP/0/0/CPU0:R4#ping ff35::232:123:123:123 count 5
Wed Oct 28 16:24:06.356 UTC
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to ff35::232:123:123:123, timeout is 2 seconds:
Reply to request 0 from 2001:10:130::4, 9 ms
Reply to request 1 from 2001:10:130::4, 19 ms
Reply to request 2 from 2001:10:130::4, 29 ms
Reply to request 3 from 2001:10:130::4, 29 ms
Reply to request 4 from 2001:10:130::4, 29 ms
```


Hurray! Everything works well in our network. You can look into configuration for IOS XR that covers both IPv4 and IPv6 multicasting at the Appendix F.

Summary

In this article we've described the operation of multicasting. Starting with the theory and ending with configuration and verification we've covered almost all the cases which you can meet. We've described the BSR as a main mechanism for distribution information about the RP and its mapping due to its vendor neutrality. It's a standard, that's why you can implement this solution in multivendor network. As well we provide the same level in-depth overview of IPv6 multicasting as nowadays we are in the process of the shift to this technology. We can outline different approach for configuration that Cisco IOS XR platform has. It's easier to configure multicasting both for IPv4 and IPv6 there due to same commands and common framework. On the other hand we can see many differences between configurations of multicasting at Cisco IOS / IOS XE platform. It seems that such differences have historical roots and shows the development of regular IOS in progress as IPv4 was introduced much earlier than IPv6.

Multicasting is very important and interesting technology which penetration in data transmission will grow with development of IoT and collaborative technologies. I hope that now you understand it better. Thanks for your time and I'll be appreciate to hear feedback from you.

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