IP Network eBook Series

BIERv6

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Preface

Author Introduction

Li Chen: Documentation engineer for Huawei data communication products. She joined Huawei in 2019 and currently develops documentation for multicast features, helping to promote related technologies.

Xuesong Geng: Senior engineer in Huawei Data Communication Standard & Patent Dept. As an expert in Bit Index Explicit Replication (BIER) standards, she joined Huawei in 2016 and currently drafts and promotes Bit Index Explicit Replication IPv6 Encapsulation (BIERv6) standards in standards organizations, such as the Internet Engineering Task Force (IETF) and China Communications Standards Association (CCSA).

About This Book

Centering on BIERv6 — a new multicast technology — this book is comprised of five parts following a brief overview. The first part describes the limitations of conventional multicast technologies in new multicast scenarios, the background of the BIERv6 technology, and its historical mission. The second part elaborates on the main business value that BIERv6 technology brings to service providers. The third part briefly introduces the fundamentals of BIERv6 to help you understand the design ideas and technical advantages of BIERv6. The fourth part explores the application prospects of BIERv6 in the industry, and the last part looks at how BIERv6 will develop in the future.

Intended Audience

This book is intended for network planning engineers, network design engineers, mid- and senior-level managers at service providers and enterprises, and readers who want to understand cutting-edge IP network technologies. Because BIERv6 involves many network concepts, readers of this book should be familiar with IP network basics, such as the IP network architecture, conventional multicast technologies, IP routing, and VPN technologies.

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Chapter 1

BIERv6 Overview

Bit Index Explicit Replication IPv6 Encapsulation (BIERv6) is a new multicast solution that forwards multicast services, such as IPTV, video conferencing, remote education, telemedicine, and online live telecasting, in a much more efficient manner than conventional solutions.

BIERv6 enables the ingress to encapsulate the set of nodes for which each packet is destined into the packet header as a BitString. Each packet is then replicated and forwarded based on this BitString. Transit nodes therefore do not need to explicitly establish a Multicast Distribution Tree (MDT) for each multicast flow or maintain per-flow states.

Because BIERv6 leverages BIER and native IPv6 packet forwarding and does not require transit nodes to explicitly establish MDTs or maintain per-flow states, it can be seamlessly integrated into SRv6 networks, reducing protocol complexity.

Chapter 2

BIERv6 Background

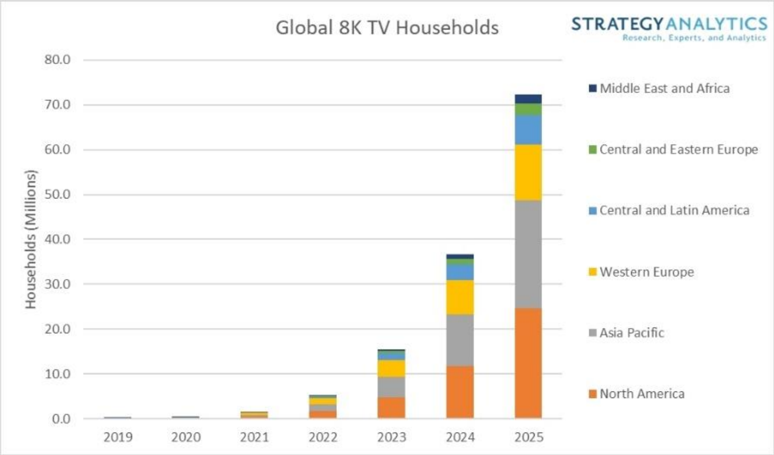
IP multicast implements Point-to-Multipoint (P2MP) real-time data transmission on IP networks. Based on the usage scope of IP multicast protocols, they are classified as either multicast member management protocols or multicast routing protocols. The former type of protocols run between a host and routing device and include Internet Group Management Protocol (IGMP) and Multicast Listener Discovery (MLD), whereas the latter type of protocols run between routing devices and include Protocol Independent Multicast (PIM), Multicast VPN (MVPN), and BIER, as well as the next-generation protocol — BIERv6. Given the new direction that multicast technologies are taking, what are the limitations of conventional multicast routing technologies? And why is BIERv6 chosen as the next-generation multicast routing technology? This chapter answers these questions by describing the application trends of multicast technologies and the development of conventional multicast technologies.

2.1 Application Trends of Multicast Technologies

Video traffic — including video calls, video sharing, and video conferences — accounts for a large proportion of today's Internet traffic. Furthermore, High Definition (HD) videos and new interactive videos are likely to become the main forms of social networking in the future, and media is gradually evolving to Virtual Reality (VR) and Augmented Reality (AR). These new services pose new requirements on network bandwidth and user experience.

In terms of home broadband services, the demand for 3D and 4K TVs is exploding, and the IPTV market share continues to grow. Based on a service provider's fixed broadband network and service platform, IPTV provides multiple interactive services for users through Set-Top Boxes (STBs) or other digital terminals that possess audio and video encoding and decoding capabilities by integrating various technologies, such as Internet, multimedia, and communication technologies. As shown in Figure 2-1, a growing number of households worldwide will adopt 8K TVs over the next few years, reaching 72 million by 2025 according to Strategy Analytics. In addition, service providers are focusing more attention on introducing new video services, with interactive multimedia regarded as a new growth opportunity for IPTV to boost the IPTV market.

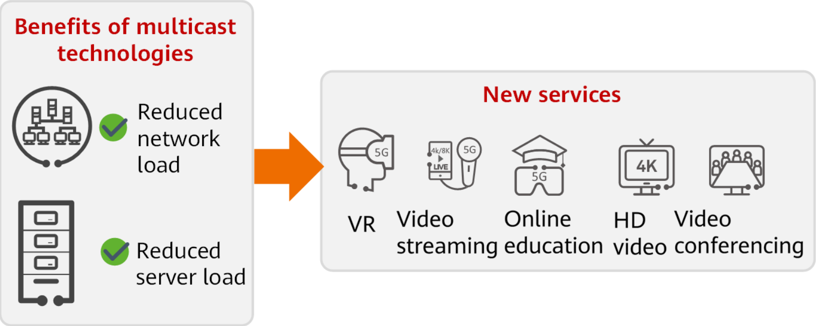
Figure 2-1 Predicted number of households worldwide with 8K TVs



Data source: Strategy Analytics

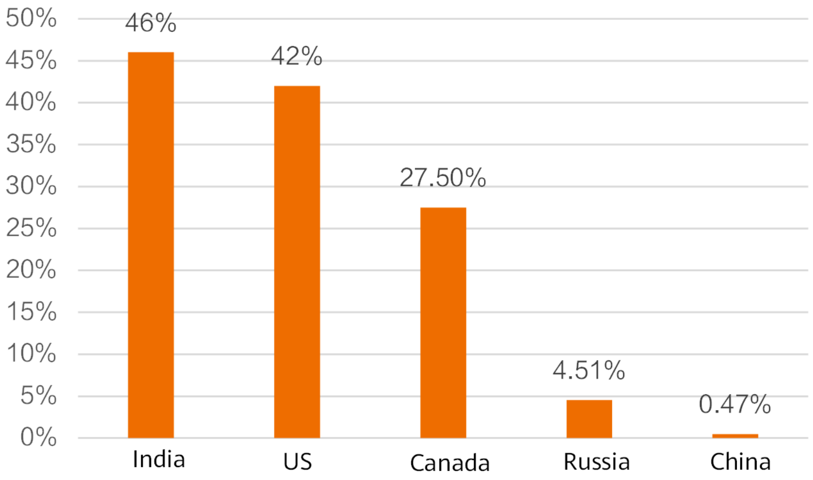
By implementing P2MP data forwarding, multicast reduces the volume of redundant traffic and load on the network. It also reduces the load on the application platform's servers and CPUs, and minimizes the impact on the multicast source as the number of users increases. These characteristics enable multicast to offer unique benefits in various scenarios, such as video streaming, online education, video conferencing, and HD video scenarios, as shown in Figure 2-2.

Figure 2-2 Benefits of multicast technologies for new services



While the potential applications of multicast are booming, the trend of adopting IPv6-based networks becomes more and more prominent. As traditional IPv4 applications continue to expand, the number of nodes and connections that the network needs to support will increase to an unprecedented scale. However, the IPv4 address space is limited and therefore cannot meet the address requirements of devices on the network. This is where IPv6 comes into play, as it provides a huge address space, which supports large-scale expansion and connections. Worldwide, many countries are vigorously developing IPv6 networks, and the number of IPv6 users is increasing rapidly. By June 2020, the global IPv6 penetration rate had exceeded 32%; IPv6 accounted for more than 40% of deployments in parts of regions, such as Europe, America, Asia, and Oceania; and 2697 websites globally had received IPv6 Enabled WWW Logo certification. Figure 2-3 shows the percentage of IPv6 users in several countries.

