"IPv6+" Video Service Solution Based on Metropolitan Area Cloud Network

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Abstract—**The popularity of 5G and cloud technology have created conditions for the development of novel video services, and at the same time, the services have put forward higher requirements for the network. By analyzing the problems of complex configuration, long setup cycle and poor scalability of traditional Metropolitan Area Network (MAN) architecture in the deployment of video services, and introduce the metropolitan area cloud network (MACN) architecture. Introduce how to deploy Ethernet Virtual Private Network (EVPN) over SRv6 based on MACN to satisfy the differentiated guarantee of different video services with simple configuration and flexible efficiency taking the cross-provincial unicast video service as an example. Taking Internet Protocol Television (IPTV) service as an example, introduce the solution of deploying Bit Index Explicit Replication IPv6 (BIERv6) multicast technology based on MACN to simplify multicast service configuration, reduce redundant video traffic in the network, shorten service turn-up cycle and improve user experience.**

Keywords—Metropolitan Area Cloud Network，SRv6，BIERv6，EVPN，Metropolitan Area Network

I. Introduction

The development of 5G and cloud technology will solve the key problems of novel video business, and novel video services such as distance education, telemedicine, Augmented Reality (AR) ,Virtual Reality (VR) and so on will usher in development opportunities. Compared with the traditional video services, the novel video services have higher requirements for bandwidth and delay of the bearer network. The novel video services scenes are different, and the demand for network performance is also differentiated. It requires the bearer network to be intelligent to meet the different Service Level Agreement (SLA) .

At present, traditional networks mainly use Internet Protocol (IP) and Multi-protocol Label Switching (MPLS) technology to provide QoS guarantee for users. MPLS technology needs to deploy MPLS on each of IP backbone network, MAN and mobile bearer network. However, each MPLS domain is independent and if interconnecting MPLS domains, it needs to use complex technologies such as cross-domain Virtual Private Network (VPN) . It causes the deployment of end-to-end services is complex, which cannot meet the requirements of cloud network convergence. In the future, video traffic in the network will keep growing, and the large amount of video traffic puts a lot of pressure on the network . Traditional solutions use multicast technology to solve the problem of video traffic redundancy in the network, and the using multicast protocols include Protocol Independent Multicast (PIM), Internet Group Management Protocol (IGMP), etc. These multicast protocols are not suitable for large-scale network because they need to establish a multicast distribution tree for each multicast traffic, and each node in the distribution tree need to senses the multicast service and retains the multicast traffic state, which has problems such as complex multicast protocols, complicated deployment, and poor scalability. And it is not suitable for large-scale deployment in the network.

Compared with IPv4 technology, IPv6 technology not only expands the address space, but also simplifies the message headers and adds extended message headers to make IP networks more intelligent. Based on "IPv6+", SRv6 and BIERv6 technologies have solved the problems of complex and inflexible traditional network protocols. Both SRv6 and BIERv6 are based on native IPv6 forwarding, and can simplify control plane protocols and make unicast and multicast full-service deploy fastly combined them with EVPN technology.

At present, the traditional MAN of operators is three-layer architecture deployment including access layer, convergence layer and core layer based on the early business requirements. It mainly adopts IP/MPLS technology to bear services, which has problems such as complex configuration, poor maintainability and slow service loading, and cannot satisfy the requirements of novel video services for network intelligence. Under the background of 5G and cloud network convergence, in order to better adapt to the development of cloud, traditional MAN gradually oversteps to MACN. The MACN is designed with Spine Leaf architecture, and the forwarding equipments support IPv4 and IPv6 dual protocol stacks. MACN architecture supports to deploy EVPN over SRv6 technology to unify bearer plane, ubiquitous access, intelligent scheduling [1]. It can realize rapid and flexible deployment of services, rapid traffic forwarding, on-demand scheduling, etc. so as to meet the SLA differentiation of novel video services.

The paper analyzes the limitations of traditional MAN in the current context, introduces the MACN architecture, and introduces the SRv6 unicast scheme and BIERv6 multicast scheme based on MACN deployment in conjunction with the end-to-end network requirements of novel video-type services, illustrating the advantages of the solution in terms of flexibility, efficiency and enhanced customer experience. Also, the solution presented in the paper will enhance the functionality of beyond 5G and 6G bearer networks.

