Technical White Paper for IPv6
DS-Lite Solution

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Keywords

IPv6, transition technology, evolution, DS-Lite, Dual Stack Lite, B4, AFTR, IPv4-in-IPv6 tunnel, 4in6, dual stack, NAT, CGN

Summary

As one of the IPv6 evolution solutions, DS-Lite provides not only IPv4 and IPv6 dual stack services, but also IPv6 single stack services. In fact, the DS-Lite solution represents the ultimate model for IPv6 evolution. This document describes the DS-Lite technical solution, key technologies, and networking scenarios. Chapter 2 "Introduction to the Solution" introduces the basic concepts, technical implementation, and logical networking diagram of the DS-Lite solution. Chapter 3 "Key Technologies" introduces IPv4/IPv6 address allocation, the IPv4-in-IPv6 tunnel, and NAT technology. Chapter 4 "Typical Application” describes scenarios involving centralized and distributed CGNs.
1 Preface

The primary driver promoting IPv6 is the exhaustion of IPv4 addresses.

The following factors must be considered in terms of IPv6 evolution technology:

- The ultimate way of deploying IPv6
- The provision of IPv4 services through IPv6 networks coupled with a method for solving IPv4 address exhaustion.

Multiple IPv6 evolution solutions currently exist; for example, dual stack + NAT44/NAT444, DS-Lite, 6RD, and NAT64. Although the application of a specific solution depends on carriers’ individual requirements and IPv6 evolution strategies, the industry has reached the consensus that DS-Lite represents the ultimate model for IPv6 evolution. On an IPv6 network, the DS-Lite solution provides not only IPv4 and IPv6 dual stack services, but also IPv6 single stack services. As IPv6 services are developing into major services and IPv4 services are relegated into a secondary position, the technical architecture of DS-Lite is designed to meet future development trends.

Firstly, DS-Lite does not necessitate secondary network upgrades as the solution directly uses IPv6 single stack for the bearer network. Comparatively, the 6RD solution uses an IPv4 single stack, which increases the cost of IPv6 deployment as a secondary network upgrade is required.

Secondly, unlike the NAT 64 solution, DS-Lite technology does not need to translate between different address families as it is similar to dual stack technology. The difference between IPv4 and IPv6 protocols must be considered in NAT 64 as handling is more complex than in IPv4-in-IPv4 NAT.
The DS-Lite solution was developed by Comcast in 2008 and adopted as the IETF software draft in March 2009. In 2010, the DS-Lite mapping subsidiary protocols were formulated, including DHCPv6 AFTR-Name option, RADIUS attribute, and MIB.
2 Introduction to the Solution

DS-Lite technology directly transmits IPv6 services on an IPv6 network and deploys an IPv4-in-IPv6 tunnel to transmit IPv4 services.

DS-Lite refers to a lightweight dual stack. Comparing to the DS-Lite solution, DS solutions require that dual stack must be enabled on dual stack nodes with an awareness of IP addresses. However, the DS-Lite solution provides dual stack silo interconnection on an IPv6 network.

Notably, DS-Lite technology enables IPv6 and IPv4 source addresses to communicate only with their respective IPv6 and IPv4 destination addresses. This makes translation between different address families unnecessary, which greatly simplifies the processing of application protocols when IP addresses are carried in payloads. Moreover, DS-Lite network architecture enables IPv6 services to be directly transmitted across an IPv6 network.

Remainder of this document mainly describes the transmission of the IPv4 services.

2.1 Basic Concepts

B4

The B4 (base bridging broadband element) network element provides the following functions:

- Dual stack capability. This is implemented on the host or customer premises equipment (CPE). The CPE functions as the home gateway in carrier networking.
- The capability to create an IPv4-in-IPv6 tunnel that terminates on the address family transition router element (AFTR).
AFTR

The IPv4-in-IPv6 tunnel terminates on the AFTR. The AFTR implements the NAT IPv4-IPv4 function and is a carrier grade NAT (CGN) on the carrier network. The CGN can be either an independent CGN device or a plug-in card (for example, the CGN can be configured by inserting the CGN board into the service control node).

For details, see RFC6333.
2.2 Technical Implementation

The DS-Lite solution uses two well-known technologies to implement IPv4 service transmission.

- IPv4-in-IPv6 (IPinIP) tunnel:
  The IPv4-in-IPv6 tunnel is required to access IPv4 services. It exists between the B4, where it is created, and the AFTR, where it terminates. By directly encapsulating IPv4 packets with IPv6 packet headers, the IPv4-in-IPv6 tunnel enables IPv4 packets to be forwarded on a single stack IPv6 network.

- Network Address Translation (NAT):
  The IPv4 address obtained by a home network user is a private network IPv4 address, which the AFTR translates into a public network IPv4 address at the termination point of the IPv4-in-IPv6 tunnel.