Figure 2-3 Percentage of IPv6 users in June 2020



Data source: 2020 Global IPv6 Support White Paper

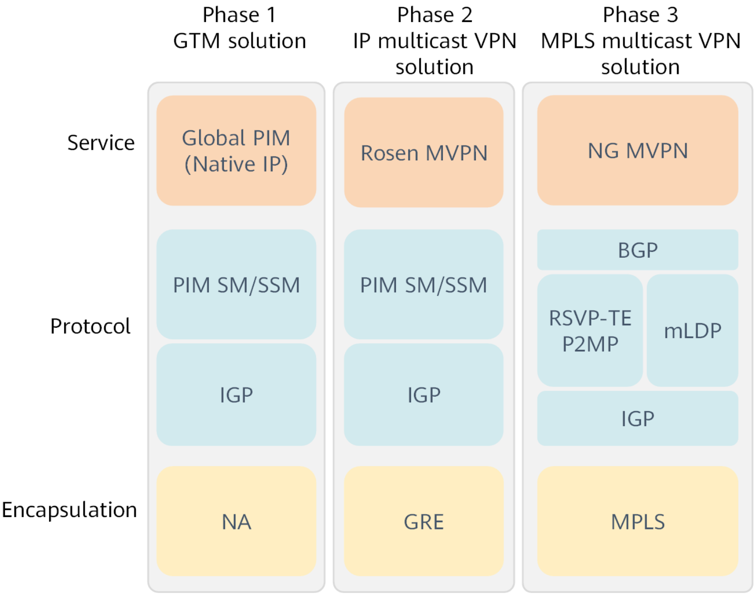
As IPv6 becomes more widely adopted and new service scenarios require higher bandwidth and better user experience, multicast technologies on IPv6 networks need to continuously evolve in order to keep pace with new service scenarios and technology development trends.

2.2 Development of Conventional Multicast Technologies

History of Multicast Technology Development

Figure 2-4 shows the history of multicast technology development, which involves three key phases: the Global Table Multicast (GTM) solution, IP multicast VPN solution, and MPLS multicast VPN solution phases.

Figure 2-4 Development phases of multicast technologies



In the first phase — the GTM solution phase — PIM multicast is used on the public IP network. PIM is independent of the type of unicast routing protocol used on the network and, as long as reachable unicast routes exist between network devices, it can establish an MDT (forwarding table) using these routes to guide multicast data forwarding. The MDT changes dynamically as users join and leave multicast groups.

In the second phase — the IP multicast VPN solution phase — Rosen MVPN is used for multicast VPN services, and PIM is used for GTM. Rosen MVPN transmits multicast data and control messages of PIM C-instances over a public network to remote VPN sites. Specifically, PIM protocol messages are directly forwarded through tunnels without being processed by BGP extension, and all VPN protocol and data packets are transparently transmitted over the public network.

In the third phase — the MPLS multicast VPN solution phase — NG MVPN is adopted. NG MVPN, which is based on MPLS tunneling technologies, uses BGP to transmit C-multicast routes and utilizes MPLS P2MP tunnels to carry C-multicast traffic. PIM messages are converted into BGP MVPN messages and transmitted between PEs. MVPN data packets are quickly forwarded based on the MPLS label forwarding information bases (FIBs) on devices along the P2MP tunnel on the bearer network.

Limitations of Existing Multicast Technologies

The limitations of existing multicast technologies are becoming more obvious as new services continue to emerge, restricting the large-scale application of multicast on the network. For example:

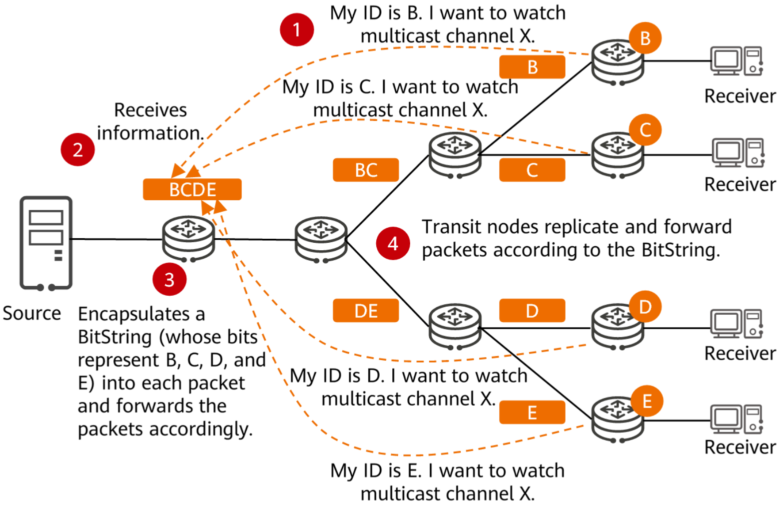
1. Complex protocols and poor scalability: Transit nodes maintain per-flow states and use multicast routing protocols (such as PIM, mLDP, and RSVP-TE P2MP) to create MDTs, requiring complex control signaling on the network. In addition, creating MDTs consumes a large number of resources, such as memory and CPU resources, hindering large-scale network deployment.
2. Low reliability and poor user experience: More multicast flows on a network mean that more MDTs need to be established, leading to higher network overheads. Because post-fault convergence is subject to the number of multicast states, service re-convergence takes longer to complete if many multicast flows exist. As a result, user experience is severely affected for services that require low latency and fast convergence.
3. Difficult deployment and O&M: The network needs to support various protocols, such as PIM, mLDP, and RSVP-TE P2MP. As such, network and service deployment and O&M are complex.

2.3 From BIER to BIERv6

BIER

As mentioned earlier, conventional multicast technology solutions such as GTM and IP multicast VPN have a number of limitations. To address these issues, the Bit Index Explicit Replication (BIER) technology was proposed. BIER does not depend on PIM, mLDP, or RSVP-TE. Instead, it instructs devices to replicate and forward multicast packets to specified receiver PEs according to the BitString encapsulated into the BIER header of each BIER packet. Each bit in the BitString represents a specific receiver node. Transit nodes replicate and forward packets based on the BitString and do not need to be aware of multicast group states. In this way, BIER implements multicast traffic forwarding without the need for maintaining multicast group states, offering a brand-new multicast forwarding architecture. Figure 2-5 shows the fundamentals of BIER.

Figure 2-5 Fundamentals of BIER

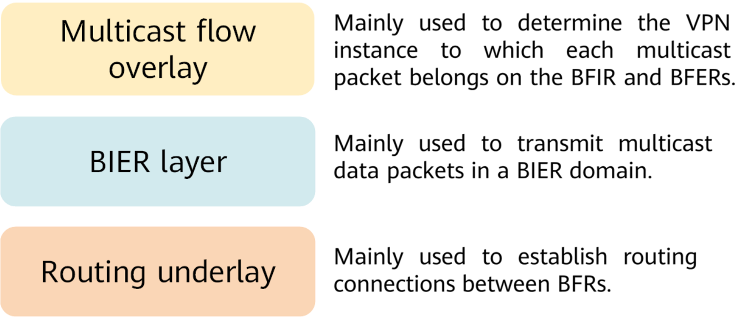


Network domains that support BIER forwarding are referred to as BIER domains. A BIER domain can be divided into multiple sub-domains, and each BIER domain contains at least one sub-domain. A router that supports BIER forwarding in a domain is called a Bit Forwarding Router (BFR). In a BIER domain, BFRs are also called Bit Forwarding Ingress Routers (BFIRs) or Bit Forwarding Egress Routers (BFERs) when they function as ingress or egress routers, respectively.

A BFIR is a source node in a BIER domain, whereas a BFER is a destination node in a BIER domain. BFIRs and BFERs are collectively referred to as edge BFRs. Each edge BFR has a dedicated BFR-ID, which is an integer ranging from 1 to 65535. For example, each edge node on a network with 256 such nodes needs to be configured with a unique value from 1 to 256. In this case, a 256-bit (32-byte) BitString represents the set of destination nodes, and the position or index of each bit in the BitString indicates a specific edge node.

BIER adopts a hierarchical network architecture, which is comprised of the routing underlay, BIER layer, and multicast flow overlay. These layers work together to forward multicast traffic. Figure 2-6 shows the architecture.

Figure 2-6 BIER architecture



The functions of each layer are described as follows:

- Routing underlay: It determines the next-hop Bit Forwarding Router (BFR) of each BFR, establishes adjacencies between BFRs, and generates the Bit Index Forwarding Table (BIFT) to implement network interworking. An IGP such as IS-IS or OSPF is typically used as the underlay routing protocol, but some networks may instead use BGP.
- BIER layer: It transmits multicast data packets in a BIER domain, advertises BFR information, and consists of the control plane (which advertises BIER information) and the data plane (which processes BIER data packets). On this layer, the Bit Forwarding Ingress Router (BFIR) encapsulates a BIER header into each multicast packet, transit BFRs replicate and forward BIER packets and modify BIER headers, and Bit Forwarding Egress Routers (BFERs)

decapsulate received BIER packets and distribute them to the processing module on the multicast flow overlay.