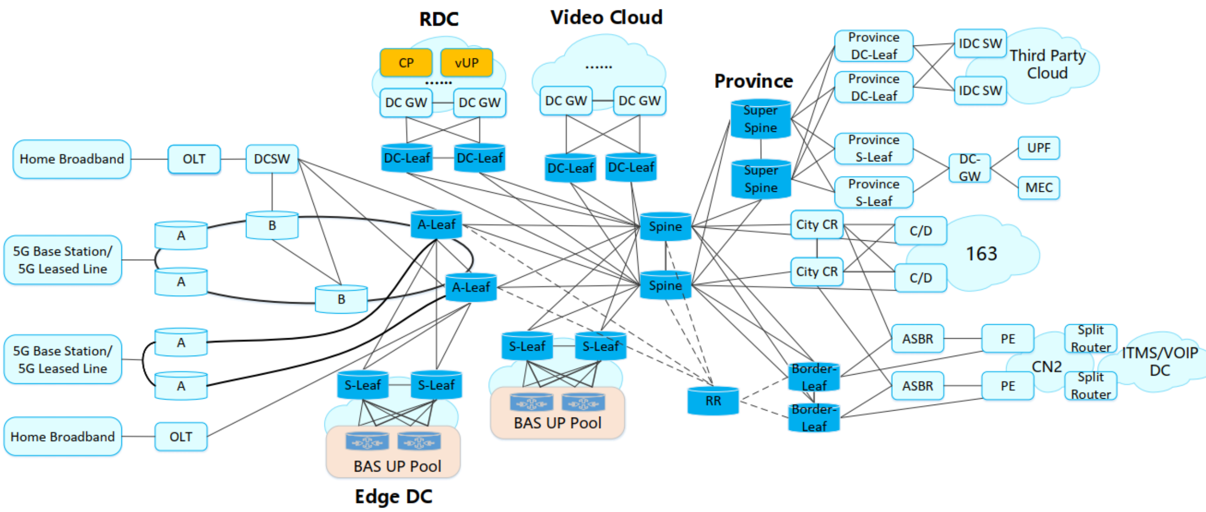

Fig. 1. Metropolitan Area Cloud Network Architecture

II. Introduction of Metropolitan Area Cloud Network

A. General Architecture

In order to solve the problems of traditional MAN and better satisfy the network requirements of novel video scenes such as 5G and cloud services, this paper introduces a MACN architecture, as shown in Fig.1.

The target architecture of MACN is to adapt to the demand of traffic localization and calculation subsidence, and to provide large bandwidth, low latency, end-to-end slicing, flexible path-on-demand, secure and trustworthy capability, and to meet carrying demand of cloud leased line, cloud edge collaboration, enterprise leased line, cloud network ultra-wide bearing leased line. It also meets the needs of cloud-based deployment such as 5G base stations, 5G core networks, Mobile Edge Computing (MEC), etc. The architecture is centered on Data Center (DC) and constructed by Point of Delivery (PoD). The intra-city network consists of access layer, aggregation layer and core layer, and the provincial core network consists of provincial Super Spine, provincial Spine-Leaf (S-Leaf), provincial Border-Leaf and provincial DC-Leaf, etc.

Spine is connected to Border-Leaf, Cloud Provider Edge (PE), MAN Core Router (CR), provincial Super Spine and 163 backbone network in the north direction, and to Access-Leaf (A-Leaf), DC-Leaf, S-Leaf and Regional Convergence Equipment (B) in the south direction.Spine connects with 163 backbone network and CR to meet the business requirements of users accessing ChinaNet online.The interconnection links of Spine and CR mainly carry the services of MACN Internet private line, Chinatelecom Next Carrier Network (CN2) boutique network, international interoperability, etc. Spine is converged with metro Edge Route (ER) or MER of Smart Transport Network (STN) to realize the service access needs of metro cloud network mobile users. The north bound interface of Border-Leaf is connected with CN2 PE devices, MAN Autonomous System Boundary Router (ASBR) devices, multi-cloud interconnection network PE or P (Provider) devices . Cross-domain VPN services are deployed at Border-Leaf. The Route Reflector (RR) device acts as a Border Gateway Protocol (BGP) route reflector and establishes peer relationships with Border-Leaf, Spine, A-Leaf, DC-Leaf, S-Leaf, Broadband Access Server Up (BAS-UP), B devices respectively, for configuring SRv6 TE (Traffic Engineering) paths for services, carrying EVPN and L3VPN services through SRv6 tunnels, etc. Broadband Remote Access Server (BAS) adopts a kind of forwarding control separation system, which NFVizes and centralizes the compute-intensive user management function , while retaining the high forwarding performance of BAS devices. BAS-CP is deployed centrally in the core DC. UP-Pool is deployed uniformly in the core DC or edge DC, and S-Leaf accesses Spine in the up hanging UP-Pool scene, and S-Leaf accesses A-leaf in the low hanging UP-Pool scene.