2.3 Logical Networking Diagram

Scenario with Directed Connection

Figure 2-1 shows the scenario in which the hosts connect to the AFTR directly. The B4 is implemented by the host and the AFTR is implemented by the CGN.
- The CPE is the bridging home gateway and the host is a dual stack host.
- The single stack IPv6 network exists between the host and the CGN.
- The network between the host and service network must be able to transmit IPv4 and IPv6 services.

In this scenario, the B4 must be implemented by a terminal (such as the host) because not all terminals support DS-Lite and carriers do not necessarily provide terminals that are similar to the host.

Therefore, the following CPE scenario is recommended for deployment.

**CPE Scenario**

In the CPE scenario, the B4 is implemented by the CPE, as shown in Figure 2-2.

**Figure 2-2 CPE scenario**

The WAN interface on the CPE implements the B4 whereas the CGN implements AFTR (NAT IPv4-IPv4). It is not necessary for the DS-Lite solution to provide the NAT function at the CPE internal interface and the WAN interface. Therefore, two classes of NATs (one class of the NAT is configured on the CPE; the other on the CGN) are not required in this technical scenario.

Scenario characteristics:

- **The CPE is a routed mode home gateway.** The home network is a dual stack network.
- The single stack IPv6 network exists between the CPE and the CGN.
The network between the home network and service network must be able to transmit IPv4 and IPv6 services.

In this scenario, the CPE uses DHCPv6 to learn one IPv6 address only from the DNS recursive server as the IPv6 single stack network exists between the CPE and CGN. The DHCPv6 protocol cannot carry IPv4 DNS information and only defines the DHCP DNS Recursive Name Server option. Therefore, the CPE cannot obtain the IPv4 address of the recursive DNS server. The following two solutions can solve this problem:

- **Solution 1:** Using IPv4-IPv6 DNS proxy technology to store IPv4 DNS information in IPv6 packets. For example, the CPE uses an IPv6 packet to send the DNS IPv4 request received by the host to the DNS server in the carrier network.

- **Solution 2:** Using TR069 or manual static configuration to notify the CPE DNS of the IPv4 address of the DNS recursive server if applicable. The host then uses the IPv4 packet to send the IPv4 DNS request. A binding table is created on the AFTR for each DNS request.

In solution 2, a large number of DNS requests may directly affect the utilization rate of NAT table items on the AFTR. Therefore, solution 1 is recommended in an actual deployment.
3 Key Technologies

Requirements on the AFTR are the same in both of the above scenarios. This chapter describes the key technologies based on the CPE scenario for its ease of deployment.

3.1 IPv4 Address Allocation

The CPE prompts the DHCPv4 server to allocate addresses to users in the IPv4 address space (for example, 192.168.0.0/16) of a private network.

If a user wants to access IPv4 services, an IPv4 address from a private network is used to pass through the IPv4-in-IPv6 tunnel and reach the CGN. The CGN then translates the IPv4 address of a private network to that of a public network.

3.2 IPv6 Address Allocation

The BRAS manages IPv6 address information only.

3.3 IPv4-in-IPv6 Tunnel

The IPv4-in-IPv6 tunnel between the B4 and AFTR is bidirectional and stateless.

Before the tunnel is created, the B4 must obtain the IPv6 address of the AFTR and the AFTR must obtain the B4 address. The B4 obtains the AFTR name by using the DHCPv6 protocol; the AFTR obtains the B4 address from the NAT binding table. In actual deployment, the B4 address is the address of the CPE WAN interface.
AFTR Discovery

To create the IPv4-in-IPv6 tunnel, the B4 must obtain the IPv6 address of the AFTR. The B4 can obtain the AFTR name through the DHCPv6 option and then resolve the AFTR name to an IPv6 address through the DNS service.

Tunnel Creation

Creation of the tunnel is triggered by IPv4 traffic on the home network.

Tunnel Release

In PPPoE access mode, the tunnel is released because the PPPoE session is interrupted.

In IPoE access mode, this tunnel is released because the mapping neighbor relationship is removed.

Packet Encapsulation and Decapsulation

Figure 3-1 Process of packet encapsulation and decapsulation

![Diagram of packet encapsulation and decapsulation]

An IPv4 packet is initiated when a user connected to B4 wishes to access IPv4 services. The process is as follows:

- **Encapsulation:** The B4 encapsulates the IPv4 packet as an IPv6 packet by directly encapsulating the IPv4 packet with an IPv6 packet header. The source address of the packet header is the WAN interface address and the destination address is the AFTR address. The packet is forwarded on the IPv6 network between the B4 and ATRF based on the destination address of the IPv6 packet header.
• **Decapsulation**: The AFTR decapsulates the received packet by removing the IPv6 packet header and exposing the IPv4 packet. Then, the AFTR translates the private network address into a public network address.