- Multicast flow overlay: It processes the multicast flow to which each multicast data packet belongs. The BFIR and BFERs determine the VPN instance to which each multicast packet belongs. Specifically, the BFIR determines the BFERs to which the multicast flow received from outside the BIER domain is to be sent. After receiving a BIER packet, each BFER determines the VPN or public network instance to which the packet belongs, and then replicates and forwards the inner multicast packet according to the VPN or public network instance.

Conventional multicast requires a protocol such as PIM for establishing MDTs whereas BIER does not. On a network running BIER, transit nodes, which do not have multicast services, do not need to establish an MDT for each multicast flow, eliminating associated overheads. However, BIER has some limitations in certain application scenarios.

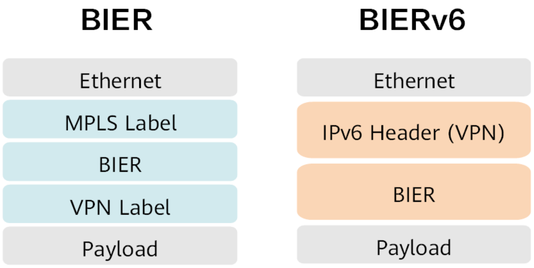
For example, BIER depends on MPLS and is therefore applicable to MPLS networks. However, some existing multicast services, such as IPTV services, are deployed based on non-MPLS networks or technologies, or on an MPLS-incapable network. Deploying BIER-MPLS on such a network requires the upgrade of all devices on the network. And on MPLS-capable networks that carry IPTV services without using MPLS multicast, deploying BIER-MPLS is difficult in terms of network management and maintenance.

Another limitation is found on MPLS multicast VPN networks. In this case, configuring BIER-MPLS to advertise BIER information and establish BIFTs across ASs is particularly complex.

BIERv6

In terms of unicast forwarding, SRv6, which is based on the IPv6 data plane, has developed rapidly and surpassed SR-MPLS, which is based on the MPLS data plane. In terms of multicast, however, a solution was urgently needed to use the BIER architecture and encapsulation in order to implement MPLS-independent technologies and match the development trend of IPv6 networks. Against this backdrop, BIERv6, which inherits the core design concept of BIER, was proposed in the industry. It uses the BitString to guide multicast packet replication and forwarding to specified receivers and does not require transit nodes to establish MDTs, thereby implementing stateless forwarding. Like BIER, BIERv6 uses a hierarchical architecture, in which the layers interwork to forward multicast data flows. As shown in Figure 2-7, the main difference between BIERv6 and BIER is that BIERv6 is a multicast solution based on native IPv6 rather than MPLS labels.

Figure 2-7 Comparison between BIER and BIERv6 encapsulation



BIERv6 is a hotly debated topic in standard organizations such as the IETF, which has formulated related standards drafts. Table 2-1 describes several major drafts.

Table 2-1 BIERv6 standards drafts

Type	Draft Name	Description
BIERv6 requirements and cases	draft-ietf-bier-ipv6-requirements	It describes the technical requirements of BIER on IPv6 networks, including the ability to support the BIER technical architecture and how IPv6 can be extended to support BIERv6.
BIERv6 encapsulation format	draft-xie-bier-ipv6-encapsulation	It defines the BIERv6-specific IPv6 Destination Options Header to carry the standard BIER header, and a specific IPv6 address is used to instruct BIERv6 forwarding.
IS-IS extensions for BIERv6	draft-xie-bier-ipv6-isis-extension	It describes how to extend IS-IS to flood the IPv6 addresses used to guide BIERv6 forwarding on the network.

Type	Draft Name	Description
BIERv6 inter-AS solution	draft-geng-bier-ipv6-inter-domain	It describes how to use static configurations to implement inter-AS BIERv6.

In February 2021, Huawei and one of its customers completed the first test of a live BIERv6-based network, covering service scenarios such as intra-AS multicast, inter-AS multicast, dual-root protection, and dual-homing upstream protection. The test verified the availability of BIERv6 in implementing multicast functions on the metro network, laying a solid technical foundation for deploying multicast services on metro and bearer networks.

Chapter 3

Technical Benefits of BIERv6

BIERv6 simplifies protocols and network deployment, thereby better coping with the challenges of future network development. The core advantage of BIERv6 is the native IPv6 attribute, allowing BIERv6 to work together with SRv6 in order to unify unicast and multicast services in the IPv6 data plane, without relying on MPLS labels. Thanks to the native IPv6 attribute, BIERv6 offers significant advantages in network protocol simplification, deployment, and O&M.

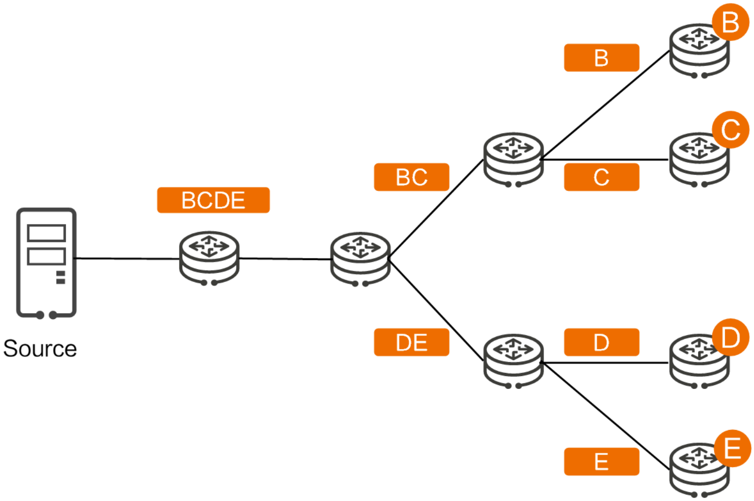
3.1 Simplified Network Protocols

Similar to the SRv6 SID's Function field, which is used to guide forwarding for services such as L3VPN and L2VPN services, the IPv6 addresses used in BIERv6 guide MVPN and GTM service forwarding. This further simplifies protocols and eliminates the need for allocating, managing, and maintaining MPLS labels.

BIERv6 has high extensibility as it complies with the design concept of SDN and network programming. As shown in Figure 3-1, the ingress encapsulates the set of destination nodes as a BitString into the packet header before forwarding a packet. After receiving the packet, a transit node forwards it to the next node based on the address information contained in the packet header, without needing to create or manage complex protocol or tunnel entries. When a destination node of a service changes, BIERv6 can update the BitString to implement flexible control.

This forwarding mode also applies to large-scale networks, facilitating network expansion.

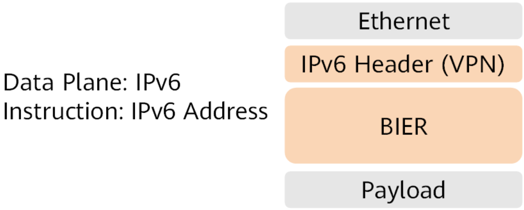
Figure 3-1 Encapsulation used for forwarding on involved BIERv6 nodes



3.2 Simplified Deployment and O&M

With the introduction and rapid development of SRv6, the industry has gradually shifted its focus toward network programming based on the IPv6 data plane. As shown in Figure 3-2, BIERv6 uses an IPv6 extension header to carry BIER forwarding instructions, eliminating the need for MPLS label-based forwarding. IPv6 extensibility facilitates the evolution and addition of new features, such as IPv6 packet fragmentation and reassembly, multicast network slicing, and In-situ Flow Information Telemetry (iFIT). Because services are deployed only on the ingress and egresses, transit nodes do not need to be aware of multicast service changes. When the network topology changes, there is no need to withdraw or re-establish numerous MDTs, thereby greatly simplifying O&M.

Figure 3-2 MPLS-label-free BIERv6 forwarding



BIERv6 also eliminates the difficulty involved in deploying inter-AS BIER, which requires all devices on the network to have MPLS capabilities because BIER-MPLS is based on the MPLS data plane. By leveraging IPv6 unicast route reachability, BIERv6 allows multicast traffic to be easily transmitted across ASs, simplifying network deployment. And because BIERv6 can be used even if BIERv6-incapable devices exist between a multicast source and a multicast user, BIERv6 offers greater compatibility with live networks.