B. EVPN over SRv6 Forwarding Scheme

SRv6 combines the Source Routing idea of Segment Routing (SR) technology with IPv6 forwarding packets technology, and the control plane uses EVPN technology, which can achieve the effect of simplifying IP bearer network protocols [2]. SRv6 is based on native IPv6 forwarding packets, and when cross-domain is needed, only IPv6 routes from the local domain need to be directed to the opposite domain through BGP extension protocol, then cross-domain service deployment can be carried out, thus reducing the complexity. The core feature of SRv6 is that it has path and service orchestration capability, and the planned optimal path can be encapsulated in the IP header through flexible IPv6 extension headers and distributed to devices by Software Defined Networking (SDN) controllers, replacing complex tunneling protocols such as Label Distribution Protocol/Resource Reservation Protocol (LDP/RSVP), realizing network programmability. It can better meet the requirements of different types of video services on the network.

SRv6 is adopted in the underlay layer protocol of MACN. The B, A-Leaf, Spine, RR, DC-Leaf, S-Leaf, BAS-UP, Border-Leaf devices enable IPv6 forwarding ability and all devices enable SRv6 function at the same time. The MANC devices are in the same Interior Gateway Protocol (IGP)

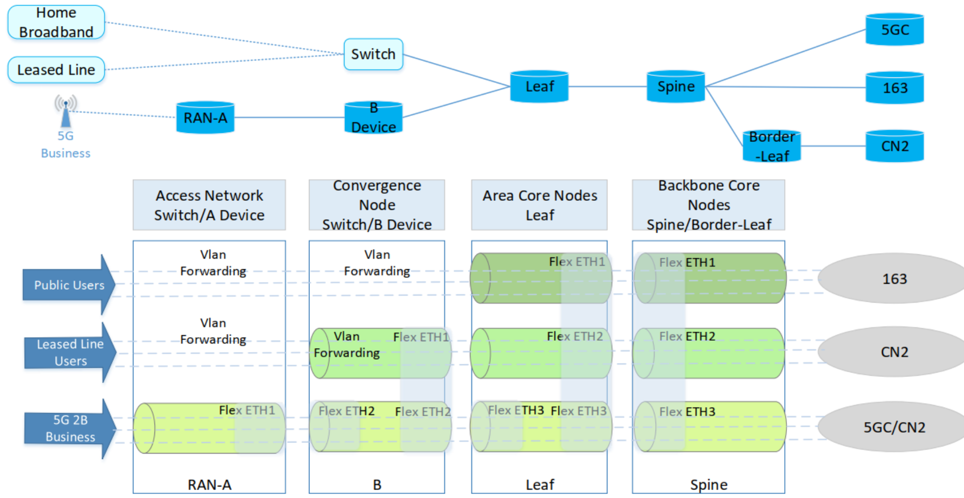

Fig. 2. Slicing Configuration Scheme for MACN

domain, and the devices are reachable through IGP to establish end-to-end SRv6 forwarding paths. Independent RRs are deployed within the MACN to do route reflection. For Internet services such as fixed network home broadband, fixed network Internet private line, STN access Internet private line, mobile network 2C services, cloud network ultra-broadband services, etc., the EVPN over SRv6 Best Effort (BE) path is used for bearing [3]. For 5G 2B services and group network leased lines (including fixed network access and mobile network access), SRv6 Policy is issued through SDN controller and carried by SRv6 TE slicing path to provide highly reliable and differentiated services for different users.