The following process applies when the IPv4 service system returns an IPv4 packet:

• **Encapsulation**: After receiving the packet, the AFTR locates the mapping NAT binding table based on the triplet or quintuplet information in the IPv4 packet. The AFTR then translates the public network address into a private network address. Based on the private network information (private network address and private network port number or ICMP identifier), the AFTR obtains the B4 address through indexes. The AFTR encapsulates the IPv4 packet as an IPv6 packet by directly encapsulating the IPv4 packet with an IPv6 packet header (the source address of the packet header is the CGN address and the destination address is the B4 address).

• **Decapsulation**: The B4 decapsulates the received packet by removing the IPv6 packet header and exposing the IPv4 packet.

**Segmentation and Reassembly**

The PMTU is a mandatory attribute of IPv6 transmission. Segmentation and reassembly may be required during IPv6 packet transmission. Segmentation is performed after tunnel encapsulation and reassembly is performed before decapsulation.

**3.4 NAT**

The NAT binding table extends the source IPv6 address of incoming traffic, which is the B4 IPv6 address. In actual deployment, the source address is the address of the CPE WAN interface, and different CPEs use different WAN interface addresses. Using IPv6 addresses resolves the problem of duplicate IPv4 addresses on home network hosts.

As the NAT function of the AFTR inherits all the features of the known NAT function, problems such as the NAT traversal and user source tracing still occur.

- **NAT traversal (identical to the common NAT function):** Solved by ALG.
- **User source tracing**: Solved by port pre-allocation, which simplifies source tracing by specifically identifying user information. The port pre-allocation process evaluates and specifies the number of external ports used by a user. External ports of the same user can be distributed in the same port segment of the same IPv4 address.
on the public network, which enables users in the same family to share a public network IPv4 address. In actual application scenarios, a public network IPv4 address may be shared by multiple families.
4 Typical Application

DS-Lite technology can be used on networks on a lower layer than the backbone network. Typically, the CGN can be deployed in distributed mode by inserting a CGN card into a device such as the BRAS, or centrally deployed by using an independent CGN device.

Distributed CGN

Figure 4-1 Distributed CGN (with the CGN board inserted into the service control node)

Centralized CGN

Figure 4-2 shows a centralized CGN, which is usually an independent device that provides CGN functionality.
Figure 4-2 Centralized CGN

IPv4-in-IPv6 Tunnel
IPv4 traffic
IPv6 traffic
DS-Lite can implement IPv4 service transmission on an IPv6 single stack network, enable one-stop evolution to IPv6 network, continue to provide IPv4 services, and greatly reduce IPv4 address requirements. The BRAS allocates only IPv6 addresses, while the B4 (CPE) allocates the IPv4 addresses of home network hosts.

Therefore, the DS-Lite solution meets future development trends and represents the ultimate IPv6 evolution solution.
1. RFC6333: Dual-Stack Lite Broadband Deployments Following IPv4 Exhaustion
2. RFC6334: Dynamic Host Configuration Protocol for IPv6 (DHCPv6) Option for Dual-Stack Lite
3. RFC1191: Path MTU discovery
4. RFC1918: Address Allocation for Private Internets
5. RFC2663: IP Network Address Translator (NAT) Terminology and Considerations
6. RFC2993: Architectural Implications of NAT
7. RFC4033: DNS Security Introduction and Requirements,
8. RFC4787: Network Address Translation (NAT) Behavioral Requirements for Unicast UDP
9. RFC4987: TCP SYN Flooding Attacks and Common Mitigations
10. RFC5320: The Subnetwork Encapsulation and Adaptation Layer (SEAL)
11. RFC5382: NAT Behavioral Requirements for TCP
12. RFC5508: NAT Behavioral Requirements for ICMP
13. RFC5571: Softwire Hub and Spoke Deployment Framework with Layer Two Tunneling Protocol Version 2 (L2TPv2)
14. RFC6269: Issues with IP Address Sharing
15. RFC6302: Logging Recommendations for Internet-Facing Servers
# B Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym and Abbreviation</th>
<th>Full Name</th>
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<tbody>
<tr>
<td>AFTR</td>
<td>DS-Lite Address Family Transition Router element</td>
</tr>
<tr>
<td>CGN</td>
<td>Carrier Grade NAT</td>
</tr>
<tr>
<td>CPE</td>
<td>Customer Premises Equipment</td>
</tr>
<tr>
<td>DHCP</td>
<td>Dynamic Host Configuration Protocol</td>
</tr>
<tr>
<td>DS-Lite</td>
<td>Dual Stack Lite</td>
</tr>
<tr>
<td>NAT</td>
<td>Network Address Translation</td>
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