3.3 High Network Reliability

BIERv6 uses IGP extension to flood BIER information that each node uses to establish a multicast forwarding table for data forwarding. BIERv6 uses unicast routes to forward traffic, sparing MDT establishment. This eliminates the need for complex protocol processing, such as multicast source sharing and SPT switching. In addition, BIERv6 reduces the number of entries that need to be stored because it does not need to maintain per-flow MDT states. If a fault occurs on the network, devices only need to update entries in their BIFTs after the underlay route convergence. This ensures fast BIERv6 convergence if a fault occurs, thereby improving reliability and enhancing user experience.

Chapter 4

BIERv6 Fundamentals

BIERv6 is a new native-IPv6 multicast solution that combines the advantages of IPv6 and BIER and addresses the challenges involved in future multicast service development. This chapter describes IPv6 extensions for BIERv6, forwarding fundamentals of BIERv6, support for MVPN services by BIERv6, IGP/BGP extensions for BIERv6, and reliability of BIERv6.

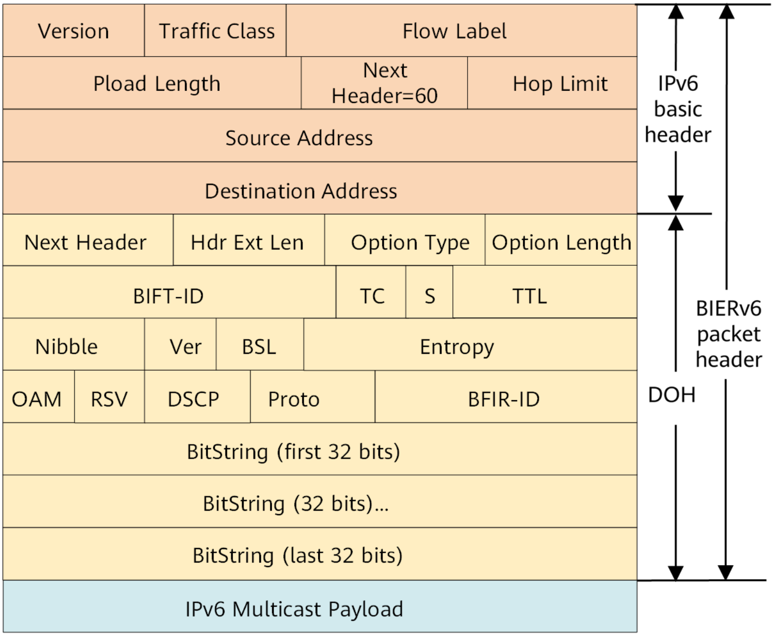
4.1 How Is IPv6 Extended to Support BIERv6?

IPv6 Packet Extension

To support various options without changing the existing packet format, IPv6 packets adopt extension headers, offering significant flexibility while also maintaining a simple packet header. BIERv6 uses this IPv6 characteristic to implement its own functions.

The destination address (End.BIER address) in an IPv6 packet identifies the IPv6 address of a BIER forwarding node and instructs this node to perform BIERv6 forwarding processing. The source address in an IPv6 packet identifies the source of the BIERv6 packet and also indicates the multicast VPN instance to which the multicast packet belongs. BIERv6 uses the IPv6 Destination Options Header (DOH) to carry the standard BIER header, which together with the IPv6 header forms the BIERv6 packet header. BFRs read and update the BitString in the BIERv6 extension header and replicate and forward packets according to their BIFTs. Figure 4-1 shows the BIERv6 packet header format.

Figure 4-1 BIERv6 packet header format



The following describes the key fields in the BIERv6 DOH:

- Option Length: indicates the ID of the BIFT.
- TTL: indicates the maximum number of hops through which a packet can be forwarded using BIERv6. The TTL value decrements by 1 each time the packet passes through a BIERv6 forwarding node. When the TTL becomes 0, the packet is discarded.
- Ver: indicates the BIERv6 packet format version.

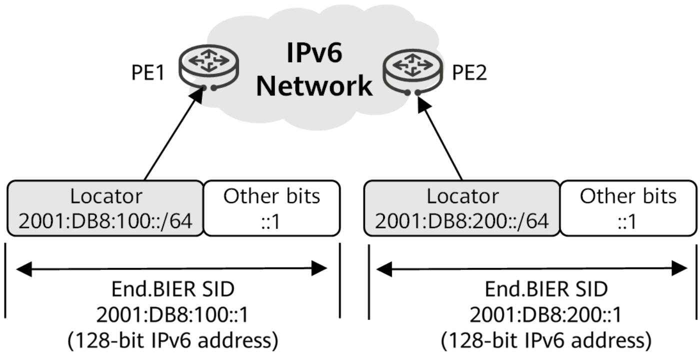
- BSL: indicates the BitString length. The values 0001, 0010, and 0011 indicate that the BSL is 64-, 128-, and 256-bits long, respectively. One or more BSLs can be configured in a BIERv6 sub-domain.
- Proto: indicates the protocol type of the payload following the BIERv6 packet header. The payload type is defined by the Internet Assigned Numbers Authority (IANA).
- BFIR-ID: indicates the ID of the BFIR. The default value is the BFIR's BFR-ID. If the BFR-ID is not set, the value 0 is used.
- BitString: indicates the set of destination nodes of a multicast packet.

End.BIER

End.BIER is a new type of SID defined for BIERv6 to support packet forwarding based on the IPv6 extension header. It can be used as an IPv6 destination address and instruct the forwarding plane to process the BIERv6 extension header in the packet. When receiving and processing a BIERv6 packet, each BIERv6 forwarding node encapsulates the End.BIER SID of the next-hop node into the outer IPv6 destination address of the BIERv6 packet (note that the destination nodes of the inner multicast packet are defined through the BitString). Upon receiving the BIERv6 packet, the next-hop node forwards it according to the BIERv6 process. The End.BIER SID can also fully utilize IPv6 unicast route reachability to allow services to be transmitted across the network, even if some IPv6 nodes do not support BIERv6.

As shown in Figure 4-2, an End.BIER SID consists of two parts: Locator and other bits. Locator indicates a BIERv6 forwarding node and provides the location function (the same as that defined in SRv6). After a locator is configured for a node, the system generates a locator route and propagates the route throughout the SRv6 domain using an IGP, allowing other nodes to locate this node based on the received route information. All SRv6 SIDs advertised by this node are reachable through the propagated route. The End.BIER SID directs packets to the specified BFR. After receiving a multicast packet, the BFR identifies that the packet's destination address is the local End.BIER SID and forwards the packet according to the BIERv6 process.

Figure 4-2 End.BIER format



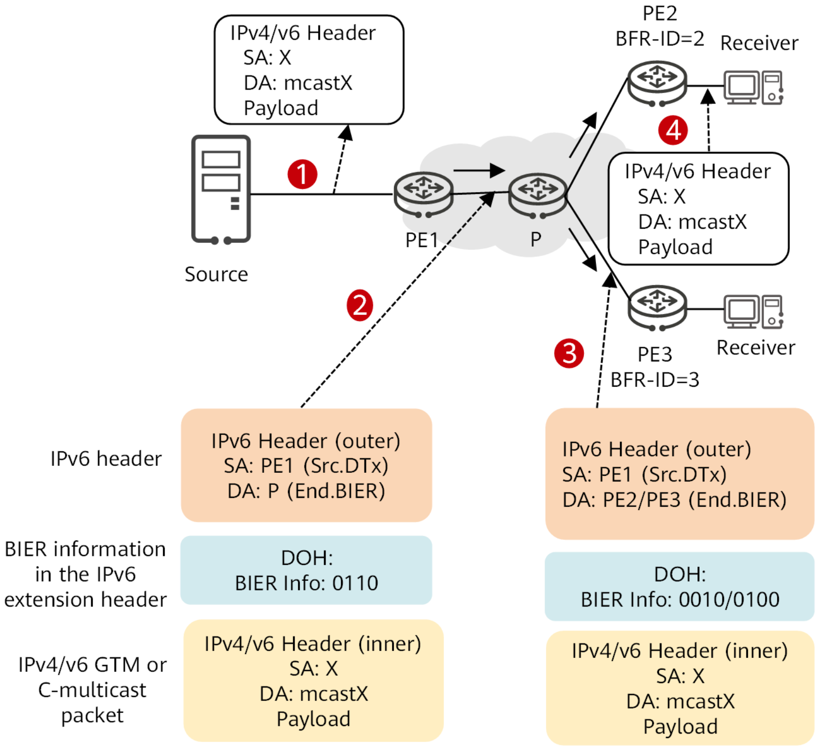
In the preceding figure, the locator of PE1 is 2001:DB8:100::/64, and the other bits are ::1. The combination of these two parts forms PE1's End.BIER SID (2001:DB8:100::1). Similarly, PE2's locator is 2001:DB8:200::/64 and its other bits are ::1, resulting in PE2's End.BIER SID being (2001:DB8:200::1).

4.2 How Does BIERv6 Forward Multicast Packets?

How Are Packets Forwarded?

Figure 4-3 shows the BIERv6 packet forwarding process.