C. *FlexE-based Slicing Bearer technology*

Flexible Ethernet (FlexE) is an interface technology to achieve service isolation and network slicing in the bearer network. FlexE bandwidth expansion technology guarantees that services are strictly and evenly distributed on each physical interface of FlexE Group through time slot control, and can adjust the network bandwidth resource occupation in real time by dynamically increasing or decreasing the number of time slots, and respond to the real-time changes of service traffic [4]. The service bandwidth is decoupled from the physical interface bandwidth to meet the customer's demand of hard pipe isolation and bandwidth allocation on demand. In actual production, FlexE slicing technology combined with QoS service is used to guarantee service bearing .

Fig.2 shows the MACN slicing scheme. MACN deploy L3 EVPN over SRv6 in A-Leaf, Spine, Border-Leaf, etc. to deliver both VPNv4 and VPNv6 routes. MP-BGP declares both L3 EVPN routes and L3 VPN routes, and forwards them in the data plane preferentially based on SRv6. A-Leaf establish BGP neighbors with S-Leaf, B-Leaf, and DC-Leaf. In the L3 EVPN over SRv6 scene, the next hop of the 2C VPN route is set to 2C locator and the next hop of the 2B VPN route is set to 2B locator when announcing the L3 EVPN route. Thus it is ensured that the 2C and 2B service traffic enter the corresponding slice.

The paper takes L3 EVPN over SRv6 slice deployment scheme as an example to introduce the 2C and 2B slice. It is shown in the Fig.3. Slices are deployed in the following ranges: Spine-MER, Spine-Border Leaf, Spine-Aleaf, Spine-Sleaf, ALeaf-Sleaf, Aleaf-B, B-B, etc., carrying To Custom (2C) and To Business (2B) services respectively. And horizontal links are not deployed with FlexE slices, and only distinguish 2C and 2B traffic through different VLANs. Considering the MACN and STN network convergence, the MACN slicing scheme is realized by dual-stack single-process combined with SRv6 policy, with public services carried on the default slice through SRv6 BE tunnel, with 5G 2B services and leased line slicing services carried on 5G 2B slice and leased line slicing through SRv6 policy respectively.

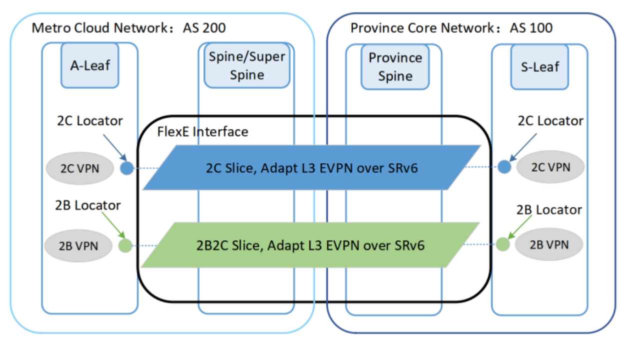

Fig. 3. L3 EVPN over Srv6 Slice Deploying Scheme

D. *SDN Controller for Metropolitan Area Cloud Network*

Configuration service and assurance SLA for MACN require global SDN controller to achieve intelligent network control, network scheduling, visualized operation and maintenance. The SDN controller of MACN achieves end-to-end assurance SLA and traffic balancing by means of end-to-end topology visibility, performance visibility and path control. It specifically includes the functions as follows.

1) Data collection of topology and routing prefixes across domains (including multi-IGP areas and multi-AS domains) through protocols such as Border Gateway Protocol Link-State (BGP-LS). Formation of topology database of all-IP network.