Figure 4-3 BIERv6 packet forwarding process



When a multicast packet enters the BIERv6 domain, the BFIR encapsulates it with a BIERv6 extension header, thereby transforming the packet into a BIERv6 one. This BIERv6 extension header and the IPv6 header form the BIERv6 packet header. In the IPv6 header, the Source Address (SA) field must be set to a routable IPv6 unicast address of the BFIR, and the Destination Address (DA) field is set to the End.BIER address of the next-hop BFR. The BIERv6 packet is then replicated and forwarded to the next-hop BFR.

After receiving the BIERv6 packet, a transit BFR processes it according to the general process involved in processing IPv6 packets. This BFR first processes the IPv6 header. If the IPv6 destination address in the packet is the same as the BFR's End.BIER IPv6 unicast address, the BFR needs to perform BIERv6 forwarding on the packet and parse the corresponding fields in the BIERv6 extension header. Then, according to the forwarding process described earlier, the BFR replicates the packet to the next BFR.

When a BFER receives the multicast packet, if the bit corresponding to the BFR-ID of the local node in the BitString of the packet is set, the BFER removes the IPv6 encapsulation and extracts the BFIR-ID from the BIERv6 header to determine the root node from which the packet was received. It then determines the VPN instance to which the packet belongs based on the source address of the packet, and searches the routing table of the VPN instance to forward the packet.

The BIFT is mandatory for each BFR in a BIERv6 sub-domain to forward multicast packets. Each entry in the BIFT includes a BFR neighbor (represented by **Nbr**) and Forwarding Bit Mask (FBM). The FBM indicates the set of BFERs that are reachable through the BFR neighbor.

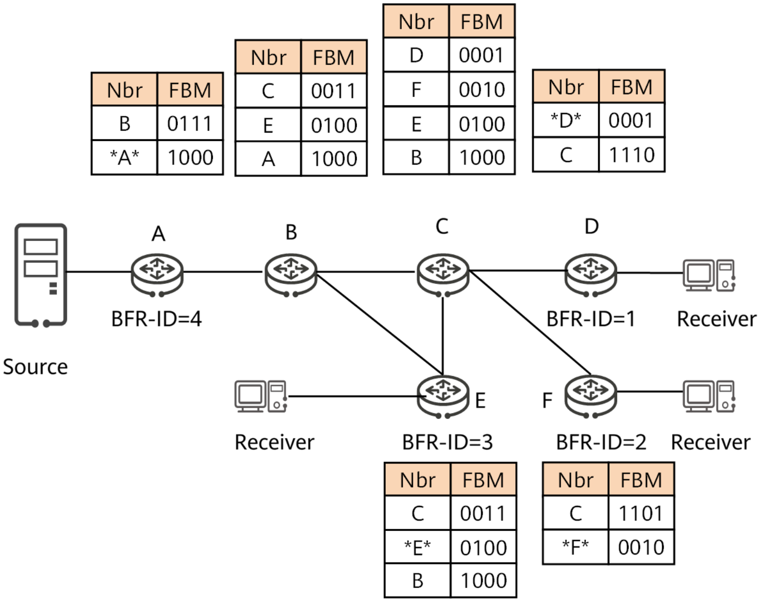
Each BFR in a BIERv6 sub-domain uses an IGP to advertise information to other BFRs (for example, it advertises the local BFR-prefix, sub-domain ID, BFR-ID, BSL, and path calculation algorithm) and obtains the BFR neighbor to each BFER through path calculation. The FBM is represented by a BitString and is the same length as the BitString used for packet forwarding. For example, if the BSL used for packet forwarding is 256 bits, the FBM in the BIERv6 BIFT is also 256 bits long. A bitwise AND operation is performed between the BitString in the packet and the FBM in the BIFT during packet forwarding.

As shown in Figure 4-4, nodes A, D, E, and F are edge nodes, and their BFR-IDs are 4, 1, 3, and 2, respectively. Nodes A to F establish their BIFTs based on the information advertised by the control plane. Node B is used as an example here to describe how a BIFT is established. After receiving the BIERv6 information flooded by other BFRs, node B generates forwarding information about the next hop to each node with a valid BFR-ID.

- The next hop for packets to reach the node whose BFR-ID is 4 is node A.
- The next hop for packets to reach the node whose BFR-ID is 3 is node E.
- The next hop for packets to reach the node whose BFR-ID is 1 or 2 is node C.

In this way, node B establishes its BIFT, which contains three neighbors. According to this BIFT, node B then replicates and forwards received BIER packets.

Figure 4-4 Schematic diagram of BIERv6 BIFTs



Nbr	FBM
B	0111
A	1000

Nbr	FBM
C	0011
E	0100
A	1000

Nbr	FBM
D	0001
F	0010
E	0100
B	1000

Nbr	FBM
D	0001
C	1110

Nbr	FBM
C	0011
E	0100
B	1000

Nbr	FBM
C	1101
F	0010

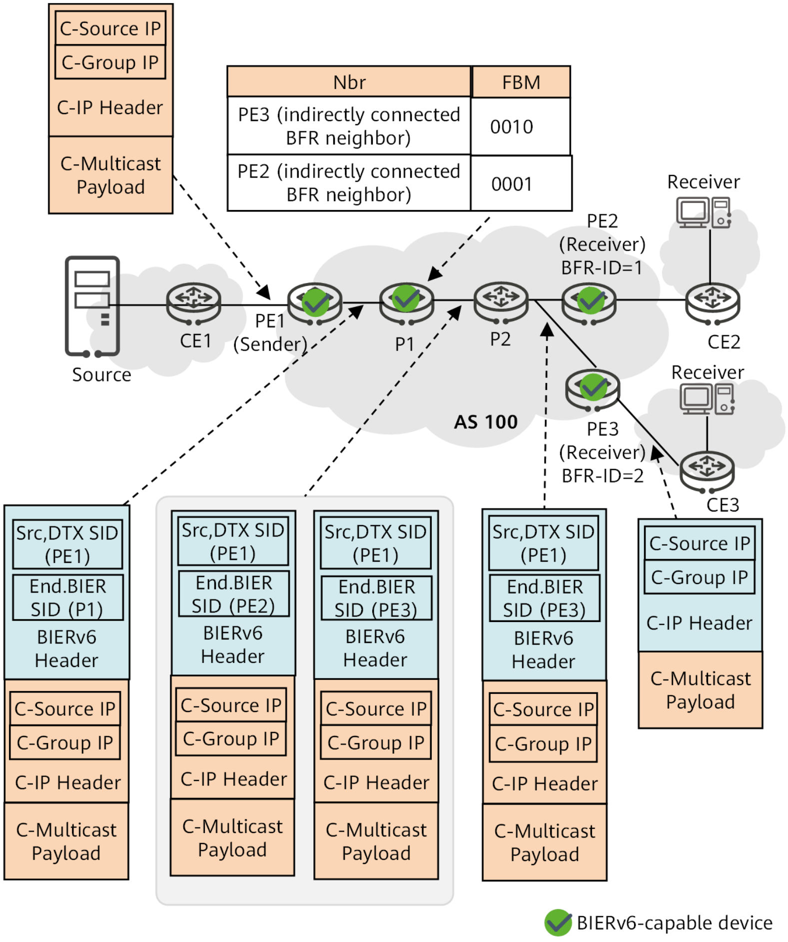
* indicates that the neighbor is the local node itself.

How Do Packets Traverse BIERv6-incapable Devices?

BIERv6 is a multicast technology based on native IPv6 and does not depend on MPLS during encapsulation. Instead, it uses IPv6 addresses to identify nodes and can forward packets as long as routes are reachable, even across BIERv6-incapable devices, which facilitates BIERv6 deployment on the network. If some BIERv6-incapable nodes exist on a single-AS BIERv6 network, the BIERv6-capable nodes can still generate forwarding entries through the underlay IGP. Multicast packets can automatically traverse the BIERv6-incapable nodes, requiring no additional configurations on these nodes and their upstream and downstream nodes.

Figure 4-5 shows the process of intra-AS BIERv6 packet forwarding across BIERv6-incapable devices. In this example, P2 is a BIERv6-incapable device, whereas devices PE1, P1, PE2, and PE3 are BIERv6-capable and have established their BIFTs based on the information flooded through an IGP. P1, whose BIFT contains two neighbors (PE2 and PE3), generates an IPv6 packet containing information about PE2 and PE3 based on its BIFT. P2 learns that the packet needs to be sent to PE2 and PE3 based on its IP routing table.

Figure 4-5 Packet forwarding across BIERv6-incapable devices



Nbr	FBM
PE3 (indirectly connected BFR neighbor)	0010
PE2 (indirectly connected BFR neighbor)	0001

As mentioned earlier, multicast packets can be forwarded as long as IPv6 addresses are reachable. This eliminates the need for all devices on the entire network to support BIERv6, thereby facilitating smooth network deployment and significantly reducing associated costs.

4.3 How Does BIERv6 Implement Inter-AS Forwarding?

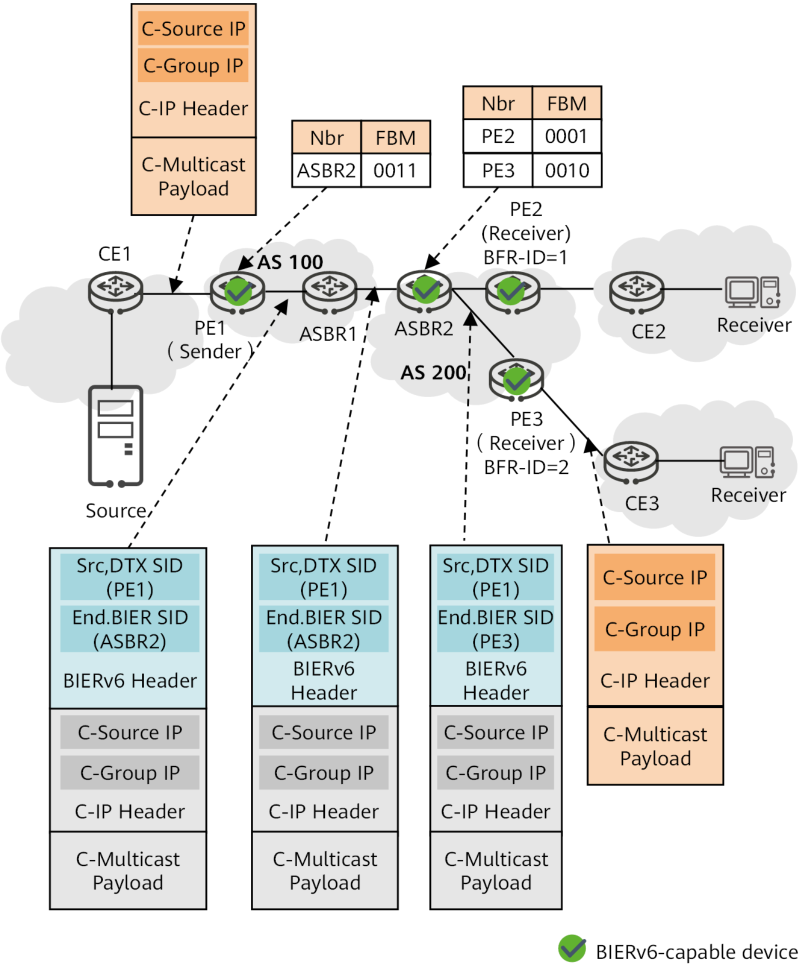
Deploying multicast services in inter-AS scenarios is a common occurrence. For example, an IPTV multicast source server may be connected to a PE on a carrier's IP backbone network belonging to one AS, whereas IPTV users may be connected to BNGs on metro networks belonging to another AS. BIERv6 allows multicast packets to traverse different ASs based on static configurations.

The inter-AS BIERv6 scenario shown in Figure 4-6 is used as an example to describe how BIERv6 forwards multicast packets in the scenario. In this example, it is required that the multicast traffic sent by the multicast source reach the receivers through AS 100 and AS 200. ASBR1 in AS 100 functions as a border router and does not support BIERv6, whereas all devices in AS 200 support BIERv6.

The process for BIERv6 packets to traverse ASBR1 is as follows:

1. ASBR2's End.BIER SID must be manually set on PE1 as the next hop for the multicast packets sent to the nodes with BFR-ID 1 and BFR-ID 2.
2. PE1 generates a BIFT according to the standard BIERv6 BIFT generation process.
3. Because the BFR neighbor in the BIFT is ASBR2, PE1 encapsulates ASBR2's End.BIER SID into the Destination Address field of packets and forwards the packets based on the BitString and BIFT using the standard BIERv6 forwarding process.
4. After receiving the packets, ASBR1 parses their Destination Address field and then forwards them to ASBR2 according to the native IPv6 forwarding process.
5. After receiving the packets, ASBR2 forwards them to PE2 and PE3 according to the BIERv6 forwarding process.

Figure 4-6 Fundamentals of inter-AS static traversal



4.4 How Does BIERv6 Support MVPN?

BIERv6 can carry both IPv4 and IPv6 MVPN services. MVPN over BIERv6 allows IPv4 MVPN services to be carried over an IPv6 network in scenarios where the multicast service system (including the STB and IPTV ingress system) runs IPv4 multicast, but the transport network runs IPv6. MVPNv6 over BIERv6 allows IPv6

MVPN services to be carried over an IPv6 network in scenarios where both the multicast service system and the transport network run IPv6.

Figure 4-7 Network diagram of MVPN over BIERv6

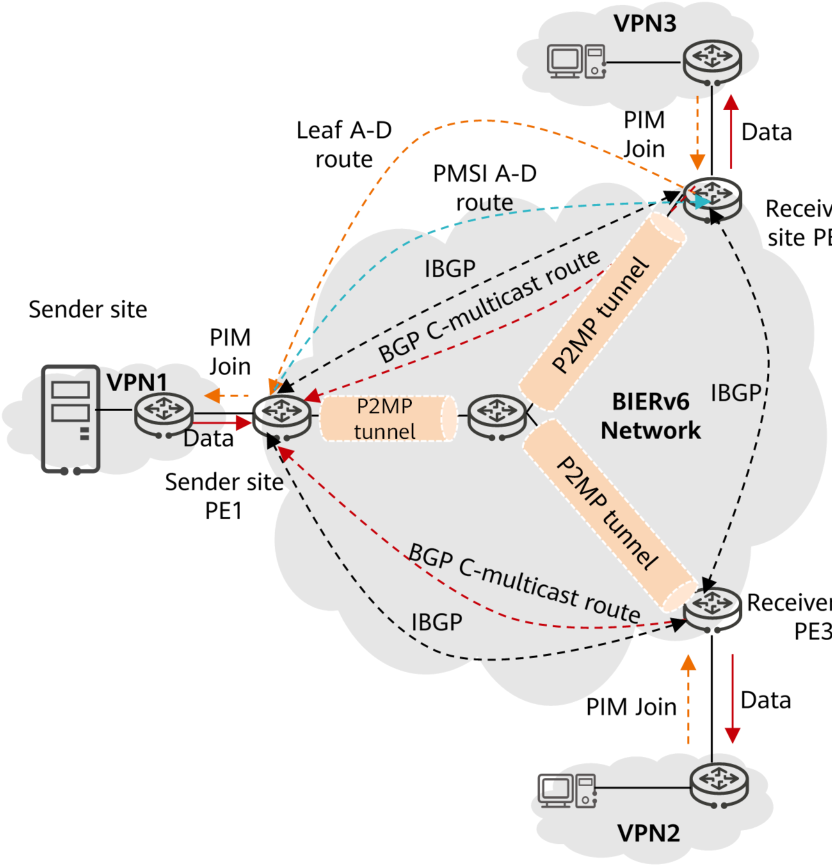


Figure 4-7 shows an MVPN over BIERv6 service scenario. The BGP MVPN sub-address family transmits MVPN control messages to implement functions such as automatic member discovery, Provider Multicast Service Interface (PMSI) tunnel establishment, and C-multicast route advertisement.

1. The sender site PE and receiver site PEs send Intra-AS I-PMSI Auto-Discovery (A-D) routes to all their BGP peers. After receiving the routes, the PEs accept them based on the configured VPN target rules.
2. The sender site PE1 sends Type 1 BGP A-D routes carrying MVPN target and PMSI tunnel attributes to its BGP peers: PE2 and PE3.
3. The receiver site PE2 responds with a Leaf A-D route carrying its sub-domain ID, BFR-ID, and BFR-prefix.
4. The receiver site PEs each construct a BGP C-multicast route based on the PIM Join information received from a VPN and send the route to all BGP MVPN peers.
5. After receiving the BGP C-multicast route, the sender site PE1 accepts it if the IP address in the RT carried in the route is this PE's IP address. This PE then determines the VPN instance based on the VRF corresponding to the RT and generates a C-multicast PIM Join message.

4.5 How Are Protocols Extended to Implement BIERv6?

BFRs forward BIERv6 packets based on the BIER BIFT, whose establishment depends on the BFR information flooded through an IGP to determine the next-hop BFR. In order to transmit traffic from one BFR to the next, the routing underlay establishes routes between the BFRs. MVPN over BIERv6 control messages are used to implement automatic MVPN member discovery, establish and maintain PMSI tunnels, and transmit C-multicast routes for C-multicast members to join or leave multicast groups. The control messages are carried in the Network Layer Reachability Information (NLRI) field of BGP Update messages for transmission.