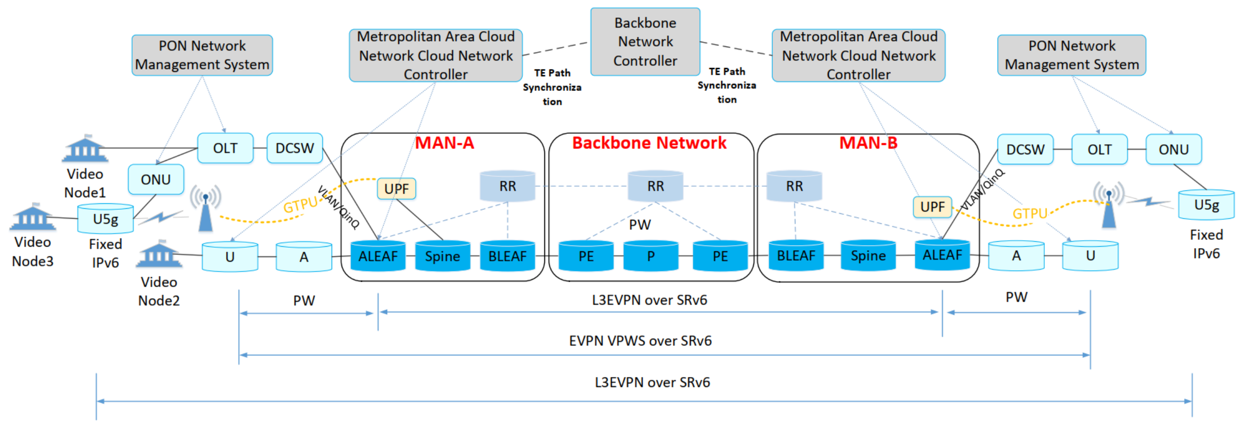

Fig. 4. Unicast Video Service Scheme for MACN

2) Completing the performance parameters of the topology database by means of multiple data collection ways on the all-IP network, including link bandwidth, delay, jitter, utilization rate and other indicators.

3) For a given end-to-end SLA demand or network event, perform end-to-end path calculation based on the topology database, and the path calculation taking into account both customer SLA demand and network traffic balancing and reliability requirements.

4) Generate the SRv6 Policy from the path calculation results and distribute the policy to the control network element devices through Path Computation Element Communication Protocol (PCEP) or BGP protocols to achieve end-to-end traffic path control.

III. Metropolitan Area Cloud Network Video Network Solution

A. Unicast Video Solution for Metropolitan Area Cloud Network

Unicast is a one-to-one communication method from one host to another. For unicast type of video services such as telemedicine, the network is required to have high reliability and low latency. Traditional network solutions mainly use MPLS/VPN technology to establish end-to-end VPN private lines for customers to provide stable bandwidth and latency guarantees. MPLS protocols need to be deployed independently in each network domain, causing the tunnels carrying the services to be independent of each other as well. For cross-domain services, complex technologies such as cross-domain VPNs need to be configured, resulting in long service setup cycles and complex configurations, and the problem also makes MPLS technology unsuitable for incoming cloud services. In view of the problems of traditional MPLS VPN technology, combined with the general background of cloud network convergence, this paper adopts EVPN over SRv6 networking private line scheme based on MACN to provide highly reliable network guarantee for unicast video services.

For online video business scenes such as telemedicine, the two parties may belong to two different provinces, i.e., corresponding to cross-province business.As shown in Fig.4, the scene uses SRv6 Policy to achieve end-to-end cross-domain assurance of services. The SDN controller of MACN and backbone network collect network topology, including node link information, link overhead, bandwidth, delay and other TE attributes through BGP-LS, etc., calculates the path to meet users' requirements according to service demands, and sends the path information to the head node of the network through BGP/PCEP and other protocols to achieve global tuning of traffic, bandwidth reservation and end-to-end cross-domain, etc.

In the above scheme, the access point of the video destination host is on the A-Leaf, and according to the access characteristics, it can be divided into four access methods.

1) Access to A-Leaf via convergence switch or OLT.

2) Access to A-Leaf via U equipment.

3) Access to A-Leaf via U device and via STN-A.

4) access to A-Leaf via U5g and via OLT or 4G/5G/IPv6 underlay tunnel.

The Passive Optical Network (PON) network manager is required to complete the configuration of Optical Line Terminal (OLT) access after the video site is online. MACN controller completes the configuration of IP Radio Access Network (IP-RAN) access mode and VPN configuration of A-Leaf on demand, and the backbone network controller is responsible for the end-to-end BE or TE tunnel path splicing work. The backbone RR acts as the primary RR and the MACN RR acts as the secondary RR (Client of the primary RR). The A-Leaf at both ends uses SRv6 to achieve cross-domain and can use end-to-end BE or TE paths, and service traffic is forwarded via direct link between metro core Spine device and backbone P device.