To implement BIERv6 functions, an IGP and BGP need to be extended. The following section describes how the two protocols are extended to support BIERv6.

IGP Extensions

Based on the existing IGP for BIER, the IGP extension for BIERv6 uses a sub-sub-TLV to carry BIERv6 encapsulation information and another sub-sub-TLV to flood End.BIER information. Currently, IS-IS has protocol extensions defined for BIERv6, as listed in Table 4-1.

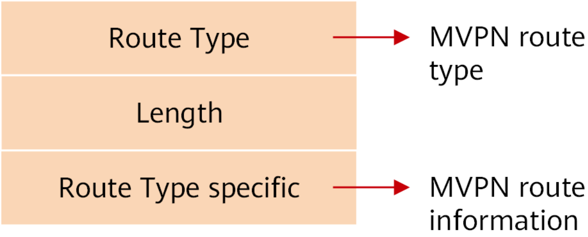
Table 4-1 IS-IS extensions for BIERv6

Type	Name	Function	Carried In
TLV	Extended IS Reachability TLV (IPv6)	Advertises BFR-prefixes and floods BFR node information in a sub-domain. The BFR-prefix is a loopback interface IPv6 address of a BFR in a sub-domain.	IS-IS packets
Sub-TLV	BIER Info Sub-TLV	Advertises information such as sub-domain IDs and BFR-IDs.	TLV (Type = 237) in IS-IS packets
Sub-sub-TLV	End.BIER Info Sub-sub-TLV	Advertises End.BIER SIDs.	BIER Info Sub-TLV
	BIERv6 Encapsulation Sub-sub-TLV	Advertises the Max SI (short for set ID), BSL, and start BIFT-ID.	BIER Info Sub-TLV

BGP Extensions

Each MVPN over BIERv6 control message is carried in the NLRI field in a BGP Update message. Figure 4-8 shows the format of the NLRI field.

Figure 4-8 MVPN NLRI format

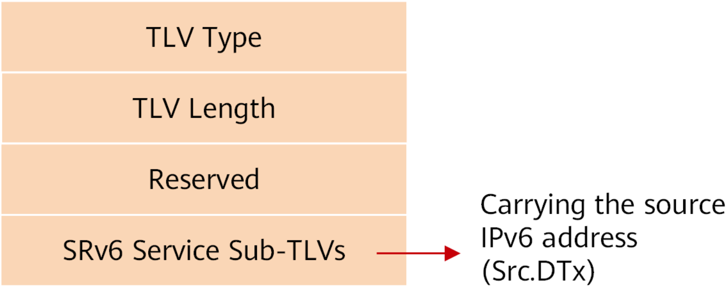


The Route Type field indicates the type of a BGP MVPN route. Seven types of BGP MVPN routes are available, among which, five are used for MVPN member auto-discovery and PMSI tunnel establishment. These five types of routes, also called MVPN A-D routes, are described as follows:

- **Intra**-AS I-PMSI A-D route: applies to single-AS scenarios. It is used for intra-AS MVPN member auto-discovery and is advertised by each PE with MVPN enabled.
- **Inter**-AS I-PMSI A-D route: applies to inter-AS scenarios. It is used for inter-AS MVPN member auto-discovery and is advertised by each ASBR with MVPN enabled.
- **S-PMSI** A-D route: is used by a sender PE to send a notification of establishing a selective P-tunnel for a particular (C-S, C-G).
- **Leaf** A-D route: is used to respond to a Type 1 Intra-AS I-PMSI A-D route with the Flags field in the PMSI attribute being 1 or a Type 3 S-PMSI A-D route. If a receiver PE has a request for establishment of an S-PMSI tunnel, it sends a Leaf A-D route to help the sender PE collect tunnel information.
- **Source Active** A-D route: is used by the sender PE to advertise C-multicast source information to other PEs in the same MVPN when the sender PE discovers a new C-multicast source.

BIERv6 extends I-PMSI or S-PMSI A-D routes to carry the source IPv6 address (Src.DTx) of an MVPN instance in the existing BGP Prefix-SID attribute. Figure 4-9 shows the format of the BGP Prefix-SID attribute.

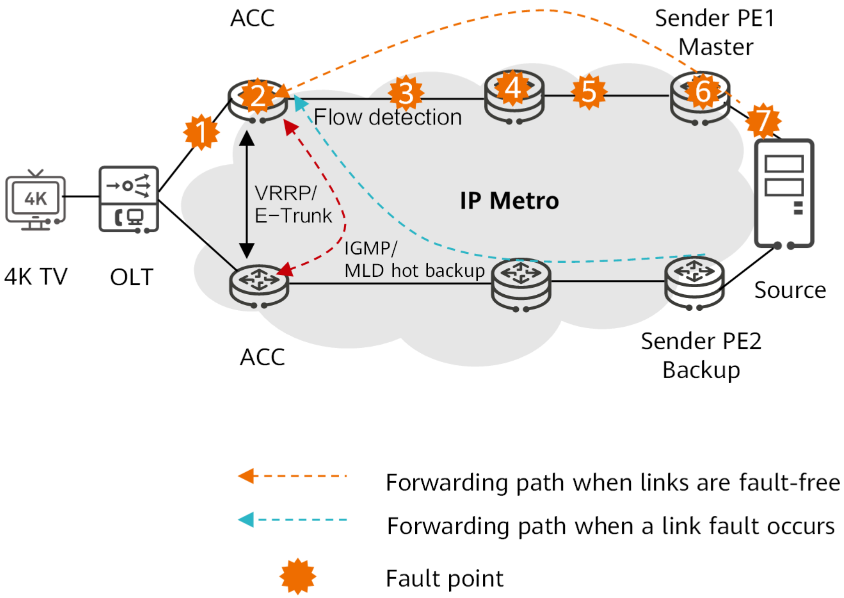
Figure 4-9 Prefix-SID attribute format



4.6 How Does BIERv6 Ensure High Reliability?

Multicast technologies can be applied to services that have high requirements on network reliability and network latency, such as IPTV, finance, video conferencing, and online live telecasting services. BIERv6 provides an E2E protection mechanism, which consists of access-side protection and network-side protection. Figure 4-10 shows the networking for BIERv6's reliability protection mechanism. The following describes the mechanism from the two sides: access side and network side.

Figure 4-10 BIERv6 reliability protection mechanism



E-Trunk or Virtual Router Redundancy Protocol (VRRP) dual-device protection is deployed between access devices to improve device reliability, and IGMP/MLD dual-device hot backup is deployed for multicast user entries to speed up switchovers. If a fault (at fault point 1 or 2) occurs on the access network, a master/backup switchover is performed so that traffic can be forwarded through the backup device.

Deploying MVPN over BIERv6 dual-root 1+1 protection on network-side devices can speed up fault-triggered BGP convergence, which in turn accelerates multicast service convergence.

Two sender PEs are deployed on the network side, and the same MVPN is deployed for them. Each receiver node establishes two BIERv6 tunnels: one rooted at sender PE1 and working as the primary tunnel, and the other rooted at sender PE2 and working as the backup tunnel. Traffic detection-based C-multicast Fast Reroute (FRR) is configured on each receiver node. When links are fault-free, the same multicast traffic is forwarded through both the primary and backup tunnels. In this case, each receiver node accepts the traffic received through the primary tunnel with sender PE1 as the ingress and discards the traffic received through the backup tunnel with sender PE2 as the ingress. If a fault occurs on the network side (at any fault point 3–7), each receiver node detects that the traffic on the primary tunnel is interrupted and immediately checks whether the traffic on the backup tunnel is normal. If the traffic on the backup tunnel is normal, each receiver node performs a primary/backup tunnel switchover and forwards the traffic received through the original backup tunnel to the corresponding VPN.

In order to prevent failures from leading to prolonged interruption of multicast services, it is advisable to plan separate paths for the primary and backup tunnels when deploying MVPN over BIERv6 dual-root 1+1 protection.

Chapter 5

Applications of BIERv6

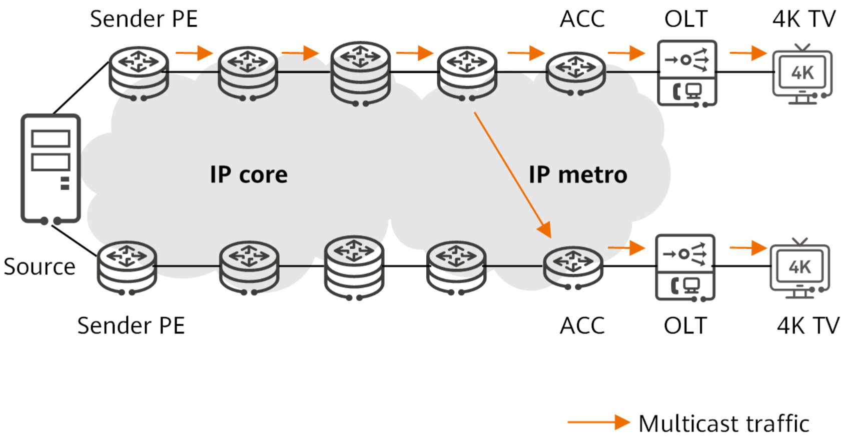
BIERv6, as the next-generation multicast routing technology, provides new opportunities for expanding multicast applications. This chapter describes the potential application scenarios of BIERv6 in three service scenarios: IPTV, meteorological, and video streaming media scenarios.

5.1 BIERv6 Application in IPTV Scenarios

IP video services include live TV (news, sports events, and live webcasting), Video on Demand (VOD), and video surveillance. Video transmission service applications such as 4K IPTV, 8K VR, smart city, smart home, autonomous driving, telemedicine, and safe city are expected to grow dramatically in the near future, especially in countries and regions with fast economic development.

In Figure 5-1, MVPN over BIERv6 is deployed on the public network to carry IPTV traffic. In addition to reducing the network load and improving user experience (for example, delivering fast VOD, clear images, and smooth playback), BIERv6 multicast technology simplifies deployment, O&M, and capacity expansion. This makes BIERv6 an ideal choice for large-scale deployment.

Figure 5-1 BIERv6 application in an IPTV scenario



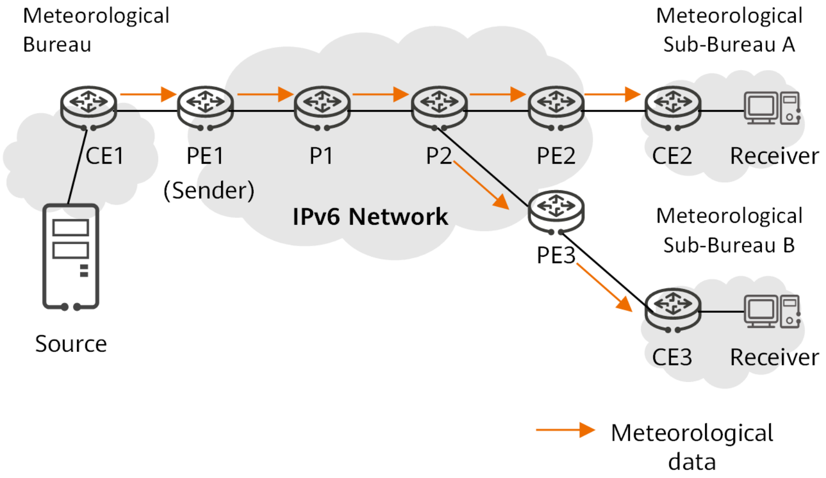
5.2 BIERv6 Application in the Meteorological Industry

Meteorological networks are huge and involve the WAN systems of meteorological departments at the national, provincial, municipal, and county levels. Most of the conventional meteorological network systems use P2P unicast transmission. BIERv6 multicast technology can effectively implement efficient P2MP transmission of meteorological data.

In addition, meteorological networks are likely to contain some devices that do not support multicast communication. Using conventional multicast technologies to implement multicast data forwarding in this case would involve complex deployment. In contrast, because BIERv6 supports data transmission across BIERv6-incapable IPv6 devices, it allows meteorological data to be transmitted smoothly even if some devices do not support multicast communication.

On the meteorological network shown in Figure 5-2, BIERv6 multicast technology is used to synchronously distribute the data obtained by a country's meteorological bureau to sub-bureaus located throughout the country, ensuring the timeliness of meteorological data transmission.

Figure 5-2 BIERv6 application in the meteorological industry

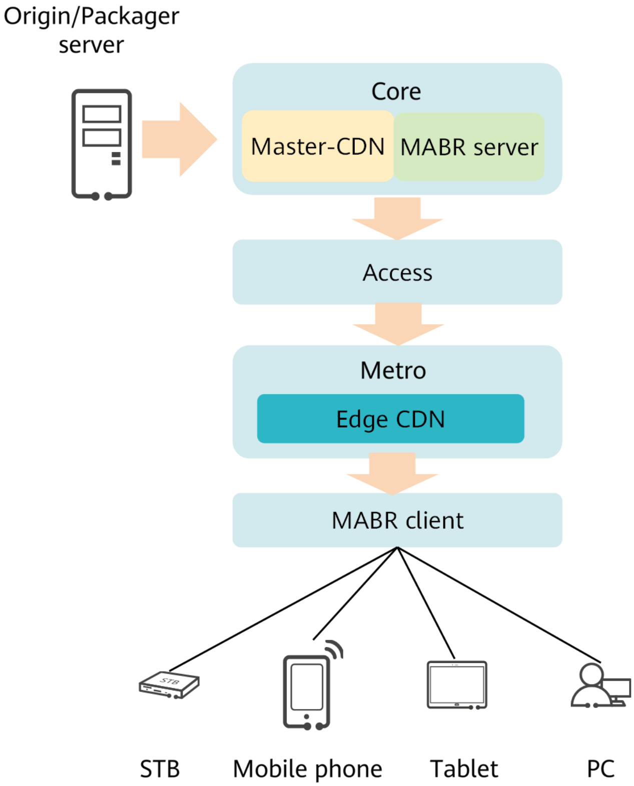


5.3 Joint Application of BIERv6 and CDN Technologies

Multicast Adaptive Bit Rate (MABR) — a new multicast streaming media technology — can be used to multicast standard HTTP data traffic. Using this technology, data traffic is transmitted to a home network in multicast mode over the carrier network, converted into unicast data on the home network, and then forwarded to each device on the home network. And to solve network access delay problems caused by distribution, bandwidth, and server performance, Content Delivery Network (CDN) technologies can be used in scenarios such as VOD and live telecasting. In this way, the nearest CDN server delivers the requested data to users, speeding up access to network resources.

Using MABR and CDN technologies can make network distribution more efficient. This solution can also conserve bandwidth resources and ensure the continuity, real-time performance, and order of streaming media services. Figure 5-3 shows the technical framework, in which BIERv6 multicast technology can be used to maximize the advantages of this solution.

Figure 5-3 Joint use of MABR and CDN



Chapter 6

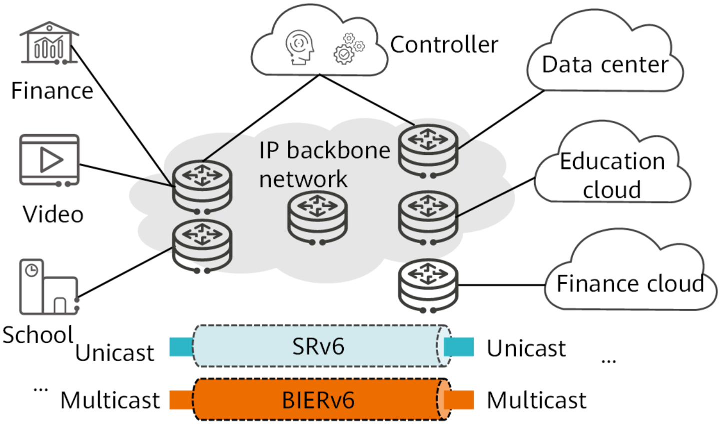
Future Development of BIERv6

In the future, cloud networks will become increasingly popular, the number of devices that access the Internet will increase sharply, and users will have higher requirements on network service quality. SRv6 and BIERv6 help transmit data on IPv6 networks more efficiently and conveniently in unicast and multicast modes, respectively.

The BIERv6 multicast technology solution combines the advantages of native IPv6 and BIER. It encapsulates a standard BIER header into an IPv6 extension header and uses a unicast IPv6 address as the destination address in the IPv6 header. In addition, based on IPv6 unicast address reachability, this solution implements functions such as BIERv6 multicast replication, inter-AS forwarding, and transmission across BIERv6-incapable devices.

SRv6 combines the advantages of the source routing mechanism used in Segment Routing (SR) along with the simplicity and extensibility that IPv6 offers. In addition, SRv6 provides a multi-dimensional programming space. SRv6 uses SRv6 SIDs at the service layer to identify various services, reducing technical complexity, and uses IGP and BGP extensions to implement underlay and tunnel functions, simplifying signaling protocols.

Figure 6-1 Unicast and multicast data transmission on an IPv6 network



As shown in Figure 6-1, BIERv6 can be deployed on a service provider's core network to transmit multicast traffic for services that require multicast data transmission. For services that require unicast data transmission, SRv6 can be used to forward data. Working with SRv6, BIERv6 allows both unicast and multicast services to be transmitted based on a unified IPv6 data plane and a unified IGP/BGP control plane, thereby simplifying protocols. It is therefore unsurprising that networks have taken on this course of development.

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