After the backbone network controller completes the topology acquisition and path calculation, it synchronizes the SRv6 Policy to the MACN controller. The MACN and the backbone network achieve cross-domain interoperability through the Binding Segment ID (BSID) mechanism. For the traffic entering the backbone network from the MACN, the SRv6 Policy of the backbone network is published to the Border-Leaf device of the MACN through the BSID. For traffic entering the MACN from the backbone network, the SRv6 Policy of the MACN is published to the backbone PE device through the BSID. For the service messages entering the MACN from the backbone network, the local MACN

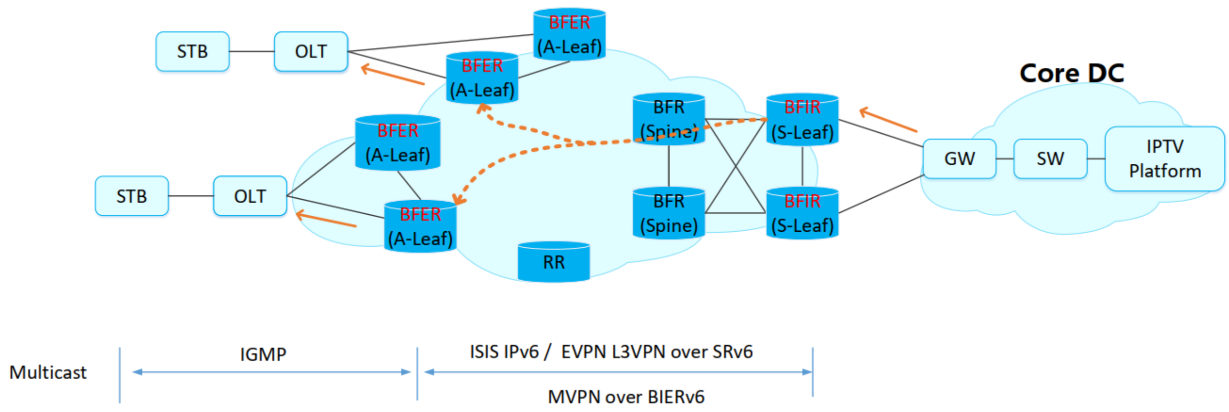

Fig. 5. Multicast Video Scheme Based on IPTV Service for MACN

declares the service-level BSID to the backbone network and the peer MACN, and the SRv6 Policy header device of peer MACN completes the encapsulation of the service messages (SRH carries the corresponding service-level BSID) [5]. After the local MACN Border-Leaf device receives the service message, it matches the corresponding service-level SRv6 Policy by parsing the service-level BSID, and imports it into the corresponding MACN service-level slice, thus realizing service diversion.

B. Multicast Video Solution for Metropolitan Area Cloud Network

Multicast technology is a one-to-many communication method. The principle of traditional multicast technology is to create a multicast distribution tree for each multicast traffic, and each node in the distribution tree has to sense the multicast service and retain the multicast traffic state. The disadvantages of this technology include the following.

1) Relying on multicast protocols such as Protocol Independent Multicast (PIM) to establish multicast distribution trees, which are complex for multicast protocols and not conducive to scaling.

2) Slow service reconvergence and poor user experience when the network fails.

3) Requires network equipment to support multicast protocols, and the deployment, operation and maintenance at a great cost when there are complex network scenes such as cross-domain.

Bit Index Explicit Replication (BIER) is a new multicast technology proposed by Internet Engineering Task Force (IETF), which encapsulates the BitString composed of multicast message destination nodes in the BIER message header of the packet, and the network intermediate nodes replicate the message and forward then according to the corresponding destination nodes of the BitString[6]. BIERv6 is a multicast technology based on BIER and IPv6 technology. Through BitString, multicast messages are forwarded to designated multicast group receiving members, and the underly layer is based on native IPv6 forwarding packages. Intermediate nodes do not need to build and maintain multicast distribution trees, and no longer rely on complex multicast routing protocols such as PIM and MPLS labels, solving the problems of complex protocols, poor user experience and deployment difficulties of traditional multicast technologies. Meanwhile, when multicast users join a multicast group, they only need to send authentication messages from the leaf node to the head node, which is suitable for configuration using SDN controller and improves service turn-up efficiency. As shown in Fig.5, take IPTV service scene as an example and introduce the multicast scheme of deploying BIERv6 in MACN.

In the scheme, the gateway of Set Top Box (STB) is on A-Leaf device, using non-Session level IP over Ethernet (IPoE) to access Multicast Virtual Private Network (MVPN). Internet Group Management Protocol (IGMP) protocol is configured between STB and A-Leaf, STB sends join request to A-Leaf to join the multicast group to achieve the sparing of multicast traffic. MVPN over BIERv6 is configured between A-Leaf and S-Leaf , and A-Leaf as Bit Forwarding Egress Router (BFER), and S-Leaf as Bit Forwarding Ingress Router (BFIR). BFIR and BFER establish Multiprotocol Internal BGP (MP-IBGP) neighbors with RR respectively, and establish MVPN and EVPN neighbors between BFIR and BFER through RR, and BFER joins multicast service through MVPN. Configure static routes to the BIERv6 domain within the IPTV network to achieve route reachability for both domains. Make the BFIR as the root node, configure BIERv6 as the Inclusive Provider Multicast Service Interface (I-PMSI) tunnel type , and configure the IPv6 source address src.DTX information of the MVPN instance. Assign a BFIR Forwarding Router Identifier (BFR-ID) to each BFER that identifies this leaf node and is used to generate BitString.

When the BFIR receives a multicast message from a multicast source, it matches the Provider Multicast Service Interface (PMSI) tunnel according to the information in the message header, encapsulates the BIERv6 message header in the outer layer of the multicast message according to the tunnel attributes, and completes the settings of BitString and Src.DTX, etc. The BFIR encapsulates the End.BIER SID of the next-hop node as the outer IPv6 destination address of the BIERv6 message. For non-BFR nodes, forwarding packages according to native IPv6 is sufficient.

The deployment of MVPN over BIERv6 based on MACN carries IPTV service traffic, which can reduce the redundant video traffic in the network and quickly converge when the service fails to improve user experience.

IV. Conclusion and Future Works

With the development of 5G and cloud technology, novel video services will usher in a period of growth, putting forward higher requirements for operators' networks. The MACN adopts spine-leaf architecture, with DC as the center and configuring by PoD construction, combined with IPv6 technology, to solve the shortcomings of traditional MAN with complex configuration and poor flexibility. The network paths of MCAN, backbone network and cloud data center can be optimized to meet different scenes of video services. Taking cross-province video service scene as an example, SRv6 Policy generation and distribution process is introduced to achieve end-to-end cross-domain, global tuning, bandwidth reservation, etc. to meet different SLA for differentiated service assurance.

BIERv6 multicast technology combines the advantages of BIER technology and flexible extension of IPv6 message headers, encapsulating destination node information in the form of bit strings in IPv6 extension message headers, and intermediate nodes replicate and forward messages according to the address information in the message headers, which is easy to deploy and efficient in operation and maintenance. Taking IPTV service scene as an example, introduce the multicast deployment scheme based on BIERv6 to reduce the redundant video traffic in the network and improve user experience.

In the future, the SRv6 technology of MACN will help to enhance the bearer network in Beyond 5G and 6G networks.

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References

[1] Filsfils, C., Ed., Camarillo, P., Ed., Leddy, J., Voyer, D., Matsushima, S., and Z. Li, "Segment Routing over IPv6 (SRv6) Network Programming", RFC 8986, RFC8986, February 2021.

[2] T. Sugiura, K. Takahashi, K. Ichikawa and H. Iida, "Acar: An application-aware network routing system using SRv6," 2022 IEEE 19th Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, NV, USA, 2022, pp. 751-752.

[3] K. A. Noghani and A. Kassier, "SDN enhanced ethernet VPN for data center interconnect," 2017 IEEE 6th International Conference on Cloud Networking (CloudNet), Prague, Czech Republic, 2017, pp. 1-6.

[4] J. Song, D. Yong, C. Hao, J. Ping, L. Pei and B. Yang, "A Novel FlexE-Based Slicing Business Hosting Equipment Empowering Energy Internet," 2022 IEEE 4th International Conference on Power, Intelligent Computing and Systems (ICPICS), Shenyang, China, 2022, pp. 547-551.

[5] H. Yoo, S. Byun, S. Yang and N. Ko, "A Service Programmable Network Architecture based on SRv6," 2022 13th International Conference on Information and Communication Technology Convergence (ICTC), Jeju Island, Korea, Republic of, 2022, pp. 2068-2070.

[6] Y. Desmouceaux, T. H. Clausen, J. A. C. Fuertes and W. M. Townsley, "Reliable multicast with B.I.E.R.," in Journal of Communications and Networks, vol. 20, no. 2, pp. 182-197, April 2018.